The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, January 26, 2012 — 1:15 to 4:15 p.m., only

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in the examination booklet.

The answers to *all* questions in this examination are to be written in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All work should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers in your answer booklet.

When you have completed the examination, you must sign the statement printed on the first page of your answer booklet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

The use of any communications device is strictly prohibited when taking this examination. If you use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, write in your answer booklet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry*.

1 What is the number of electrons in a completely filled second shell of an atom?

(1) 32   (3) 18
(2) 2   (4) 8

2 What is the number of electrons in an atom that has 3 protons and 4 neutrons?

(1) 1   (3) 3
(2) 7   (4) 4

3 As a result of the gold foil experiment, it was concluded that an atom

(1) contains protons, neutrons, and electrons
(2) contains a small, dense nucleus
(3) has positrons and orbitals
(4) is a hard, indivisible sphere

4 Which statement describes the distribution of charge in an atom?

(1) A neutral nucleus is surrounded by one or more negatively charged electrons.
(2) A neutral nucleus is surrounded by one or more positively charged electrons.
(3) A positively charged nucleus is surrounded by one or more negatively charged electrons.
(4) A positively charged nucleus is surrounded by one or more positively charged electrons.

5 Which atom in the ground state has an outermost electron with the most energy?

(1) Cs   (3) Li
(2) K   (4) Na

6 Which particle has the *least* mass?

(1) alpha particle   (3) neutron
(2) beta particle   (4) proton

7 The elements in Group 2 are classified as

(1) metals   (3) nonmetals
(2) metalloids   (4) noble gases

8 Which list includes elements with the most similar chemical properties?

(1) Br, Ga, Hg   (3) O, S, Se
(2) Cr, Pb, Xe   (4) N, O, F

9 The notation for the nuclide $^{137}_{55}Cs$ gives information about

(1) mass number, only
(2) atomic number, only
(3) both mass number and atomic number
(4) neither mass number nor atomic number

10 Which pair represents two forms of an element in the same phase at STP but with different structures and different properties?

(1) $I_2(s)$ and $I_2(g)$ (3) $H_2(g)$ and $Hg(g)$
(2) $O_2(g)$ and $O_3(g)$ (4) $H_2O(s)$ and $H_2O(\ell)$

11 The elements on the Periodic Table are arranged in order of increasing

(1) atomic mass   (3) molar mass
(2) atomic number   (4) oxidation number

12 What is the IUPAC name for the compound ZnO?

(1) zinc oxide   (3) zinc peroxide
(2) zinc oxalate   (4) zinc hydroxide

13 Which atom attains a stable valence electron configuration by bonding with another atom?

(1) neon   (3) helium
(2) radon   (4) hydrogen

14 An ionic bond can be formed when one or more electrons are

(1) equally shared by two atoms
(2) unequally shared by two atoms
(3) transferred from the nucleus of one atom to the nucleus of another atom
(4) transferred from the valence shell of one atom to the valence shell of another atom

15 Which sample of CO_2 has a definite shape and a definite volume?

(1) $CO_2(aq)$ (3) $CO_2(\ell)$
(2) $CO_2(g)$ (4) $CO_2(s)$

16 What occurs in order to break the bond in a Cl_2 molecule?

(1) Energy is absorbed.
(2) Energy is released.
(3) The molecule creates energy.
(4) The molecule destroys energy.

17 A sealed, rigid 1.0-liter cylinder contains He gas at STP. An identical sealed cylinder contains Ne gas at STP. These two cylinders contain the same number of

(1) atoms   (3) ions
(2) electrons   (4) protons

18 Which statement describes a chemical change?

(1) Alcohol evaporates.
(2) Water vapor forms snowflakes.
(3) Table salt (NaCl) is crushed into powder.
(4) Glucose $(C_6H_{12}O_6)$ and oxygen produce CO_2 and H_2O.

19 Which statement describes the particles of an ideal gas according to the kinetic molecular theory?

(1) The gas particles are arranged in a regular geometric pattern.
(2) The gas particles are in random, constant, straight-line motion.
(3) The gas particles are separated by very small distances, relative to their sizes.
(4) The gas particles are strongly attracted to each other.

20 Which sample of matter is classified as a substance?

(1) air   (3) milk
(2) ammonia   (4) seawater

21 Which element has the *lowest* electronegativity value?

(1) F   (3) Cl
(2) Fr   (4) Cr

22 At standard pressure, CH_4 boils at 112 K and H_2O boils at 373 K. What accounts for the higher boiling point of H_2O at standard pressure?

(1) covalent bonding   (3) hydrogen bonding
(2) ionic bonding   (4) metallic bonding

23 A mixture of sand and table salt can be separated by filtration because the substances in the mixture differ in

(1) boiling point   (3) freezing point
(2) density at STP   (4) solubility in water

24 Systems in nature tend to undergo changes toward

(1) lower energy and lower entropy
(2) lower energy and higher entropy
(3) higher energy and lower entropy
(4) higher energy and higher entropy

25 In the wave-mechanical model of the atom, an orbital is the most probable location of

(1) a proton   (3) a neutron
(2) a positron   (4) an electron

26 Functional groups are used to classify

(1) organic compounds
(2) inorganic compounds
(3) heterogeneous mixtures
(4) homogeneous mixtures

27 Which class of compounds contains *at least one* element from Group 17 of the Periodic Table?

(1) aldehyde   (3) ester
(2) amine   (4) halide

28 In a propanal molecule, an oxygen atom is bonded with a carbon atom. What is the total number of pairs of electrons shared between these atoms?

(1) 1   (3) 3
(2) 2   (4) 4

29 When a voltaic cell operates, ions move through the

(1) anode   (3) salt bridge
(2) cathode   (4) external circuit

30 When dissolved in water, an Arrhenius base yields

(1) hydrogen ions   (3) hydroxide ions
(2) hydronium ions   (4) oxide ions

Answer all questions in this part.

Directions (31–50): For *each* statement or question, write in your answer booklet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry*.
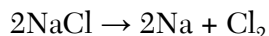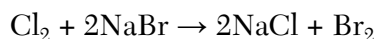
31 What is the total number of valence electrons in a germanium atom in the ground state?

(1) 22   (3) 32
(2) 2   (4) 4

32 Which element is paired with an excited-state electron configuration for an atom of the element?

(1) Ca: 2-8-8-2   (3) K: 2-6-8-3
(2) Na: 2-8-2   (4) F: 2-8

33 Given the balanced equations representing two chemical reactions:

$$Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$$

$$2NaCl \rightarrow 2Na + Cl_2$$

Which types of chemical reactions are represented by these equations?

(1) single replacement and decomposition
(2) single replacement and double replacement
(3) synthesis and decomposition
(4) synthesis and double replacement

34 An ion that consists of 7 protons, 6 neutrons, and 10 electrons has a net charge of

(1) 4–   (3) 3+
(2) 3–   (4) 4+

35 Which Lewis electron-dot diagram represents a molecule having a nonpolar covalent bond?
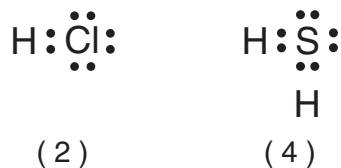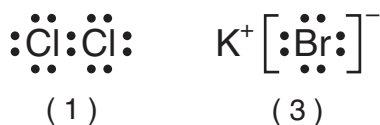
36 Which quantity is equal to 50 kilojoules?

(1) 0.05 J   (3) 5×10^3 J
(2) 500 J   (4) 5×10^4 J

37 Which compound is formed from its elements by an exothermic reaction at 298 K and 101.3 kPa?

(1) C_2H_4(g)   (3) H_2O(g)
(2) HI(g)   (4) NO_2(g)

38 At which temperature is the vapor pressure of ethanol equal to 80. kPa?

(1) 48°C   (3) 80.°C
(2) 73°C   (4) 101°C

39 At 25°C, gas in a rigid cylinder with a movable piston has a volume of 145 mL and a pressure of 125 kPa. Then the gas is compressed to a volume of 80. mL. What is the new pressure of the gas if the temperature is held at 25°C?

(1) 69 kPa   (3) 160 kPa
(2) 93 kPa   (4) 230 kPa

40 A 2400.-gram sample of an aqueous solution contains 0.012 gram of NH_3. What is the concentration of NH_3 in the solution, expressed as parts per million?

(1) 5.0 ppm   (3) 20. ppm
(2) 15 ppm   (4) 50. ppm

41 Which equation represents a change that results in an increase in disorder?

(1) I_2(s) $\rightarrow$ I_2(g)
(2) CO_2(g) $\rightarrow$ CO_2(s)
(3) $2Na$(s) + Cl_2(g) $\rightarrow$ $2NaCl$(s)
(4) $2H_2$(g) + O_2(g) $\rightarrow$ $2H_2O(\ell)$

42 A solution consists of 0.50 mole of $CaCl_2$ dissolved in 100. grams of H_2O at 25°C. Compared to the boiling point and freezing point of 100. grams of H_2O at standard pressure, the solution at standard pressure has

(1) a lower boiling point and a lower freezing point
(2) a lower boiling point and a higher freezing point
(3) a higher boiling point and a lower freezing point
(4) a higher boiling point and a higher freezing point

43 Given the balanced ionic equation representing a reaction:

$$2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$$
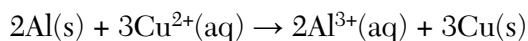
Which half-reaction represents the reduction that occurs?

(1) $Al \rightarrow Al^{3+} + 3e$
(2) $Al^{3+} + 3e \rightarrow Al$
(3) $Cu \rightarrow Cu^{2+} + 2e$
(4) $Cu^{2+} + 2e \rightarrow Cu$

44 Given the equation and potential energy diagram representing a reaction:

A + B → C

Reaction Coordinate
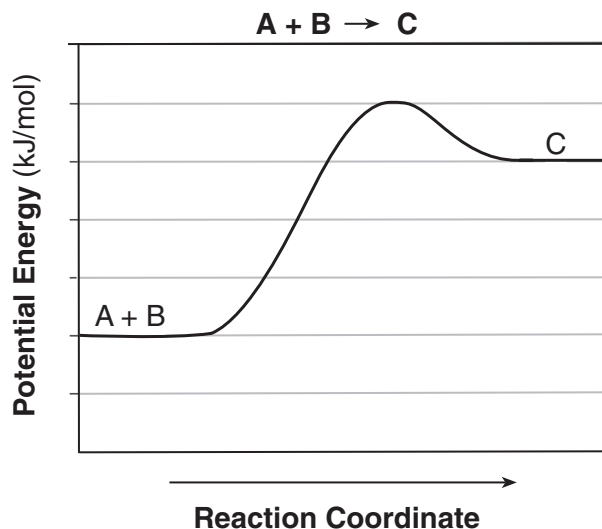
If each interval on the axis labeled "Potential Energy (kJ/mol)" represents 10. kJ/mol, what is the heat of reaction?

(1) +60. kJ/mol   (3) +30. kJ/mol
(2) +20. kJ/mol   (4) +40. kJ/mol

45 Some solid KNO_3 remains at the bottom of a stoppered flask containing a saturated $KNO_3(aq)$ solution at 22°C. Which statement explains why the contents of the flask are at equilibrium?

(1) The rate of dissolving is equal to the rate of crystallization.
(2) The rate of dissolving is greater than the rate of crystallization.
(3) The concentration of the solid is equal to the concentration of the solution.
(4) The concentration of the solid is greater than the concentration of the solution.

46 Which formula represents the product of the addition reaction between ethene and chlorine, Cl_2?
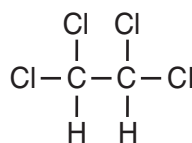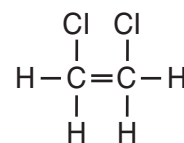
(1)   (3)
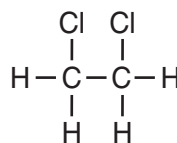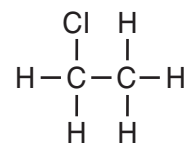
(2)   (4)

47 Based on Reference Table J, which two reactants react spontaneously?

(1) $Mg(s) + ZnCl_2(aq)$ (3) $Pb(s) + ZnCl_2(aq)$
(2) $Cu(s) + FeSO_4(aq)$ (4) $Co(s) + NaCl(aq)$

48 When the pH value of a solution is changed from 2 to 1, the concentration of hydronium ions

(1) decreases by a factor of 2
(2) increases by a factor of 2
(3) decreases by a factor of 10
(4) increases by a factor of 10

49 Given the balanced equation representing a nuclear reaction:

$$^{2}_{1}\text{H} + ^{3}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + ^{1}_{0}\text{n}$$
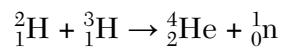
Which phrase identifies and describes this reaction?

(1) fission, mass converted to energy
(2) fission, energy converted to mass
(3) fusion, mass converted to energy
(4) fusion, energy converted to mass

50 Given the equation representing a reversible reaction:

$$\text{NH}_3(g) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}(aq)$$
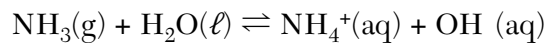
According to one acid-base theory, the reactant that donates an H^+ ion in the forward reaction is

(1) $\text{NH}_3(g)$
(2) $\text{H}_2\text{O}(\ell)$
(3) $\text{NH}_4^+(aq)$
(4) $\text{OH}(aq)$

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 51 through 54 on the information below.

The atomic radius and the ionic radius for some Group 1 and some Group 17 elements are given in the tables below.

Atomic and Ionic Radii of Some Elements

Group 1			Group 17	

Particle	Radius (pm)
Li atom	130.
Li$^+$ ion	78
Na atom	160.
Na$^+$ ion	98
K atom	200.
K$^+$ ion	133
Rb atom	215
Rb$^+$ ion	148

Particle	Radius (pm)
F atom	60.
F$^-$ ion	133
Cl atom	100.
Cl$^-$ ion	181
Br atom	117
Br$^-$ ion	?
I atom	136
I$^-$ ion	220.

51 Estimate the radius of a Br ion. [1]

52 Explain, in terms of electron shells, why the radius of a K$^+$ ion is greater than the radius of an Na$^+$ ion. [1]

53 Write *both* the name and the charge of the particle that is gained by an F atom when the atom becomes an F ion. [1]

54 State the relationship between atomic number and first ionization energy as the elements in Group 1 are considered in order of increasing atomic number. [1]

Base your answers to questions 55 through 57 on the information below.

Starting as a gas at 206°C, a sample of a substance is allowed to cool for 16 minutes. This process is represented by the cooling curve below.

Cooling Curve for a Substance
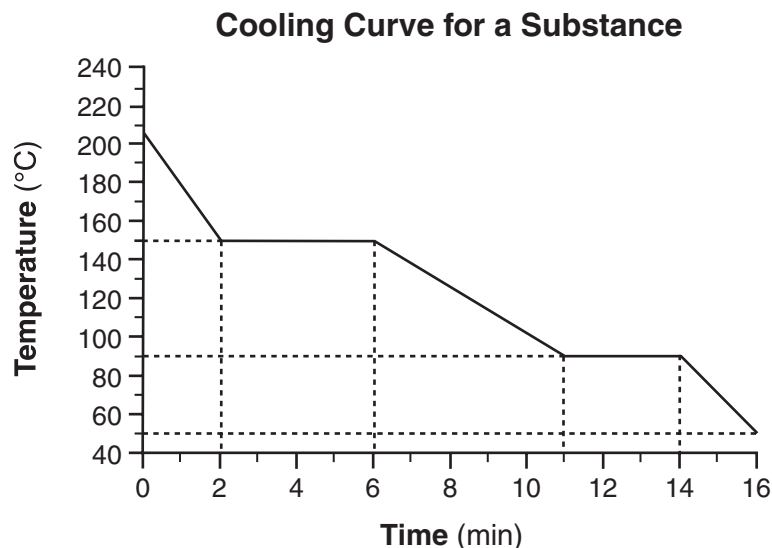
55 What is the melting point of this substance? [1]

56 At what time do the particles of this sample have the *lowest* average kinetic energy? [1]

57 Using the key *in your answer booklet,* draw *two* particle diagrams to represent the *two* phases of the sample at minute 4. Your response must include *at least six* particles for *each* diagram. [1]

Base your answers to questions 58 and 59 on the information below.

Two hydrocarbons that are isomers of each other are represented by the structural formulas and molecular formulas below.

Hydrocarbon 1

C_5H_8

Hydrocarbon 2

C_5H_8
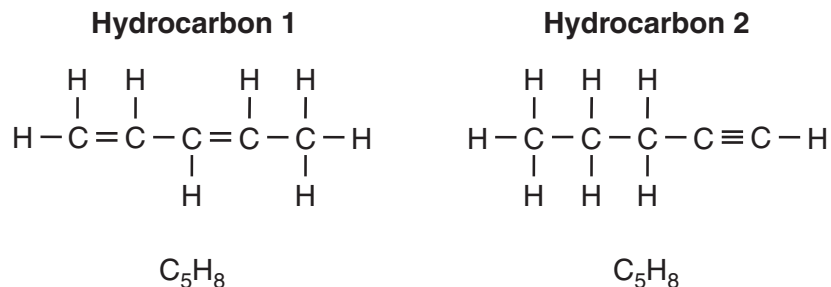
58 Explain, in terms of bonds, why these hydrocarbons are unsaturated. [1]

59 Explain, in terms of structural formulas and molecular formulas, why these hydrocarbons are isomers of each other. [1]

Base your answers to questions 60 through 62 on the information below.

The diagram below represents an operating electrolytic cell used to plate silver onto a nickel key. As the cell operates, oxidation occurs at the silver electrode and the mass of the silver electrode decreases.

60 Identify the cathode in the cell. [1]

61 State the purpose of the power source in the cell. [1]

62 Explain, in terms of Ag atoms and Ag⁺(aq) ions, why the mass of the silver electrode *decreases* as the cell operates. [1]

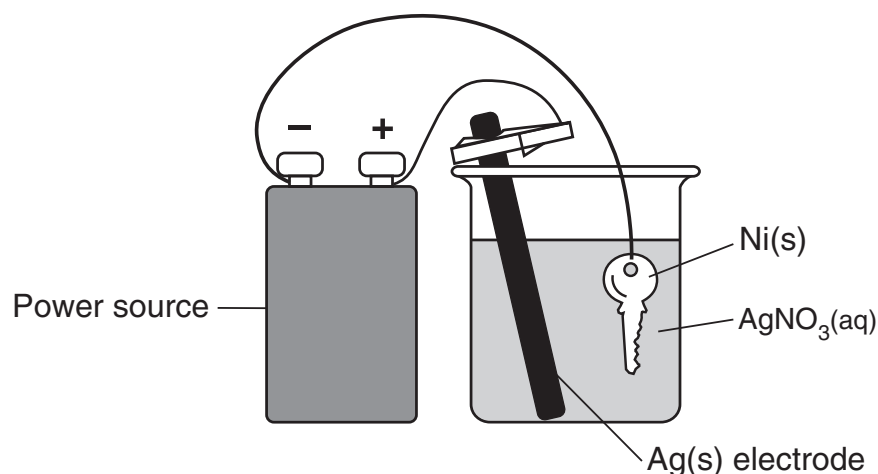Base your answers to questions 63 through 65 on the information below.

In a titration, a few drops of an indicator are added to a flask containing 35.0 milliliters of HNO_3(aq) of unknown concentration. After 30.0 milliliters of 0.15 M NaOH(aq) solution is slowly added to the flask, the indicator changes color, showing the acid is neutralized.

63 The volume of the NaOH(aq) solution is expressed to what number of significant figures? [1]

64 Complete the equation *in your answer booklet* for this neutralization reaction by writing the formula of *each* product. [1]

65 In the space *in your answer booklet,* show a numerical setup for calculating the concentration of the HNO_3(aq) solution. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry*.

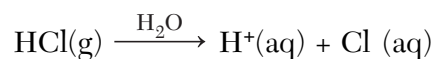Base your answers to questions 66 through 69 on the information below.

During a fireworks display, salts are heated to very high temperatures. Ions in the salts absorb energy and become excited. Spectacular colors are produced as energy is emitted from the ions in the form of light.

The color of the emitted light is characteristic of the metal ion in each salt. For example, the lithium ion in lithium carbonate, Li_2CO_3, produces a deep-red color. The strontium ion in strontium carbonate, $SrCO_3$, produces a bright-red color. Similarly, calcium chloride is used for orange light, sodium chloride for yellow light, and barium chloride for green light.

66 Write the formula for the salt used to produce green light in a fireworks display. [1]

67 Identify the *two* types of chemical bonds found in the salt used to produce a deep-red color. [1]

68 Determine the oxidation state of carbon in the salt used to produce a bright-red color. [1]

69 Explain, in terms of subatomic particles and energy states, how the colors in a fireworks display are produced. [1]

Base your answers to questions 70 and 71 on the information below.

A scientist makes a solution that contains 44.0 grams of hydrogen chloride gas, $HCl(g)$, in 200. grams of water, $H_2O(\ell)$, at 20.°C. This process is represented by the balanced equation below.

$$HCl(g) \xrightarrow{\ H_2O\ } H^+(aq) + Cl (aq)$$

70 Based on Reference Table *G*, identify, in terms of saturation, the type of solution made by the scientist. [1]

71 Explain, in terms of the distribution of particles, why the solution is a homogeneous mixture. [1]

Base your answers to questions 72 through 74 on the information below.

Iron has been used for thousands of years. In the air, iron corrodes. One reaction for the corrosion of iron is represented by the balanced equation below.

Equation 1: $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
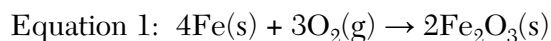
In the presence of water, iron corrodes more quickly. This corrosion is represented by the unbalanced equation below.

Equation 2: $Fe(s) + O_2(g) + H_2O(\ell) \rightarrow Fe(OH)_2(s)$
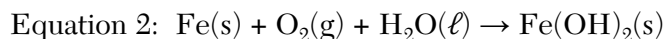
72 Identify *one* substance in the passage that can *not* be broken down by a chemical change. [1]

73 Using equation 1, describe *one* chemical property of iron. [1]

74 Balance the equation *in your answer booklet*, using the smallest whole-number coefficients. [1]

Base your answers to questions 75 through 78 on the information below.

Vitamin C, also known as ascorbic acid, is water soluble and cannot be produced by the human body. Each day, a person's diet should include a source of vitamin C, such as orange juice. Ascorbic acid has a molecular formula of $C_6H_8O_6$ and a gram-formula mass of 176 grams per mole.

75 What is the color of the indicator thymol blue after it is added to an aqueous solution of vitamin C? [1]

76 Determine the number of moles of vitamin C in an orange that contains 0.071 gram of vitamin C. [1]

77 In the space *in your answer booklet*, show a numerical setup for calculating the percent composition by mass of oxygen in ascorbic acid. [1]

78 Write the empirical formula for ascorbic acid. [1]

Base your answers to questions 79 through 81 on the information below.

Several steps are involved in the industrial production of sulfuric acid. One step involves the oxidation of sulfur dioxide gas to form sulfur trioxide gas. A catalyst is used to increase the rate of production of sulfur trioxide gas. In a rigid cylinder with a movable piston, this reaction reaches equilibrium, as represented by the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + 392 \text{ kJ}$$
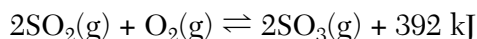
79 Explain, in terms of collision theory, why increasing the pressure of the gases in the cylinder increases the rate of the forward reaction. [1]

80 Determine the amount of heat released by the production of 1.0 mole of $SO_3(g)$. [1]

81 State, in terms of the concentration of $SO_3(g)$, what occurs when more $O_2(g)$ is added to the reaction at equilibrium. [1]

Base your answers to questions 82 through 85 on the information below.

Nuclear radiation is harmful to living cells, particularly to fast-growing cells, such as cancer cells and blood cells. An external beam of the radiation emitted from a radioisotope can be directed on a small area of a person to destroy cancer cells within the body.
Cobalt-60 is an artificially produced radioisotope that emits gamma rays and beta particles. One hospital keeps a 100.0-gram sample of cobalt-60 in an appropriate, secure storage container for future cancer treatment.

82 State *one* risk to human tissue associated with the use of radioisotopes to treat cancer. [1]

83 Compare the penetrating power of the two emissions from the Co-60. [1]

84 Complete the nuclear equation *in your answer booklet* for the beta decay of the Co-60 by writing an isotopic notation for the missing product. [1]

85 Determine the total time that will have elapsed when 12.5 grams of the original Co-60 sample at the hospital remains unchanged. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, January 24, 2013 — 1:15 to 4:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

1 Which particles have approximately the same mass?

(1) alpha particle and beta particle
(2) alpha particle and proton
(3) neutron and positron
(4) neutron and proton

2 Which phrase describes an atom?

(1) a negatively charged nucleus surrounded by positively charged protons
(2) a negatively charged nucleus surrounded by positively charged electrons
(3) a positively charged nucleus surrounded by negatively charged protons
(4) a positively charged nucleus surrounded by negatively charged electrons

3 An orbital is defined as a region of the most probable location of

(1) an electron   (3) a nucleus
(2) a neutron   (4) a proton

4 The bright-line spectrum of an element in the gaseous phase is produced as

(1) protons move from lower energy states to higher energy states
(2) protons move from higher energy states to lower energy states
(3) electrons move from lower energy states to higher energy states
(4) electrons move from higher energy states to lower energy states

5 An atom of lithium-7 has an equal number of

(1) electrons and neutrons
(2) electrons and protons
(3) positrons and neutrons
(4) positrons and protons

6 In which type of chemical reaction do two or more reactants combine to form one product, only?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

7 Which statement explains why neon is a Group 18 element?

(1) Neon is a gas at STP.
(2) Neon has a low melting point.
(3) Neon atoms have a stable valence electron configuration.
(4) Neon atoms have two electrons in the first shell.

8 Which element has chemical properties that are most similar to the chemical properties of fluorine?

(1) boron   (3) neon
(2) chlorine   (4) oxygen

9 What occurs as two atoms of fluorine combine to become a molecule of fluorine?

(1) A bond is formed as energy is absorbed.
(2) A bond is formed as energy is released.
(3) A bond is broken as energy is absorbed.
(4) A bond is broken as energy is released.

10 What is the number of pairs of electrons that are shared between the nitrogen atoms in a molecule of N_2?

(1) 1   (3) 3
(2) 2   (4) 6

11 Which set of values represents standard pressure and standard temperature?

(1) 1 atm and 101.3 K
(2) 1 kPa and 273 K
(3) 101.3 kPa and 0°C
(4) 101.3 atm and 273°C

12 Which statement about one atom of an element identifies the element?

(1) The atom has 1 proton.
(2) The atom has 2 neutrons.
(3) The sum of the number of protons and neutrons in the atom is 3.
(4) The difference between the number of neutrons and protons in the atom is 1.

13 A substance is classified as either an element or a

(1) compound
(2) solution
(3) heterogeneous mixture
(4) homogeneous mixture

14 A solid element that is malleable, a good conductor of electricity, and reacts with oxygen is classified as a

(1) metal   (3) noble gas
(2) metalloid   (4) nonmetal

15 Three forms of energy are

(1) chemical, exothermic, and temperature
(2) chemical, thermal, and electromagnetic
(3) electrical, nuclear, and temperature
(4) electrical, mechanical, and endothermic

16 What is the total amount of heat required to vaporize 1.00 gram of $H_2O(\ell)$ at 100.°C and 1 atmosphere?

(1) 4.18 J   (3) 373 J
(2) 334 J   (4) 2260 J

17 What is required for a chemical reaction to occur?

(1) standard temperature and pressure
(2) a catalyst added to the reaction system
(3) effective collisions between reactant particles
(4) an equal number of moles of reactants and products

18 Which compound is soluble in water?

(1) PbS   (3) Na_2S
(2) BaS   (4) Fe_2S_3

19 Compared to a 26-gram sample of NaCl(s) at STP, a 52-gram sample of NaCl(s) at STP has

(1) a different density
(2) a different gram-formula mass
(3) the same chemical properties
(4) the same volume

20 A gas changes directly to a solid during

(1) fusion   (3) saponification
(2) deposition   (4) decomposition

21 The phase of a sample of a molecular substance at STP is *not* determined by its

(1) arrangement of molecules
(2) intermolecular forces
(3) number of molecules
(4) molecular structure

22 Which atom has the *weakest* attraction for electrons in a chemical bond?

(1) a boron atom   (3) a fluorine atom
(2) a calcium atom   (4) a nitrogen atom

23 Which statement describes a chemical reaction at equilibrium?

(1) The products are completely consumed in the reaction.
(2) The reactants are completely consumed in the reaction.
(3) The concentrations of the products and reactants are equal.
(4) The concentrations of the products and reactants are constant.

24 Which element has atoms that can bond to each other in rings and networks?

(1) aluminum   (3) hydrogen
(2) carbon   (4) oxygen

25 In an oxidation-reduction reaction, the total number of electrons lost is
   (1) equal to the total number of electrons gained
   (2) equal to the total number of protons gained
   (3) less than the total number of electrons gained
   (4) less than the total number of protons gained

26 Which compounds are electrolytes?
   (1) C_2H_5OH and H_2SO_4
   (2) C_2H_5OH and CH_4
   (3) KOH and H_2SO_4
   (4) KOH and CH_4

27 Which compounds yield hydrogen ions as the only positive ions in an aqueous solution?
   (1) H_2CO_3 and $HC_2H_3O_2$
   (2) H_2CO_3 and $NaHCO_3$
   (3) NH_3 and $HC_2H_3O_2$
   (4) NH_3 and $NaHCO_3$

28 Nuclei of U-238 atoms are
   (1) stable and spontaneously absorb alpha particles
   (2) stable and spontaneously emit alpha particles
   (3) unstable and spontaneously absorb alpha particles
   (4) unstable and spontaneously emit alpha particles

29 Which nuclear emission has the greatest penetrating power?
   (1) proton   (3) gamma radiation
   (2) beta particle   (4) positron

30 The dating of geological formations is an example of a beneficial use of
   (1) isomers
   (2) electrolytes
   (3) organic compounds
   (4) radioactive nuclides

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 Which electron configuration represents a selenium atom in an excited state?

(1) 2-7-18-6   (3) 2-8-18-6
(2) 2-7-18-7   (4) 2-8-18-7

32 When the hydronium ion concentration of a solution is increased by a factor of 10, the pH value of the solution

(1) decreases 1 pH unit
(2) decreases 10 pH units
(3) increases 1 pH unit
(4) increases 10 pH units

33 In the formula XF_2, the element represented by X can be classified as a

(1) Group 1 metal   (3) Group 1 nonmetal
(2) Group 2 metal   (4) Group 2 nonmetal

34 Which compound has the *smallest* percent composition by mass of chlorine?

(1) HCl   (3) LiCl
(2) KCl   (4) NaCl

35 Given the incomplete equation representing a reaction:

$$2C_6H_{14} + \underline{} O_2 \rightarrow 12CO_2 + 14H_2O$$

What is the coefficient of O_2 when the equation is completely balanced using the smallest whole-number coefficients?

(1) 13   (3) 19
(2) 14   (4) 26

36 What is the oxidation number of iodine in KIO_4?

(1) +1   (3) +7
(2) −1   (4) −7

37 What is the chemical formula for zinc carbonate?

(1) $ZnCO_3$ (3) Zn_2CO_3
(2) $Zn(CO_3)_2$ (4) Zn_3CO_2

38 Which statement explains why a molecule of CH_4 is nonpolar?

(1) The bonds between the atoms in a CH_4 molecule are polar.
(2) The bonds between the atoms in a CH_4 molecule are ionic.
(3) The geometric shape of a CH_4 molecule distributes the charges symmetrically.
(4) The geometric shape of a CH_4 molecule distributes the charges asymmetrically.

39 Which atom in the ground state has the same electron configuration as a calcium ion, Ca^{2+}, in the ground state?

(1) Ar   (3) Mg
(2) K   (4) Ne

40 In the compound $KHSO_4$, there is an ionic bond between the

(1) KH^+ and $SO_4{}^{2-}$ ions
(2) $KHSO_3{}^+$ and O^{2-} ions
(3) K^+ and HS^- ions
(4) K^+ and $HSO_4{}^-$ ions

41 Given the balanced equation representing a reaction:

$$^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{15}P + ^{1}_{0}n$$
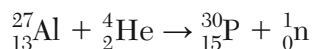
Which type of reaction is represented by this equation?

(1) combustion (3) saponification
(2) decomposition (4) transmutation

42 A 220.0-mL sample of helium gas is in a cylinder with a movable piston at 105 kPa and 275 K. The piston is pushed in until the sample has a volume of 95.0 mL. The new temperature of the gas is 310. K. What is the new pressure of the sample?

(1) 51.1 kPa (3) 243 kPa
(2) 216 kPa (4) 274 kPa

43 Given the cooling curve of a substance:
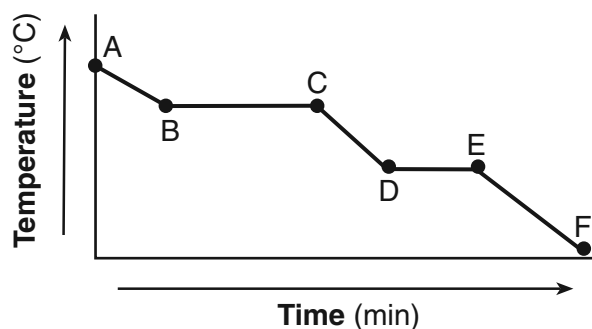
During which intervals is potential energy decreasing and average kinetic energy remaining constant?

(1) *AB* and *BC* (3) *DE* and *BC*
(2) *AB* and *CD* (4) *DE* and *EF*

44 Which metal will spontaneously react with Zn^{2+}(aq), but will *not* spontaneously react with Mg^{2+}(aq)?

(1) Mn(s) (3) Ni(s)
(2) Cu(s) (4) Ba(s)

45 Which particle diagram represents the arrangement of F_2 molecules in a sample of fluorine at 95 K and standard pressure?
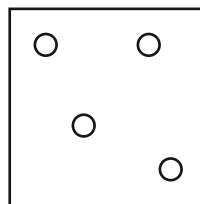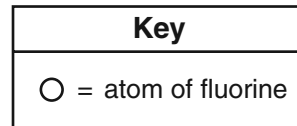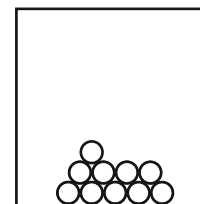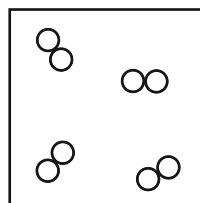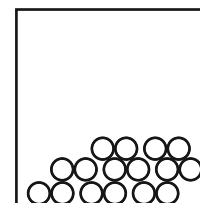
46 Given the formulas of four organic compounds:
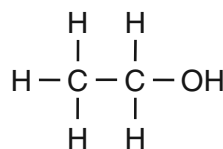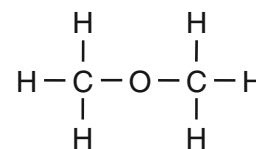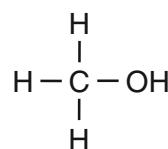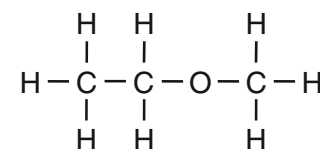
Which compounds have the same molecular formula?

(1) *A* and *B* (3) *D* and *B*
(2) *A* and *C* (4) *D* and *C*

47 Given the incomplete equation representing a reaction:

$$2Na(s) + 2H_2O(\ell) \rightarrow 2Na^+(aq) + 2\text{\_\_\_\_\_}(aq) + H_2(g)$$
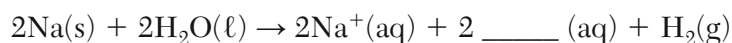
What is the formula of the missing product?

(1) O^{2-} (3) OH^-
(2) O_2 (4) OH

48 Given the equation representing a reaction where the masses are expressed in atomic mass units:

$$\text{hydrogen-2} + \text{hydrogen-1} \rightarrow \text{helium-3} + 8.814 \times 10^{-16}\text{ kJ}$$

2.014 102 u   1.007 825 u   3.016 029 u
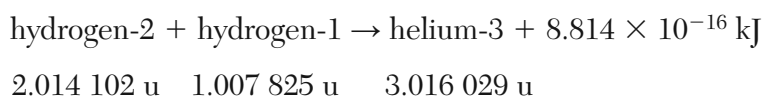
Which phrase describes this reaction?

(1) a chemical reaction and mass being converted to energy
(2) a chemical reaction and energy being converted to mass
(3) a nuclear reaction and mass being converted to energy
(4) a nuclear reaction and energy being converted to mass

49 Given the diagram representing a process being used to separate the colored dyes in food coloring:
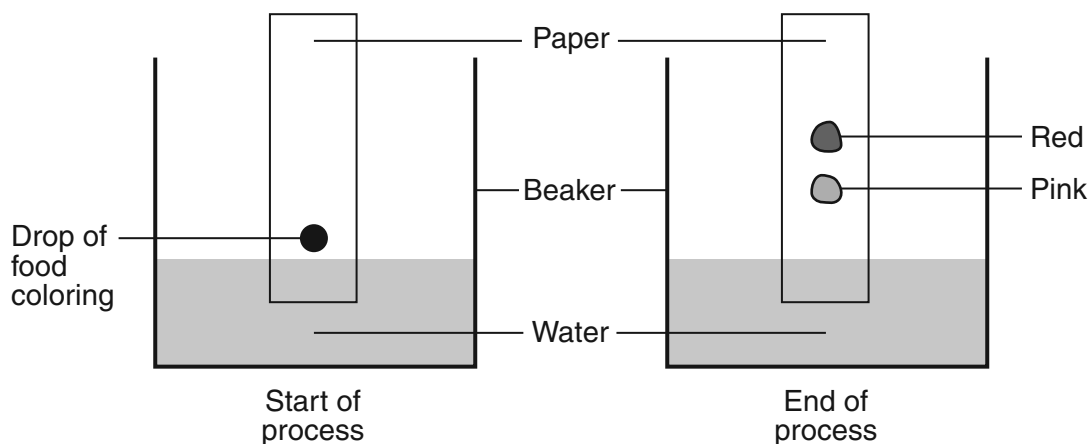
Which process is represented by this diagram?

(1) chromatography   (3) distillation
(2) electrolysis   (4) titration

50 Given the diagram representing a reaction:
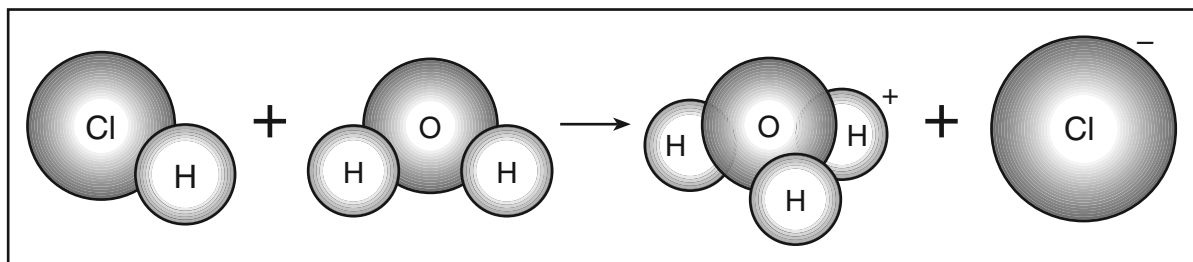
According to one acid-base theory, the water acts as

(1) a base because it accepts an H^+ (3) an acid because it accepts an H^+

(2) a base because it donates an H^+ (4) an acid because it donates an H^+

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Draw a Lewis electron-dot diagram for an atom of silicon. [1]

Base your answers to questions 52 through 54 on the information below.

The potential energy diagram and balanced equation shown below represent a reaction between solid carbon and hydrogen gas to produce 1 mole of $C_2H_4(g)$ at 101.3 kPa and 298 K.

$$2C(s) + 2H_2(g) + 52.4 \text{ kJ} \rightarrow C_2H_4(g)$$
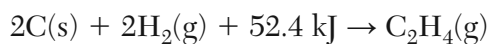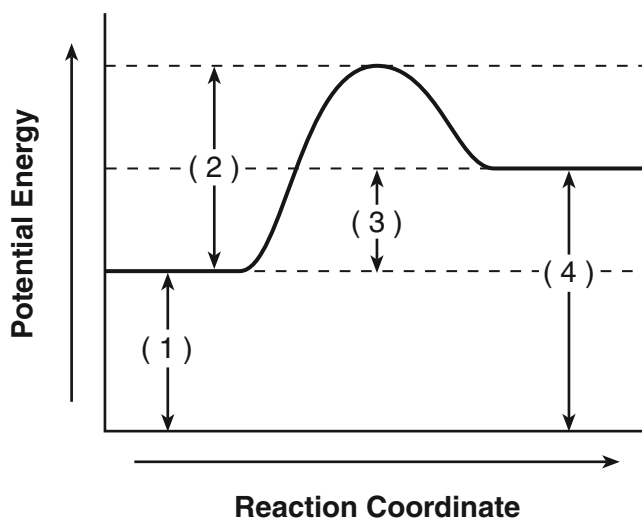
52 State what interval 3 represents. [1]

53 Determine the net amount of energy absorbed when 2.00 moles of $C_2H_4(g)$ are produced. [1]

54 Identify *one* change in the reaction conditions, other than adding a catalyst, that can increase the rate of this reaction. [1]

Base your answers to questions 55 through 58 on the information below.

The atomic number and corresponding atomic radius of the Period 3 elements are shown in the data table below.

Data Table

Atomic Number	Atomic Radius (pm)
11	160.
12	140.
13	124
14	114
15	109
16	104
17	100.
18	101

55 On the grid *in your answer booklet*, mark an appropriate scale on the axis labeled "Atomic Radius (pm)." [1]

56 On the grid *in your answer booklet*, plot the data from the data table. Circle and connect the points. [1]

57 State the general relationship between the atomic number and the atomic radius for the Period 3 elements. [1]

58 Explain, in terms of electrons, the change in radius when a sodium atom becomes a sodium ion. [1]

Base your answers to questions 59 through 61 on the information below.

The equation below represents the reaction between 1-butene and bromine to form the compound 1,2-dibromobutane, $C_4H_8Br_2$.

$$
\begin{array}{c}
\text{H} \quad \text{H} \quad \text{H} \\
| \quad | \quad | \\
\text{H}-\text{C}=\text{C}-\text{C}-\text{C}-\text{H} \quad + \quad Br_2 \quad \longrightarrow \\
| \quad\quad | \quad | \\
\text{H} \quad\quad \text{H} \quad \text{H}
\end{array}
\qquad
\begin{array}{c}
\text{Br} \quad \text{H} \quad \text{H} \quad \text{H} \\
| \quad | \quad | \quad | \\
\text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\
| \quad | \quad | \quad | \\
\text{H} \quad \text{Br} \quad \text{H} \quad \text{H}
\end{array}
$$
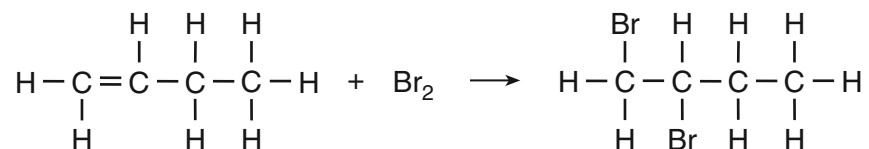
59 Explain, in terms of bonding, why the hydrocarbon reactant is an unsaturated hydrocarbon. [1]

60 Determine the gram-formula mass of 1-butene. [1]

61 Write the empirical formula for the product. [1]

_____

Base your answers to questions 62 through 65 on the information below.

Ammonium chloride is dissolved in water to form a 0.10 M $NH_4Cl(aq)$ solution. This dissolving process is represented by the equation below.

$$ NH_4Cl(s) + heat \xrightarrow{\text{H}_2\text{O}} NH_4^+(aq) + Cl^-(aq) $$
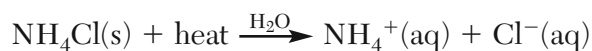
62 Determine the number of moles of $NH_4Cl(s)$ used to produce 2.0 liters of this solution. [1]

63 State evidence that indicates the dissolving of ammonium chloride is an endothermic process. [1]

64 Explain, in terms of ions, why a 10.0-milliliter sample of 0.30 M $NH_4Cl(aq)$ is a better conductor of electricity than a 10.0-milliliter sample of the 0.10 M $NH_4Cl(aq)$. [1]

65 Determine the minimum mass of $NH_4Cl(s)$ required to produce a saturated solution in 100. grams of water at 40.°C. [1]

_____

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below.

Nitrogen gas and oxygen gas make up about 99% of Earth's atmosphere. Other atmospheric gases include argon, carbon dioxide, methane, ozone, hydrogen, etc.

The amount of carbon dioxide in the atmosphere can vary. Data for the concentration of CO_2(g) from 1960 to 2000 are shown in the table below.

Atmospheric Concentration of CO_2(g)

Year	Concentration (ppm)
1960	316.9
1980	338.7
2000	369.4

66 Identify *one* diatomic element found in the atmosphere. [1]

67 Explain, in terms of types of matter, why methane can be broken down by chemical means, but argon can *not* be broken down by chemical means. Your response must include *both* methane and argon. [1]

68 Show a numerical setup for calculating the mass of carbon dioxide in a 100.0-gram sample of air taken in 1980. [1]

69 Explain why the atmosphere is classified as a mixture. [1]

Base your answers to questions 70 through 72 on the information below.

Metallic elements are obtained from their ores by reduction. Some metals, such as zinc, lead, iron, and copper, can be obtained by heating their oxides with carbon.

More active metals, such as aluminum, magnesium, and sodium, can *not* be reduced by carbon. These metals can be obtained by the electrolysis of their molten (melted) ores. The diagram below represents an incomplete cell for the electrolysis of molten NaCl. The equation below represents the reaction that occurs when the completed cell operates.

$$2NaCl(\ell) \rightarrow 2Na(\ell) + Cl_2(g)$$
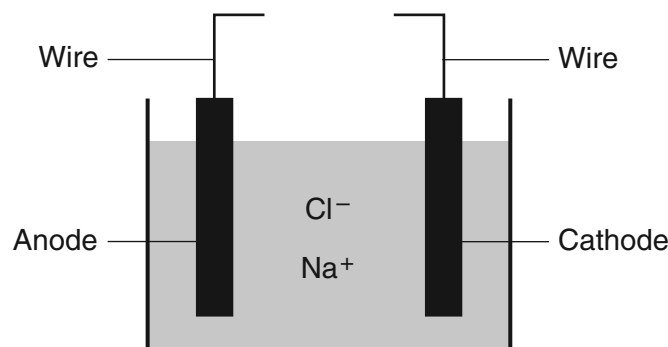
70 Identify the component required for the electrolysis of molten NaCl that is missing from the cell diagram.   [1]

71 Identify *one* metal from the passage that is more active than carbon and *one* metal from the passage that is *less* active than carbon.   [1]

72 Write a balanced half-reaction equation for the reduction of the iron ions in iron(III) oxide to iron atoms.   [1]

Base your answers to questions 73 through 76 on the information below.

The element boron, a trace element in Earth's crust, is found in foods produced from plants. Boron has only two naturally occurring stable isotopes, boron-10 and boron-11.

73 Compare the abundance of the two naturally occurring isotopes of boron.   [1]

74 Write an isotopic notation of the heavier isotope of the element boron. Your response must include the atomic number, the mass number, and the symbol of this isotope.   [1]

75 State, in terms of subatomic particles, *one* difference between the nucleus of a carbon-11 atom and the nucleus of a boron-11 atom.   [1]

76 One sample of a green vegetable contains 0.0035 gram of boron. Determine the total number of moles of boron in this sample.   [1]

Base your answers to questions 77 through 79 on the information below.

The active ingredient in the pain reliever aspirin is acetylsalicylic acid. This compound can be produced by reacting salicylic acid with acetic acid. The label of one aspirin bottle indicates that the accepted mass of acetylsalicylic acid in each tablet is 325 milligrams.

In a laboratory, an aspirin tablet is crushed and mixed with water to dissolve all of the acetylsalicylic acid. The measured pH of the resulting solution is 3.0.

77 Write the chemical formula for the acetic acid. [1]

78 State the color of methyl orange indicator after the indicator is placed in the solution. [1]

79 The mass of acetylsalicylic acid in one aspirin tablet is determined to be 320. milligrams. Show a numerical setup for calculating the percent error for the mass of acetylsalicylic acid in this aspirin tablet. [1]

Base your answers to questions 80 through 82 on the information below.

A student investigated heat transfer using a bottle of water. The student placed the bottle in a room at 20.5°C. The student measured the temperature of the water in the bottle at 7 a.m. and again at 3 p.m. The data from the investigation are shown in the table below.

Water Bottle Investigation Data

7 a.m.		3 p.m.	
Mass of Water (g)	Temperature (°C)	Mass of Water (g)	Temperature (°C)
800.	12.5	800.	20.5

80 Compare the average kinetic energy of the water molecules in the bottle at 7 a.m. to the average kinetic energy of the water molecules in the bottle at 3 p.m. [1]

81 State the direction of heat transfer between the surroundings and the water in the bottle from 7 a.m. to 3 p.m. [1]

82 Show a numerical setup for calculating the change in the thermal energy of the water in the bottle from 7 a.m. to 3 p.m. [1]

Base your answers to questions 83 through 85 on the information below.

In one method of making bread, starch is broken down into glucose. Zymase, an enzyme present in yeast, acts as a catalyst for the reaction in which the glucose reacts to produce ethanol and carbon dioxide. The carbon dioxide gas causes the bread dough to rise. The balanced equation below represents the catalyzed reaction.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{zymase}} 2CH_3CH_2OH(aq) + 2CO_2(g)$$

83 Identify the type of organic reaction represented by this equation. [1]

84 Identify the functional group in an ethanol molecule. [1]

85 State how the catalyst, zymase, increases the rate of this reaction. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, January 29, 2014 — 1:15 to 4:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

1 What is the approximate mass of a proton?
(1) 1 u
(3) 1 g
(2) 0.0005 u
(4) 0.0005 g

2 An electron in a sodium atom gains enough energy to move from the second shell to the third shell. The sodium atom becomes
(1) a positive ion
(2) a negative ion
(3) an atom in an excited state
(4) an atom in the ground state

3 Which particle has *no* charge?
(1) electron
(3) positron
(2) neutron
(4) proton

4 Which quantity represents the number of protons in an atom?
(1) atomic number
(2) oxidation number
(3) number of neutrons
(4) number of valence electrons

5 The element sulfur is classified as a
(1) metal
(3) nonmetal
(2) metalloid
(4) noble gas

6 The elements in Group 2 have similar chemical properties because each atom of these elements has the same
(1) atomic number
(2) mass number
(3) number of electron shells
(4) number of valence electrons

7 What is formed when two atoms of bromine bond together?
(1) a monatomic molecule
(2) a diatomic molecule
(3) a heterogeneous mixture
(4) a homogeneous mixture

8 Gold can be flattened into an extremely thin sheet. The malleability of gold is due to the
(1) radioactive decay mode of the isotope Au-198
(2) proton-to-neutron ratio in an atom of gold
(3) nature of the bonds between gold atoms
(4) reactivity of gold atoms

9 Which term represents the attraction one atom has for the electrons in a bond with another atom?
(1) electronegativity
(2) electrical conductivity
(3) first ionization energy
(4) mechanical energy

10 Salt water is classified as a
(1) compound because the proportion of its atoms is fixed
(2) compound because the proportion of its atoms can vary
(3) mixture because the proportion of its components is fixed
(4) mixture because the proportion of its components can vary

11 Which substance can *not* be broken down by a chemical change?
(1) ammonia
(3) ethane
(2) arsenic
(4) propanal

12 Some physical properties of two samples of iodine-127 at two different temperatures are shown in the table below.

Selected Physical Properties of Iodine-127 Samples at 1 atm

Sample	Sample Temperature (K)	Description	Density (g/cm³)
1	298	dark-gray crystals	4.933
2	525	dark-purple gas	0.006

These two samples are two different

(1) mixtures
(2) substances

(3) phases of matter
(4) isotopes of iodine

13 Powdered iron is magnetic, but powdered sulfur is *not*. What occurs when they form a mixture in a beaker at room temperature?

(1) The iron retains its magnetic properties.
(2) The iron loses its metallic properties.
(3) The sulfur gains magnetic properties.
(4) The sulfur gains metallic properties.

14 Which property is a measure of the average kinetic energy of the particles in a sample of matter?

(1) mass   (3) pressure
(2) density   (4) temperature

15 According to the kinetic molecular theory, which statement describes the particles of an ideal gas?

(1) The gas particles are arranged in a regular pattern.
(2) The force of attraction between the gas particles is strong.
(3) The gas particles are hard spheres in continuous circular motion.
(4) The collisions of the gas particles may result in the transfer of energy.

16 The concentration of a solution can be expressed in

(1) milliliters per minute
(2) parts per million
(3) grams per kelvin
(4) joules per gram

17 Two hydrogen atoms form a hydrogen molecule when

(1) one atom loses a valence electron to the other atom
(2) one atom shares four electrons with the other atom
(3) the two atoms collide and both atoms gain energy
(4) the two atoms collide with sufficient energy to form a bond

18 Which type of formula represents the simplest whole-number ratio of atoms of the elements in a compound?

(1) molecular formula   (3) empirical formula
(2) condensed formula   (4) structural formula

19 The coefficients in a balanced chemical equation represent

(1) the mass ratios of the substances in the reaction
(2) the mole ratios of the substances in the reaction
(3) the total number of electrons in the reaction
(4) the total number of elements in the reaction

20 Systems in nature tend to undergo changes toward

(1) lower energy and higher entropy
(2) lower energy and lower entropy
(3) higher energy and higher entropy
(4) higher energy and lower entropy

21 Which formula represents an organic compound?

(1) CaH_2 (3) H_2O_2

(2) C_4H_8 (4) P_2O_5

22 Which class of organic compounds contains nitrogen?

(1) aldehyde   (3) amine

(2) alcohol   (4) ether

23 Which term identifies a type of organic reaction?

(1) deposition   (3) esterification

(2) distillation   (4) sublimation

24 Which compound is classified as a hydrocarbon?

(1) butanal   (3) 2-butanol

(2) butyne   (4) 2-butanone

25 In an oxidation-reduction reaction, the number of electrons lost is

(1) equal to the number of electrons gained

(2) equal to the number of protons gained

(3) less than the number of electrons gained

(4) less than the number of protons gained

26 Which substance is an electrolyte?

(1) $C_6H_{12}O_6(s)$ (3) $NaOH(s)$

(2) $C_2H_5OH(\ell)$ (4) $H_2(g)$

27 Which energy conversion must occur in an operating electrolytic cell?

(1) electrical energy to chemical energy

(2) electrical energy to nuclear energy

(3) chemical energy to electrical energy

(4) chemical energy to nuclear energy

28 Which compound yields H^+ ions as the only positive ions in an aqueous solution?

(1) KOH   (3) CH_3OH

(2) NaOH   (4) CH_3COOH

29 Which statement describes the relative masses of two different particles?

(1) A neutron has less mass than a positron.

(2) A beta particle has less mass than a neutron.

(3) An alpha particle has less mass than a positron.

(4) An alpha particle has less mass than a beta particle.

30 Which term represents a type of nuclear reaction?

(1) condensation

(2) vaporization

(3) single replacement

(4) natural transmutation

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which ion has the *smallest* radius?

  (1) O^{2-} (3) Se^{2-}

  (2) S^{2-} (4) Te^{2-}

32 Equal amounts of ethanol and water are mixed at room temperature and at 101.3 kPa. Which process is used to separate ethanol from the mixture?

  (1) distillation   (3) filtration

  (2) reduction   (4) ionization

33 A sample of a substance has these characteristics:

- melting point of 984 K
- hard, brittle solid at room temperature
- poor conductor of heat and electricity as a solid
- good conductor of electricity as a liquid or in an aqueous solution

This sample is classified as

  (1) a metallic element

  (2) a radioactive element

  (3) a molecular compound

  (4) an ionic compound

34 Given the balanced equation representing a reaction:

$$N_2 + energy \rightarrow N + N$$

Which statement describes this reaction?

  (1) Bonds are broken, and the reaction is endothermic.

  (2) Bonds are broken, and the reaction is exothermic.

  (3) Bonds are formed, and the reaction is endothermic.

  (4) Bonds are formed, and the reaction is exothermic.

35 When lithium reacts with bromine to form the compound LiBr, each lithium atom

  (1) gains one electron and becomes a negatively charged ion

  (2) gains three electrons and becomes a negatively charged ion

  (3) loses one electron and becomes a positively charged ion

  (4) loses three electrons and becomes a positively charged ion

36 A beaker with water and the surrounding air are all at 24°C. After ice cubes are placed in the water, heat is transferred from

  (1) the ice cubes to the air

  (2) the beaker to the air

  (3) the water to the ice cubes

  (4) the water to the beaker

37 A sample of chlorine gas is at 300. K and 1.00 atmosphere. At which temperature and pressure would the sample behave more like an ideal gas?

  (1) 0 K and 1.00 atm

  (2) 150. K and 0.50 atm

  (3) 273 K and 1.00 atm

  (4) 600. K and 0.50 atm

38 When a sample of a gas is heated in a sealed, rigid container from 200. K to 400. K, the pressure exerted by the gas is

  (1) decreased by a factor of 2

  (2) increased by a factor of 2

  (3) decreased by a factor of 200.

  (4) increased by a factor of 200.

39 The bright-line spectra produced by four elements are represented in the diagram below.
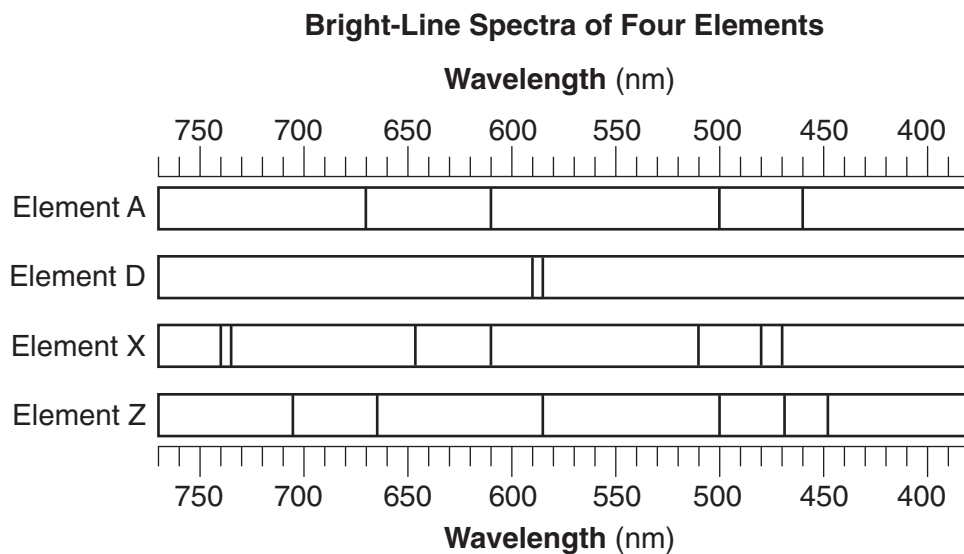
Bright-Line Spectra of Four Elements

Wavelength (nm)

| 750 | 700 | 650 | 600 | 550 | 500 | 450 | 400 |

Element A

Element D

Element X

Element Z

| 750 | 700 | 650 | 600 | 550 | 500 | 450 | 400 |

Wavelength (nm)

Given the bright-line spectrum of a mixture formed from two of these elements:

| 750 | 700 | 650 | 600 | 550 | 500 | 450 | 400 |

Wavelength (nm)
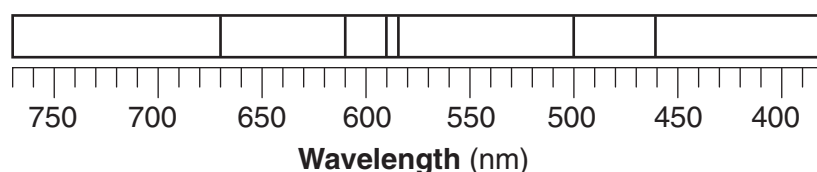
Which elements are present in this mixture?

(1) *A* and *D*   (3) *Z* and *D*
(2) *A* and *X*   (4) *Z* and *X*

40 The graph below represents the relationship between time and temperature as heat is added at a constant rate to a sample of a substance.
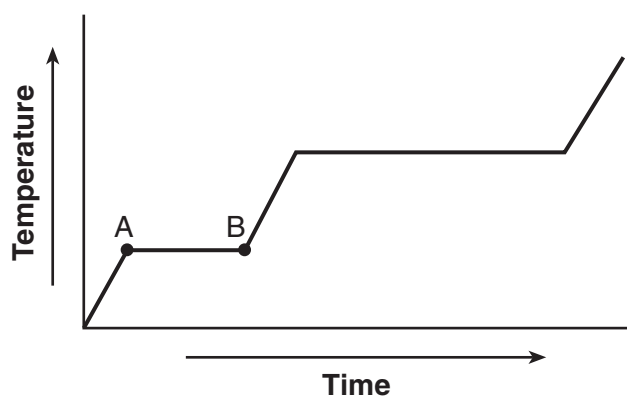
During interval *AB*, which energy change occurs for the particles in this sample?

(1) The potential energy of the particles increases.
(2) The potential energy of the particles decreases.
(3) The average kinetic energy of the particles increases.
(4) The average kinetic energy of the particles decreases.

41 Given the potential energy diagram for a reversible chemical reaction:

Reaction Coordinate
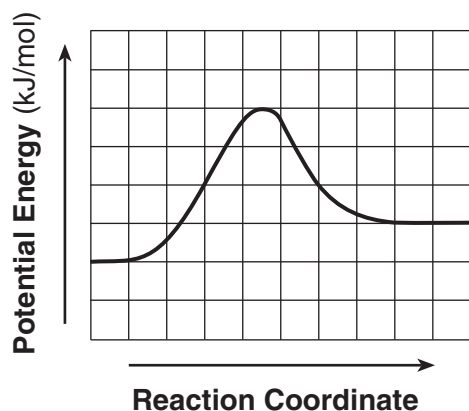
Each interval on the axis labeled "Potential Energy (kJ/mol)" represents 10. kilojoules per mole. What is the activation energy of the forward reaction?

(1) 10. kJ/mol   (3) 40. kJ/mol
(2) 30. kJ/mol   (4) 60. kJ/mol

42 Which condensed structural formula represents an unsaturated compound?

(1) $CH_3CHCHCH_3$ (3) CH_3CH_3
(2) $CH_3CH_2CH_3$ (4) CH_4

43 Which element reacts spontaneously with 1.0 M HCl(aq) at room temperature?

(1) copper   (3) silver
(2) gold   (4) zinc

44 Given the balanced ionic equation:

$$3Pb^{2+}(aq) + 2Cr(s) \rightarrow 3Pb(s) + 2Cr^{3+}(aq)$$

What is the number of moles of electrons gained by 3.0 moles of lead ions?

(1) 5.0 mol   (3) 3.0 mol
(2) 2.0 mol   (4) 6.0 mol

45 What is the amount of heat energy released when 50.0 grams of water is cooled from 20.0°C to 10.0°C?
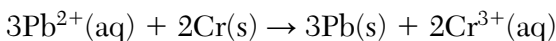
(1) 5.00×10^2 J   (3) 1.67×10^5 J
(2) 2.09×10^3 J   (4) 1.13×10^6 J

46 What occurs at one of the electrodes in both an electrolytic cell and a voltaic cell?

(1) Oxidation occurs as electrons are gained at the cathode.
(2) Oxidation occurs as electrons are lost at the anode.
(3) Reduction occurs as electrons are gained at the anode.
(4) Reduction occurs as electrons are lost at the cathode.

47 Given the balanced equation representing a reaction:

$$H_2O(\ell) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$$
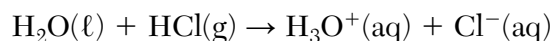
According to one acid-base theory, the $H_2O(\ell)$ molecules

(1) accept H^+ ions   (3) donate H^+ ions
(2) accept OH^- ions   (4) donate OH^- ions

48 When an atom of the unstable isotope Na-24 decays, it becomes an atom of Mg-24 because the Na-24 atom spontaneously releases

(1) an alpha particle   (3) a neutron
(2) a beta particle   (4) a positron

49 Which balanced equation represents nuclear fusion?

(1) $^3_1H \rightarrow {}^3_2He + {}^0_{-1}e$
(2) $^{235}_{92}U \rightarrow {}^{231}_{90}Th + {}^4_2He$
(3) $^2_1H + {}^2_1H \rightarrow {}^4_2He$
(4) $^{235}_{92}U + {}^1_0n \rightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + 3{}^1_0n$

50 Which reaction releases the greatest amount of energy per kilogram of reactants?

(1) $^1_0n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^1_0n$
(2) $2C + H_2 \rightarrow C_2H_2$
(3) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$
(4) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 51 through 54 on the information below and on your knowledge of chemistry.

The diagram below represents three elements in Group 13 and three elements in Period 3 and their relative positions on the Periodic Table.

Al	Si	P
Ga		
In		

Some elements in the solid phase exist in different forms that vary in their physical properties. For example, at room temperature, red phosphorus has a density of 2.16 g/cm^3 and white phosphorus has a density of 1.823 g/cm^3.

51 Identify the element from the diagram that will react with chlorine to form a compound with the general formula XCl_4. [1]

52 Consider the Period 3 elements in the diagram in order of increasing atomic number. State the trend in electronegativity for these elements. [1]

53 Compare the number of atoms per cubic centimeter in red phosphorus with the number of atoms per cubic centimeter in white phosphorus. [1]

54 Identify *one* element from the diagram that will combine with phosphorus in the same ratio of atoms as the ratio in aluminum phosphide. [1]

Base your answers to questions 55 through 57 on the information below and on your knowledge of chemistry.

The compounds KNO_3 and $NaNO_3$ are soluble in water.

55 Compare the entropy of 30. grams of solid KNO_3 at 20.°C with the entropy of 30. grams of KNO_3 dissolved in 100. grams of water at 20.°C. [1]

56 Explain why the total thermal energy of a sample containing 22.2 grams of $NaNO_3$ dissolved in 200. grams of water at 20.°C is greater than the total thermal energy of a sample containing 11.1 grams of $NaNO_3$ dissolved in 100. grams of water at 20.°C. [1]

57 Compare the boiling point of a $NaNO_3$ solution at standard pressure to the boiling point of water at standard pressure. [1]

Base your answers to questions 58 through 61 on the information below and on your knowledge of chemistry.

Ethene and hydrogen can react at a faster rate in the presence of the catalyst platinum. The equation below represents a reaction between ethene and hydrogen.
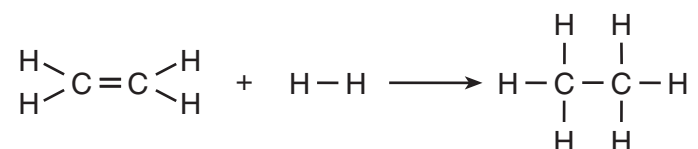
58 Determine the molar mass of the product. [1]

59 State the number of electrons shared between the carbon atoms in one molecule of the reactant ethene. [1]

60 Explain, in terms of activation energy, why the catalyzed reaction occurs at a faster rate. [1]

61 Explain why the reaction is classified as an addition reaction. [1]

Base your answers to questions 62 and 63 on the information below and on your knowledge of chemistry.

   In a titration, 50.0 milliliters of 0.026 M HCl(aq) is neutralized by 38.5 milliliters of KOH(aq).

62 In the space *in your answer booklet*, show a numerical setup for calculating the molarity of the KOH(aq).   [1]

63 Complete the equation *in your answer booklet* for the neutralization by writing the formula of the missing product.   [1]

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

   Table sugar, sucrose, is a combination of two simple sugars, glucose and fructose. The formulas below represent these simple sugars.

$$
\begin{array}{cc}
\begin{array}{c}
\mathrm{O} \\
\parallel \\
\mathrm{H-C} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{HO-C-H} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{H}
\end{array}
&
\begin{array}{c}
\mathrm{H} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{C=O} \\
| \\
\mathrm{HO-C-H} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{H-C-OH} \\
| \\
\mathrm{H}
\end{array} \\
\text{Glucose} & \text{Fructose}
\end{array}
$$
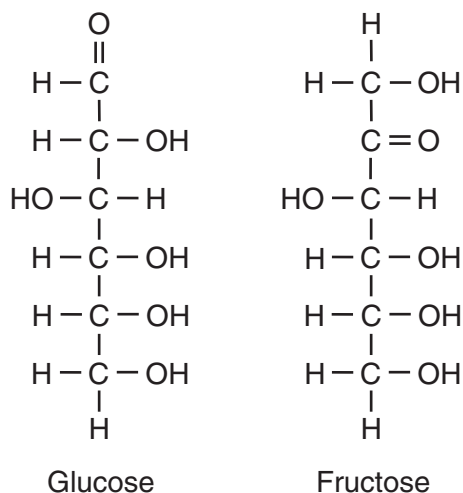
64 Identify the functional group that appears more than once in the fructose molecule.   [1]

65 Explain, in terms of atoms and molecular structure, why glucose and fructose are isomers of each other.   [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 70 on the information below and on your knowledge of chemistry.

Baking soda, $NaHCO_3$, can be commercially produced during a series of chemical reactions called the Solvay process. In this process, $NH_3(aq)$, $NaCl(aq)$, and other chemicals are used to produce $NaHCO_3(s)$ and $NH_4Cl(aq)$.

To reduce production costs, $NH_3(aq)$ is recovered from $NH_4Cl(aq)$ through a different series of reactions. This series of reactions can be summarized by the overall reaction represented by the unbalanced equation below.

$$NH_4Cl(aq) + CaO(s) \rightarrow NH_3(aq) + H_2O(\ell) + CaCl_2(aq)$$
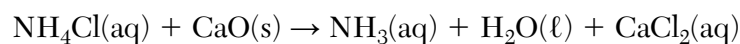
66 Write a chemical name for baking soda. [1]

67 Determine the percent composition by mass of carbon in baking soda (gram-formula mass = 84 grams per mole). [1]

68 State the color of bromcresol green in a sample of $NH_3(aq)$. [1]

69 Determine the mass of NH_4Cl that must be dissolved in 100. grams of H_2O to produce a saturated solution at 70.°C. [1]

70 Balance the equation *in your answer booklet* for the overall reaction used to recover $NH_3(aq)$, using the smallest whole-number coefficients. [1]

Base your answers to questions 71 through 75 on the information below and on your knowledge of chemistry.

   Rubbing alcohol is a product available at most pharmacies and supermarkets. One rubbing alcohol solution contains 2-propanol and water. The boiling point of 2-propanol is 82.3°C at standard pressure.

71 Explain, in terms of electronegativity differences, why a $C-O$ bond is more polar than a $C-H$ bond.   [1]

72 Identify a strong intermolecular force of attraction between an alcohol molecule and a water molecule in the solution.   [1]

73 Determine the vapor pressure of water at a temperature equal to the boiling point of the 2-propanol.   [1]

74 Explain, in terms of charge distribution, why a molecule of the 2-propanol is a polar molecule.   [1]

75 In the space *in your answer booklet*, draw a structural formula for the 2-propanol.   [1]

Base your answers to questions 76 and 77 on the information below and on your knowledge of chemistry.

   Silver-plated utensils were popular before stainless steel became widely used to make eating utensils. Silver tarnishes when it comes in contact with hydrogen sulfide, H_2S, which is found in the air and in some foods. However, stainless steel does *not* tarnish when it comes in contact with hydrogen sulfide.

76 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for the compound that tarnishes silver.   [1]

77 In the ground state, an atom of which noble gas has the same electron configuration as the sulfide ion in Ag_2S?   [1]

Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

Common household bleach is an aqueous solution containing hypochlorite ions. A closed container of bleach is an equilibrium system represented by the equation below.

$$Cl_2(g) + 2OH^-(aq) \rightleftharpoons ClO^-(aq) + Cl^-(aq) + H_2O(\ell)$$

78 Compare the rate of the forward reaction to the rate of the reverse reaction for this system. [1]

79 State the change in oxidation number for chlorine when the $Cl_2(g)$ changes to $Cl^-(aq)$ during the forward reaction. [1]

80 Explain why the container must be closed to maintain equilibrium. [1]

81 State the effect on the concentration of the ClO^- ion when there is a *decrease* in the concentration of the OH^- ion. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

Iodine has many isotopes, but only iodine-127 is stable and is found in nature. One radioactive iodine isotope, I-108, decays by alpha particle emission. Iodine-131 is also radioactive and has many important medical uses.

82 Determine the number of neutrons in an atom of I-127. [1]

83 Explain, in terms of protons and neutrons, why I-127 and I-131 are different isotopes of iodine. [1]

84 Complete the equation *in your answer booklet* for the nuclear decay of I-108. [1]

85 Determine the total time required for an 80.0-gram sample of I-131 to decay until only 1.25 grams of the sample remains unchanged. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, January 28, 2015 — 1:15 to 4:15 p.m., only

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 According to the modern model of the atom, the nucleus of an atom is surrounded by one or more

(1) electrons   (3) positrons
(2) neutrons   (4) protons

2 Which particle has a mass of approximately 1 atomic mass unit?

(1) an alpha particle   (3) an electron
(2) a beta particle   (4) a neutron

3 A specific amount of energy is emitted when excited electrons in an atom in a sample of an element return to the ground state. This emitted energy can be used to determine the

(1) mass of the sample
(2) volume of the sample
(3) identity of the element
(4) number of moles of the element

4 According to the wave-mechanical model, an orbital is defined as the

(1) circular path for electrons
(2) circular path for neutrons
(3) most probable location of electrons
(4) most probable location of neutrons

5 All phosphorus atoms have the same

(1) atomic number
(2) mass number
(3) number of neutrons plus the number of electrons
(4) number of neutrons plus the number of protons

6 At STP, which element is a good conductor of electricity?

(1) chlorine   (3) silver
(2) iodine   (4) sulfur

7 Which phrase describes the molecular structure and properties of two solid forms of carbon, diamond and graphite?

(1) the same molecular structures and the same properties
(2) the same molecular structures and different properties
(3) different molecular structures and the same properties
(4) different molecular structures and different properties

8 Which quantity is equal to one mole of Au?

(1) the atomic mass in grams
(2) the atomic number in grams
(3) the mass of neutrons in grams
(4) the number of neutrons in grams

9 Given the balanced equation representing the reaction between methane and oxygen:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

According to this equation, what is the mole ratio of oxygen to methane?

(1) $\dfrac{1 \text{ gram O}_2}{2 \text{ grams CH}_4}$ (3) $\dfrac{2 \text{ grams O}_2}{1 \text{ gram CH}_4}$

(2) $\dfrac{1 \text{ mole O}_2}{2 \text{ moles CH}_4}$ (4) $\dfrac{2 \text{ moles O}_2}{1 \text{ mole CH}_4}$

10 Which list includes three types of chemical reactions?

(1) decomposition, single replacement, and solidification
(2) decomposition, single replacement, and double replacement
(3) solidification, double replacement, and decomposition
(4) solidification, double replacement, and single replacement

11 Which compound has the greatest percent composition by mass of sulfur?

(1) BaS   (3) MgS
(2) CaS   (4) SrS

12 Two molecules of HBr collide and then form H_2 and Br_2. During the collision, the bonds in the HBr molecules are

(1) broken as energy is absorbed
(2) broken as energy is released
(3) formed as energy is absorbed
(4) formed as energy is released

13 Which atom in the ground state has a stable electron configuration?

(1) carbon   (3) neon
(2) magnesium   (4) oxygen

14 Which statement describes a multiple covalent bond?

(1) Two electrons are shared.
(2) Four electrons are shared.
(3) Two electrons are transferred.
(4) Four electrons are transferred.

15 The electronegativity difference between the atoms in a molecule of HCl can be used to determine

(1) the entropy of the atoms
(2) the atomic number of the atoms
(3) the first ionization energy of the atoms
(4) the polarity of the bond between the two atoms

16 Which two gases can *not* be broken down by chemical means?

(1) CO and He   (3) Xe and He
(2) CO and NH_3 (4) Xe and NH_3

17 Two substances in a mixture differ in density and particle size. These properties can be used to

(1) separate the substances
(2) chemically combine the substances
(3) determine the freezing point of the mixture
(4) predict the electrical conductivity of the mixture

18 Which unit is used to express an amount of thermal energy?

(1) gram   (3) joule
(2) mole   (4) pascal

19 Under which conditions of temperature and pressure does a real gas behave most like an ideal gas?

(1) low temperature and low pressure
(2) low temperature and high pressure
(3) high temperature and low pressure
(4) high temperature and high pressure

20 According to the kinetic molecular theory for an ideal gas, all gas particles

(1) are in random, constant, straight-line motion
(2) are separated by very small distances relative to their sizes
(3) have strong intermolecular forces
(4) have collisions that decrease the total energy of the system

21 Which mathematical expression represents the heat of reaction for a chemical reaction?

(1) (the heat of fusion) – (the heat of vaporization)
(2) (the heat of vaporization) – (the heat of fusion)
(3) (the potential energy of the products) – (the potential energy of the reactants)
(4) (the potential energy of the reactants) – (the potential energy of the products)

22 At 101.3 kPa and 298 K, a 1.0-mole sample of which compound absorbs the greatest amount of heat as the entire sample dissolves in water?

(1) LiBr   (3) NaOH
(2) NaCl   (4) NH_4Cl

23 For a reaction at equilibrium, which change can increase the rates of the forward and reverse reactions?

(1) a decrease in the concentration of the reactants
(2) a decrease in the surface area of the products
(3) an increase in the temperature of the system
(4) an increase in the activation energy of the forward reaction

24 Which reaction produces ethanol?

(1) combustion   (3) fermentation
(2) esterification   (4) polymerization

25 The chemical process in which electrons are gained by an atom or an ion is called

(1) addition   (3) reduction
(2) oxidation   (4) substitution

26 Which process occurs in an operating voltaic cell?

(1) Electrical energy is converted to chemical energy.
(2) Chemical energy is converted to electrical energy.
(3) Oxidation takes place at the cathode.
(4) Reduction takes place at the anode.

27 What can be explained by the Arrhenius theory?

(1) the behavior of many acids and bases
(2) the effect of stress on a phase equilibrium
(3) the operation of an electrochemical cell
(4) the spontaneous decay of some nuclei

28 According to one acid-base theory, a water molecule acts as an acid when the molecule

(1) donates an H^+ ion
(2) accepts an H^+ ion
(3) donates an OH^- ion
(4) accepts an OH^- ion

29 Positrons and beta particles have

(1) the same charge and the same mass
(2) the same charge and different masses
(3) different charges and the same mass
(4) different charges and different masses

30 Which term identifies a type of nuclear reaction?

(1) transmutation   (3) deposition
(2) neutralization   (4) reduction

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 What is the number of electrons in an Al^{3+} ion?

(1) 10   (3) 3
(2) 13   (4) 16

32 The valence electron of which atom in the ground state has the greatest amount of energy?

(1) cesium   (3) rubidium
(2) lithium   (4) sodium

33 The numbers of protons and neutrons in each of four different atoms are shown in the table below.

Protons and Neutrons in Four Different Atoms

Atom	Number of Protons	Number of Neutrons
A	8	8
D	9	9
E	9	10
G	10	10

Which two atoms represent isotopes of the same element?

(1) *A* and *D*   (3) *E* and *D*
(2) *A* and *G*   (4) *E* and *G*

34 Which elements have the most similar chemical properties?

(1) boron and carbon
(2) oxygen and sulfur
(3) aluminum and bromine
(4) argon and silicon

35 Which element reacts with oxygen to form ionic bonds?

(1) calcium   (3) chlorine
(2) hydrogen   (4) nitrogen

36 The table below gives the atomic mass and the abundance of the two naturally occurring isotopes of chlorine.

Naturally Occurring Isotopes of Chlorine

Isotopes	Atomic Mass of the Isotope (u)	Natural Abundance (%)
^{35}Cl	34.97	75.76
^{37}Cl	36.97	24.24

Which numerical setup can be used to calculate the atomic mass of the element chlorine?

(1) (34.97 u)(75.76) + (36.97 u)(24.24)
(2) (34.97 u)(0.2424) + (36.97 u)(0.7576)
(3) (34.97 u)(0.7576) + (36.97 u)(0.2424)
(4) (34.97 u)(24.24) + (36.97 u)(75.76)

37 Which general trends in first ionization energy and electronegativity values are demonstrated by Group 15 elements as they are considered in order from top to bottom?

(1) The first ionization energy decreases and the electronegativity decreases.
(2) The first ionization energy increases and the electronegativity increases.
(3) The first ionization energy decreases and the electronegativity increases.
(4) The first ionization energy increases and the electronegativity decreases.

38 An aluminum sample has a mass of 80.01 g and a density of 2.70 g/cm^3. According to the data, to what number of significant figures should the calculated volume of the aluminum sample be expressed?

(1) 1   (3) 3
(2) 2   (4) 4

39 Given four particle models:

Key
◯ = an atom of element T
⊙ = an atom of element X
◖ = an atom of element Z

I   **II**   **III**   **IV**
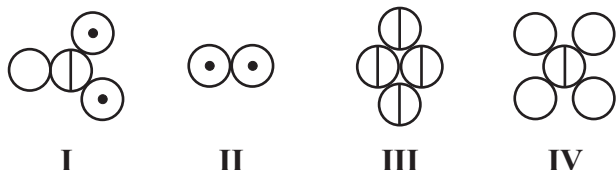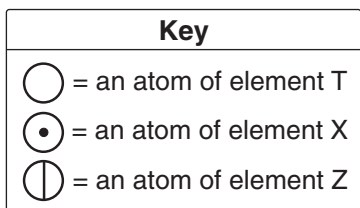
Which two models can be classified as elements?

(1) I and II   (3) II and III
(2) I and IV   (4) II and IV

40 After being thoroughly stirred at 10.°C, which mixture is heterogenous?

(1) 25.0 g of KCl and 100. g of H_2O
(2) 25.0 g of KNO_3 and 100. g of H_2O
(3) 25.0 g of NaCl and 100. g of H_2O
(4) 25.0 g of $NaNO_3$ and 100. g of H_2O

41 Which two compounds are electrolytes?

(1) KOH and CH_3COOH
(2) KOH and C_5H_{12}
(3) CH_3OH and CH_3COOH
(4) CH_3OH and C_5H_{12}

42 Which statement explains why a CO_2 molecule is nonpolar?

(1) Carbon and oxygen are both nonmetals.
(2) Carbon and oxygen have different electronegativities.
(3) The molecule has a symmetrical distribution of charge.
(4) The molecule has an asymmetrical distribution of charge.

43 Which temperature change indicates an increase in the average kinetic energy of the molecules in a sample?

(1) 15°C to 298 K   (3) 305 K to 0°C
(2) 37°C to 273 K   (4) 355 K to 25°C

44 Given the particle diagram:

Key
● = an atom
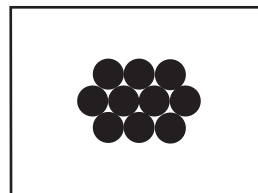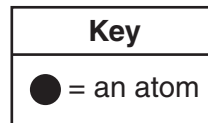
Which substance at STP can be represented by this particle diagram?

(1) N_2 (3) Mg
(2) H_2 (4) Kr

45 Which type of equilibrium exists in a sealed flask containing $Br_2(\ell)$ and $Br_2(g)$ at 298 K and 1.0 atm?

(1) static phase equilibrium
(2) static solution equilibrium
(3) dynamic phase equilibrium
(4) dynamic solution equilibrium

46 What are the products when potassium hydroxide reacts with hydrochloric acid?

(1) KH(s), Cl^+(aq), and OH^-(aq)
(2) K(s), Cl_2(g), and $H_2O(\ell)$
(3) KCl(aq) and $H_2O(\ell)$
(4) KOH(aq) and Cl_2(g)

47 In a titration, 20.0 milliliters of a 0.150 M NaOH(aq) solution exactly neutralizes 24.0 milliliters of an HCl(aq) solution. What is the concentration of the HCl(aq) solution?

(1) 0.125 M   (3) 0.250 M
(2) 0.180 M   (4) 0.360 M

48 What fraction of a Sr-90 sample remains unchanged after 87.3 years?

(1) $\dfrac{1}{2}$ (3) $\dfrac{1}{4}$

(2) $\dfrac{1}{3}$ (4) $\dfrac{1}{8}$

49 Which potential energy diagram represents the change in potential energy that occurs when a catalyst is added to a chemical reaction?

Key	
——————	reaction without catalyst
- - - - - -	reaction with catalyst
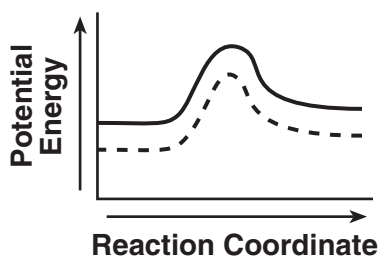
(1)
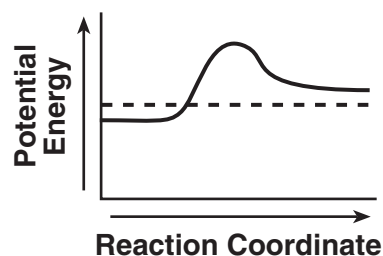
(3)
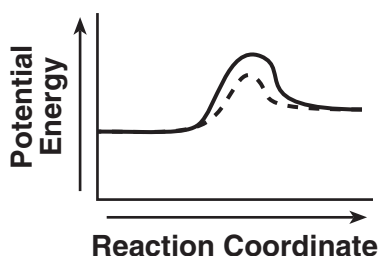
(2)
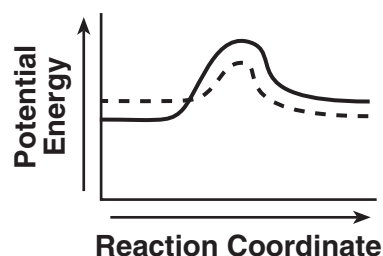
(4)

50 Which balanced equation represents a spontaneous radioactive decay?

(1) $14C + Ca_3(PO_4)_2 \rightarrow 3CaC_2 + 2P + 8CO$

(2) $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}p$

(3) $H_2CO_3 \rightarrow H_2O + CO_2$

(4) $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 51 through 53 on the information below and on your knowledge of chemistry.

The balanced equation below represents the reaction of glucose, $C_6H_{12}O_6$, with oxygen at 298 K and 101.3 kPa.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(\ell)$$
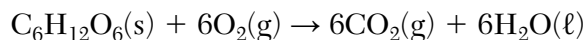
51 Determine the mass of CO_2 produced when 9.0 grams of glucose completely reacts with 9.6 grams of oxygen to produce 5.4 grams of water.   [1]

52 Compare the entropy of the reactants to the entropy of the products.   [1]

53 Write the empirical formula for glucose.   [1]

Base your answers to questions 54 and 55 on the information below and on your knowledge of chemistry.

The diagram below represents a cylinder with a movable piston. The cylinder contains 1.0 liter of oxygen gas at STP. The movable piston in the cylinder is pushed downward at constant temperature until the volume of $O_2(g)$ is 0.50 liter.

Movable piston

$O_2(g)$
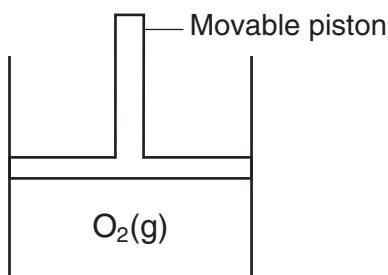
54 Determine the new pressure of $O_2(g)$ in the cylinder, in atmospheres.   [1]

55 State the effect on the frequency of gas molecule collisions when the movable piston is pushed farther downward into the cylinder.   [1]

Base your answers to questions 56 through 58 on the information below and on your knowledge of chemistry.

The formulas and the boiling points at standard pressure for ethane, methane, methanol, and water are shown in the table below.

Information for Four Compounds

Name	Formula	Boiling Point (°C)
ethane	H H | | H — C — C — H | | H H	−88.6
methane	H | H — C — H | H	−161.5
methanol	H | H — C — OH | H	64.6
water	H — O | H	100.0

56 Identify the compound that has the strongest intermolecular forces.   [1]

57 State the change in potential energy that takes place in a sample of methane as it boils at −161.5°C.   [1]

58 Explain, in terms of molecular polarity, why the solubility of methanol in water is greater than the solubility of methane in water.   [1]

Base your answers to questions 59 through 61 on the information below and on your knowledge of chemistry.

The diagrams below represent ball-and-stick models of two molecules. In a ball-and-stick model, each ball represents an atom, and the sticks between balls represent chemical bonds.

Key
● = an atom of hydrogen
○ = an atom of carbon
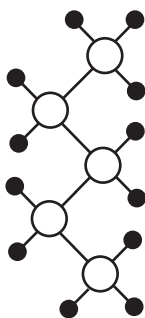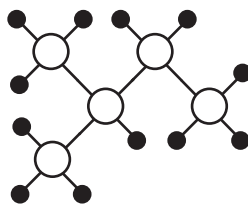
Diagram A   **Diagram B**

59 Draw a Lewis electron-dot diagram for an atom of the element present in all organic compounds. [1]

60 Explain, in terms of carbon-carbon bonds, why the hydrocarbon represented in diagram *B* is saturated. [1]

61 Explain why the molecules in diagrams *A* and *B* are isomers of each other. [1]

Base your answers to questions 62 and 63 on the information below and on your knowledge of chemistry.

The nuts, bolts, and hinges that attach some gates to a playground fence can be made of iron. The iron can react with oxygen in the air. The unbalanced equation representing this reaction is shown below.

$$Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$$
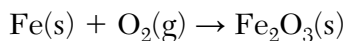
62 Balance the equation *in your answer booklet* for the reaction, using the smallest whole-number coefficients. [1]

63 Determine the change in oxidation state for oxygen in this reaction. [1]

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

The pH of various aqueous solutions are shown in the table below.

pH of Various Aqueous Solutions

Aqueous Solution	pH
HCl(aq)	2
$HC_2H_3O_2$(aq)	3
NaCl(aq)	7
NaOH(aq)	12

64 Complete the table *in your answer booklet* by writing the color of thymol blue in the NaCl(aq) and in the NaOH(aq) solutions.   [1]

65 State how many times greater the hydronium ion concentration in the HCl(aq) is than the hydronium ion concentration in the $HC_2H_3O_2$(aq).   [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

There are six elements in Group 14 on the Periodic Table. One of these elements has the symbol Uuq, which is a temporary, systematic symbol. This element is now known as flerovium.

66 Identify an element in Group 14 that is classified as a metalloid. [1]

67 Explain, in terms of electron shells, why each successive element in Group 14 has a larger atomic radius, as the elements are considered in order of increasing atomic number. [1]

68 State the expected number of valence electrons in an atom of the element flerovium in the ground state. [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

A student made a copper bracelet by hammering a small copper bar into the desired shape. The bracelet has a mass of 30.1 grams and was at a temperature of 21°C in the classroom. After the student wore the bracelet, the bracelet reached a temperature of 33°C. Later, the student removed the bracelet and placed it on a desk at home, where it cooled from 33°C to 19°C. The specific heat capacity of copper is 0.385 J/g•K.

69 Explain, in terms of heat flow, the change in the temperature of the bracelet when the student wore the bracelet. [1]

70 Determine the number of moles of copper in the bracelet. [1]

71 Show a numerical setup for calculating the amount of heat released by the bracelet as it cooled on the desk. [1]

72 Explain, in terms of chemical activity, why copper is a better choice than iron to make the bracelet. [1]

Base your answers to questions 73 through 75 on the information below and on your knowledge of chemistry.

Seawater contains dissolved salts in the form of ions. Some of the ions found in seawater are Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-, HCO_3^-, and SO_4^{2-}.

An investigation was conducted to determine the concentration of dissolved salts in seawater at one location. A 300.-gram sample of the seawater was placed in an open container. After a week, all the water had evaporated and 10. grams of solid salts remained in the container.

73 Determine the concentration, expressed as percent by mass, of the dissolved salts in the original sample of seawater. [1]

74 At standard pressure, compare the freezing point of seawater to the freezing point of distilled water. [1]

75 Explain why the evaporation that occurred during the investigation is an endothermic process. [1]

Base your answers to questions 76 through 78 on the information below and on your knowledge of chemistry.

A student makes an aqueous solution of lactic acid. A formula for one form of lactic acid is shown below.
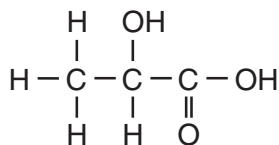
The solution is placed in a sealed flask to be used in a laboratory investigation. The equation below represents the lactic acid equilibrium system in the flask.

$$CH_3CHOHCOOH(aq) \rightleftharpoons H^+(aq) + CH_3CHOHCOO^-(aq)$$

lactic acid   lactate ion
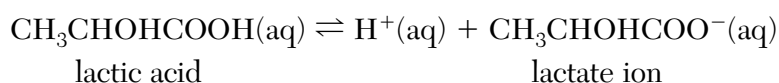
76 Identify *one* organic functional group in a molecule of lactic acid. [1]

77 Explain, in terms of the reaction rates, why the concentrations of the reactants and products remain constant in this system. [1]

78 Explain, in terms of LeChatelier's principle, why increasing the concentration of $H^+(aq)$ increases the concentration of lactic acid. [1]

Base your answers to questions 79 through 81 on the information below and on your knowledge of chemistry.

Copper can be used for water pipes in homes. When the pipes corrode, copper atoms oxidize to form Cu^{2+} ions in the water.

A homeowner has a water quality report prepared for a sample of water taken from pipes in the home. According to the report, the 550.-gram sample contains 6.75×10^{-4} gram of dissolved Cu^{2+} ions.

79 Using the key *in your answer booklet*, draw *two* water molecules in the box, showing the orientation of *each* water molecule toward the Cu^{2+} ion. [1]

80 Show a numerical setup for calculating the concentration, in parts per million, of dissolved Cu^{2+} ions in the sample of water tested. [1]

81 Write a balanced half-reaction equation for the corrosion that forms the Cu^{2+} ions. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

A breeder reactor is one type of nuclear reactor. In a breeder reactor, uranium-238 is transformed in a series of nuclear reactions into plutonium-239.

The plutonium-239 can undergo fission as shown in the equation below. The *X* represents a missing product in the equation.

$$^{1}_{0}n + ^{239}_{94}Pu \rightarrow X + ^{94}_{36}Kr + 2^{1}_{0}n$$
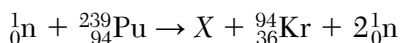
82 Determine the number of neutrons in an atom of the uranium isotope used in the breeder reactor. [1]

83 Based on Table *N*, identify the decay mode of the plutonium radioisotope produced in the breeder reactor. [1]

84 Compare the amount of energy released by 1 mole of completely fissioned plutonium-239 to the amount of energy released by the complete combustion of 1 mole of methane. [1]

85 Write a notation for the nuclide represented by missing product *X* in this equation. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, January 27, 2016 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which phrase describes the charge and mass of a neutron?

(1) a charge of +1 and no mass
(2) a charge of +1 and an approximate mass of 1 u
(3) no charge and no mass
(4) no charge and an approximate mass of 1 u

2 What is the number of electrons in a potassium atom?

(1) 18   (3) 20
(2) 19   (4) 39

3 The number of valence electrons in each atom of an element affects the element's

(1) chemical properties (3) decay mode
(2) number of isotopes   (4) half-life

4 The nuclides I-131 and I-133 are classified as

(1) isomers of the same element
(2) isomers of Xe-131 and Cs-133
(3) isotopes of the same element
(4) isotopes of Xe-131 and Cs-133

5 The elements on the Periodic Table are arranged in order of increasing

(1) mass number
(2) atomic number
(3) number of isotopes
(4) number of valence electrons

6 Compared to a 1.0-gram sample of chlorine gas at standard pressure, a 1.0-gram sample of solid aluminum at standard pressure has

(1) a lower melting point
(2) a higher boiling point
(3) a lower density
(4) a greater volume

7 Which processes represent one chemical change and one physical change?

(1) freezing and melting
(2) freezing and vaporization
(3) decomposition and melting
(4) decomposition and combustion

8 In the ground state, an atom of each of the elements in Group 2 has a different

(1) oxidation state
(2) first ionization energy
(3) number of valence electrons
(4) number of electrons in the first shell

9 Which statement explains why water is classified as a compound?

(1) Water can be broken down by chemical means.
(2) Water is a liquid at room temperature.
(3) Water has a heat of fusion of 334 J/g.
(4) Water is a poor conductor of electricity.

10 Which formula is an empirical formula?

(1) CH_4 (3) C_3H_6
(2) C_2H_6 (4) C_4H_{10}

11 Which compound contains both ionic and covalent bonds?

(1) KI   (3) CH_2Br_2
(2) $CaCl_2$ (4) NaCN

12 Given the balanced equation representing a reaction:

$$H_2 \rightarrow H + H$$

What occurs during this reaction?

(1) Energy is absorbed as bonds are formed.
(2) Energy is absorbed as bonds are broken.
(3) Energy is released as bonds are formed.
(4) Energy is released as bonds are broken.

13 Parts per million is used to express the

(1) atomic mass of an element
(2) concentration of a solution
(3) volume of a substance
(4) rate of heat transfer

14 According to Table *F*, which ions combine with chloride ions to form an insoluble compound?

(1) Fe^{2+} ions   (3) Li^+ ions
(2) Ca^{2+} ions   (4) Ag^+ ions

15 At 1 atm, equal masses of $H_2O(s)$, $H_2O(\ell)$, and $H_2O(g)$ have

(1) the same density
(2) the same distance between molecules
(3) different volumes
(4) different percent compositions

16 Which list includes three forms of energy?

(1) chemical, mechanical, electromagnetic
(2) chemical, mechanical, temperature
(3) thermal, pressure, electromagnetic
(4) thermal, pressure, temperature

17 At STP, a 1-liter sample of Ne(g) and a 1-liter sample of Kr(g) have the same

(1) mass
(2) density
(3) number of atoms
(4) number of electrons

18 A reaction will most likely occur if the colliding particles have the proper

(1) mass, only
(2) mass and volume
(3) orientation, only
(4) orientation and energy

19 Which factors have the greatest effect on the rate of a chemical reaction between $AgNO_3(aq)$ and Cu(s)?

(1) solution concentration and temperature
(2) solution concentration and pressure
(3) molar mass and temperature
(4) molar mass and pressure

20 Which expression represents the heat of reaction for a chemical change in terms of potential energy, *PE*?

(1) $(PE_{products}) + (PE_{reactants})$
(2) $(PE_{products}) - (PE_{reactants})$
(3) $(PE_{products}) \times (PE_{reactants})$
(4) $(PE_{products}) \div (PE_{reactants})$

21 When a chemical reaction is at equilibrium, the concentration of each reactant and the concentration of each product must be

(1) constant   (3) equal
(2) variable   (4) zero

22 Which element is present in all organic compounds?

(1) nitrogen   (3) carbon
(2) oxygen   (4) sulfur

23 Two types of organic reactions are

(1) deposition and saponification
(2) deposition and transmutation
(3) polymerization and saponification
(4) polymerization and transmutation

24 Given the balanced equation representing a reaction:

$$2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$$

Which particles are transferred in this reaction?

(1) electrons   (3) positrons
(2) neutrons   (4) protons

25 In an operating voltaic cell, reduction occurs

(1) at the anode   (3) in the salt bridge
(2) at the cathode   (4) in the wire

26 Which type of substance yields hydrogen ions, H^+, in an aqueous solution?

(1) an Arrhenius acid
(2) an Arrhenius base
(3) a saturated hydrocarbon
(4) an unsaturated hydrocarbon

27 Phenolphthalein is pink in an aqueous solution having a pH of

(1) 5

(3) 7

(2) 2

(4) 12

28 According to one acid-base theory, NH_3 acts as a base when an NH_3 molecule

(1) accepts an H^+ ion

(2) donates an H^+ ion

(3) accepts an OH^- ion

(4) donates an OH^- ion

29 Which reaction releases the greatest amount of energy per mole of reactant?

(1) decomposition

(3) fermentation

(2) esterification

(4) fission

30 Which nuclear emission is negatively charged?

(1) an alpha particle

(3) a neutron

(2) a beta particle

(4) a positron

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which electron configuration represents an atom of chlorine in an excited state?

(1) 2-7-7
(3) 2-8-7
(2) 2-7-8
(4) 2-8-8

32 Given the balanced equation representing a reaction occurring at 101.3 kilopascals and 298 K:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell) + energy$$
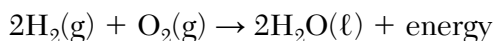
What is the net amount of energy released when *one* mole of $H_2O(\ell)$ is produced?

(1) 241.8 kJ
(3) 483.6 kJ
(2) 285.8 kJ
(4) 571.6 kJ

33 Element *X* reacts with copper to form the compounds Cu*X* and Cu*X*$_2$. In which group on the Periodic Table is element *X* found?

(1) Group 1
(3) Group 13
(2) Group 2
(4) Group 17

34 What is the mass of 1.5 moles of CO_2?

(1) 66 g
(3) 33 g
(2) 44 g
(4) 29 g

35 Given the balanced equation representing a reaction:
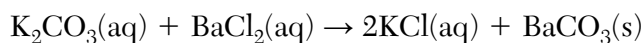
$$K_2CO_3(aq) + BaCl_2(aq) \rightarrow 2KCl(aq) + BaCO_3(s)$$

Which type of reaction is represented by this equation?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

36 Which sample, when dissolved in 1.0 liter of water, produces a solution with the highest boiling point?

(1) 0.1 mole KI
(3) 0.1 mole $MgCl_2$
(2) 0.2 mole KI
(4) 0.2 mole $MgCl_2$

37 Given the balanced equation representing a reaction:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$
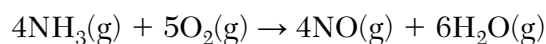
What is the number of moles of $H_2O(g)$ formed when 2.0 moles of $NH_3(g)$ react completely?

(1) 6.0 mol
(3) 3.0 mol
(2) 2.0 mol
(4) 4.0 mol

38 A rigid cylinder with a movable piston contains a sample of gas. At 300. K, this sample has a pressure of 240. kilopascals and a volume of 70.0 milliliters. What is the volume of this sample when the temperature is changed to 150. K and the pressure is changed to 160. kilopascals?

(1) 35.0 mL
(3) 70.0 mL
(2) 52.5 mL
(4) 105 mL

39 A 100.-gram sample of $H_2O(\ell)$ at 22.0°C absorbs 8360 joules of heat. What will be the final temperature of the water?

(1) 18.3°C
(3) 25.7°C
(2) 20.0°C
(4) 42.0°C

40 Which compound has the strongest hydrogen bonding at STP?

(1) H_2O
(3) H_2Se
(2) H_2S
(4) H_2Te

41 Which formula represents an unsaturated hydrocarbon?

(1) C_2H_4
(3) C_4H_{10}
(2) C_3H_8
(4) C_5H_{12}

42 Which radioisotope is used in dating geological formations?

(1) I-131
(3) Ca-37
(2) U-238
(4) Fr-220

43 The heating curve below represents a sample of a substance starting as a solid below its melting point and being heated over a period of time.
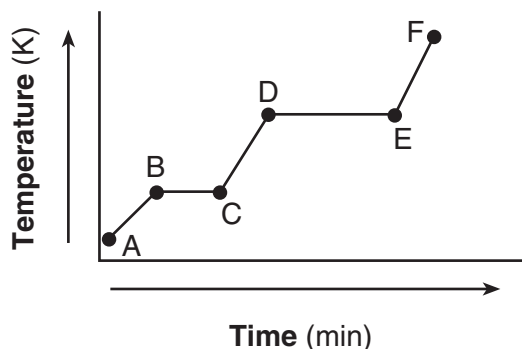
Which statement describes the energy of the particles in this sample during interval *DE*?

(1) Both potential energy and average kinetic energy increase.
(2) Both potential energy and average kinetic energy decrease.
(3) Potential energy increases and average kinetic energy remains the same.
(4) Potential energy remains the same and average kinetic energy increases.

44 Given the potential energy diagram for a reaction:

Reaction Coordinate
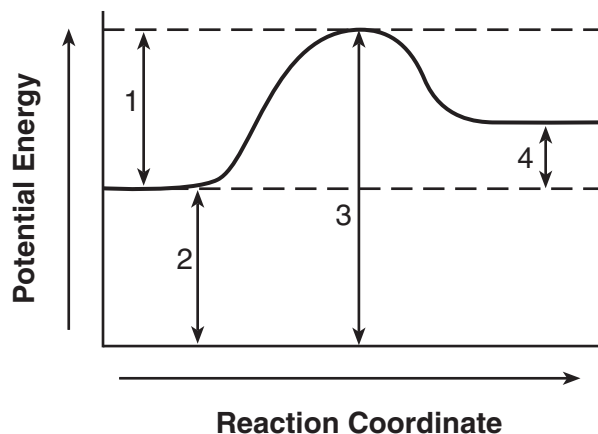
Which intervals are affected by the addition of a catalyst?

(1) 1 and 2   (3) 2 and 4
(2) 1 and 3   (4) 3 and 4

45 Which balanced equation represents a redox reaction?

(1) $Mg + Cl_2 \rightarrow MgCl_2$
(2) $CaO + H_2O \rightarrow Ca(OH)_2$
(3) $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$
(4) $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

46 The pH of a solution is 7. When acid is added to the solution, the hydronium ion concentration becomes 100 times greater. What is the pH of the new solution?

(1) 1   (3) 9
(2) 5   (4) 14

47 Given the formula for a compound:
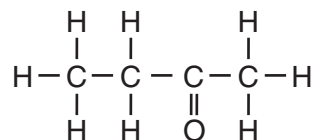
A chemical name for this compound is

(1) butanal   (3) butanone
(2) butanol   (4) butanoic acid

48 What occurs in both fusion and fission reactions?

(1) Small amounts of energy are converted into large amounts of matter.
(2) Small amounts of matter are converted into large amounts of energy.
(3) Heavy nuclei are split into lighter nuclei.
(4) Light nuclei are combined into heavier nuclei.

49 Given the reaction:

$$^{27}_{13}Al + ^{4}_{2}He \rightarrow X + ^{1}_{0}n$$
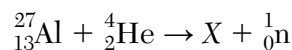
Which particle is represented by *X*?

(1) $^{28}_{12}Mg$ (3) $^{30}_{14}Si$
(2) $^{28}_{13}Al$ (4) $^{30}_{15}P$

50 A radioactive isotope has a half-life of 2.5 years. Which fraction of the original mass remains unchanged after 10. years?

(1) 1/2   (3) 1/8
(2) 1/4   (4) 1/16

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Based on Table *H*, state the vapor pressure of ethanol at 75ºC.   [1]

52 Show a numerical setup for calculating the percent composition by mass of silicon in SiO_2.   [1]

53 Explain, in terms of element classification, why K_2O is an ionic compound.   [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

The bright-line spectra observed in a spectroscope for three elements and a mixture of two of these elements are represented in the diagram below.

Selected Bright-Line Spectra
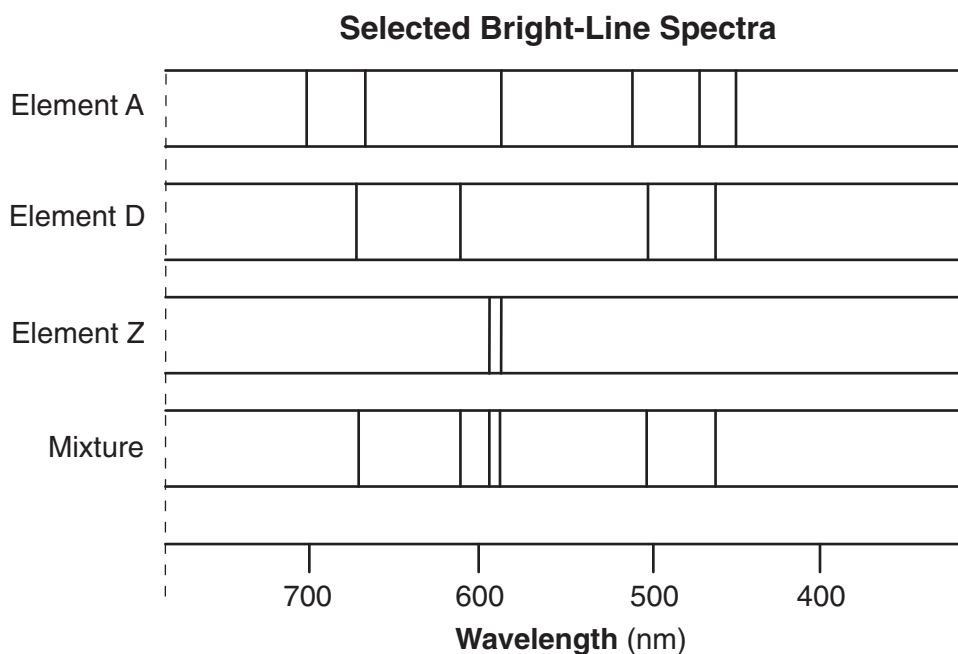
54 State evidence from the bright-line spectra that indicates element *A* is *not* present in the mixture.   [1]

55 Explain why the spectrum produced by a 1-gram sample of element Z would have the same spectral lines at the same wavelengths as the spectrum produced by a 2-gram sample of element Z.   [1]

56 Describe, in terms of *both* electrons and energy states, how the light represented by the spectral lines is produced.   [1]

Base your answers to questions 57 through 61 on the information below and on your knowledge of chemistry.

The Lewis electron-dot diagrams for three substances are shown below.

$K^+ \left[:\ddot{Br}: \right]^-$ $H:\ddot{N}:H$ $H:\ddot{C}:H$ (with H above and below)
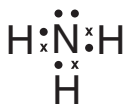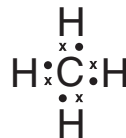
Diagram 1   Diagram 2   Diagram 3

57 Describe, in terms of valence electrons, how the chemical bonds form in the substance represented in diagram 1. [1]

58 Determine the total number of electrons in the bonds between the nitrogen atom and the three hydrogen atoms represented in diagram 2. [1]

59 Explain, in terms of distribution of charge, why a molecule of the substance represented in diagram 3 is nonpolar. [1]

60 Draw a Lewis electron-dot diagram for a molecule of Br_2. [1]

61 Identify the noble gas that has atoms with the same electron configuration as the positive ion represented in diagram 1, when both the atoms and the ion are in the ground state. [1]

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

A NaOH(aq) solution and an acid-base indicator are used to determine the molarity of an HCl(aq) solution. A 25.0-milliliter sample of the HCl(aq) is exactly neutralized by 15.0 milliliters of 0.20 M NaOH(aq).

62 Identify the laboratory process described in this passage. [1]

63 Complete the equation *in your answer booklet* for the neutralization reaction that occurs, by writing a formula for *each* product. [1]

64 Based on the data, the calculated molarity of the HCl(aq) solution should be expressed to what number of significant figures? [1]

65 Using the data, determine the concentration of the HCl(aq). [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

Elements with an atomic number greater than 92 can be artificially produced in nuclear reactions by bombarding a naturally occurring nuclide with a different nuclide. One of these elements is roentgenium, Rg. The equation below represents a nuclear reaction that produces Rg-272.

$$^{209}_{83}\text{Bi} + {}^{64}_{28}\text{Ni} \rightarrow {}^{272}_{111}\text{Rg} + {}^{1}_{0}\text{n}$$
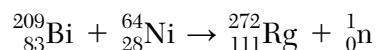
66 State the location and the total charge of the protons in a Ni-64 atom. [1]

67 Determine the number of neutrons in an atom of Rg-272. [1]

68 Based on the Periodic Table, classify the element produced by this nuclear reaction as a metal, metalloid, nonmetal, or noble gas. [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

Hydrazine, N_2H_4, is a compound that is very soluble in water and has a boiling point of 113°C at standard pressure. Unlike water, hydrazine is very reactive and is sometimes used as a fuel for small rockets. One hydrazine reaction producing gaseous products is represented by the balanced equation below.

$$N_2H_4(\ell) \rightarrow N_2(g) + 2H_2(g) + \text{heat}$$
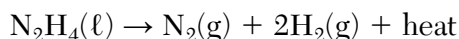
69 Compare the entropy of the products to the entropy of the reactant for this reaction. [1]

70 Based on Table *S*, determine the electronegativity difference for the N-H bond in hydrazine. [1]

71 Explain, in terms of molecular polarity, why N_2H_4 is very soluble in water. [1]

72 Explain, in terms of intermolecular forces, why the boiling point of hydrazine at standard pressure is higher than the boiling point of water at standard pressure. [1]

Base your answers to questions 73 through 75 on the information below and on your knowledge of chemistry.

A laboratory technician is given the table below and a sample of one of the three substances listed in the table. The technician makes an aqueous solution with a portion of the sample. When a conductivity tester is lowered into the solution, the lightbulb on the tester glows brightly. Another portion of the sample is placed in a heat-resistant container that is placed in an oven at 450.°C. The sample melts.

Some Properties of Three Substances

Property	Substance		
	Sodium nitrate	Potassium chromate	Sulfur
solubility in water at 20.°C	soluble	soluble	insoluble
electrical conductivity of aqueous solution	good	good	not applicable
melting point (°C)	307	974	115

73 Identify the substance given to the technician. [1]

74 State evidence that makes it necessary to use more than one property to identify the substance given to the technician. [1]

75 Explain, in terms of ions, why an aqueous solution of potassium chromate conducts an electric current. [1]

Base your answers to questions 76 through 78 on the information below and on your knowledge of chemistry.

Natural gas and coal are two fuels burned to produce energy. Natural gas consists of approximately 80% methane, 10% ethane, 4% propane, 2% butane, and other components.

The burning of coal usually produces sulfur dioxide, $SO_2(g)$, and sulfur trioxide, $SO_3(g)$, which are major air pollutants. Both $SO_2(g)$ and $SO_3(g)$ react with water in the air to form acids.

76 Write the general formula for the homologous series that includes the components of the natural gas listed in this passage. [1]

77 Draw a structural formula for the hydrocarbon that is approximately 2% of natural gas. [1]

78 Complete the equation *in your answer booklet* representing the reaction of sulfur trioxide with water to produce sulfuric acid, by writing the formula of the missing reactant and the formula of the missing product. [1]

Base your answers to questions 79 through 82 on the information below and on your knowledge of chemistry.

A student prepares two 141-gram mixtures, A and B. Each mixture consists of NH_4Cl, sand, and H_2O at 15°C. Both mixtures are thoroughly stirred and allowed to stand. The mass of each component used to make the mixtures is listed in the data table below.

Mass of the Components in Each Mixture

Component	Mixture A (g)	Mixture B (g)
NH_4Cl	40.	10.
sand	1	31
H_2O	100.	100.

79 State evidence from the table indicating that the proportion of the components in a mixture can vary. [1]

80 Which type of mixture is mixture B? [1]

81 Determine the temperature at which all of the NH_4Cl in mixture A dissolves to form a saturated solution. [1]

82 Describe *one* property of sand that would enable the student to separate the sand from the other components in mixture B. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Fossil fuels produce air pollution and may eventually be depleted. Scientists are researching ways to use hydrogen as an alternate fuel.

A device called an artificial leaf was invented to produce hydrogen and oxygen using sunlight and water. The artifical leaf is an electrochemical cell. Equations 1 and 2 below represent the reactions taking place in the leaf. Equation 3 represents a reaction of hydrogen when used as fuel.

Equation 1: $2H_2O$ + energy from sunlight $\rightarrow O_2 + 4H^+ + 4e^-$

Equation 2: $4H^+ + 4e^- \rightarrow 2H_2$

Equation 3: $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ + energy
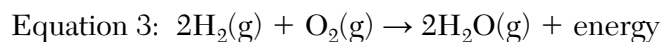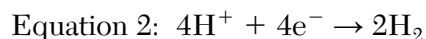
83 State *one* benefit of using the artificial leaf to produce hydrogen. [1]

84 Explain, in terms of energy, why the artificial leaf is an electrolytic cell. [1]

85 State the change in oxidation number of oxygen during the reaction represented in equation 3. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, January 25, 2017 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which statement describes the location of two types of subatomic particles in a helium atom?

(1) Protons and neutrons are located in the nucleus.
(2) Protons and neutrons are located outside the nucleus.
(3) Protons and electrons are located in the nucleus.
(4) Protons and electrons are located outside the nucleus.

2 An atom that contains six protons, six neutrons, and six electrons has a mass of approximately

(1) 12 u   (3) 18 u
(2) 12 g   (4) 18 g

3 Which term identifies the most probable location of an electron in the wave-mechanical model of the atom?

(1) anode   (3) nucleus
(2) orbital   (4) cathode

4 Which element has atoms in the ground state with the greatest number of valence electrons?

(1) tin   (3) arsenic
(2) sulfur   (4) fluorine

5 Which group on the Periodic Table has two elements that exist as gases at STP?

(1) Group 1   (3) Group 16
(2) Group 2   (4) Group 17

6 Which list of elements contains a metal, a metalloid, and a nonmetal?

(1) Ag, Si, I_2 (3) K, Cu, Br_2
(2) Ge, As, Ne (4) S, Cl_2, Ar

7 What is the charge of the nucleus of a copper atom?

(1) +1   (3) +29
(2) +2   (4) +64

8 At STP, $O_2(g)$ and $O_3(g)$ have different properties because $O_3(g)$ has

(1) more dense nuclei than in $O_2(g)$
(2) more protons per atom than in $O_2(g)$
(3) molecules with a different structure than in $O_2(g)$
(4) molecules with fewer covalent bonds than in $O_2(g)$

9 A compound is a substance composed of two or more elements that are

(1) physically mixed in a fixed proportion
(2) physically mixed in a variable proportion
(3) chemically combined in a fixed proportion
(4) chemically combined in a variable proportion

10 Which element has the highest boiling point at standard pressure?

(1) Mg   (3) Rb
(2) Na   (4) Sr

11 How many pairs of electrons are shared between the nitrogen atoms in a molecule of N_2?

(1) 5   (3) 3
(2) 2   (4) 6

12 A molecule must be nonpolar if the molecule

(1) is linear
(2) is neutral
(3) has ionic and covalent bonding
(4) has a symmetrical charge distribution

13 Which property is used to determine the degree of polarity between two bonded atoms?

(1) density   (3) pressure
(2) electronegativity (4) temperature

14 In a chemical reaction, a catalyst provides an alternate reaction pathway that

(1) decreases the concentration of the products
(2) increases the concentration of the reactants
(3) has a lower activation energy
(4) has a higher activation energy

15 Which substance can be decomposed by chemical means?

(1) cobalt   (3) methane
(2) krypton   (4) zirconium

16 Which sample of matter represents a mixture?

(1) aqueous ammonia (3) liquid mercury
(2) gaseous ethane   (4) solid iodine

17 Differences in which property allow the separation of a sample of sand and seawater by filtration?

(1) concentration of ions
(2) volume of sample
(3) mass of sample
(4) particle size

18 Which process is a chemical change?

(1) evaporating an alcohol
(2) subliming of iodine
(3) melting an ice cube
(4) rusting of iron

19 Which term represents an intermolecular force in a sample of water?

(1) hydrogen bonding
(2) covalent bonding
(3) metallic bonding
(4) ionic bonding

20 Which sample of matter has particles arranged in a crystalline structure?

(1) $Ne(g)$ (3) $NaCl(aq)$

(2) $Br_2(\ell)$ (4) $CuSO_4(s)$

21 Which term is defined as a measure of the randomness of a system?

(1) heat   (3) pressure
(2) entropy   (4) temperature

22 Which formula represents an alkane?

(1) C_2H_2 (3) C_3H_4
(2) C_2H_4 (4) C_3H_8

23 Which term represents a chemical reaction?

(1) deposition   (3) sublimation
(2) combustion   (4) vaporization

24 Which type of reaction includes esterification and polymerization?

(1) decomposition   (3) organic
(2) neutralization (4) nuclear

25 In a redox reaction, the total number of electrons lost is

(1) less than the total number of electrons gained
(2) greater than the total number of electrons gained
(3) equal to the total number of electrons gained
(4) unrelated to the total number of electrons gained

26 Which type of equation can represent the oxidation occurring in a reaction?

(1) a double-replacement reaction equation
(2) a half-reaction equation
(3) a neutralization reaction equation
(4) a transmutation reaction equation

27 The electrical conductivity of an aqueous solution depends on the concentration of which particles in the solution?

(1) molecules   (3) atoms
(2) electrons   (4) ions

28 An electrolytic cell differs from a voltaic cell because an electrolytic cell

(1) generates its own energy from a spontaneous physical reaction
(2) generates its own energy from a nonspontaneous physical reaction
(3) requires an outside energy source for a spontaneous chemical reaction to occur
(4) requires an outside energy source for a nonspontaneous chemical reaction to occur

29 A sample of which radioisotope emits particles having the greatest mass?

(1) ^{137}Cs
(2) ^{53}Fe
(3) ^{220}Fr
(4) ^{3}H

30 Which term represents a nuclear reaction?

(1) combustion
(2) fermentation
(3) transmutation
(4) saponification

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which electron configuration represents the distribution of electrons in a potassium atom in the ground state?

(1) 2-8-8-1   (3) 2-8-5
(2) 2-8-7-2   (4) 2-7-6

32 At STP, which element is malleable and a good conductor of electricity?

(1) xenon   (3) platinum
(2) silicon   (4) hydrogen

33 Which general trends in atomic radius and electronegativity are observed as the elements in Period 3 are considered in order of increasing atomic number?

(1) Atomic radius decreases and electronegativity increases.
(2) Atomic radius increases and electronegativity decreases.
(3) Both atomic radius and electronegativity increase.
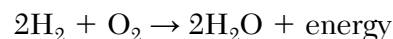(4) Both atomic radius and electronegativity decrease.

34 What is the chemical name for Na_2SO_3?

(1) sodium sulfite   (3) sodium sulfide
(2) sodium sulfate   (4) sodium thiosulfate

35 Which molecular formula is also an empirical formula?

(1) C_6H_6 (3) N_2H_4
(2) H_2O_2 (4) N_2O_5

36 Given the balanced equation representing a reaction:
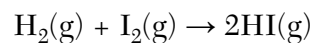
$$2H_2 + O_2 \rightarrow 2H_2O + energy$$

Which mass of oxygen completely reacts with 4.0 grams of hydrogen to produce 36.0 grams of water?

(1) 8.0 g   (3) 32.0 g
(2) 16.0 g   (4) 40.0 g

37 What is the gram-formula mass of $Ca(OH)_2$?

(1) 29 g/mol   (3) 57 g/mol
(2) 54 g/mol   (4) 74 g/mol

38 Given the equation representing a reaction:

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$

Which statement describes the energy changes that occur in this reaction?

(1) Energy is absorbed as bonds are formed, only.
(2) Energy is released as bonds are broken, only.
(3) Energy is absorbed as bonds are formed, and energy is released as bonds are broken.
(4) Energy is absorbed as bonds are broken, and energy is released as bonds are formed.

39 Based on Table *F*, which compound is *least* soluble in water?

(1) $AlPO_4$ (3) $Ca(OH)_2$
(2) Li_2SO_4 (4) $AgC_2H_3O_2$

40 How many joules of heat are absorbed to raise the temperature of 435 grams of water at 1 atm from 25°C to its boiling point, 100.°C?

(1) 4.5×10^4 J   (3) 2.5×10^7 J
(2) 1.4×10^5 J   (4) 7.4×10^7 J

41 Which temperature represents the highest average kinetic energy of the particles in a sample of matter?

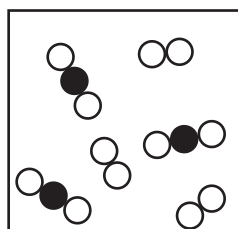(1) 298 K (3) 27°C
(2) 267 K (4) 12°C

42 Which change in the H^+ ion concentration of an aqueous solution represents a *decrease* of one unit on the pH scale?

(1) a tenfold increase
(2) a tenfold decrease
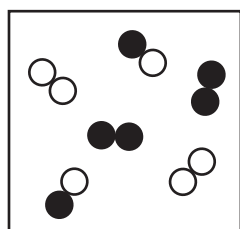(3) a hundredfold increase
(4) a hundredfold decrease

43 Which particle diagram represents a mixture of three substances?
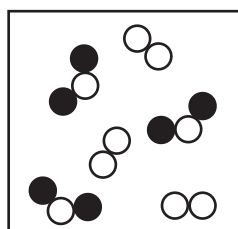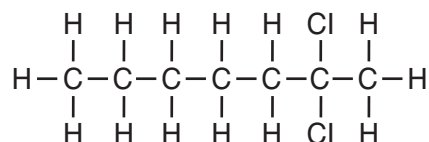
Key
○ = an atom of one element
● = an atom of a different element
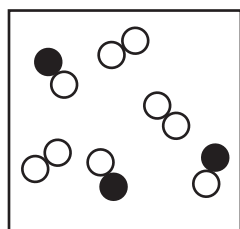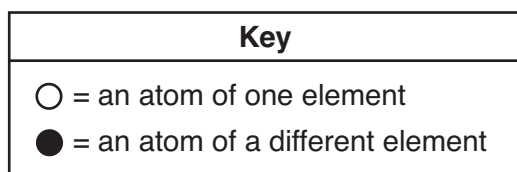
(1)

(3)

(2)

(4)

44 Given the equation representing a system at equilibrium:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Which statement describes this system?

(1) The concentration of $PCl_5(g)$ is increasing.
(2) The concentration of $PCl_5(g)$ is decreasing.
(3) The concentrations of $PCl_5(g)$ and $PCl_3(g)$ are equal.
(4) The concentrations of $PCl_5(g)$ and $PCl_3(g)$ are constant.

45 Given the formula representing a compound:

$$
\begin{array}{ccccccc}
H & H & H & H & H & Cl & H \\
| & | & | & | & | & | & | \\
H-C-C-C-C-C-C-C-H \\
| & | & | & | & | & | & | \\
H & H & H & H & H & Cl & H
\end{array}
$$

What is the IUPAC name of this compound?

(1) 2-chloroheptane
(2) 6-chloroheptane
(3) 2,2-dichloroheptane
(4) 6,6-dichloroheptane

46 Given the equation representing a reaction:

$$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$$
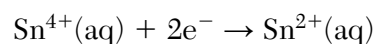
Which term best describes this reaction?

(1) ionization (3) oxidation
(2) neutralization (4) reduction

47 Which ionic equation represents a spontaneous reaction that can occur in a voltaic cell?

(1) $Cu(s) + Zn(s) \rightarrow Cu^{2+}(aq) + Zn^{2+}(aq)$
(2) $Cu(s) + Zn^{2+}(aq) \rightarrow Cu^{2+}(aq) + Zn(s)$
(3) $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$
(4) $Cu^{2+}(aq) + Zn^{2+}(aq) \rightarrow Cu(s) + Zn(s)$

48 Given the formulas representing two compounds at standard pressure:

$$\begin{array}{ccc} & H\ \ H\ \ H & & H & H\ \ H \\ & |\ \ \ |\ \ \ | & & | & |\ \ \ | \\ H-&C-C-C&-O-H \qquad H-&C-O-&C-C-H \\ & |\ \ \ |\ \ \ | & & | & |\ \ \ | \\ & H\ \ H\ \ H & & H & H\ \ H \end{array}$$

1 – propanol   methyl ethyl ether

The compounds can be differentiated by their

(1) boiling points
(2) gram-formula masses
(3) numbers of hydrogen atoms
(4) percent compositions by mass of carbon

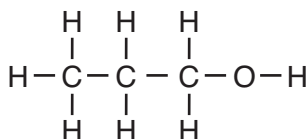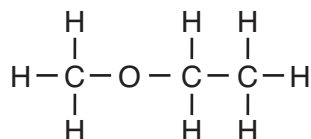49 The table below shows the atomic mass and natural abundance of the two naturally occurring isotopes of lithium.

Naturally Occurring Isotopes of Lithium

Isotope	Atomic Mass (u)	Natural Abundance (%)
Li-6	6.015	7.6
Li-7	7.016	92.4

Which numerical setup can be used to determine the atomic mass of naturally occurring lithium?

(1) $(7.6)(6.015\ u) + (92.4)(7.016\ u)$

(2) $(0.076)(6.015\ u) + (0.924)(7.016\ u)$

(3) $\dfrac{(7.6)(6.015\ u) + (92.4)(7.016\ u)}{2}$

(4) $\dfrac{(0.076)(6.015\ u) + (0.924)(7.016\ u)}{2}$

50 Given the equation representing a reaction at equilibrium:

$$H_2S(aq) + CH_3NH_2(aq) \rightleftharpoons HS^-(aq) + CH_3NH_3^+(aq)$$
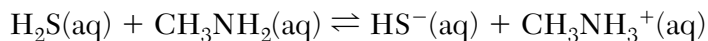
According to one acid-base theory, the forward reaction is classified as an acid-base reaction because

(1) H_2S is a H^+ donor and CH_3NH_2 is a H^+ acceptor
(2) CH_3NH_2 is a H^+ donor and H_2S is a H^+ acceptor
(3) HS^- and $CH_3NH_3^+$ are both H^+ donors
(4) $CH_3NH_3^+$ and HS^- are both H^+ acceptors

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Explain, in terms of electron configuration, why arsenic and antimony are chemically similar. [1]

52 Identify the element in Period 3 that is an unreactive gas at STP. [1]

53 Compare the energy of an electron in the first shell of a cadmium atom to the energy of an electron in the third shell of the same atom. [1]

Base your answers to questions 54 and 55 on the information below and on your knowledge of chemistry.

The densities for two forms of carbon at room temperature are listed in the table below.

Densities of Two Forms of Carbon

Element Form	Density (g/cm³)
carbon (graphite)	2.2
carbon (diamond)	3.513

54 Compare the number of carbon atoms in a 0.30-cm³ sample of graphite and a 0.30-cm³ sample of diamond. [1]

55 A student calculated the density of a sample of graphite to be 2.3 g/cm³. Show a numerical setup for calculating the student's percent error for the density of graphite. [1]

Base your answers to questions 56 and 57 on the information below and on your knowledge of chemistry.

A sample of calcium carbonate, $CaCO_3$, has a mass of 42.2 grams. Calcium carbonate has a gram-formula mass of 100. g/mol.

56 Show a numerical setup for calculating the number of moles in the sample of $CaCO_3$. [1]

57 Determine the percent composition by mass of oxygen in the $CaCO_3$. [1]

Base your answers to questions 58 and 59 on the information below and on your knowledge of chemistry.

Carbon monoxide, $CO(g)$, is a toxic gas found in automobile exhaust. The concentration of $CO(g)$ can be decreased by using a catalyst in the reaction between $CO(g)$ and $O_2(g)$. This reaction is represented by the balanced equation below.

$$2CO(g) + O_2(g) \xrightarrow{\text{catalyst}} 2CO_2(g) + \text{energy}$$

58 Explain, in terms of collision theory, why an increase in temperature increases the rate of the reaction.   [1]

59 On the labeled axes *in your answer booklet*, draw the potential energy curve for the reaction represented by this equation.   [1]

_____

Base your answers to questions 60 and 61 on the information below and on your knowledge of chemistry.

The diagram and data below represent a gas and the conditions of pressure, volume, and temperature of the gas in a rigid cylinder with a moveable piston.

$N_2(g)$
$P = 1.0$ atm
$V = 2.5$ L
$T = 298$ K
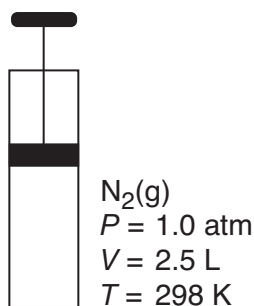
60 Determine the volume of the gas in the cylinder at STP.   [1]

61 State *one* change in temperature and *one* change in pressure that will cause the gas in the cylinder to behave more like an ideal gas.   [1]

_____

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

During a titration, 10.00 mL of acetic acid, $HC_2H_3O_2$(aq), is completely neutralized by adding 12.50 mL of 0.64 M sodium hydroxide, NaOH(aq).

62 Identify the only positive ion in the $HC_2H_3O_2$(aq).   [1]

63 State the number of significant figures used to express the volume of the acetic acid.   [1]

64 Determine the molarity of the acetic acid.   [1]

65 Explain why it is better to use data from multiple trials to determine the molarity of acetic acid, rather than data from a single trial.   [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

Carbon dioxide, CO_2, changes from the solid phase to the gas phase at 1 atm and 194.5 K. In the solid phase, CO_2 is often called dry ice. When dry ice sublimes in air at 298 K, the water vapor in the air can condense, forming a fog of small water droplets. This fog is often used for special effects at concerts and in movie-making.

66 State the direction of heat flow between the dry ice and the water vapor in the air.   [1]

67 At 1 atm and 298 K, compare the potential energies of the water molecules before and after the water vapor condenses.   [1]

68 At 1 atm and 190. K, compare the amount of thermal energy in a 1.0-kilogram block of dry ice to the amount of thermal energy in a 2.0-kilogram block of dry ice.   [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

A solution of ethylene glycol and water can be used as the coolant in an engine-cooling system. The ethylene glycol concentration in a coolant solution is often given as percent by volume. For example, 100. mL of a coolant solution that is 40.% ethylene glycol by volume contains 40. mL of ethylene glycol diluted with enough water to produce a total volume of 100. mL. The graph below shows the freezing point of coolants that have different ethylene glycol concentrations.

Freezing Points of Coolants

Percent by Volume of Ethylene Glycol (%)
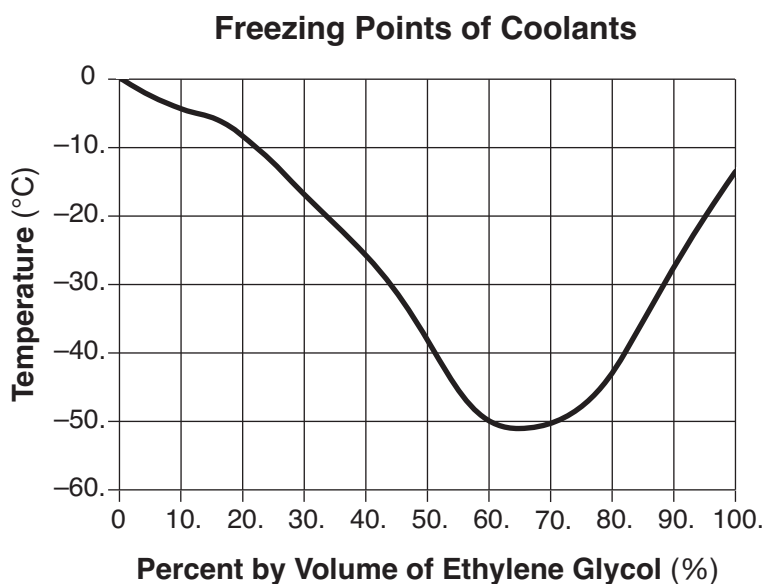
69 Explain, in terms of particle distribution, why a coolant solution is a homogeneous mixture. [1]

70 Explain, in terms of the molecular polarity, why ethylene glycol dissolves in water to form a solution. [1]

71 Identify the percent by volume of ethylene glycol in a solution that freezes at −10.°C. [1]

72 One engine-cooling system has a volume of 6400 mL. Determine the volume of ethylene glycol in the completely filled engine-cooling system when the concentration of ethylene glycol is 50.% by volume. [1]

Base your answers to questions 73 through 77 on the information below and on your knowledge of chemistry.

Molecules containing two carbon atoms and a functional group have many home and industrial uses. These compounds can be produced by a variety of reactions, as shown by the equations below.

$$\text{Equation 1: } C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

$$\text{Equation 2: } 2CH_3CH_2OH + O_2 \rightarrow 2CH_3CHO + 2H_2O$$

$$\text{Equation 3: } 2CH_3CHO + O_2 \rightarrow 2CH_3COOH$$
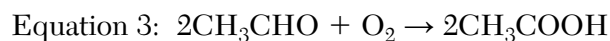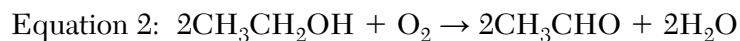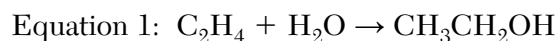
73 Explain, in terms of bonding, why the hydrocarbon reactant in equation 1 is unsaturated. [1]

74 Draw a structural formula of the ethanal molecule in equation 2. [1]

75 Explain, in terms of atoms, why CH_3CH_2OH and CH_3CHO are *not* isomers of each other. [1]

76 Identify the class of organic compounds to which the product in equation 3 belongs. [1]

77 Determine the number of moles of oxygen required to completely react with six moles of CH_3CHO in equation 3. [1]

___

Base your answers to questions 78 and 79 on the information below and on your knowledge of chemistry.

The hydrangea is a flowering plant. The color of the flowers it produces can change depending on the pH value of the soil in which the plant grows. Adding aluminum sulfate makes the soil more acidic and adding calcium hydroxide makes the soil more basic.
A student performed an experiment by varying soil pH and recording the color of the flowers. The following table summarizes the results of the experiment.

Hydrangea Soil pH and Flower Color

Soil pH	Flower Color
5.5 and below	blue
between 5.5 and 6.5	purple
6.5 and above	pink

78 Identify the independent variable in this experiment. [1]

79 Hydrangea plants can be grown in soil that turns litmus red. What color are the flowers of the plants grown in this soil? [1]

___

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

The diagram and balanced ionic equation below represent two half-cells connected to produce an operating voltaic cell in a laboratory investigation. The half-cells are connected by a salt bridge.

Voltaic Cell

$$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$$
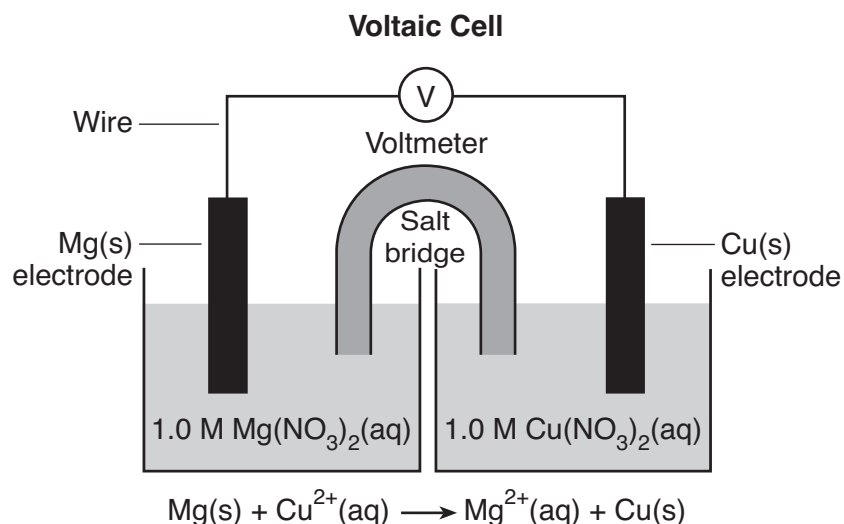
80 Determine the oxidation number of nitrogen in the negative ion in the aqueous solutions. [1]

81 State the purpose of the salt bridge in this voltaic cell.   [1]

82 Explain, in terms of atoms and ions, why the mass of the Mg(s) electrode decreases as the cell operates.   [1]

___

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

The radioisotope Mo-99 naturally decays to produce the metastable isotope Tc-99m, which is used in medical diagnosis. A doctor can obtain images of organs and bones by injecting a patient with a solution of Tc-99m. The half-life of the metastable Tc-99m is six hours.

83 Complete the nuclear equation *in your answer booklet* for the nuclear decay of Mo-99.   [1]

84 State *both* the number of protons and the number of neutrons in a Tc-99 nuclide.   [1]

85 Determine the fraction of an original sample of metastable Tc-99m that remains unchanged after 24 hours.   [1]

___

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, January 25, 2018 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

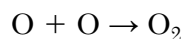**DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.**

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which statement describes the location of protons and neutrons in an atom of helium?

(1) Protons and neutrons are in the nucleus.
(2) Protons and neutrons are outside the nucleus.
(3) Protons are outside the nucleus, and neutrons are in the nucleus.
(4) Protons are in the nucleus, and neutrons are outside the nucleus.

2 Given a list of atomic model descriptions:

A: electron shells outside a central nucleus
B: hard, indivisible sphere
C: mostly empty space

Which list of atomic model descriptions represents the order of historical development from the earliest to most recent?

(1) *A, B, C*   (3) *B, C, A*
(2) *A, C, B*   (4) *B, A, C*

3 Which list represents the classification of the elements nitrogen, neon, magnesium, and silicon, respectively?

(1) metal, metalloid, nonmetal, noble gas
(2) nonmetal, noble gas, metal, metalloid
(3) nonmetal, metalloid, noble gas, metal
(4) noble gas, metal, metalloid, nonmetal

4 In the ground state, all atoms of Group 15 elements have the same number of

(1) valence electrons
(2) electron shells
(3) neutrons
(4) protons

5 What is the chemical formula for ammonium sulfide?

(1) $(NH_4)_2S$ (3) $(NH_4)_2SO_4$
(2) $(NH_4)_2SO_3$ (4) $(NH_4)_2S_2O_3$

6 Which formula is an empirical formula?

(1) N_2O_4 (3) C_3H_6
(2) NH_3 (4) P_4O_{10}

7 Chemical properties can be used to

(1) determine the temperature of a substance
(2) determine the density of a substance
(3) differentiate between two compounds
(4) differentiate between two neutrons

8 Ice, $H_2O(s)$, is classified as

(1) an ionic compound
(2) a molecular compound
(3) a homogeneous mixture
(4) a heterogeneous mixture

9 Which phrase describes the molecular polarity and distribution of charge in a molecule of carbon dioxide, CO_2?

(1) polar and symmetrical
(2) polar and asymmetrical
(3) nonpolar and symmetrical
(4) nonpolar and asymmetrical

10 Which element tends *not* to react with other elements?

(1) helium   (3) phosphorus
(2) hydrogen   (4) potassium

11 Given the equation representing a reaction:

$$O + O \rightarrow O_2$$

Which statement describes the changes that occur as the oxygen molecule is produced?

(1) Energy is absorbed as bonds are broken.
(2) Energy is absorbed as bonds are formed.
(3) Energy is released as bonds are broken.
(4) Energy is released as bonds are formed.

12 Which term represents the strength of the attraction an atom has for the electrons in a chemical bond?

(1) electrical conductivity
(2) electronegativity
(3) first ionization energy
(4) specific heat capacity

13 Compared to a 15-gram sample of Cu(s) at 25°C, a 25-gram sample of Cu(s) at 25°C has

(1) the same density and the same chemical properties
(2) the same density and different chemical properties
(3) a different density and the same chemical properties
(4) a different density and different chemical properties

14 Which substance can *not* be broken down by a chemical change?

(1) ammonia   (3) tungsten
(2) ethanol   (4) water

15 The kinetic molecular theory states that all particles of an ideal gas are

(1) colliding without transferring energy
(2) in random, constant, straight-line motion
(3) arranged in a regular geometric pattern
(4) separated by small distances relative to their size

16 Which sample of gas at STP has the same number of molecules as 6 liters of $Cl_2(g)$ at STP?

(1) 3 liters of $O_2(g)$ (3) 3 moles of $O_2(g)$
(2) 6 liters of $N_2(g)$ (4) 6 moles of $N_2(g)$

17 A chemical reaction is most likely to occur when the colliding particles have the proper

(1) energy and orientation
(2) solubility and density
(3) ionic radii and mass
(4) atomic radii and volume

18 The energy absorbed and the energy released during a chemical reaction are best represented by a

(1) cooling curve
(2) heating curve
(3) kinetic energy diagram
(4) potential energy diagram

19 A catalyst increases the rate of a chemical reaction by

(1) providing an alternate reaction pathway
(2) providing the required heat of reaction
(3) increasing the potential energy of the products
(4) increasing the activation energy of the reaction

20 Which formula represents an alkyne?

(1) C_nH_n (3) C_nH_{2n+2}
(2) $C_{2n}H_n$ (4) C_nH_{2n-2}

21 Which process involves the transfer of electrons?

(1) double replacement
(2) neutralization
(3) oxidation-reduction
(4) sublimation

22 Which change occurs at the anode in an operating electrochemical cell?

(1) gain of protons   (3) loss of protons
(2) gain of electrons (4) loss of electrons

23 Which device requires electrical energy to produce a chemical change?

(1) electrolytic cell   (3) voltaic cell
(2) salt bridge   (4) voltmeter

24 Which substance is an Arrhenius acid?

(1) HBr   (3) NaOH
(2) NaBr   (4) NH_3

25 Which laboratory process is used to determine the concentration of one solution by using a volume of another solution of known concentration?

(1) crystallization   (3) filtration
(2) distillation   (4) titration

26 Which type of reaction occurs when $H^+(aq)$ reacts with $OH^-(aq)$?

(1) combustion   (3) fermentation
(2) decomposition (4) neutralization

27 According to one acid-base theory, a molecule acts as an acid when the molecule

(1) accepts an H^+ (3) donates an H^+
(2) accepts an OH^- (4) donates an OH^-

28 In which type of reaction can an atom of one element be converted to an atom of another element?

(1) addition   (3) substitution
(2) reduction   (4) transmutation

29 An unstable nucleus spontaneously releases a positron. This is an example of

(1) radioactive decay
(2) nuclear fusion
(3) chemical decomposition
(4) thermal conductivity

30 Which phrase describes a risk associated with producing energy in a nuclear power plant?

(1) depletion of atmospheric hydrogen (H_2)
(2) depletion of atmospheric carbon dioxide (CO_2)
(3) production of wastes needing long-term storage
(4) production of wastes that cool surrounding water supplies

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 An ion that consists of 7 protons, 9 neutrons, and 10 electrons has a net charge of
(1) 2−   (3) 3+
(2) 2+   (4) 3−

32 Which electron configuration represents the electrons of an atom in an excited state?
(1) 2–2   (3) 2–8
(2) 2–2–1   (4) 2–8–1

33 The table below gives the atomic mass and the abundance of the two naturally occurring isotopes of boron.

Naturally Occurring Isotopes of Boron

Isotope	Atomic Mass (u)	Natural Abundance (%)
B–10	10.01	19.9
B–11	11.01	80.1

Which numerical setup can be used to determine the atomic mass of the element boron?

(1) $\dfrac{(10.01 \text{ u})(19.9) + (11.01 \text{ u})(80.1)}{100}$

(2) $\dfrac{(10.01 \text{ u})(0.199) + (11.01 \text{ u})(0.801)}{100}$

(3) $\dfrac{10.01 \text{ u} + 11.01 \text{ u}}{2}$

(4) $\dfrac{19.9\% + 80.1\%}{2}$

34 In which group on the Periodic Table would a nonmetallic element belong if atoms of this element tend to gain two electrons to complete their valence shell?
(1) 14   (3) 16
(2) 15   (4) 17

35 Which trend is observed as the first four elements in Group 17 on the Periodic Table are considered in order of increasing atomic number?
(1) Electronegativity increases.
(2) First ionization energy decreases.
(3) The number of valence electrons increases.
(4) The number of electron shells decreases.

36 What is the number of moles of KF in a 29-gram sample of the compound?
(1) 1.0 mol   (3) 0.50 mol
(2) 2.0 mol   (4) 5.0 mol

37 Which bond is most polar?
(1) C–O   (3) N–O
(2) H–O   (4) S–O

38 Based on Table *F*, which equation represents a saturated solution having the *lowest* concentration of Cl^- ions?
(1) $NaCl(s) \rightleftharpoons Na^+(aq) + Cl^-(aq)$
(2) $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$
(3) $NH_4Cl(s) \rightleftharpoons NH_4^+(aq) + Cl^-(aq)$
(4) $KCl(s) \rightleftharpoons K^+(aq) + Cl^-(aq)$

39 What is the molarity of a solution that contains 0.500 mole of KNO_3 dissolved in 0.500-liter of solution?

(1) 1.00 M   (3) 0.500 M

(2) 2.00 M   (4) 4.00 M

40 Given samples of water:

    Sample 1: 100. grams of water at 10.°C
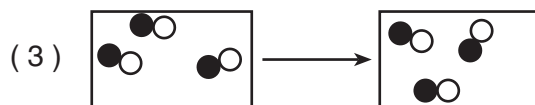   Sample 2: 100. grams of water at 20.°C

Compared to sample 1, sample 2 contains

(1) molecules with a lower average kinetic energy
(2) molecules with a lower average velocity
(3) less heat energy
(4) more heat energy

41 Given the key:

Key
○ = an atom of element A
● = an atom of element Z

Which particle model diagram represents a chemical change?

42 Based on Table *H*, what is the vapor pressure of CH_3COOH at 90.°C?

(1) 40. kPa   (3) 114 kPa

(2) 48 kPa   (4) 150. kPa

43 The arrangement of particles is most ordered in a sample of

(1) NaCl(aq)   (3) NaCl(g)

(2) NaCl(ℓ)   (4) NaCl(s)

44 What is the net amount of heat released when two moles of $C_2H_6(g)$ are formed from its elements at 101.3 kPa and 298 K?

(1) 42.0 kJ   (3) 126.0 kJ

(2) 84.0 kJ   (4) 168.0 kJ

45 Which compounds are isomers of each other?

(1) methanol and methanal
(2) propanoic acid and pentanoic acid
(3) 1-propanol and 2-propanol
(4) 1-chloropropane and 2-bromopropane

46 A reaction between an alcohol and an organic acid is classified as

(1) esterification   (3) saponification

(2) fermentation   (4) substitution

47 Why is potassium nitrate classified as an electrolyte?

(1) It is a molecular compound.
(2) It contains a metal.
(3) It can conduct electricity as a solid.
(4) It releases ions in an aqueous solution.

48 When the concentration of hydrogen ions in a solution is *decreased* by a factor of ten, the pH of the solution

(1) increases by 1   (3) decreases by 1

(2) increases by 10   (4) decreases by 10

49 The cooling curve below represents the uniform cooling of a substance, starting at a temperature above its boiling point.

Cooling Curve
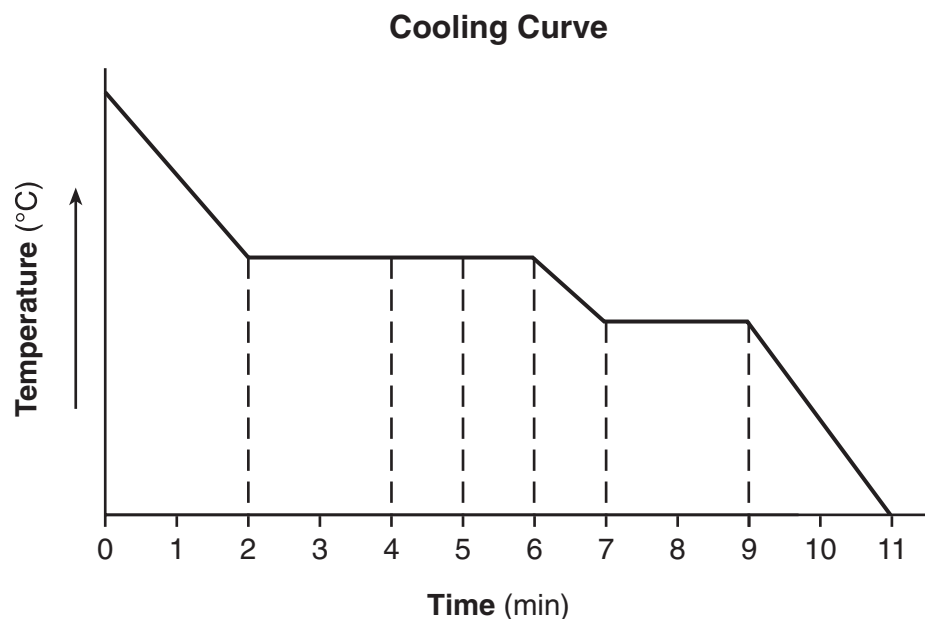
During which time interval does the substance exist as both a liquid and a solid?

(1) min 2 to min 4
(2) min 4 to min 5
(3) min 5 to min 7
(4) min 7 to min 9

50 Given the balanced equation representing a reaction:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + energy$$
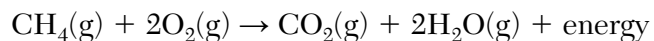
Which change in reaction conditions will increase the frequency of effective collisions between reactant molecules?

(1) decreasing the pressure of the reactants
(2) decreasing the temperature of the reactants
(3) increasing the concentration of the reactants
(4) increasing the volume of the reactants

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Convert the melting point of mercury to degrees Celsius. [1]

52 Draw a Lewis electron-dot diagram for a molecule of hydrogen fluoride, HF. [1]

53 Show a numerical setup for calculating the quantity of heat in joules required to completely vaporize 102.3 grams of $H_2O(\ell)$ at 100.°C and 1.0 atm. [1]

54 State the color of methyl orange indicator after the indicator is placed in a solution of 0.10 M NH_3(aq). [1]

Base your answers to questions 55 and 56 on the information below and on your knowledge of chemistry.

The bright-line spectra for four elements and a mixture of elements are shown in the diagram below.

Bright-Line Spectra

Wavelength (nm)
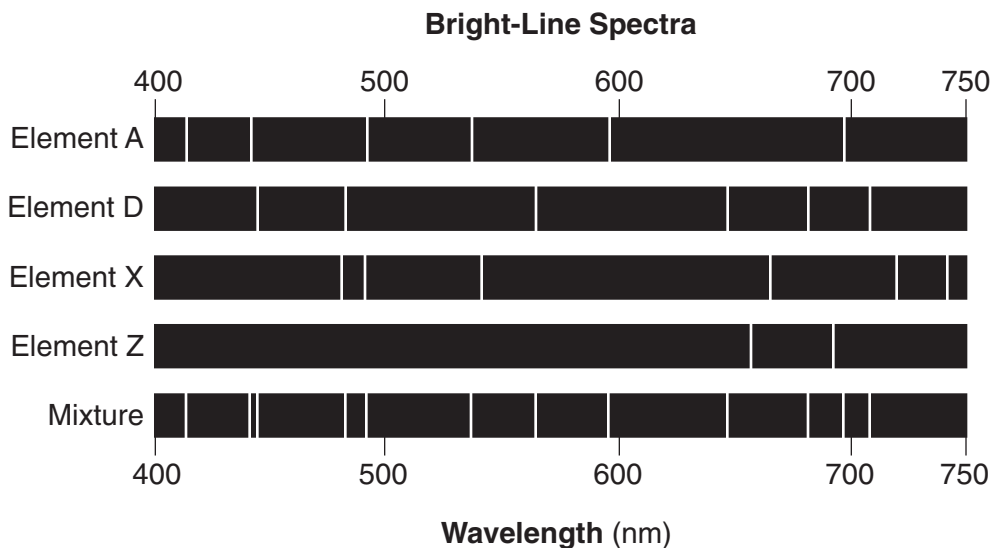
55 Write the letter of each element present in the mixture. [1]

56 Explain, in terms of electrons and energy states, how the light emitted by excited atoms is produced. [1]

Base your answers to questions 57 through 59 on the information below and on your knowledge of chemistry.

Rubidium and iodine have different chemical and physical properties. Some of these properties are shown in the table below.

Some Physical and Chemical Properties of Rubidium and Iodine

| Rubidium	Iodine
silvery-white solid	bluish-black lustrous solid
forms ionic compounds with nonmetals	forms ionic bonds with active metals
reacts with oxygen in the air	sublimes at room temperature
specific heat = 0.363 J/g•K	specific heat = 0.214 J/g•K

57 State the chemical property of iodine listed in this table. [1]

58 Compare the atomic radius of an atom of iodine to the atomic radius of an atom of rubidium when both atoms are in the ground state. [1]

59 Compare the electrical conductivity of these two elements at STP. [1]

Base your answers to questions 60 through 62 on the information below and on your knowledge of chemistry.

Given the unbalanced equation showing the reactants and product of a reaction occurring at 298 K and 100. kPa:

$$P_4(s) + Cl_2(g) \rightarrow PCl_3(\ell) + energy$$
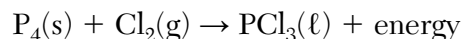
60 Balance the equation *in your answer booklet* for the reaction, using the smallest whole-number coefficients. [1]

61 State why this reaction is a synthesis reaction. [1]

62 Show a numerical setup for calculating the percent composition by mass of chlorine in $PCl_3(\ell)$ (gram-formula mass = 137 g/mol). [1]

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

The diagram below shows the first three steps in the uranium-238 radioactive decay series.
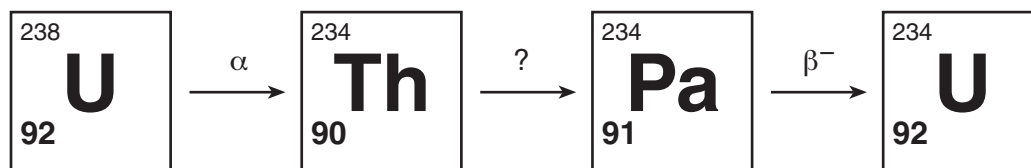
The decay mode for the first and third steps is shown above the arrows. The decay mode for the second step is not shown in the diagram. Thorium-234 has a half-life of 24.10 days.

63 Explain, in terms of neutrons and protons, why U-238 and U-234 are different isotopes of uranium. [1]

64 Identify the decay mode particle emitted from the Th-234. [1]

65 Determine the total time that must elapse until only $\frac{1}{16}$ of an original sample of Th-234 remains unchanged. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answer to question 66 on the information below and on your knowledge of chemistry.

Tetrachloroethene, C_2Cl_4, is a solvent used in many dry cleaning processes.

66 Write the empirical formula for tetrachloroethene. [1]

_____

Base your answers to questions 67 through 69 on the information below and on your knowledge of chemistry.

Thermal energy is absorbed as chemical reactions occur during the process of baking muffins. The batter for muffins often contains baking soda, $NaHCO_3(s)$, which decomposes as the muffins are baked in an oven at 200.°C. The balanced equation below represents this reaction, which releases $CO_2(g)$ and causes the muffins to rise as they bake. The $H_2O(\ell)$ is released into the air of the oven as it becomes a vapor.

$$2NaHCO_3(s) + heat \rightarrow Na_2CO_3(s) + H_2O(\ell) + CO_2(g)$$
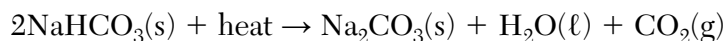
67 Based on Table *E*, identify the polyatomic ion in the solid product of the reaction. [1]

68 State the direction of heat flow between the air in the oven and the muffin batter when the muffin batter is first placed in the preheated oven at 200.°C. [1]

69 Compare the potential energy of the liquid water molecules to the potential energy of the water vapor molecules. [1]

_____

Base your answers to questions 70 through 72 on the information below and on your knowledge of chemistry.

A bubble of air at the bottom of a lake rises to the surface of the lake. Data for the air inside the bubble at the bottom of the lake and at the surface of the lake are listed in the table below.

Data for the Air Inside the Bubble

Location in Lake	Temperature (K)	Pressure (kPa)	Volume (mL)	Density (g/mL)
surface	293	104.0	2.5	0.0012
bottom	282	618.3	?	———

70 State the number of significant figures used to express the pressure at the surface of the lake. [1]

71 Show a numerical setup for calculating the volume of the bubble at the bottom of the lake. [1]

72 Determine the mass of the air in the bubble at the surface of the lake. [1]

Base your answers to questions 73 through 77 on the information below and on your knowledge of chemistry.

Nitrogen dioxide, NO_2, is a dark brown gas that is used to make nitric acid and to bleach flour. Nitrogen dioxide has a boiling point of 294 K at 101.3 kPa. In a rigid cylinder with a movable piston, nitrogen dioxide can be in equilibrium with colorless dinitrogen tetroxide, N_2O_4. This equilibrium is represented by the equation below.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) + 58 \text{ kJ}$$

73 State evidence from the equation that the forward reaction is exothermic. [1]

74 Compare the rate of the forward reaction to the rate of the reverse reaction when the system has reached equilibrium. [1]

75 State one stress, other than adding or removing $NO_2(g)$ or $N_2O_4(g)$, that would increase the amount of the dark brown gas. [1]

76 At standard pressure, compare the strength of intermolecular forces in $NO_2(g)$ to the strength of intermolecular forces in $N_2(g)$. [1]

77 Determine the oxidation state of nitrogen in nitrogen dioxide. [1]

Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

A student sets up a voltaic cell using magnesium and zinc electrodes. The porous barrier in the cell has the same purpose as a salt bridge. The diagram and the ionic equation below represent this operating cell.

Voltaic Cell

$$Mg(s) + Zn^{2+}(aq) \rightarrow Zn(s) + Mg^{2+}(aq)$$
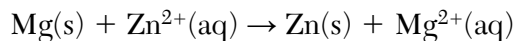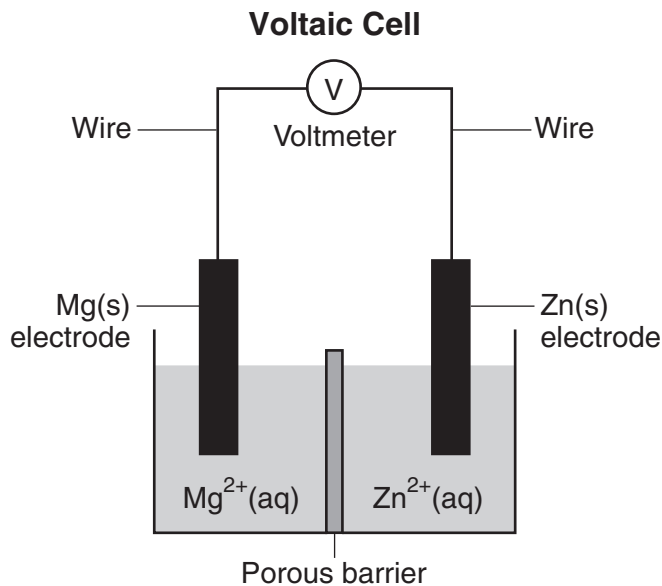
78 Determine the number of moles of $Mg^{2+}(aq)$ ions produced when 2.5 moles of $Zn^{2+}(aq)$ react completely in this cell.   [1]

79 State, in terms of ions, how the porous barrier functions as a salt bridge in this cell.   [1]

80 State, in terms of the relative activity of metals, why the reaction in this cell occurs.   [1]

81 Write a balanced half-reaction equation for the oxidation that occurs in this operating cell.   [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

Polyvinyl chloride (PVC) is a polymer used to make drain pipes, flooring, electric wire insulation, and some plastic bottles. Making PVC requires several reactions. The first step is represented by the equation below.

Equation 1: C_2H_4 + Cl_2 $\rightarrow$ $C_2H_4Cl_2$
                    ethene   chlorine   1,2-dichloroethane
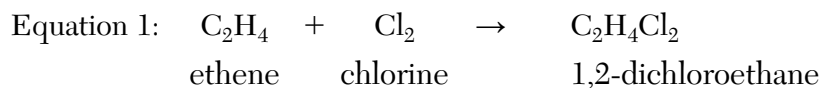
The 1,2-dichloroethane is converted to vinyl chloride. To produce PVC, the vinyl chloride monomer is polymerized, as represented by the equation below.

Equation 2:

Vinyl chloride
(monomer)

PVC
(polymer)
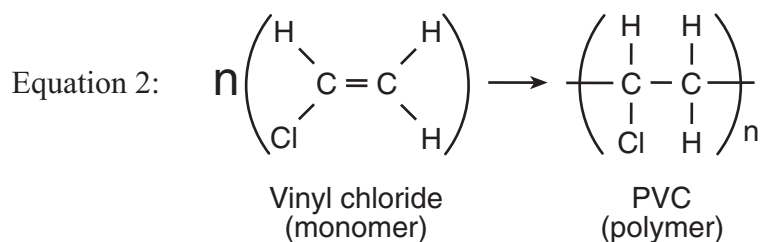
Note: n and n represent the same large number
in the equation.

82 Explain, in terms of chemical bonds, why the hydrocarbon in equation 1 is unsaturated. [1]

83 Identify the class of organic compounds to which the product of equation 1 belongs. [1]

84 Draw a structural formula for the product of equation 1.   [1]

85 State the number of electrons shared between the carbon atoms in a molecule of vinyl chloride.   [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Friday, January 25, 2019 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

1 The results of the gold foil experiment led to the conclusion that an atom is

(1) mostly empty space and has a small, negatively charged nucleus
(2) mostly empty space and has a small, positively charged nucleus
(3) a hard sphere and has a large, negatively charged nucleus
(4) a hard sphere and has a large, positively charged nucleus

2 Atoms are neutral because the number of

(1) protons equals the number of neutrons
(2) protons equals the number of electrons
(3) neutrons is greater than the number of protons
(4) neutrons is greater than the number of electrons

3 In the ground state, valence electrons of a krypton atom are found in

(1) the first shell
(2) the outermost shell
(3) both the nucleus and the first shell
(4) both the first shell and the outermost shell

4 According to the wave-mechanical model of the atom, electrons are located in

(1) orbitals
(2) circular paths
(3) a small, dense nucleus
(4) a hard, indivisible sphere

5 Which electron configuration represents the electrons in an atom of sodium in the ground state at STP?

(1) 2-8-1   (3) 2-8-6
(2) 2-7-2   (4) 2-7-7

6 The elements on the Periodic Table of the Elements are arranged in order of increasing

(1) atomic number
(2) mass number
(3) number of neutrons
(4) number of valence electrons

7 Which element is malleable at STP?

(1) chlorine   (3) helium
(2) copper   (4) sulfur

8 At 298 K and 1 atm, which noble gas has the lowest density?

(1) Ne   (3) Xe
(2) Kr   (4) Rn

9 Which two terms represent types of chemical formulas?

(1) empirical and molecular
(2) polar and nonpolar
(3) synthesis and decomposition
(4) saturated and concentrated

10 Which quantities are conserved in all chemical reactions?

(1) charge, pressure, and energy
(2) charge, mass, and energy
(3) volume, pressure, and energy
(4) volume, mass, and pressure

11 Which term represents the sum of the atomic masses of the atoms in a molecule?

(1) atomic number
(2) mass number
(3) formula mass
(4) percent composition by mass

12 Which equation represents energy being absorbed as a bond is broken?

(1) $H + H \rightarrow H_2$ + energy
(2) $H + H$ + energy $\rightarrow H_2$
(3) $H_2 \rightarrow H + H$ + energy
(4) H_2 + energy $\rightarrow H + H$

13 Which term is used to describe the attraction that an oxygen atom has for the electrons in a chemical bond?

(1) alkalinity
(2) electronegativity
(3) electron configuration
(4) first ionization energy

14 Which substance can *not* be decomposed by chemical means?

(1) C   (3) CO_2
(2) CO   (4) C_3O_2

15 A beaker contains a dilute sodium chloride solution at 1 atmosphere. What happens to the number of solute particles in the solution and the boiling point of the solution, as more sodium chloride is dissolved?

(1) The number of solute particles increases, and the boiling point increases.
(2) The number of solute particles increases, and the boiling point decreases.
(3) The number of solute particles decreases, and the boiling point increases.
(4) The number of solute particles decreases, and the boiling point decreases.

16 Which form of energy is transferred when an ice cube at 0°C is placed in a beaker of water at 50°C?

(1) chemical   (3) nuclear
(2) electrical   (4) thermal

17 The average kinetic energy of the particles in a sample of matter is expressed as

(1) density   (3) pressure
(2) volume   (4) temperature

18 At STP, which gas sample has the same number of molecules as 2.0 liters of $CH_4(g)$ at STP?

(1) 1.0 liter of $C_2H_6(g)$
(2) 2.0 liters of $O_2(g)$
(3) 5.0 liters of $N_2(g)$
(4) 6.0 liters of $CO_2(g)$

19 Given the equation:

$$I_2(s) \rightarrow I_2(g)$$

Which phrase describes this change?

(1) endothermic chemical change
(2) endothermic physical change
(3) exothermic chemical change
(4) exothermic physical change

20 Which term identifies a factor that will shift a chemical equilibrium?

(1) atomic radius   (3) decay mode
(2) catalyst   (4) temperature

21 According to which theory or law is a chemical reaction most likely to occur when two particles with the proper energy and orientation interact with each other?

(1) atomic theory
(2) collision theory
(3) combined gas law
(4) law of conservation of matter

22 Addition of a catalyst can speed up a reaction by providing an alternate reaction pathway that has a

(1) lower activation energy
(2) higher activation energy
(3) lower heat of reaction
(4) higher heat of reaction

23 Which compound is saturated?

(1) butane   (3) heptene
(2) ethene   (4) pentyne

24 An alcohol and an ether have the same molecular formula, C_2H_6O. These two compounds have

(1) the same functional group and the same physical and chemical properties
(2) the same functional group and different physical and chemical properties
(3) different functional groups and the same physical and chemical properties
(4) different functional groups and different physical and chemical properties

25 Which metal is most easily oxidized?

(1) Ag   (3) Cu
(2) Co   (4) Mg

26 Which substance is an Arrhenius acid?

(1) H_2 (3) KCl
(2) HCl   (4) NH_3

27 Which statement describes an electrolyte?

(1) An electrolyte conducts an electric current as a solid and dissolves in water.
(2) An electrolyte conducts an electric current as a solid and does not dissolve in water.
(3) When an electrolyte dissolves in water, the resulting solution conducts an electric current.
(4) When an electrolyte dissolves in water, the resulting solution does not conduct an electric current.

28 Which type of reaction occurs when an Arrhenius acid reacts with an Arrhenius base to form a salt and water?

(1) combustion   (3) neutralization
(2) decomposition   (4) saponification

29 Compared to the energy released per mole of reactant during chemical reactions, the energy released per mole of reactant during nuclear reactions is

(1) much less   (3) slightly less
(2) much greater   (4) slightly greater

30 Which phrase describes a risk of using the radioisotope Co-60 in treating cancer?

(1) production of acid rain
(2) production of greenhouse gases
(3) increased biological exposure
(4) increased ozone depletion

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 The three nuclides, U-233, U-235, and U-238, are isotopes of uranium because they have the same number of protons per atom and

(1) the same number of electrons per atom
(2) the same number of neutrons per atom
(3) a different number of electrons per atom
(4) a different number of neutrons per atom

32 Given the information in the table below:

Two Forms of Carbon

Form	Bonding	Hardness	Electrical Conductivity
diamond	Each carbon atom bonds to four other carbon atoms in a three-dimensional network.	very hard	no
graphite	Each carbon atom bonds to three other carbon atoms in two-dimensional sheets.	soft	yes

Diamond and graphite have different properties because they have different

(1) crystal structures
(2) electronegativities
(3) numbers of protons per atom
(4) numbers of valence electrons per atom

33 Given the equation representing a chemical reaction:

$$NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$$
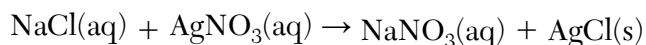
This reaction is classified as a

(1) synthesis reaction
(2) decomposition reaction
(3) single replacement reaction
(4) double replacement reaction

34 What is the formula for iron(II) oxide?

(1) FeO (3) Fe_2O
(2) FeO_2 (4) Fe_2O_3

35 Given the reaction:

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

How many moles of $KClO_3$ must completely react to produce 6 moles of O_2?

(1) 1 mole (3) 6 moles
(2) 2 moles (4) 4 moles

36 What is the number of moles of CO_2 in a 220.-gram sample of CO_2 (gram-formula mass = 44 g/mol)?

(1) 0.20 mol (3) 15 mol
(2) 5.0 mol (4) 44 mol

37 A solution contains 25 grams of KNO_3 dissolved in 200. grams of H_2O. Which numerical setup can be used to calculate the percent by mass of KNO_3 in this solution?

(1) $\dfrac{25\,g}{175\,g} \times 100$ (3) $\dfrac{25\,g}{225\,g} \times 100$

(2) $\dfrac{25\,g}{200.\,g} \times 100$ (4) $\dfrac{200.\,g}{225\,g} \times 100$

38 What is the molarity of 0.50 liter of an aqueous solution that contains 0.20 mole of NaOH (gram-formula mass = 40. g/mol)?

(1) 0.10 M (3) 2.5 M
(2) 0.20 M (4) 0.40 M

39 A mixture consists of ethanol and water. Some properties of ethanol and water are given in the table below.

Some Properties of Ethanol and Water

Property	Ethanol	Water
boiling point at standard pressure	78°C	100.°C
density at STP	0.80 g/cm³	1.00 g/cm³
flammability	flammable	nonflammable
melting point	−114°C	0.°C

Which statement describes a property of ethanol after being separated from the mixture?

(1) Ethanol is nonflammable.
(2) Ethanol has a melting point of 0.°C.
(3) Ethanol has a density of 0.80 g/cm³ at STP.
(4) Ethanol has a boiling point of 89°C at standard pressure.

40 A rigid cylinder with a movable piston contains a sample of hydrogen gas. At 330. K, this sample has a pressure of 150. kPa and a volume of 3.50 L. What is the volume of this sample at STP?
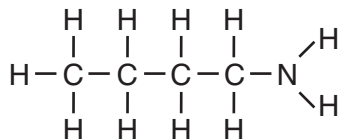
(1) 0.233 L (3) 4.29 L
(2) 1.96 L (4) 6.26 L

41 Which numerical setup can be used to calculate the heat energy required to completely melt 100. grams of $H_2O(s)$ at 0°C?

(1) (100. g)(334 J/g)
(2) (100. g)(2260 J/g)
(3) (100. g)(4.18 J/g•K)(0°C)
(4) (100. g)(4.18 J/g•K)(273 K)

42 During which phase change does the entropy of a sample of H_2O increase?

(1) $H_2O(g) \rightarrow H_2O(\ell)$
(2) $H_2O(g) \rightarrow H_2O(s)$
(3) $H_2O(\ell) \rightarrow H_2O(g)$
(4) $H_2O(\ell) \rightarrow H_2O(s)$

43 Given the formula for a compound:

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-N\overset{H}{\underset{H}{}}$$
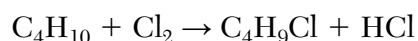
What is a chemical name for this compound?

(1) 1-butanamide   (3) 1-butanamine
(2) 4-butanamide   (4) 4-butanamine

44 Given the equation for a reaction:

$$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$$

Which type of reaction is represented by the equation?

(1) addition   (3) fermentation
(2) substitution   (4) polymerization

45 Which half-reaction equation represents reduction?

(1) $Cu \rightarrow Cu^{2+} + 2e^-$
(2) $Cu^{2+} + 2e^- \rightarrow Cu$
(3) $Ag + e^- \rightarrow Ag^+$
(4) $Ag^+ \rightarrow Ag + e^-$

46 Given the balanced ionic equation representing a reaction:

$$Zn(s) + Co^{2+}(aq) \rightarrow Zn^{2+}(aq) + Co(s)$$
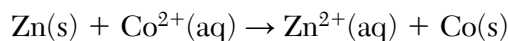
Which statement describes the electrons involved in this reaction?

(1) Each Zn atom loses 2 electrons, and each Co^{2+} ion gains 2 electrons.
(2) Each Zn atom loses 2 electrons, and each Co^{2+} ion loses 2 electrons.
(3) Each Zn atom gains 2 electrons, and each Co^{2+} ion loses 2 electrons.
(4) Each Zn atom gains 2 electrons, and each Co^{2+} ion gains 2 electrons.

47 What are the two oxidation states of nitrogen in NH_4NO_2?

(1) $+3$ and $+5$ (3) -3 and $+3$
(2) $+3$ and -5 (4) -3 and -3

48 The table below shows the molar concentrations of hydronium ion, H_3O^+, in four different solutions.
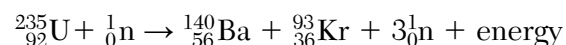
Molar Concentration of H_3O^+ Ions in Four Solutions

Solution	Molar Concentration of H_3O^+ Ion (M)
A	0.1
B	0.01
C	0.001
D	0.0001

Which solution has the highest pH?

(1) A   (3) C
(2) B   (4) D

49 Given the equation:

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{56}Ba + {}^{93}_{36}Kr + 3{}^{1}_{0}n + energy$$

Which type of nuclear reaction is represented by the equation?

(1) fission   (3) beta decay
(2) fusion   (4) alpha decay

50 Which nuclear emission has the *least* penetrating power and the greatest ionizing ability?

(1) alpha particle   (3) gamma ray
(2) beta particle   (4) positron

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 51 through 54 on the information below and on your knowledge of chemistry.

The formulas and names of four chloride compounds are shown in the table below.

Formula	Name
CCl_4	carbon tetrachloride
RbCl	rubidium chloride
CsCl	cesium chloride
HCl	hydrogen chloride

51 Identify the noble gas that has atoms with the same electron configuration as the metal ions in rubidium chloride, when both the atoms and the ions are in the ground state.   [1]

52 Explain, in terms of atomic structure, why the radius of a cesium ion in cesium chloride is smaller than the radius of a cesium atom when both are in the ground state.   [1]

53 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for a molecule of HCl.   [1]

54 Explain, in terms of charge distribution, why a molecule of carbon tetrachloride is a nonpolar molecule.   [1]

Base your answers to questions 55 through 57 on the information below and on your knowledge of chemistry.

Some isotopes of neon are Ne-19, Ne-20, Ne-21, Ne-22, and Ne-24. The neon-24 decays by beta emission. The atomic mass and natural abundance for the naturally occurring isotopes of neon are shown in the table below.

Naturally Occurring Isotopes of Neon

Isotope Notation	Atomic Mass (u)	Natural Abundance (%)
Ne-20	19.99	90.48
Ne-21	20.99	0.27
Ne-22	21.99	9.25

55 Identify the decay mode of Ne-19. [1]

56 State the number of neutrons in an atom of Ne-20 and the number of neutrons in an atom of Ne-22. [1]

57 Show a numerical setup for calculating the atomic mass of neon. [1]

Base your answers to questions 58 through 60 on the information below and on your knowledge of chemistry.

Periodic trends are observed in the properties of the elements in Period 3 on the Periodic Table. These elements vary in physical properties, such as phase, and in chemical properties, such as their ability to lose or gain electrons during a chemical reaction.

58 Identify the metals in Period 3 on the Periodic Table. [1]

59 Identify the element in Period 3 that requires the *least* amount of energy to remove the most loosely held electrons from a mole of gaseous atoms of the element in the ground state. [1]

60 State the general trend in atomic radius as the elements in Period 3 are considered in order of increasing atomic number. [1]

Base your answers to questions 61 through 63 on the information below and on your knowledge of chemistry.

A thiol is very similar to an alcohol, but a thiol has a sulfur atom instead of an oxygen atom in the functional group. The equation below represents a reaction of methanethiol and iodine, producing dimethyl disulfide and hydrogen iodide.

$$2\left(\begin{array}{c} H \\ | \\ H-C-S-H \\ | \\ H \end{array}\right) + I_2 \longrightarrow \begin{array}{cc} H & H \\ | & | \\ H-C-S-S-C-H \\ | & | \\ H & H \end{array} + 2HI$$

Methanethiol   Dimethyl disulfide
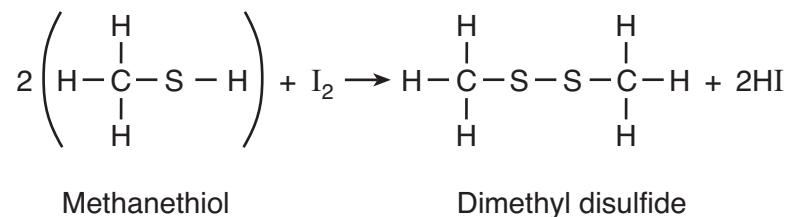
61 State the number of electrons shared between the sulfur atoms in the dimethyl disulfide. [1]

62 Identify the polarity of an H–I bond and the polarity of an S–S bond. [1]

63 Explain, in terms of electron configuration, why sulfur atoms and oxygen atoms form compounds with similar molecular structures. [1]

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

A student constructs an electrochemical cell. A diagram of the operating cell and the unbalanced ionic equation representing the reaction occurring in the cell are shown below.
The blue color of the solution in the copper half-cell indicates the presence of Cu^{2+} ions. The student observes that the blue color becomes less intense as the cell operates.

$$Fe(s) + Cu^{2+}(aq) \longrightarrow Fe^{2+}(aq) + Cu(s)$$
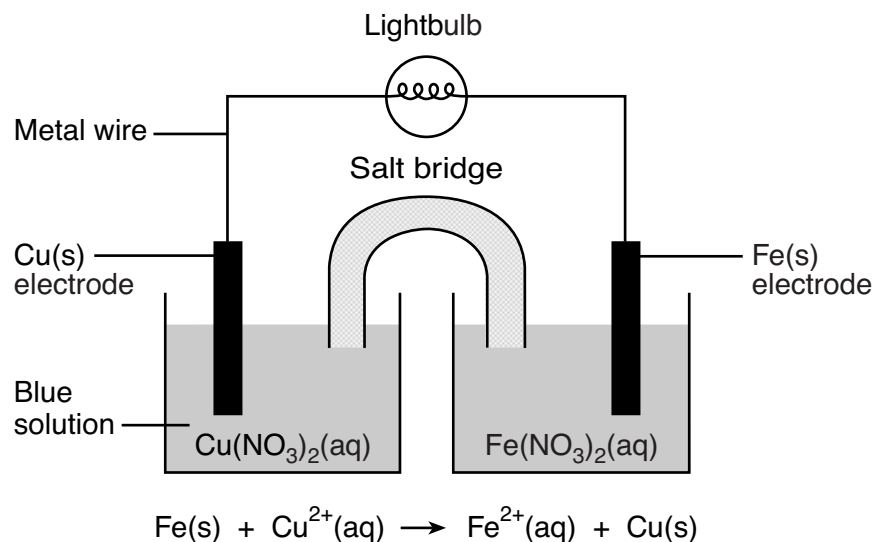
64 Identify the type of electrochemical cell represented by the diagram. [1]

65 State *one* inference that the student can make about the concentration of the Cu^{2+} ions based on the change in intensity of the color of the $Cu(NO_3)_2(aq)$ solution as the cell operates. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

In a laboratory investigation, a student is given a sample that is a mixture of 3.0 grams of NaCl(s) and 4.0 grams of sand, which is mostly SiO_2(s). The purpose of the investigation is to separate and recover the compounds in the sample. In the first step, the student places the sample in a 250-mL flask. Then, 50. grams of distilled water are added to the flask, and the contents are thoroughly stirred. The mixture in the flask is then filtered, using the equipment represented by the diagram below.
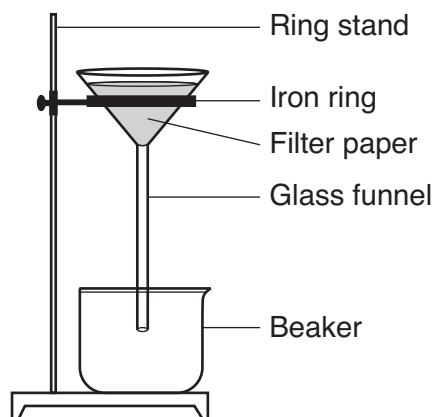
66 Explain, in terms of solubility, why the mixture in the flask remains heterogeneous even after thorough stirring.   [1]

67 Based on Table *G*, state evidence that all of the NaCl(s) in the flask would dissolve in the distilled water at 20.°C.   [1]

68 Describe a procedure to remove the water from the mixture that passes through the filter and collects in the beaker.   [1]

69 The student reports that 3.4 grams of NaCl(s) were recovered from the mixture. Show a numerical setup for calculating the student's percent error.   [1]

Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

In a laboratory activity, the volume of helium gas in a rigid cylinder with a movable piston is varied by changing the temperature of the gas. The activity is done at a constant pressure of 100. kPa. Data from the activity are plotted on the graph below.

**Volume of He(g) Versus
Temperature at 100. kPa**
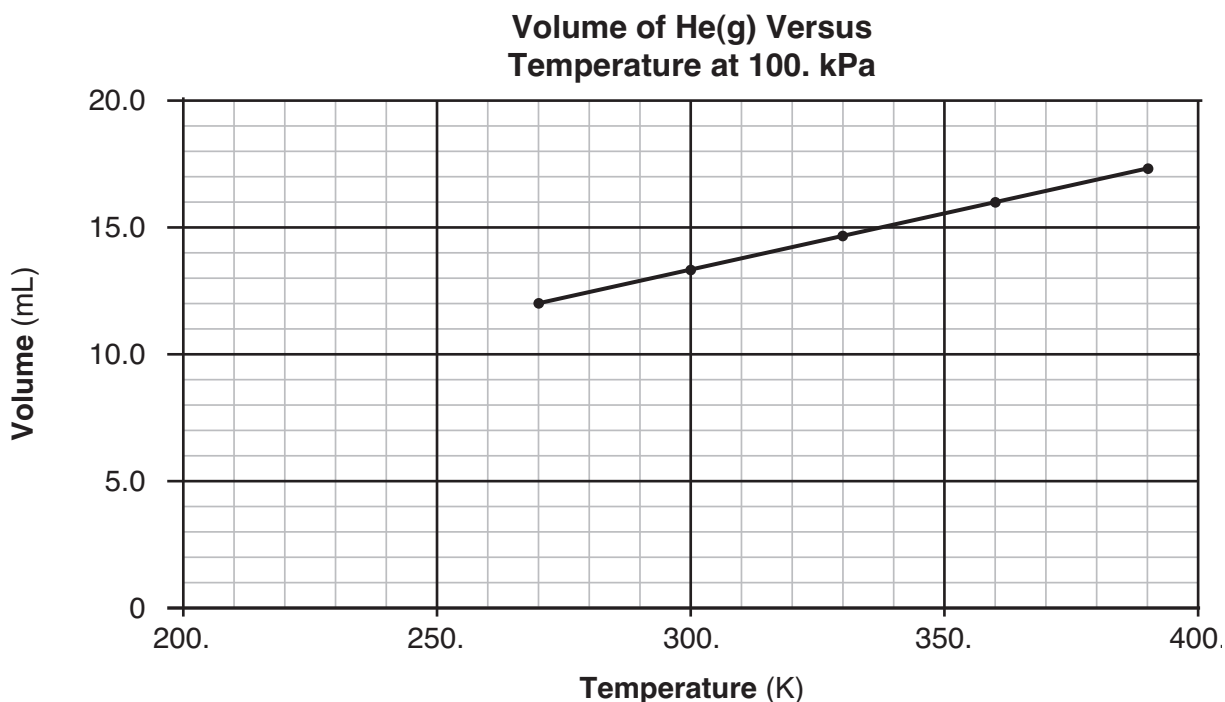
70 Determine the temperature of the He(g) at a volume of 15.0 mL.   [1]

71 Explain, in terms of particle volume, why the sample of helium can *not* be compressed by the piston to zero volume.   [1]

72 State what happens to the average distance between the He atoms as the gas is heated.   [1]

73 State a change in pressure that will cause the helium in the cylinder to behave more like an ideal gas.   [1]

Base your answers to questions 74 through 76 on the information below and on your knowledge of chemistry.

The balanced equation below represents the reaction between a 5.0-gram sample of zinc metal and a 0.5 M solution of hydrochloric acid. The reaction takes place in an open test tube at 298 K and 1 atm in a laboratory activity.

$$Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq) + energy$$
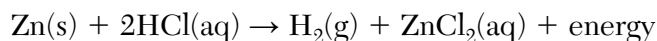
74 State *one* change in reaction conditions, other than adding a catalyst, that will increase the rate of the reaction. [1]

75 On the labeled axes *in your answer booklet*, draw a potential energy diagram for this reaction. [1]

76 Explain why this reaction will *not* reach equilibrium. [1]

Base your answers to questions 77 through 79 on the information below and on your knowledge of chemistry.

Crude oil, primarily a mixture of hydrocarbons, is separated into useful components in a fractionating tower. At the bottom of the tower, the crude oil is heated to about 400°C. The gases formed rise and cool. Most of the gases condense and are collected as liquid fractions. The table below shows the temperature ranges for collecting various hydrocarbon fractions.

Hydrocarbon Fractions Collected

Number of Carbon Atoms per Molecule	Temperature Range (°C)
1-4	below 40
5-12	40-200
12-16	200-300
16-20	300-370
>20	above 370

77 Determine the number of carbon atoms in one molecule of an alkane that has 22 hydrogen atoms in the molecule. [1]

78 State the temperature range for the fraction collected that contains octane molecules. [1]

79 Draw a structural formula for 3-ethylhexane. [1]

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

In a laboratory activity, a student titrates a 20.0-milliliter sample of HCl(aq) using 0.025 M NaOH(aq). In one of the titration trials, 17.6 milliliters of the base solution exactly neutralizes the acid sample.

80 Identify the positive ion in the sample of HCl(aq).   [1]

81 Show a numerical setup for calculating the concentration of the hydrochloric acid using the titration data.   [1]

82 The concentration of the base is expressed to what number of significant figures?   [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

In the past, some paints that glowed in the dark contained zinc sulfide and salts of Ra-226. As the radioisotope Ra-226 decayed, the energy released caused the zinc sulfide in these paints to emit light. The half-lives for Ra-226 and two other radioisotopes used in these paints are listed on the table below.

Radioisotopes in the Paints

Radioisotope	Half-Life (y)
Pm-147	2.6
Ra-226	1599
Ra-228	5.8

83 Explain, in terms of half-lives, why Ra-226 may have been used more often than the other isotopes in these paints. [1]

84 Complete the nuclear equation *in your answer booklet* for the beta decay of Pm-147 by writing an isotopic notation for the missing product. [1]

85 What fraction of an original Ra-228 sample remains unchanged after 17.4 years? [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Friday, January 24, 2020 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which statement describes a concept included in the wave-mechanical model of the atom?

(1) Protons, neutrons, and electrons are located in the nucleus.
(2) Electrons orbit the nucleus in shells at fixed distances.
(3) Atoms are hard, indivisible spheres.
(4) Electrons are located in regions called orbitals.

2 As an electron in an atom moves from a higher energy state to a lower energy state, the atom

(1) becomes a negative ion
(2) becomes a positive ion
(3) releases energy
(4) absorbs energy

3 Two atoms that are different isotopes of the same element have

(1) the same number of protons and the same number of neutrons
(2) the same number of protons but a different number of neutrons
(3) a different number of protons but the same number of neutrons
(4) a different number of protons and a different number of neutrons

4 The element in Group 14, Period 3, of the Periodic Table is classified as a

(1) metal   (3) metalloid
(2) noble gas   (4) nonmetal

5 Which element has chemical properties that are most similar to potassium?

(1) calcium   (3) nitrogen
(2) cesium   (4) sulfur

6 Which element requires the *least* amount of energy to remove the most loosely held electron from a gaseous atom in the ground state?

(1) Na   (3) P
(2) Ar   (4) Cl

7 Which terms identify two different categories of compounds?

(1) covalent and molecular
(2) covalent and empirical
(3) ionic and molecular
(4) ionic and empirical

8 Which statement describes the energy and bonding changes as two atoms of fluorine become a molecule of fluorine?

(1) Energy is absorbed as a bond is broken.
(2) Energy is absorbed as a bond is formed.
(3) Energy is released as a bond is broken.
(4) Energy is released as a bond is formed.

9 Which part of a calcium atom in the ground state is represented by the dots in its Lewis electron-dot diagram?

(1) the electrons in the first shell
(2) the electrons in the fourth shell
(3) the protons in the nucleus
(4) the neutrons in the nucleus

10 Based on Table S, an atom of which element has the strongest attraction for electrons in a chemical bond?

(1) aluminum   (3) magnesium
(2) chlorine   (4) sulfur

11 Which substance can *not* be broken down by chemical means?

(1) aluminum
(2) ammonia
(3) aluminum oxide
(4) ammonium chloride

12 Which statement describes the particles of an ideal gas, based on the kinetic molecular theory?

(1) There are attractive forces between the particles.
(2) The particles move in circular paths.
(3) The collisions between the particles reduce the total energy of the gas.
(4) The volume of the gas particles is negligible compared with the total volume of the gas.

13 What is the amount of heat released by 1.00 gram of liquid water at 0°C when it changes to 1.00 gram of ice at 0°C?

(1) 4.18 J   (3) 334 J
(2) 273 J   (4) 2260 J

14 Which term identifies a type of intermolecular force?

(1) covalent bonding   (3) ionic bonding
(2) hydrogen bonding   (4) metallic bonding

15 Which statement describes a reaction at equilibrium?

(1) The mass of the products must equal the mass of the reactants.
(2) The entropy of the reactants must equal the entropy of the products.
(3) The rate of formation of the products must equal the rate of formation of the reactants.
(4) The number of moles of the reactants must equal the number of moles of the products.

16 Entropy is a measure of

(1) accuracy
(2) precision
(3) the disorder of a system
(4) the attraction of a nucleus for an electron

17 Systems in nature tend to undergo changes toward

(1) lower energy and less randomness
(2) higher energy and less randomness
(3) lower energy and greater randomness
(4) higher energy and greater randomness

18 Which organic prefix is matched with the number of carbon atoms that it represents?

(1) hept-, 7   (3) pent-, 3
(2) non-, 8   (4) prop-, 4

19 Which terms represent two types of organic reactions?

(1) sublimation and deposition
(2) sublimation and fermentation
(3) saponification and deposition
(4) saponification and fermentation

20 Given the organic functional group:

$$-\overset{\overset{\displaystyle O}{\|}}{C}-H$$

Which class of organic compounds has molecules with this functional group?

(1) aldehydes   (3) ketones
(2) esters   (4) organic acids

21 Which particles are transferred during a redox reaction?

(1) atoms   (3) neutrons
(2) electrons   (4) positrons

22 Which process can be represented by a half-reaction equation?

(1) distillation   (3) sublimation
(2) oxidation   (4) vaporization

23 Which form of energy is converted to electrical energy in a voltaic cell?

(1) chemical   (3) nuclear
(2) mechanical   (4) thermal

24 Which compound is an Arrhenius base?

(1) HCl
(3) $Ca(OH)_2$
(2) H_3PO_4
(4) CH_3COOH

25 In a neutralization reaction, an aqueous solution of an Arrhenius acid reacts with an aqueous solution of an Arrhenius base to produce

(1) an ether and water
(2) an ether and an alcohol
(3) a salt and water
(4) a salt and an alcohol

26 According to one acid-base theory, a base is an

(1) H_2 acceptor
(3) H^+ acceptor
(2) H_2 donor
(4) H^+ donor

27 Based on Table *N*, uranium-238 and uranium-235 have different

(1) decay modes
(2) half-lives
(3) numbers of protons
(4) numbers of electrons

28 A change in the nucleus of an atom that converts the atom from one element to another element is called

(1) oxidation-reduction
(2) single replacement
(3) substitution
(4) transmutation

29 Which radioactive emission has the greatest penetrating power, but the *least* ionizing power?

(1) alpha particle
(3) gamma ray
(2) beta particle
(4) positron

30 Which statement describes a benefit of using fission reactions?

(1) Radioactive waste must be stored for long periods of time.
(2) Nuclear fuel consists of stable isotopes.
(3) Gamma radiation is produced.
(4) Large amounts of energy are produced per mole of reactant.

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Given the table representing the subatomic particles in four different atoms:

Atom	Number of Protons	Number of Neutrons	Number of Electrons
A	4	4	4
E	5	7	5
G	6	7	6
J	12	12	12

Which atom has a mass of 12 u?
(1) *A*   (3) *G*
(2) *E*   (4) *J*

32 Which electron configuration could represent the electrons in a sodium atom in an excited state?
(1) 2-8   (3) 2-7-1
(2) 2-8-1   (4) 2-7-2

33 What is the number of valence electrons in a nitrogen atom in the ground state?
(1) 5   (3) 7
(2) 2   (4) 14

34 Graphite and diamond are both solid forms of the element carbon. Which statement explains the different properties of these two forms of carbon?

(1) Diamond has ionic bonding and graphite has metallic bonding.
(2) Diamond has metallic bonding and graphite has ionic bonding.
(3) Diamond has a different crystal structure from graphite.
(4) Diamond has carbon atoms with more valence electrons than graphite.

35 A measured value for the atomic radius of platinum atoms was determined to be 143 picometers. Based on Table *S*, what is the percent error of this measured value?
(1) 0.10%   (3) 10.%
(2) 9.1%   (4) 13%

36 What is the chemical formula for sodium oxalate?
(1) NaO (3) NaC_2O_4
(2) Na_2O (4) $Na_2C_2O_4$

37 Given the formula of a compound:

$$\underset{H}{\overset{H}{\diagdown}}C=\underset{H}{\overset{H}{\vert}}C-\underset{H}{\overset{H}{\underset{\vert}{\overset{\vert}{C}}}}-H$$
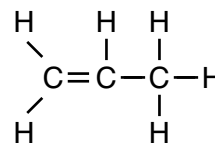
What is the molecular formula for this compound?
(1) CH (3) CH_3
(2) CH_2 (4) C_3H_6

38 Which equation represents conservation of charge?
(1) $I^- + 2e^- \rightarrow I_2$ (3) $Br_2 \rightarrow 2Br^- + 2e^-$
(2) $2I^- \rightarrow I_2 + 2e^-$ (4) $Br + 2e^- \rightarrow Br^-$

39 Which equation represents a single replacement reaction?
(1) $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$
(2) $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$
(3) $2AlCl_3(s) \rightarrow 2Al(s) + 3Cl_2(g)$
(4) $AlCl_3(aq) + 3KOH(aq) \rightarrow Al(OH)_3(s) + 3KCl(aq)$

40 The bond between which two atoms is most polar?
(1) C–O   (3) H–O
(2) F–F   (4) N–H

41 The table below shows the volume and temperature of four different gas samples at 100. kPa.

| Gas Sample	Volume (L)	Temperature (°C)
helium	1	25
neon	2	50.
argon	1	25
krypton	2	25

Which two gas samples contain equal numbers of atoms?

(1) helium and neon
(2) helium and argon
(3) neon and argon
(4) neon and krypton

42 Given the equation representing a solution equilibrium:

$$BaSO_4(s) \xrightleftharpoons{H_2O} Ba^{2+}(aq) + SO_4^{2-}(aq)$$
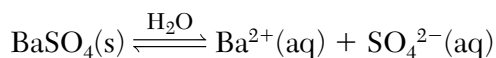
What occurs when $Na_2SO_4(s)$ is added to this system, increasing the concentration of $SO_4^{2-}(aq)$?

(1) The equilibrium shifts to the left, and the concentration of $Ba^{2+}(aq)$ decreases.
(2) The equilibrium shifts to the left, and the concentration of $Ba^{2+}(aq)$ increases.
(3) The equilibrium shifts to the right, and the concentration of $Ba^{2+}(aq)$ decreases.
(4) The equilibrium shifts to the right, and the concentration of $Ba^{2+}(aq)$ increases.

43 Given the formula for a compound:

```
     H   H   H   O
     |   |   |   ||
 H — C — C — C — C — N — H
     |   |   |       |
     H   H   H       H
```
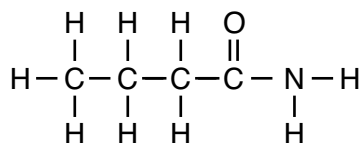
What is a chemical name for the compound?

(1) 1-butanamine   (3) butanamide
(2) 1-butanol   (4) butanoic acid

44 Given the potential energy diagram representing a reaction:

Reaction Coordinate
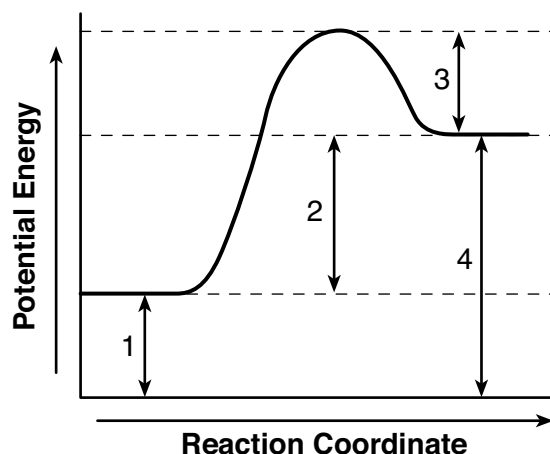
Which numbered interval represents the heat of reaction?

(1) 1   (3) 3
(2) 2   (4) 4

45 When comparing voltaic cells to electrolytic cells, oxidation occurs at the

(1) anode in both types of cells
(2) cathode in both types of cells
(3) anode in voltaic cells, only
(4) cathode in voltaic cells, only

46 Based on Table J, which metal is more active than tin, but less active than zinc?

(1) Ag   (3) Cs
(2) Cr   (4) Mn

47 In a titration, 10.0 mL of 0.0750 M HCl(aq) is exactly neutralized by 30.0 mL of KOH(aq) of unknown concentration. What is the concentration of the KOH(aq) solution?

(1) 0.0250 M   (3) 0.225 M
(2) 0.0750 M   (4) 0.333 M

48 Which emission causes the atomic number of a nuclide to decrease by 2 and its mass number to decrease by 4?

(1) an alpha particle   (3) gamma radiation
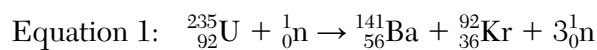(2) a beta particle   (4) a positron

49 The diagram below represents the bright-line spectra of four elements and a bright-line spectrum produced by an unidentified element.

Bright-Line Spectra

Wavelength (nm)
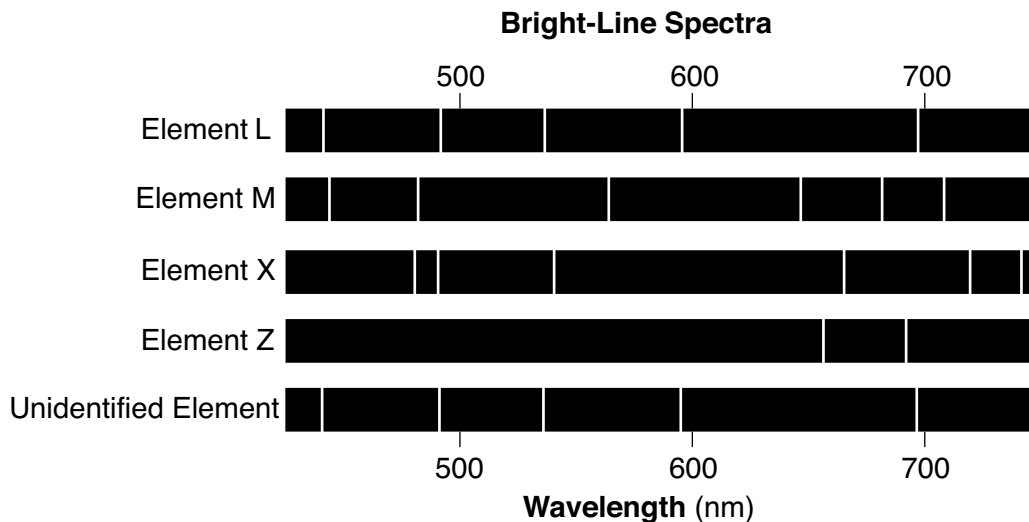
What is the unidentified element?

(1) *L*

(2) *M*

(3) *X*

(4) Z

50 Given two equations representing reactions:

$$\text{Equation 1:} \quad {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n$$

$$\text{Equation 2:} \quad {}^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He$$

Which type of reaction is represented by each of these equations?

(1) Both equations represent fission.

(2) Both equations represent fusion.

(3) Equation 1 represents fission and equation 2 represents fusion.

(4) Equation 1 represents fusion and equation 2 represents fission.

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 51 through 53 on the information below and on your knowledge of chemistry.

The four naturally occurring isotopes of sulfur are S-32, S-33, S-34, and S-36. The table below shows the atomic mass and percent natural abundance for these isotopes.

Naturally Occurring Isotopes of Sulfur

Isotope	Atomic Mass (u)	Natural Abundance (%)
S-32	31.972	94.99
S-33	32.971	0.75
S-34	33.968	4.25
S-36	35.967	0.01

51 State *both* the number of protons and the number of neutrons in an S-33 atom.   [1]

52 In the space *in your answer booklet*, show a numerical setup for calculating the atomic mass of sulfur.   [1]

53 Compare the energy of an electron in the third shell of a sulfur atom to the energy of an electron in the first shell of the same atom.   [1]

Base your answers to questions 54 through 57 on the information below and on your knowledge of chemistry.

During a laboratory activity, appropriate safety equipment is used and safety procedures are followed. A student separates a sample of rock salt that has two components; NaCl(s) and small insoluble rock particles. First, the student thoroughly stirs the sample of rock salt into a sample of water in a flask. The mixture in the flask is filtered using the lab apparatus shown below.
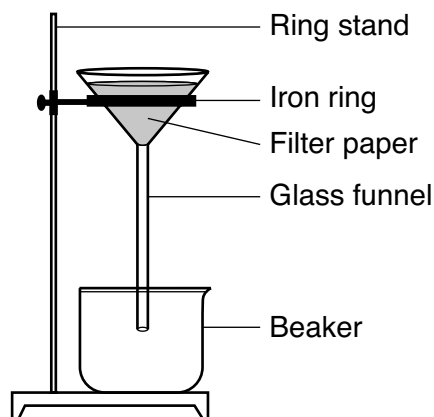
The water is evaporated from the beaker. The filter paper and its contents are dried. The data collected by the student are shown in the table below.

Rock Salt Separation Lab Data

Object or Material	Mass (g)
rock salt sample	16.4
filter paper	1.6
clean empty beaker	224.2
filter paper with dry rock particles	2.2
beaker with dry NaCl(s)	240.0

54 State evidence, other than mass, from the information given that the components of rock salt have different properties. [1]

55 Explain, in terms of particle size, why the rock particles are trapped by the filter paper. [1]

56 State the number of significant figures in the mass of the beaker with dry NaCl(s). [1]

57 Show a numerical setup for calculating the percent by mass of NaCl in the rock salt sample. [1]

Base your answers to questions 58 through 61 on the information below and on your knowledge of chemistry.

Cylinder *A* and cylinder *B* are sealed, rigid cylinders with movable pistons. Each cylinder contains 500. milliliters of a gas sample at 101.3 kPa and 298 K. Cylinder *A* contains $H_2(g)$ and cylinder *B* contains $N_2(g)$. The diagrams below represent these two cylinders.

Cylinder A   **Cylinder B**

Movable piston

$H_2(g)$ $N_2(g)$
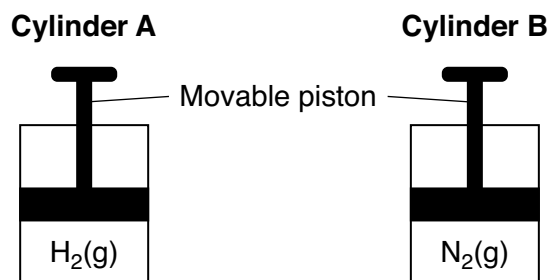
58 Compare the mass of the gas in cylinder *A* to the mass of the gas in cylinder *B*.   [1]

59 State a change in temperature and a change in pressure that will cause the gas in cylinder *A* to behave more like an ideal gas.   [1]

60 Explain, in terms of collisions between gas molecules and the walls of the container, why pushing the movable piston farther into cylinder *B* at constant temperature would increase the pressure of the N_2 gas.   [1]

61 Show a numerical setup for calculating the volume of the gas in cylinder *B* at STP.   [1]

Base your answers to questions 62 and 63 on the information below and on your knowledge of chemistry.

The electrical conductivity of three aqueous solutions was tested at room temperature. A 0.1 M HCl(aq) solution conducted, but a 6.0 M HCl(aq) solution was a better conductor. A 0.1 M $C_6H_{12}O_6$(aq) solution was also tested. During this laboratory activity, appropriate safety equipment was used and safety procedures were followed.

62 State, in terms of the concentration of ions, why the 6.0 M HCl(aq) is a better conductor of electricity than the 0.1 M HCl(aq).   [1]

63 Identify the element in $C_6H_{12}O_6$ that allows it to be classified as an organic compound.   [1]

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

Phosphorus-30 and phosphorus-32 are radioisotopes. Phosphorus-30 decays by positron emission.

64 Complete the equation *in your answer booklet* for the decay of phosphorus-30 by writing a notation for the missing product.   [1]

65 Based on Table *N*, determine the time required for an original 100.-milligram sample of P-32 to decay until only 25 milligrams of the sample remain unchanged.   [1]

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

Sir William Ramsey is one scientist credited with identifying the noble gas argon. Sir Ramsey separated nitrogen gas from the air and reacted it with an excess of magnesium, producing solid magnesium nitride. However, a small sample of an unreactive gas remained with a density different from the density of the nitrogen gas. Sir Ramsey identified the unreactive gas as argon and later went on to discover neon, krypton, and xenon.

66 Compare the chemical reactivities of nitrogen gas and argon gas based on Sir Ramsey's experiment using magnesium. [1]

67 Compare the density of nitrogen gas to the density of argon gas when both gases are at 298 K and 101.3 kPa. [1]

68 State, in terms of valence electrons, why the noble gases that Sir Ramsey discovered have similar chemical properties. [1]

69 State the trend, at standard pressure, of the boiling points of these noble gases, as they are considered in order of increasing atomic number. [1]

Base your answers to questions 70 through 72 on the information below and on your knowledge of chemistry.

A sample of normal rainwater has a pH value of 5.6 due to dissolved carbon dioxide gas from the atmosphere. Acid rain is formed when other gases, such as sulfur dioxide, dissolve in rainwater, which can result in lake water with a pH value of 4.6. The equation below represents the reaction of water with $SO_2(g)$.

$$H_2O(\ell) + SO_2(g) \rightarrow H_2SO_3(aq)$$
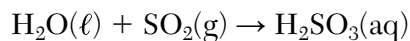
70 State how many times greater the hydronium ion concentration in the lake water is than the hydronium concentration in the sample of normal rainwater. [1]

71 State the color of methyl orange in a sample of normal rainwater. [1]

72 Based on Table *G*, describe what happens to the solubility of $SO_2(g)$ as the temperature increases from 10.°C to 30.°C at standard pressure. [1]

Base your answers to questions 73 through 77 on the information below and on your knowledge of chemistry.

A metal worker uses a cutting torch that operates by reacting acetylene gas, $C_2H_2(g)$, with oxygen gas, $O_2(g)$, as shown in the unbalanced equation below.

$$C_2H_2(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g) + heat$$

73 Write the empirical formula for acetylene.   [1]

74 *In your answer booklet*, use the key to draw a particle model diagram to represent the phase of the $O_2(g)$. Your response must include *at least six* molecules.   [1]

75 Balance the equation *in your answer booklet* for the reaction of acetylene and oxygen, using the smallest whole-number coefficients.   [1]

76 Determine the mass of 25 moles of acetylene (gram-formula mass = 26 g/mol).   [1]

77 Explain, in terms of bonding, why the hydrocarbon gas used in the cutting torch is classified as an alkyne.   [1]

Base your answers to questions 78 through 82 on the information below and on your knowledge of chemistry.

Water, H_2O, and hexane, C_6H_{14}, are commonly used as laboratory solvents because they have different physical properties and are able to dissolve different types of solutes. Some physical properties of water and hexane are listed on the table below.

Physical Properties of H_2O and C_6H_{14}

Solvent	Boiling Point (°C)	Melting Point (°C)	Vapor Pressure at 69°C (kPa)
H_2O	100.	0.	?
C_6H_{14}	69	−95	101.3

78 Compare the thermal energy of a 10.-gram sample of water at 25°C to the thermal energy of a 1000.-gram sample of water at 25°C. [1]

79 State what happens to the potential energy of the molecules in a solid sample of hexane at −95°C as heat is added until the hexane is completely melted. [1]

80 Determine the vapor pressure of water at 69°C. [1]

81 Explain, in terms of the molecular polarity, why hexane is nearly insoluble in water. [1]

82 Explain, in terms of molecular formulas and structural formulas, why 2,2-dimethylbutane is an isomer of hexane. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

In a laboratory investigation, a student constructs an electrochemical cell to decompose water, as represented in the diagram below. The water in the electrochemical cell contains a small amount of dissolved sodium sulfate, to increase conductivity. The three equations represent the reaction in each test tube and the overall reaction. During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

O_2 Test Tube: $2H_2O(\ell) \longrightarrow O_2(g) + 4H^+(aq) + 4e^-$

H_2 Test Tube: $2H^+(aq) + 2e^- \longrightarrow H_2(g)$

Overall Reaction: $2H_2O(\ell) \longrightarrow O_2(g) + 2H_2(g)$
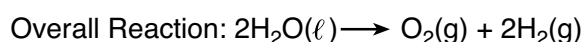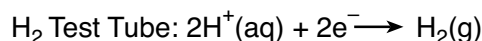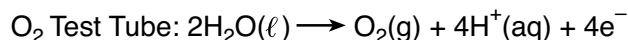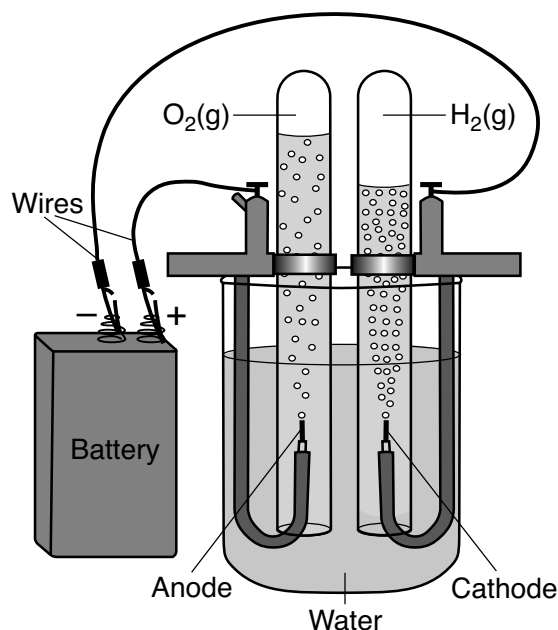
83 State the change in oxidation number that occurs for oxygen in the overall reaction. [1]

84 Compare the number of electrons lost by oxygen to the number of electrons gained by hydrogen in the overall reaction. [1]

85 Determine the number of moles of hydrogen gas produced when 0.0004 mole of oxygen gas is produced in the cell by the overall reaction. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Friday, January 27, 2023 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which conclusion was developed as a result of the gold foil experiment?
  (1) Atoms are mostly empty space.
  (2) All atoms are hard, indivisible spheres.
  (3) Atoms have different volumes.
  (4) All atoms have the same volume.

2 Which two particles each have a mass approximately equal to one atomic mass unit?
  (1) positron and proton
  (2) positron and electron
  (3) neutron and electron
  (4) neutron and proton

3 An excited potassium atom emits a specific amount of energy when one of its electrons moves from
  (1) the first shell to the fourth shell
  (2) the second shell to the fourth shell
  (3) the fourth shell to the fifth shell
  (4) the fourth shell to the second shell

4 Which list of elements includes a metal, a metalloid, and a noble gas?
  (1) Rb, Cl, Ne   (3) Rn, Cl, Ne
  (2) Sr, Si, Rn   (4) Si, Rb, Sr

5 Which element has the *lowest* density at 298 K and 101.3 kPa?
  (1) argon   (3) nitrogen
  (2) fluorine   (4) oxygen

6 Which phrase describes the crystal structure and properties of two different forms of solid carbon called diamond and graphite?
  (1) same crystal structure and same properties
  (2) same crystal structure and different properties
  (3) different crystal structures and different properties
  (4) different crystal structures and same properties

7 Which element has chemical properties most similar to sodium?
  (1) magnesium   (3) phosphorus
  (2) oxygen   (4) rubidium

8 Which substance contains elements chemically combined in a fixed proportion?
  (1) manganese   (3) silicon
  (2) methane   (4) strontium

9 Which property can be used to differentiate between a 50.-gram sample of solid potassium nitrate at STP and a 50.-gram sample of solid silver chloride at STP?
  (1) mass   (3) phase
  (2) temperature   (4) solubility

10 Which type of bond forms when electrons are equally shared between two atoms?
  (1) a polar covalent bond
  (2) a nonpolar covalent bond
  (3) a hydrogen bond
  (4) an ionic bond

11 Which statement describes the changes in bonding and energy that occur when a molecule of iodine, I_2, forms two separate atoms of iodine?

(1) A bond is formed as energy is absorbed.
(2) A bond is formed as energy is released.
(3) A bond is broken as energy is absorbed.
(4) A bond is broken as energy is released.

12 The degree of polarity in the bond between a hydrogen atom and an oxygen atom in a molecule of water can be assessed using the difference in

(1) densities
(2) electronegativities
(3) melting points
(4) intermolecular forces

13 Which substance can *not* be broken down by a chemical change?

(1) ammonia   (3) krypton
(2) ethanol   (4) water

14 Which sample of matter is a mixture?

(1) $CO_2(g)$ (3) $MgCl_2(aq)$
(2) $CCl_4(\ell)$ (4) $Sn(s)$

15 Which term is used to express the concentration of an aqueous solution?

(1) parts per million   (3) pressure at 0°C
(2) heat of fusion   (4) volume at 0°C

16 The particles in which sample have the *lowest* average kinetic energy?

(1) 50. g of sulfur at 273 K
(2) 40. g of aluminum at 298 K
(3) 30. g of sulfur at 303 K
(4) 20. g of aluminum at 323 K

17 Which process represents a chemical change?

(1) Iodine sublimes.
(2) Water evaporates.
(3) An ice cube melts.
(4) A candle burns in air.

18 Which equation represents a physical equilibrium?

(1) $NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$
(2) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
(3) $3O_2(g) \rightarrow 2O_3(g)$
(4) $N_2(\ell) \rightleftharpoons N_2(g)$

19 Systems in nature tend to undergo changes toward

(1) higher energy and higher entropy
(2) higher energy and lower entropy
(3) lower energy and higher entropy
(4) lower energy and lower entropy

20 Which formula represents a hydrocarbon?

(1) C_2H_6 (3) C_2H_5Cl
(2) C_2H_5OH (4) C_2H_6O

21 Which statement describes the bonding in an alkyne molecule?

(1) There is at least one carbon-to-carbon double bond.
(2) There is at least one carbon-to-carbon triple bond.
(3) There is at least one carbon-to-oxygen single bond.
(4) There is at least one carbon-to-oxygen double bond.

22 Which compound has a functional group that contains two oxygen atoms?

(1) 1-propanamine   (3) methyl propanoate
(2) 2-chloropropane   (4) methyl ethyl ether

23 Which term identifies a type of organic reaction?

(1) deposition   (3) polymerization
(2) distillation   (4) vaporization

24 In an electrochemical cell, oxidation occurs at the

(1) anode   (3) salt bridge
(2) cathode   (4) switch

25 Which energy conversion occurs in an operating electrolytic cell?

(1) chemical energy to electrical energy
(2) electrical energy to chemical energy
(3) nuclear energy to electrical energy
(4) electrical energy to nuclear energy

26 One acid-base theory states that a base is an

(1) H^- donor
(2) H^- acceptor
(3) H^+ donor
(4) H^+ acceptor

27 The acidity or alkalinity of a solution can be measured by its

(1) pH value
(2) electronegativity value
(3) boiling point
(4) freezing point

28 When the nucleus of an atom of neon-19 decays, which particle is emitted?

(1) ^4_2He
(2) $^0_{-1}e$
(3) ^1_0n
(4) $^0_{+1}e$

29 Which nuclear emission has the greatest mass?

(1) positron
(2) gamma ray
(3) beta particle
(4) alpha particle

30 Which statement describes the net change that occurs during nuclear fission?

(1) Electrons are converted to protons.
(2) Protons are converted to electrons.
(3) Mass is converted to energy.
(4) Energy is converted to mass.

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 What is the net charge of a monatomic ion that has 15 protons, 16 neutrons, and 18 electrons?
(1) 2+   (3) 3+
(2) 2–   (4) 3–

32 The table below shows the atomic masses and natural abundances of the two naturally occurring isotopes of rhenium.

Naturally Occurring Isotopes of Rhenium

Isotope	Atomic Mass (u)	Natural Abundance (%)
Re-185	184.95	37.40
Re-187	186.96	62.60

Which numerical setup can be used to calculate the atomic mass of rhenium?

(1) $(184.95 \text{ u})(37.40) + (186.96 \text{ u})(62.60)$

(2) $(184.95 \text{ u})(0.3740) + (186.96 \text{ u})(0.6260)$

(3) $\dfrac{(184.95 \text{ u})(37.40) + (186.96 \text{ u})(62.60)}{2}$

(4) $\dfrac{(184.95 \text{ u})(0.3740) + (186.96 \text{ u})(0.6260)}{2}$

33 Which general trend is observed as the elements in Period 2 are considered from left to right?
(1) Atomic mass decreases.
(2) Melting point increases.
(3) Electronegativity increases.
(4) First ionization energy decreases.

34 Which formula represents chromium(III) oxide?
(1) CrO_3 (3) Cr_2O_3
(2) Cr_3O (4) Cr_3O_2

35 Given the balanced equation representing a reaction:

$$2KClO_3 + \text{energy} \rightarrow 2KCl + 3O_2$$

What is the mass of KCl produced when 24.51 grams of $KClO_3$ reacts completely to produce 9.60 grams of O_2?
(1) 5.31 g   (3) 34.11 g
(2) 14.91 g   (4) 43.71 g

36 Which equation represents conservation of atoms?
(1) $TiO_2 + 2Al \rightarrow 2Al_2O_3 + Ti$
(2) $TiO_2 + 4Al \rightarrow 2Al_2O_3 + Ti$
(3) $3TiO_2 + 2Al \rightarrow 2Al_2O_3 + 3Ti$
(4) $3TiO_2 + 4Al \rightarrow 2Al_2O_3 + 3Ti$

37 One mole of bromine gas, Br_2, has a mass of
(1) 35.0 g   (3) 79.9 g
(2) 70.0 g   (4) 159.8 g

38 Given the equation representing a reaction:

$$2NaCl \rightarrow 2Na + Cl_2$$
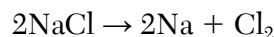
Which type of reaction does this equation represent?
(1) double replacement
(2) decomposition
(3) synthesis
(4) single replacement

39 Which statement describes the charge and the radius of the magnesium ion formed when a magnesium atom loses two electrons?

(1) The Mg ion is positive and has a radius larger than the Mg atom.
(2) The Mg ion is negative and has a radius larger than the Mg atom.
(3) The Mg ion is positive and has a radius smaller than the Mg atom.
(4) The Mg ion is negative and has a radius smaller than the Mg atom.

40 An oxide ion, O^{2-}, has the same electron configuration as an atom of which noble gas?

(1) helium   (3) argon
(2) neon   (4) krypton

41 What is the vapor pressure of propanone at 45°C?

(1) 21 kPa   (3) 70. kPa
(2) 60. kPa   (4) 79 kPa

42 Based on Table G, what is the mass of KCl that must be dissolved in 200. grams of H_2O at 10.°C to make a saturated solution?

(1) 15 g   (3) 60. g
(2) 30. g   (4) 120. g

43 Based on Table I, which chemical equation represents a reaction with a heat of reaction that indicates a net release of energy?

(1) $N_2(g) + O_2(g) \rightarrow 2NO(g)$
(2) $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
(3) $2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$
(4) $2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$

44 The greatest increase in entropy occurs when a 1.00-gram sample of water changes from

(1) solid to liquid   (3) gas to liquid
(2) solid to gas   (4) liquid to solid

45 Which particle diagram represents one substance, only?

Key
⚪ = atom of one element
⚫ = atom of a different element
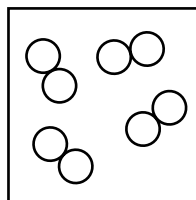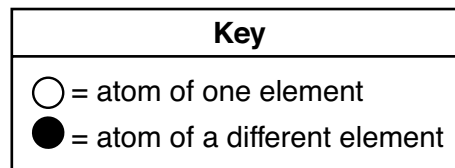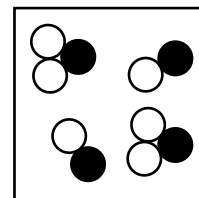
(1)   (3)
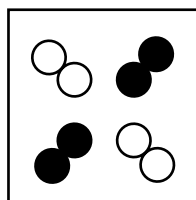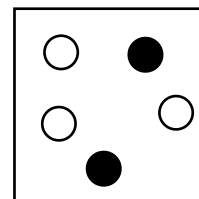
(2)   (4)

46 Based on Table J, atoms of which metal will lose electrons to Ca^{2+} ions?

(1) aluminum   (3) nickel
(2) lead   (4) potassium

47 Which aqueous solution is the best conductor of an electrical current?

(1) 0.1 M $NaNO_3$ (3) 0.01 M $NaNO_3$
(2) 0.2 M $NaNO_3$ (4) 0.02 M $NaNO_3$
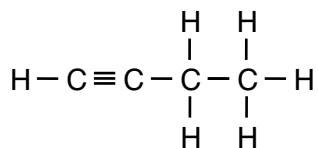
48 Given the equation representing a reaction:

$$_1^2H + {}_1^3H \rightarrow {}_2^4He + {}_0^1n$$
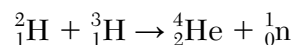
This equation represents

(1) sublimation   (3) fission
(2) condensation   (4) fusion

49 Which formula represents 2-butene?

```
    H   H   H   H                      H   H
    |   |   |   |                      |   |
H — C = C — C — C — H          H — C ≡ C — C — C — H
            |   |                          |   |
            H   H                          H   H

        ( 1 )                          ( 3 )
```
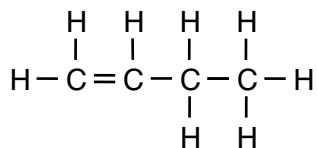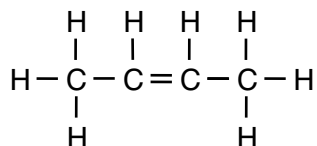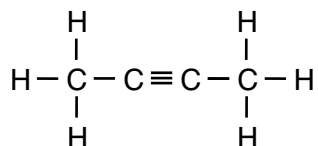
```
    H   H   H   H                      H           H
    |   |   |   |                      |           |
H — C — C = C — C — H          H — C — C ≡ C — C — H
    |           |                      |           |
    H           H                      H           H

        ( 2 )                          ( 4 )
```

50 Given a formula representing a compound:

```
            H   H   H
            |   |   |
        H — C — C — C — OH
            |   |   |
            H   H   H
```
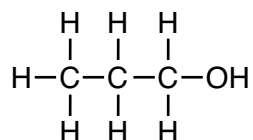
Which formula represents an isomer of the compound?

```
    H   H       H                      H   O   H
    |   |       |                      |   ||   |
H — C — C — O — C — H          H — C — C — C — H
    |   |       |                      |       |
    H   H       H                      H       H

        ( 1 )                          ( 3 )
```
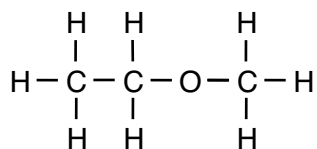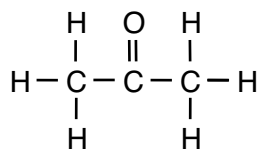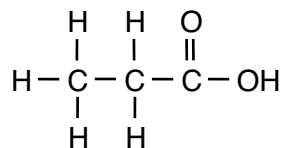
```
    H   H   O                          H   H   O
    |   |   ||                         |   |   ||
H — C — C — C — OH             H — C — C — C — H
    |   |                              |   |
    H   H                              H   H

        ( 2 )                          ( 4 )
```

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

51 Explain, in terms of neutrons and protons, why P-32 and P-31 are different isotopes of phosphorus. [1]

52 Determine the oxidation state of chromium in K_2CrO_4. [1]

Base your answers to questions 53 and 54 on the information below and on your knowledge of chemistry.

The first four elements in Group 14 are carbon, silicon, germanium, and tin. These elements form compounds with chlorine that have similar formulas. Two examples of these formulas are silicon tetrachloride, $SiCl_4$, and germanium tetrachloride, $GeCl_4$.

53 State the general trend in atomic radius as these four elements are considered in order of increasing atomic number. [1]

54 State, in terms of electron configuration, why silicon and germanium both form tetrachloride compounds. [1]

Base your answers to questions 55 through 57 on the information below and on your knowledge of chemistry.

The equation below represents the reaction between ammonia and hydrogen chloride.

$$NH_3(g) \quad + \quad HCl(g) \quad \rightarrow \quad NH_4Cl(s)$$

compound 1   compound 2
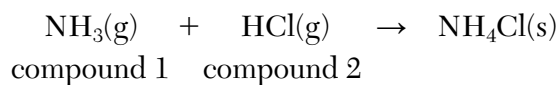
55 Explain, in terms of distribution of charge, why a molecule of compound 1 is polar. [1]

56 Draw a Lewis electron-dot diagram for a molecule of compound 2. [1]

57 Identify the *two* types of chemical bonds in the product of this reaction. [1]

Base your answers to questions 58 through 60 on the information below and on your knowledge of chemistry.

A sample of helium gas, He(g), is placed in a rigid cylinder sealed with a movable piston. The temperature of the helium is 25.0°C. The volume of the helium is 300. milliliters and the pressure is 0.500 atmosphere.

58 State, in terms of the average distance between the helium atoms, why the density of the gas increases when the piston is pushed farther into the rigid cylinder. [1]

59 Determine the volume of the helium gas when the pressure is increased to 1.50 atm and the temperature remains at 25.0°C. [1]

60 Compare the number of helium atoms in the cylinder at a pressure of 0.500 atm to the number of helium atoms in the cylinder when the pressure is increased to 1.50 atm by pushing the piston in. [1]

_____

Base your answers to questions 61 and 62 on the information below and on your knowledge of chemistry.

During a laboratory activity, a student places 21.0 mL of hydrochloric acid solution, HCl(aq), of unknown concentration into a flask. The solution is titrated with 0.125 M NaOH(aq) until the acid is exactly neutralized. The volume of NaOH(aq) added is 18.5 milliliters. During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

61 Explain, in terms of ions, why the hydrochloric acid solution can conduct an electric current. [1]

62 Determine the concentration of the HCl(aq) solution, using the titration data. [1]

_____

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

The table below lists the hydronium ion concentration and pH values of four different solutions and distilled water. The pH value is missing for sample 2.

Hydronium Concentration and pH Value for Five Samples

Sample Number	Sample Description	Hydronium Ion Concentration (M)	pH Value
1	0.1 M HCl(aq)	1×10^{-1}	1.0
2	0.01 M HCl(aq)	1×10^{-2}	?
3	distilled $H_2O(\ell)$	1×10^{-7}	7.0
4	0.01 M NaOH(aq)	1×10^{-12}	12.0
5	0.1 M NaOH(aq)	1×10^{-13}	13.0

63 Determine the pH value of sample 2. [1]

64 Identify the ion released by the compound dissolved in sample 4 that allows the compound to be classified as an Arrhenius base. [1]

65 State how many times greater the hydronium ion concentration is in sample 4 than it is in sample 5. [1]

_____

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

Boric acid, H_3BO_3, is heated to produce tetraboric acid, $H_2B_4O_7$, and water. The equation below represents the reaction to form tetraboric acid.

$$4H_3BO_3(s) \xrightarrow{\text{heat}} H_2B_4O_7(s) \quad + \quad 5H_2O(g)$$
$$\text{boric acid} \qquad\qquad \text{tetraboric acid}$$
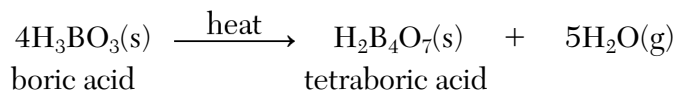
The tetraboric acid is then used to make borax, which is used as a cleaning agent. Borax, $Na_2B_4O_7 \cdot 10H_2O$, is a hydrate with a gram-formula mass of 381 grams per mole. A hydrate is a compound with water within its crystal structure. Borax has ten moles of water for every mole of $Na_2B_4O_7$.

66 Explain why the formula for tetraboric acid is an empirical formula. [1]

67 Determine the number of moles of boric acid that react in the equation to produce 10 moles of water. [1]

68 Show a numerical setup for calculating the mass, in grams, of a 0.200-mole sample of borax. [1]

Base your answers to questions 69 through 71 on the information below and on your knowledge of chemistry.

During a laboratory activity, appropriate safety equipment is used and safety procedures are followed. A student uses the lab equipment shown in the diagram below to determine the heat of combustion of candle wax.
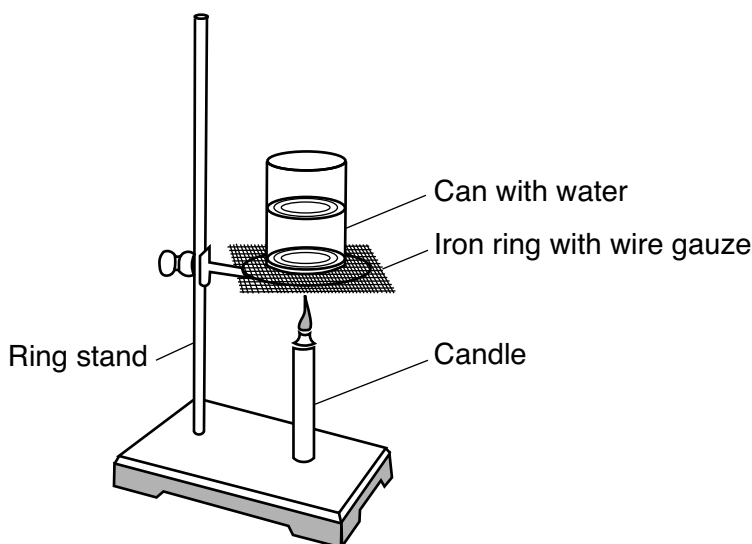
Heat of combustion is defined as the amount of heat released when a known mass of a substance is burned and can be measured in joules per gram. At the start of the activity, the mass of the candle and the mass of the water are measured. The starting temperature of the water is 5.0°C, and the air temperature in the room is 22.0°C. The candle is lit, and the water is stirred with a stirring rod. Several minutes later, the candle is extinguished, and the student measures the temperature of the water in the can. When the candle is cool, the student measures the final mass of the candle. Lab activity results are shown in the table below.

Lab Activity Results

Mass of Candle Wax Burned (g)	Mass of Water in the Can (g)	Calculated Temperature Change of Water (°C)	Heat Absorbed by the Water (J)	Calculated Heat of Combustion of Candle Wax (J/g)
0.83	190.	39	?	37 000

69 State the number of significant figures used to express the value for the mass of the water in the can. [1]

70 State the direction of the heat flow between the air and the water in the can before the candle is lit. [1]

71 Determine the amount of heat absorbed by the water. [1]

Base your answers to questions 72 through 76 on the information below and on your knowledge of chemistry.

A process was developed in 1912 to produce ammonia gas from atmospheric nitrogen gas and hydrogen gas. Iron can be used as a catalyst. The equation representing this system at equilibrium is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + 91.8 \text{ kJ}$$
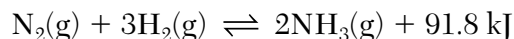
72 State evidence from the equation that the forward reaction is exothermic. [1]

73 Compare the rate of the forward reaction to the rate of the reverse reaction at equilibrium. [1]

74 On the labeled axes *in your answer booklet*, draw a potential energy diagram for the forward reaction represented in this equation. [1]

75 State, in terms of moles of gases, why the equilibrium shifts to the right due to an increase in pressure on the system at constant temperature. [1]

76 State what happens to the rate of forward reaction when the iron is added to this system. [1]

Base your answers to questions 77 through 79 on the information below and on your knowledge of chemistry.

Before the year 1828, it was thought that organic compounds were produced only by living organisms and that inorganic compounds were made from nonliving substances. Urea is an organic compound. In 1828, a chemist heated ammonium cyanate and produced urea, which is very soluble in water. The equation below represents this reaction.

$$NH_4OCN \xrightarrow{\text{heat}} H_2NCONH_2$$
ammonium cyanate   urea
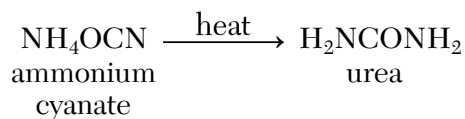
77 Identify the element present in urea that is present in all organic compounds. [1]

78 Compare the formula mass of the two compounds in the equation. [1]

79 State, in terms of molecular polarity, why urea is very soluble in water. [1]

Base your answers to questions 80 and 81 on the information below and on your knowledge of chemistry.

When a voltmeter is connected in the circuit of a voltaic cell, an electrical measurement called voltage can be read on the meter. The voltage of the cell is affected if the concentration of the solute in the half-cells is changed. The diagram, the ionic equation, and the graph below represent a copper-zinc cell. When the switch is closed, electricity flows through the circuit as the cell operates at constant temperature.

$$Cu^{2+}(aq) + Zn(s) \longrightarrow Cu(s) + Zn^{2+}(aq)$$

Cell Voltages at Different Cu^{2+} Concentrations
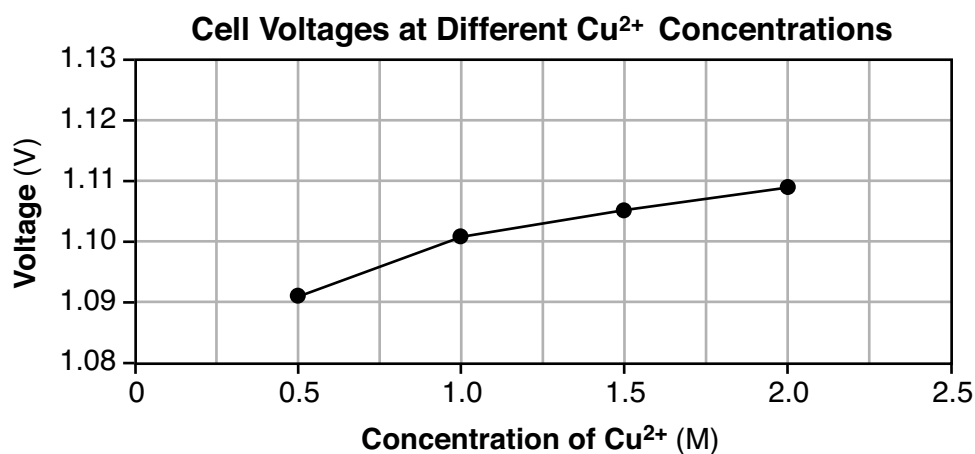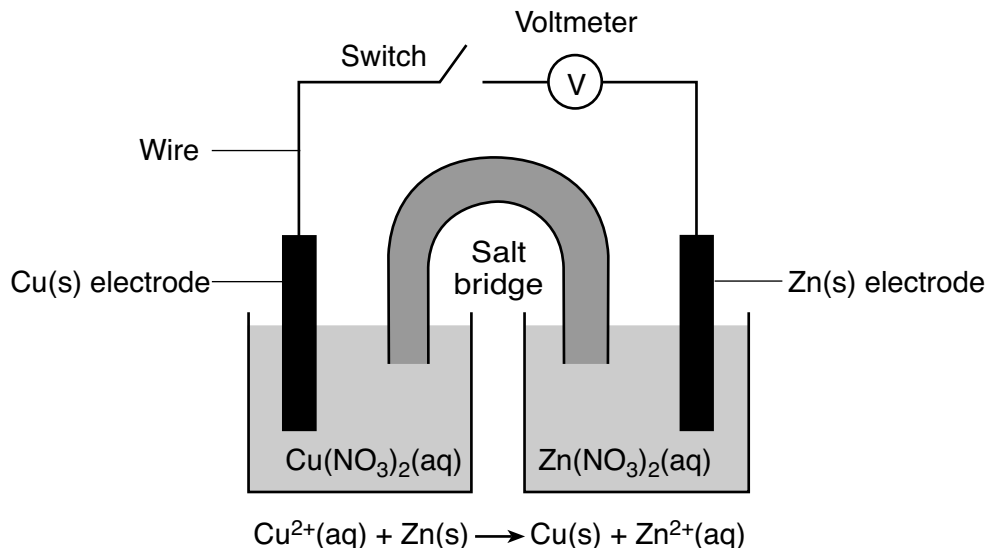
80 Based on the graph, determine the voltage of the cell if the $Cu(NO_3)_2(aq)$ concentration is 1.5 M. [1]

81 Write a balanced half-reaction equation for the oxidation of zinc that occurs in this operating cell. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

Synthetic radioisotopes may be made by bombarding other nuclides with neutrons. The equations below represent a sequence of reactions converting stable iron–58 to cobalt–60, which is used in medical treatments.

Equation 1: $^{58}_{26}Fe + ^{1}_{0}n \rightarrow ^{59}_{26}Fe$

Equation 2: $^{59}_{26}Fe \rightarrow ^{59}_{27}Co + ^{0}_{-1}e$

Equation 3: $^{59}_{27}Co + X \rightarrow ^{60}_{27}Co$
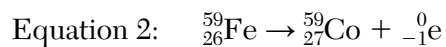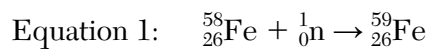
82 State the neutron to proton ratio for an atom of the ^{58}Fe in equation 1. [1]

83 State, in terms of elements, why equation 2 represents a transmutation reaction. [1]

84 Identify the particle represented by X in equation 3. [1]

85 Determine the fraction of an original sample of Co-60 that remains unchanged after 15.813 years. [1]

_____

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, June 20, 2012 — 1:15 to 4:15 p.m., only

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

The use of any communications device is strictly prohibited when taking this examination. If you use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 The mass of a proton is approximately equal to the mass of

(1) an alpha particle   (3) a positron
(2) a beta particle   (4) a neutron

2 An orbital of an atom is defined as the most probable location of

(1) an electron   (3) a positron
(2) a neutron   (4) a proton

3 What must occur when an electron in an atom returns from a higher energy state to a lower energy state?

(1) A specific amount of energy is released.
(2) A random amount of energy is released.
(3) The atom undergoes transmutation.
(4) The atom spontaneously decays.

4 Which element is a liquid at 305 K and 1.0 atmosphere?

(1) magnesium   (3) gallium
(2) fluorine   (4) iodine

5 Which list of elements consists of a metal, a metalloid, and a nonmetal?

(1) Li, Na, Rb   (3) Sn, Si, C
(2) Cr, Mo, W   (4) O, S, Te

6 At STP, which physical property of aluminum always remains the same from sample to sample?

(1) mass   (3) length
(2) density   (4) volume

7 Which statement describes a chemical property of silicon?

(1) Silicon has a blue-gray color.
(2) Silicon is a brittle solid at 20.°C.
(3) Silicon melts at 1414°C.
(4) Silicon reacts with fluorine.

8 Which diagram represents a mixture of two different molecular forms of the same element?
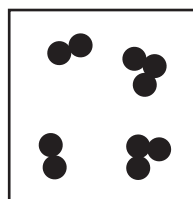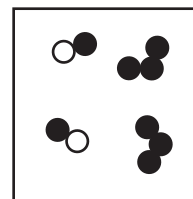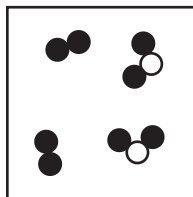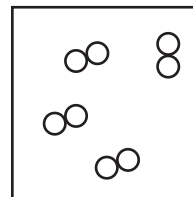

9 A compound is broken down by chemical means during

(1) chromatography   (3) electrolysis
(2) distillation   (4) filtration

10 Which quantities must be conserved in all chemical reactions?

(1) mass, charge, density
(2) mass, charge, energy
(3) charge, volume, density
(4) charge, volume, energy

11 Which phrase describes the distribution of charge and the polarity of a CH_4 molecule?

(1) symmetrical and polar
(2) symmetrical and nonpolar
(3) asymmetrical and polar
(4) asymmetrical and nonpolar

12 What is the charge of the nucleus of an oxygen atom?

(1) 0
(2) −2
(3) +8
(4) +16

13 Which ion has *no* electrons?

(1) H^+
(2) Li^+
(3) Na^+
(4) Rb^+

14 To break a chemical bond, energy must be

(1) absorbed
(2) destroyed
(3) produced
(4) released

15 Which Lewis electron-dot diagram represents a nitrogen atom in the ground state?

(1) (2) (3) (4)

16 What is the most likely electronegativity value for a metallic element?

(1) 1.3
(2) 2.7
(3) 3.4
(4) 4.0

17 Which polyatomic ion has a charge of 3−?

(1) chromate ion
(2) oxalate ion
(3) phosphate ion
(4) thiocyanate ion

18 Every chlorine atom has

(1) 7 electrons
(2) 17 neutrons
(3) a mass number of 35
(4) an atomic number of 17

19 Which substance can *not* be broken down by a chemical change?

(1) ammonia
(2) methanol
(3) propane
(4) phosphorus

20 At standard pressure, which substance becomes *less* soluble in water as temperature increases from 10.°C to 80.°C?

(1) HCl
(2) KCl
(3) NaCl
(4) NH_4Cl

21 Which type of concentration is calculated when the grams of solute is divided by the grams of the solution, and the result is multiplied by 1 000 000?

(1) molarity
(2) parts per million
(3) percent by mass
(4) percent by volume

22 Which type of energy is associated with the random motion of atoms and molecules in a sample of air?

(1) chemical energy
(2) electrical energy
(3) nuclear energy
(4) thermal energy

23 The temperature of a sample of matter is a measure of the

(1) total kinetic energy of the particles in the sample
(2) total potential energy of the particles in the sample
(3) average potential energy of the particles in the sample
(4) average kinetic energy of the particles in the sample

24 Which unit is used to express the pressure of a gas?

(1) mole
(2) joule
(3) kelvin
(4) pascal

25 Which sample of matter sublimes at room temperature and standard pressure?

(1) $Br_2(\ell)$
(2) $Cl_2(g)$
(3) $CO_2(s)$
(4) $SO_2(aq)$

26 Given the diagram representing a closed system at constant temperature:
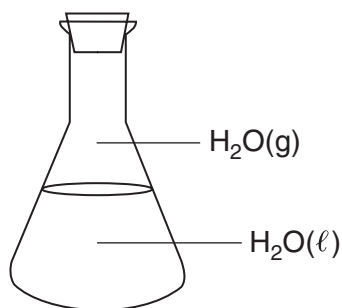
Stoppered Flask

Which statement describes this system at equilibrium?

(1) The mass of $H_2O(\ell)$ equals the mass of $H_2O(g)$.
(2) The volume of $H_2O(\ell)$ equals the volume of $H_2O(g)$.
(3) The number of moles of $H_2O(\ell)$ equals the number of moles of $H_2O(g)$.
(4) The rate of evaporation of $H_2O(\ell)$ equals the rate of condensation of $H_2O(g)$.

27 Which reaction occurs at the cathode in an electrochemical cell?

(1) combustion
(2) neutralization
(3) oxidation
(4) reduction

28 Which substance yields $H^+(aq)$ as the only positive ion in an aqueous solution?

(1) CH_3CHO
(2) CH_3CH_2OH
(3) CH_3COOH
(4) CH_3OCH_3

29 Compared to the mass and the penetrating power of an alpha particle, a beta particle has

(1) less mass and greater penetrating power
(2) less mass and less penetrating power
(3) more mass and greater penetrating power
(4) more mass and less penetrating power

30 During a nuclear reaction, mass is converted into

(1) charge
(2) energy
(3) isomers
(4) volume

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 An atom in the ground state has two electrons in its first shell and six electrons in its second shell. What is the total number of protons in the nucleus of this atom?

(1) 5   (3) 7
(2) 2   (4) 8

32 A bromine atom in an excited state could have an electron configuration of

(1) 2-8-18-6   (3) 2-8-17-7
(2) 2-8-18-7   (4) 2-8-17-8

33 The atomic masses and the natural abundances of the two naturally occurring isotopes of lithium are shown in the table below.

Lithium Isotopes

Isotope	Atomic Mass (u)	Natural Abundance (%)
Li-6	6.02	7.5
Li-7	7.02	92.5

Which numerical setup can be used to determine the atomic mass of lithium?

(1) $(0.075)(6.02 \text{ u}) + (0.925)(7.02 \text{ u})$

(2) $(0.925)(6.02 \text{ u}) + (0.075)(7.02 \text{ u})$

(3) $(7.5)(6.02 \text{ u}) + (92.5)(7.02 \text{ u})$

(4) $(92.5)(6.02 \text{ u}) + (7.5)(7.02 \text{ u})$

34 Element *X* reacts with chlorine to form an ionic compound that has the formula XCl_2. To which group on the Periodic Table could element *X* belong?

(1) Group 1   (3) Group 13
(2) Group 2   (4) Group 15

35 Which general trend is found in Period 3 as the elements are considered in order of increasing atomic number?

(1) increasing atomic radius
(2) increasing electronegativity
(3) decreasing atomic mass
(4) decreasing first ionization energy

36 Given the formula for a compound:

Which molecular formula and empirical formula represent this compound?

(1) C_2HNO_2 and CHNO

(2) C_2HNO_2 and C_2HNO_2

(3) $C_4H_2N_2O_4$ and CHNO

(4) $C_4H_2N_2O_4$ and C_2HNO_2

37 What is the gram-formula mass of $(NH_4)_3PO_4$?

(1) 112 g/mol   (3) 149 g/mol
(2) 121 g/mol   (4) 242 g/mol

38 In the ground state, which atom has a completely filled valence electron shell?

(1) C   (3) Ne
(2) V   (4) Sb

39 Given the formula:

$$\begin{array}{ccccccc} & H & & H & & H & \\ & | & & | & & | & \\ H- & C & - & C & - & C & -O-H \\ & | & & | & & | & \\ & H & & H & & H & \end{array}$$

The bond between which two atoms has the greatest degree of polarity?

(1) C and C   (3) H and C
(2) C and O   (4) H and O

40 Given the diagram representing a heating curve for a substance:

Heating Curve
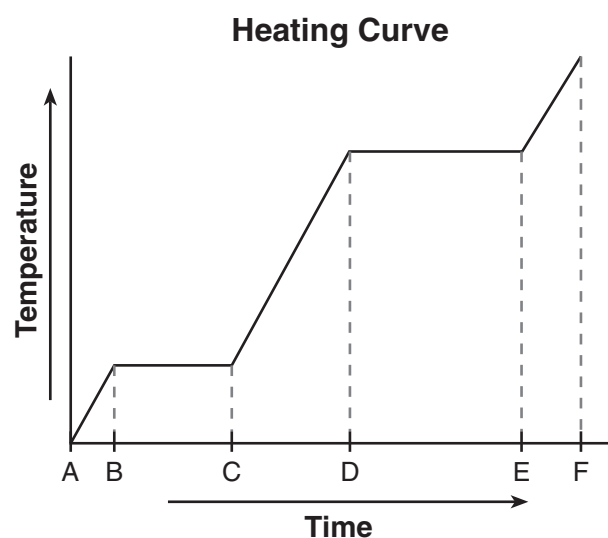
During which time interval is the average kinetic energy of the particles of the substance constant while the potential energy of the particles increases?

(1) *AC*   (3) *CD*
(2) *BC*   (4) *DF*

41 At 50.°C and standard pressure, intermolecular forces of attraction are strongest in a sample of

(1) ethanoic acid   (3) propanone
(2) ethanol   (4) water

42 At 101.3 kPa and 298 K, what is the total amount of heat released when one mole of aluminum oxide, $Al_2O_3(s)$, is formed from its elements?

(1) 393.5 kJ   (3) 1676 kJ
(2) 837.8 kJ   (4) 3351 kJ
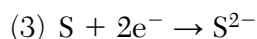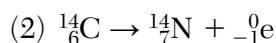
43 Given the balanced equation representing a reaction:

$$2H_2O(\ell) + 571.6 \text{ kJ} \rightarrow 2H_2(g) + O_2(g)$$
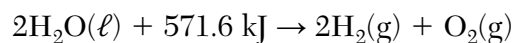
What occurred as a result of this reaction?

(1) Energy was absorbed, and entropy increased.
(2) Energy was absorbed, and entropy decreased.
(3) Energy was released, and entropy increased.
(4) Energy was released, and entropy decreased.

44 Given the potential energy diagram representing a reversible reaction:

Reaction Coordinate
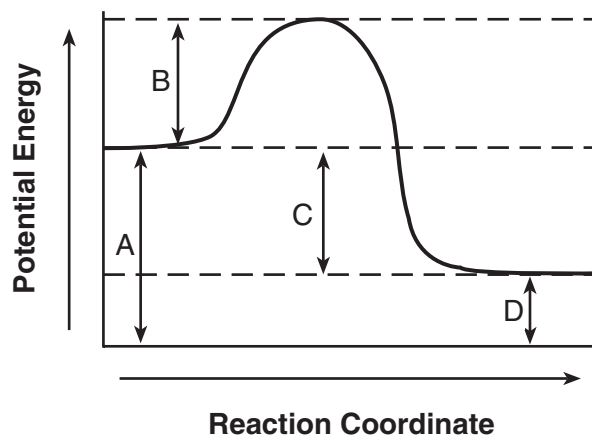
The activation energy for the reverse reaction is represented by

(1) *A + B*   (3) *B + D*
(2) *B + C*   (4) *C + D*

45 Which formula represents a molecule of 2-chlorobutane?

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{Cl}{|}}{\overset{\overset{H}{|}}{C}}-H$$

(1)

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{Cl}{|}}{\overset{\overset{H}{|}}{C}}-H$$

(3)

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{Cl}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H$$

(2)

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{Cl}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H$$
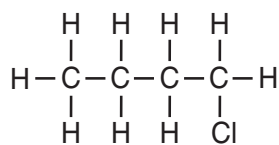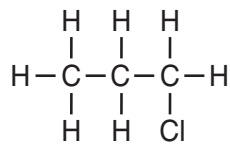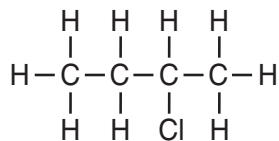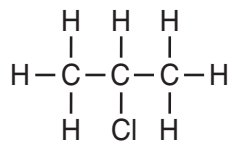
(4)

46 Which formula represents an unsaturated hydrocarbon?

(1) CH_4
(3) C_3H_8
(2) C_2H_4
(4) C_4H_{10}

47 Which ion is most easily reduced?
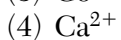
(1) Zn^{2+}
(3) Co^{2+}
(2) Mg^{2+}
(4) Ca^{2+}

48 Given the balanced equation representing a reaction:

$$HSO_4{}^-(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + SO_4{}^{2-}(aq)$$
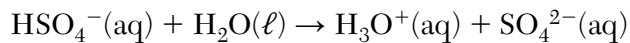
According to one acid-base theory, the $H_2O(\ell)$ molecules act as

(1) a base because they accept H^+ ions
(2) a base because they donate H^+ ions
(3) an acid because they accept H^+ ions
(4) an acid because they donate H^+ ions

49 Which equation represents an oxidation-reduction reaction?

(1) $H^+ + OH^- \rightarrow H_2O$
(2) $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^4_2He$
(3) $Zn + Sn^{4+} \rightarrow Zn^{2+} + Sn^{2+}$
(4) $3AgNO_3 + Li_3PO_4 \rightarrow Ag_3PO_4 + 3LiNO_3$
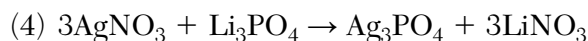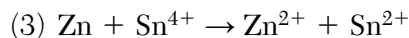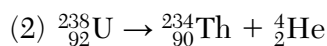
50 Which equation represents natural transmutation?
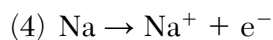
(1) $^{10}_5B + {}^4_2He \rightarrow {}^{13}_7N + {}^1_0n$
(2) $^{14}_6C \rightarrow {}^{14}_7N + {}^0_{-1}e$
(3) $S + 2e^- \rightarrow S^{2-}$
(4) $Na \rightarrow Na^+ + e^-$

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 What is the mass of $KNO_3(s)$ that must dissolve in 100. grams of water to form a saturated solution at 50.°C? [1]

Base your answers to questions 52 through 55 on the information below.

The reaction between aluminum and an aqueous solution of copper(II) sulfate is represented by the unbalanced equation below.

$$Al(s) + CuSO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + Cu(s)$$
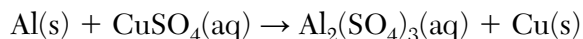
52 Identify the type of chemical reaction represented by the equation. [1]

53 Balance the equation *in your answer booklet*, using the smallest whole-number coefficients. [1]

54 Explain why the equation represents a chemical change. [1]

55 Determine the total mass of Cu produced when 1.08 grams of Al reacts completely with 9.58 grams of $CuSO_4$ to produce 6.85 grams of $Al_2(SO_4)_3$. [1]

Base your answers to questions 56 through 59 on the information below.

A total of 1.4 moles of sodium nitrate is dissolved in enough water to make 2.0 liters of an aqueous solution. The gram-formula mass of sodium nitrate is 85 grams per mole.

56 Write the chemical formula for the solute in the solution. [1]

57 Show a numerical setup for calculating the mass of the solute used to make the solution. [1]

58 Compare the boiling point of the solution at standard pressure to the boiling point of H_2O at standard pressure. [1]

59 Determine the molarity of the solution. [1]

Base your answers to questions 60 through 62 on the information below.

Calcium reacts with water. This reaction is represented by the balanced equation below. The aqueous product of this reaction can be heated to evaporate the water, leaving a white solid, $Ca(OH)_2(s)$.

$$Ca(s) + 2H_2O(\ell) \rightarrow Ca(OH)_2(aq) + H_2(g)$$
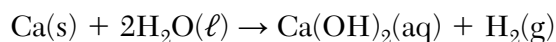
60 Compare the electrical conductivity of the aqueous product in the reaction to the electrical conductivity of the white solid that remains after the water is evaporated from the solution. [1]

61 Write the chemical name of the base produced in the reaction. [1]

62 State *one* change in reaction conditions that will increase the rate of the reaction. [1]

Base your answers to questions 63 through 65 on the information below.

In a titration, 20.0 milliliters of 0.15 M HCl(aq) is exactly neutralized by 18.0 milliliters of KOH(aq).

63 Complete the equation *in your answer booklet* for the neutralization reaction by writing the formula of *each* product. [1]

64 Compare the number of moles of $H^+(aq)$ ions to the number of moles of $OH^-(aq)$ ions in the titration mixture when the HCl(aq) is exactly neutralized by the KOH(aq). [1]

65 Determine the concentration of the KOH(aq). [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below.

John Dalton, an early scientist, sketched the structure of compounds using his own symbols for the elements known at the time. Dalton's symbols for four elements and his drawing of potassium aluminum sulfate are represented by the diagram below.

**Dalton's Drawing for
Potassium Aluminum Sulfate**
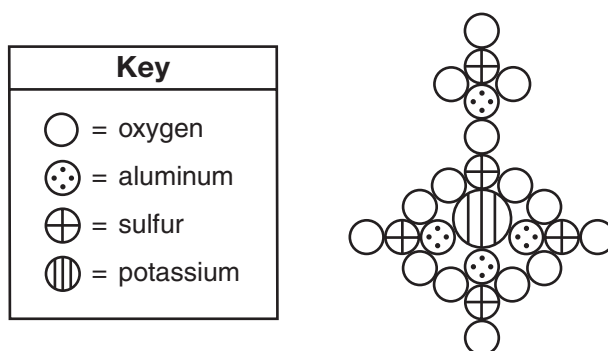
Today, it is known that the chemical formula for potassium aluminum sulfate is $KAl(SO_4)_2 \cdot 12H_2O$. It is a hydrated compound because water molecules are included within its crystal structure. There are 12 moles of H_2O for every 1 mole of $KAl(SO_4)_2$. The compound contains two different positive ions. The gram-formula mass of $KAl(SO_4)_2 \cdot 12H_2O$ is 474 grams per mole.

66 Identify *one* positive ion in the hydrated compound. Your response must include *both* the chemical symbol and charge of the ion. [1]

67 Describe, in terms of composition, *one* way in which Dalton's perception of potassium aluminum sulfate differs from what is known today about the compound. [1]

68 Show a numerical setup for calculating the percent composition by mass of water in $KAl(SO_4)_2 \cdot 12H_2O$. [1]

Base your answers to questions 69 through 71 on the information below.

At standard pressure, hydrogen peroxide, H_2O_2, melts at $-0.4°C$, boils at $151°C$, and is very soluble in water. A bottle of aqueous hydrogen peroxide, $H_2O_2(aq)$, purchased from a pharmacy has a pressure-releasing cap. Aqueous hydrogen peroxide decomposes at room temperature, as represented by the balanced equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g) + 196.0 \text{ kJ}$$
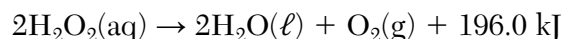
69 State, in terms of *both* melting point and boiling point, why H_2O_2 is a liquid at room temperature. [1]

70 State evidence that indicates the decomposition of $H_2O_2(aq)$ is exothermic. [1]

71 Explain why a hydrogen peroxide bottle needs a pressure-releasing cap. [1]

Base your answers to questions 72 through 75 on the information below.

A student constructs an electrochemical cell during a laboratory investigation. When the switch is closed, electrons flow through the external circuit. The diagram and equation below represent this cell and the reaction that occurs.

$$2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$$
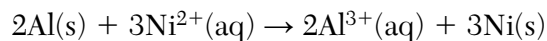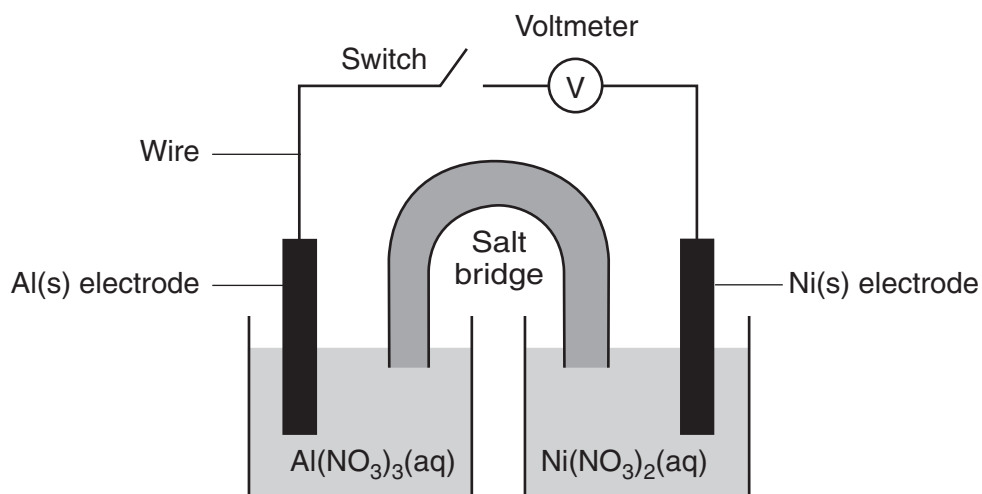
72 State the direction of electron flow through the wire when the switch is closed. [1]

73 Write a balanced half-reaction equation for the oxidation that occurs when the switch is closed. [1]

74 Determine the number of moles of $Al(s)$ needed to completely react with 9.0 moles of $Ni^{2+}(aq)$ ions. [1]

75 State, in terms of energy, why this cell is a voltaic cell. [1]

Base your answers to questions 76 through 78 on the information below.

The diagram below shows typical pH values found in four parts of the human digestive system. In the small intestine, the enzyme lipase acts as a catalyst, increasing the rate of fat digestion.

Mouth
pH = 6.7

Stomach
pH = 2.0

Small intestine
pH = 7.3
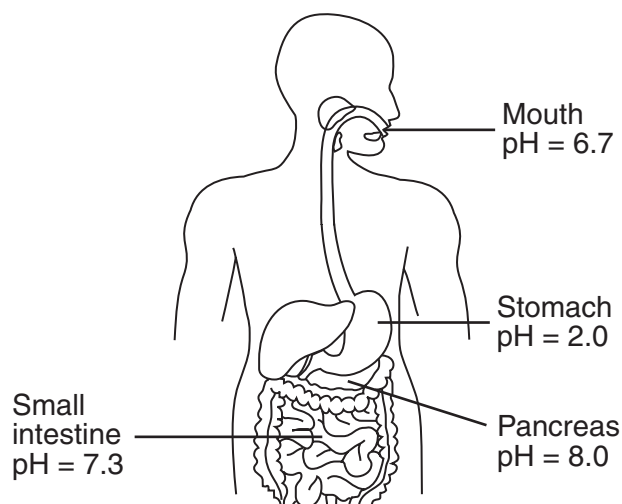
Pancreas
pH = 8.0

76 Which labeled part of the digestive system has the most acidic environment? [1]

77 What is the color of thymol blue at the pH of the small intestine? [1]

78 State how the catalyst lipase increases the rate of the fat digestion. [1]

Base your answers to questions 79 through 81 on the information below.

One type of soap is produced when ethyl stearate and sodium hydroxide react. The soap produced by this reaction is called sodium stearate. The other product of the reaction is ethanol. This reaction is represented by the balanced equation below.

$$C_{17}H_{35}-\overset{O}{\overset{||}{C}}-O-C_2H_5 \ + \ NaOH \ \longrightarrow \ C_{17}H_{35}-\overset{O}{\overset{||}{C}}-O^- \ Na^+ \ + \ C_2H_5OH$$

Ethyl stearate   Sodium hydroxide   Sodium stearate   Ethanol
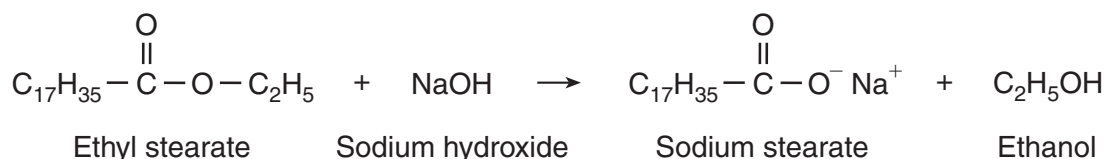
79 Identify the type of organic reaction used to make soap. [1]

80 To which class of organic compounds does ethyl stearate belong? [1]

81 Identify the *two* types of bonds in the compound sodium stearate. [1]

Base your answers to questions 82 through 85 on the information below.

Nuclear fission has been used to produce electricity. However, nuclear fusion for electricity production is still under development. The notations of some nuclides used in nuclear reactions are shown in the table below.

Some Nuclides Used in Nuclear Reactions

Reaction	Nuclides
nuclear fission	$^{233}_{92}U$, $^{235}_{92}U$
nuclear fusion	$^{1}_{1}H$, $^{3}_{1}H$

82 Compare the atomic masses of nuclides used in fusion to the atomic masses of nuclides used in fission. [1]

83 Complete the table *in your answer booklet* that compares the total number of protons and the total number of neutrons for the hydrogen nuclides used for fusion. [1]

84 Complete the nuclear equation *in your answer booklet* for the fission of $^{235}_{92}U$ by writing the notation of the missing product. [1]

85 State *one* potential benefit of using nuclear fusion instead of the current use of nuclear fission to produce electricity. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Tuesday, June 18, 2013 — 9:15 a.m. to 12:15 p.m., only

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 According to the wave-mechanical model of the atom, an orbital is a region of the most probable location of

(1) an alpha particle   (3) an electron
(2) a gamma ray   (4) a proton

2 Which particles have approximately the same mass?

(1) an electron and an alpha particle
(2) an electron and a proton
(3) a neutron and an alpha particle
(4) a neutron and a proton

3 During a flame test, a lithium salt produces a characteristic red flame. This red color is produced when electrons in excited lithium atoms

(1) are lost by the atoms
(2) are gained by the atoms
(3) return to lower energy states within the atoms
(4) move to higher energy states within the atoms

4 Compared to the energy and charge of the electrons in the first shell of a Be atom, the electrons in the second shell of this atom have

(1) less energy and the same charge
(2) less energy and a different charge
(3) more energy and the same charge
(4) more energy and a different charge

5 Which quantity can vary among atoms of the same element?

(1) mass number
(2) atomic number
(3) number of protons
(4) number of electrons

6 Which substances have atoms of the same element but different molecular structures?

(1) $He(g)$ and $Ne(g)$ (3) $K(s)$ and $Na(s)$
(2) $O_2(g)$ and $O_3(g)$ (4) $P_4(s)$ and $S_8(s)$

7 An atom that has 13 protons and 15 neutrons is an isotope of the element

(1) nickel   (3) aluminum
(2) silicon   (4) phosphorus

8 Which elements have the most similar chemical properties?

(1) Si, As, and Te   (3) Mg, Sr, and Ba
(2) N_2, O_2, and F_2 (4) Ca, Cs, and Cu

9 Which list includes three types of chemical formulas for organic compounds?

(1) covalent, metallic, isotopic
(2) covalent, metallic, molecular
(3) empirical, structural, isotopic
(4) empirical, structural, molecular

10 In a bond between an atom of carbon and an atom of fluorine, the fluorine atom has a

(1) weaker attraction for electrons
(2) stronger attraction for electrons
(3) smaller number of first-shell electrons
(4) larger number of first-shell electrons

11 A sample of $CO_2(s)$ and a sample of $CO_2(g)$ differ in their

(1) chemical compositions
(2) empirical formulas
(3) molecular structures
(4) physical properties

12 Which statement defines the temperature of a sample of matter?

(1) Temperature is a measure of the total electromagnetic energy of the particles.
(2) Temperature is a measure of the total thermal energy of the particles.
(3) Temperature is a measure of the average potential energy of the particles.
(4) Temperature is a measure of the average kinetic energy of the particles.

13 For a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the

(1) heat of fusion
(2) heat of reaction
(3) activation energy of the forward reaction
(4) activation energy of the reverse reaction

14 Which equation represents sublimation?

(1) $Hg(\ell) \rightarrow Hg(s)$
(2) $H_2O(s) \rightarrow H_2O(g)$
(3) $NH_3(g) \rightarrow NH_3(\ell)$
(4) $CH_4(\ell) \rightarrow CH_4(g)$

15 Which statement describes the particles of an ideal gas, based on the kinetic molecular theory?

(1) The motion of the gas particles is orderly and circular.
(2) The gas particles have no attractive forces between them.
(3) The gas particles are larger than the distances separating them.
(4) As the gas particles collide, the total energy of the system decreases.

16 Two grams of potassium chloride are completely dissolved in a sample of water in a beaker. This solution is classified as

(1) an element
(2) a compound
(3) a homogeneous mixture
(4) a heterogeneous mixture

17 Which compound has the strongest hydrogen bonding between its molecules?

(1) HBr
(2) HCl
(3) HF
(4) HI

18 Powdered sulfur is yellow, and powdered iron is gray. When powdered sulfur and powdered iron are mixed at 20°C, the powdered iron

(1) becomes yellow
(2) becomes a liquid
(3) remains ionic
(4) remains magnetic

19 An effective collision between reactant particles requires the particles to have the proper

(1) charge and mass
(2) charge and orientation
(3) energy and mass
(4) energy and orientation

20 Which term is defined as a measure of the disorder of a system?

(1) heat
(2) entropy
(3) kinetic energy
(4) activation energy

21 Which process is used to determine the concentration of an acid?

(1) chromatography
(2) distillation
(3) electrolysis
(4) titration

22 The compounds CH_3OCH_3 and CH_3CH_2OH have different functional groups. Therefore, these compounds have different

(1) chemical properties
(2) gram-formula masses
(3) percent compositions by mass
(4) numbers of atoms per molecule

23 Which term identifies the half-reaction that occurs at the anode of an operating electrochemical cell?

(1) oxidation
(2) reduction
(3) neutralization
(4) transmutation

24 During the operation of a voltaic cell, the cell produces

(1) electrical energy spontaneously
(2) chemical energy spontaneously
(3) electrical energy nonspontaneously
(4) chemical energy nonspontaneously

25 In which type of chemical reaction are electrons transferred?

(1) organic addition
(2) oxidation-reduction
(3) double replacement
(4) acid-base neutralization

26 A substance that dissolves in water and produces hydronium ions as the only positive ions in the solution is classified as

(1) an alcohol   (3) a base
(2) an acid   (4) a salt

27 According to one acid-base theory, a base is an

(1) H^+ acceptor   (3) Na^+ acceptor
(2) H^+ donor   (4) Na^+ donor

28 Which compound is an electrolyte?

(1) CCl_4 (3) $C_6H_{12}O_6$
(2) CH_3OH (4) $Ca(OH)_2$

29 Which term identifies a type of nuclear reaction?

(1) fermentation   (3) reduction
(2) deposition   (4) fission

30 Which radioisotopes have the same decay mode and have half-lives greater than 1 hour?

(1) Au-198 and N-16   (3) I-131 and P-32
(2) Ca-37 and Fe-53   (4) Tc-99 and U-233

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 The diagram below represents the bright-line spectra of four elements and a bright-line spectrum produced by a mixture of three of these elements.

Bright-Line Spectra

Wavelength (nm)
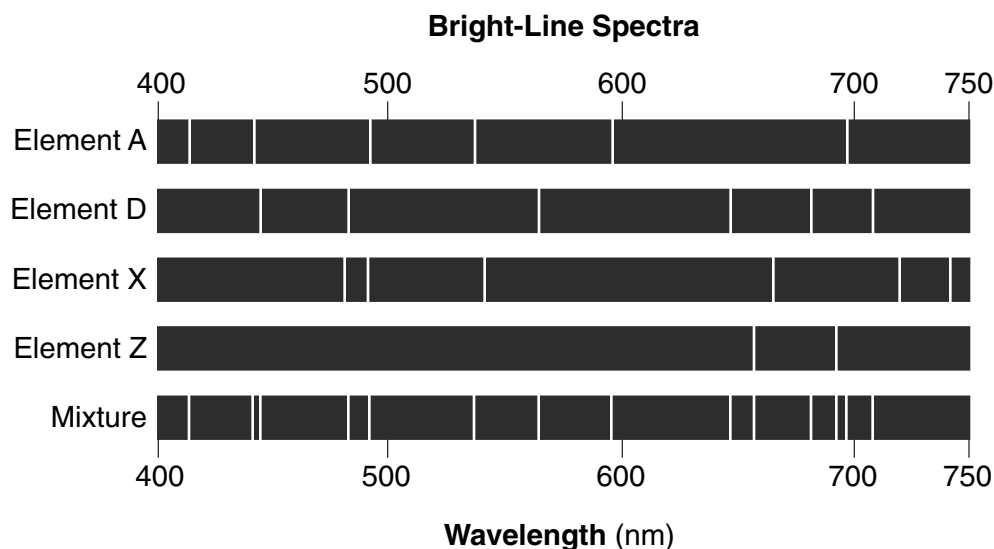
Which element is *not* present in the mixture?

(1) *A*   (3) *X*
(2) *D*   (4) *Z*

---

32 What is the overall charge of an ion that has 12 protons, 10 electrons, and 14 neutrons?

(1) 2−   (3) 4−
(2) 2+   (4) 4+

33 As the elements in Period 3 are considered in order of increasing atomic number, there is a general *decrease* in

(1) atomic mass
(2) atomic radius
(3) electronegativity
(4) first ionization energy

34 Which electron configuration represents the electrons of a sulfur atom in an excited state?

(1) 2-6-6   (3) 2-8-4
(2) 2-7-7   (4) 2-8-6

35 Given the word equation:

sodium chlorate → sodium chloride + oxygen

Which type of chemical reaction is represented by this equation?

(1) double replacement (3) decomposition
(2) single replacement   (4) synthesis

36 Which compound has the highest percent composition by mass of strontium?

(1) $SrCl_2$ (3) SrO

(2) SrI_2 (4) SrS

37 Given the formula for hydrazine:

H
  \\
   N—N
H /   \\
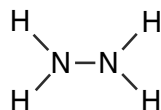
How many pairs of electrons are shared between the two nitrogen atoms?

(1) 1   (3) 3

(2) 2   (4) 4

38 Which formulas represent one ionic compound and one molecular compound?

(1) N_2 and SO_2 (3) $BaCl_2$ and N_2O_4

(2) Cl_2 and H_2S (4) $NaOH$ and $BaSO_4$

39 Which Kelvin temperature is equal to 200.°C?

(1) −73 K   (3) 200. K

(2) 73 K   (4) 473 K

40 A 10.0-gram sample of $H_2O(\ell)$ at 23.0°C absorbs 209 joules of heat. What is the final temperature of the $H_2O(\ell)$ sample?

(1) 5.0°C   (3) 28.0°C

(2) 18.0°C   (4) 50.0°C

41 Given the equation representing a system at equilibrium:

$$AgCl(s) \xrightleftharpoons{H_2O} Ag^+(aq) + Cl^-(aq)$$
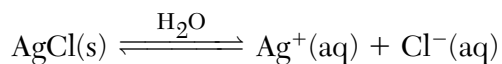
When the concentration of $Cl^-(aq)$ is increased, the concentration of $Ag^+(aq)$

(1) decreases, and the amount of $AgCl(s)$ increases

(2) decreases, and the amount of $AgCl(s)$ decreases

(3) increases, and the amount of $AgCl(s)$ increases

(4) increases, and the amount of $AgCl(s)$ decreases

42 Which particle diagram represents a sample of matter that can *not* be broken down by chemical means?

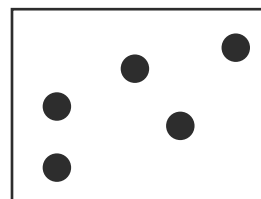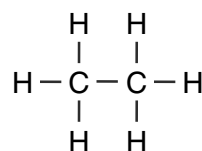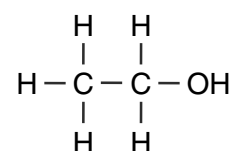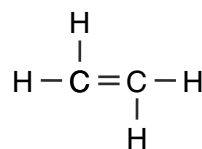| Key |
| --- |
| ○ = atom of one element |
| ● = atom of a different element |

(1)   (3)

(2)   (4)

43 Which formula represents an unsaturated hydrocarbon?

     H H
     | |
H—C—C—H
     | |
     H H

(1)

     H H
     | |
H—C—C—OH
     | |
     H H

(3)

     H
     |
H—C=C—H
        |
        H

(2)

     H O
     | ||
H—C—C—H
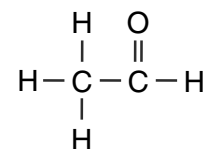 |
     H
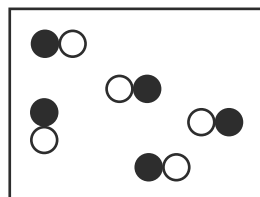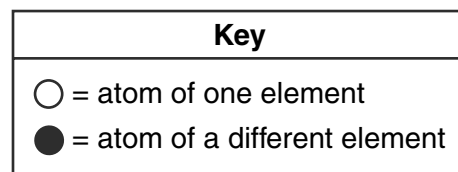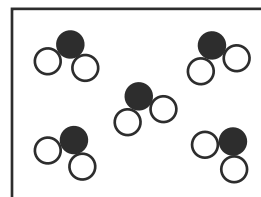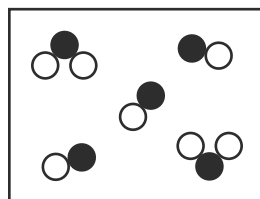
(4)

44 When the pH of a solution is changed from 4 to 3, the hydronium ion concentration of the solution

(1) decreases by a factor of 10
(2) increases by a factor of 10
(3) decreases by a factor of 100
(4) increases by a factor of 100

45 Three samples of the same solution are tested, each with a different indicator. All three indicators, bromthymol blue, bromcresol green, and thymol blue, appear blue if the pH of the solution is

(1) 4.7   (3) 7.8
(2) 6.0   (4) 9.9

46 A 10.0-milliliter sample of NaOH(aq) is neutralized by 40.0 milliliters of 0.50 M HCl. What is the molarity of the NaOH(aq)?

(1) 1.0 M   (3) 0.25 M
(2) 2.0 M   (4) 0.50 M

47 Radiation is spontaneously emitted from hydrogen-3 nuclei, but radiation is *not* spontaneously emitted from hydrogen-1 nuclei or hydrogen-2 nuclei. Which hydrogen nuclei are stable?

(1) nuclei of H-1 and H-2, only
(2) nuclei of H-1 and H-3, only
(3) nuclei of H-2 and H-3, only
(4) nuclei of H-1, H-2, and H-3

48 Given the equation representing a nuclear reaction in which X represents a nuclide:

$$^{232}_{90}\text{Th} \rightarrow {}^{4}_{2}\text{He} + X$$
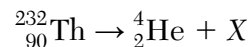
Which nuclide is represented by X?

(1) $^{236}_{92}\text{Ra}$ (3) $^{236}_{92}\text{U}$

(2) $^{228}_{88}\text{Ra}$ (4) $^{228}_{88}\text{U}$

49 After decaying for 48 hours, $\frac{1}{16}$ of the original mass of a radioisotope sample remains unchanged. What is the half-life of this radioisotope?

(1) 3.0 h   (3) 12 h
(2) 9.6 h   (4) 24 h

50 Which balanced equation represents nuclear fusion?

(1) $^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He}$

(2) $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

(3) $^{6}_{3}\text{Li} + {}^{1}_{0}\text{n} \rightarrow {}^{3}_{1}\text{H} + {}^{4}_{2}\text{He}$

(4) $\text{CaO} + \text{CO}_2 \rightarrow \text{CaCO}_3$

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 51 through 53 on the information below and on your knowledge of chemistry.

When magnesium is ignited in air, the magnesium reacts with oxygen and nitrogen. The reaction between magnesium and nitrogen is represented by the unbalanced equation below.

$$Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$$
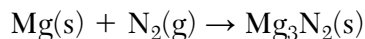
51 Balance the equation *in your answer booklet* for the reaction between magnesium and nitrogen, using the smallest whole-number coefficients.   [1]

52 In the ground state, which noble gas has atoms with the same electron configuration as a magnesium ion?   [1]

53 Explain, in terms of electrons, why an atom of the metal in this reaction forms an ion that has a smaller radius than its atom.   [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

The balanced equation below represents a reaction.

$$O_2(g) + energy \rightarrow O(g) + O(g)$$
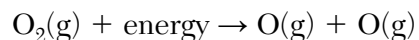
54 Identify the type of chemical bond in a molecule of the reactant.   [1]

55 In the space *in your answer booklet*, draw a Lewis electron-dot diagram of one oxygen atom.   [1]

56 Explain, in terms of bonds, why energy is absorbed during this reaction.   [1]

Base your answers to questions 57 through 59 on the information below and on your knowledge of chemistry.

Starting as a solid at $-25°C$, a sample of H_2O is heated at a constant rate until the sample is at 125°C. This heating occurs at standard pressure. The graph below represents the relationship between temperature and heat added to the sample.

Heating Curve for H$_2$O
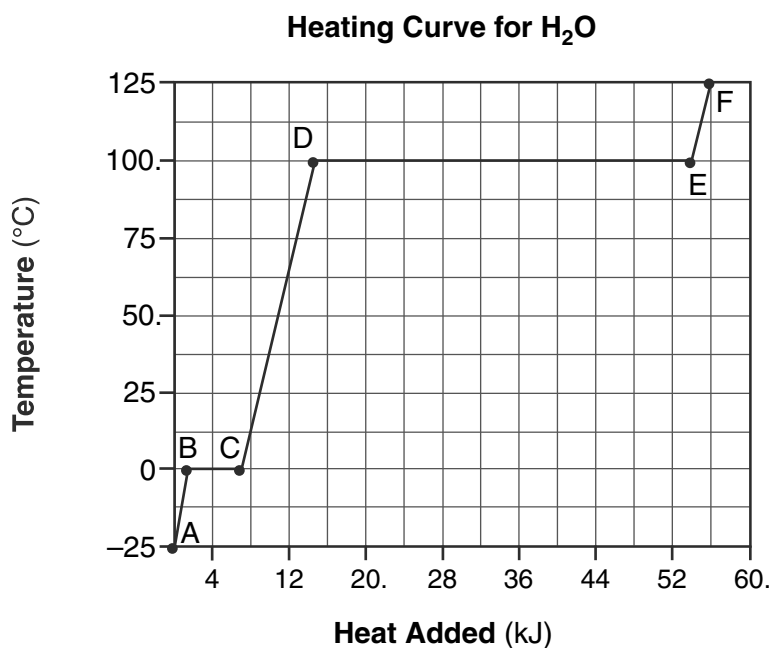
57 Describe what happens to *both* the potential energy and the average kinetic energy of the molecules in the H_2O sample during interval *AB*. [1]

58 Using the graph, determine the total amount of heat added to the sample during interval *CD*. [1]

59 Explain, in terms of heat of fusion and heat of vaporization, why the heat added during interval *DE* is greater than the heat added during interval *BC* for this sample of water. [1]

Base your answers to questions 60 through 62 on the information below and on your knowledge of chemistry.

Cylinder *A* has a movable piston and contains hydrogen gas. An identical cylinder, *B*, contains methane gas. The diagram below represents these cylinders and the conditions of pressure, volume, and temperature of the gas in each cylinder.

Cylinder A

Hydrogen gas
P = 1.2 atm
V = 1.25 L
T = 293 K

Cylinder B

Methane gas
P = 1.2 atm
V = 1.25 L
T = 293 K

60 Compare the total number of gas molecules in cylinder *A* to the total number of gas molecules in cylinder *B*.   [1]

61 State a change in temperature and a change in pressure that will cause the gas in cylinder *A* to behave more like an ideal gas.   [1]

62 In the space *in your answer booklet*, show a numerical setup for calculating the volume of the gas in cylinder *B* at STP.   [1]

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

There are several isomers of C_6H_{14}. The formulas and boiling points for two of these isomers are given in the table below.

Isomer	Formula	Boiling Point at 1 atm (°C)
1	H H H H H H ‖ ‖ ‖ ‖ ‖ ‖ H—C—C—C—C—C—C—H ‖ ‖ ‖ ‖ ‖ ‖ H H H H H H	68.7
2	(branched structure)	49.7

63 Identify the homologous series to which these isomers belong. [1]

64 Write the empirical formula for isomer 1. [1]

65 Explain, in terms of intermolecular forces, why isomer 2 boils at a lower temperature than isomer 1. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

Before atomic numbers were known, Mendeleev developed a classification system for the 63 elements known in 1872, using oxide formulas and atomic masses. He used an R in the oxide formulas to represent any element in each group. The atomic mass was listed in parentheses after the symbol of each element. A modified version of Mendeleev's classification system is shown in the table below.

Modified Version of Mendeleev's Table

Group ⟶	I	II	III	IV	V	VI	VII
Oxide formulas	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7
Series 1	H(1)						
2	Li(7)	Be(9.4)	B(11)	C(12)	N(14)	O(16)	F(19)
3	Na(23)	Mg(24)	Al(27.3)	Si(28)	P(31)	S(32)	Cl(35.5)
4	K(39)	Ca(40)		Ti(48)	V(51)	Cr(52)	Mn(55)
5	Cu(63)	Zn(65)			As(75)	Se(78)	Br(80)
6	Rb(85)	Sr(87)	Yt(88)	Zr(90)	Nb(94)	Mo(96)	
7	Ag(108)	Cd(112)	In(113)	Sn(118)	Sb(122)	Te(125)	I(127)
8	Cs(133)	Ba(137)	Di(138)	Ce(140)			

66 Identify *one* characteristic used by Mendeleev to develop his classification system of the elements. [1]

67 Based on Mendeleev's oxide formula, what is the number of electrons lost by each atom of the elements in Group III? [1]

68 Based on Table *J*, identify the *least* active metal listed in Group I on Mendeleev's table. [1]

69 Explain, in terms of chemical reactivity, why the elements in Group 18 on the modern Periodic Table were *not* identified by Mendeleev at that time. [1]

Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

In a laboratory apparatus, a sample of lead(II) oxide reacts with hydrogen gas at high temperature. The products of this reaction are liquid lead and water vapor. As the reaction proceeds, water vapor and excess hydrogen gas leave the glass tube. The diagram and balanced equation below represent this reaction.

$$PbO(s) + H_2(g) + heat \longrightarrow Pb(\ell) + H_2O(g)$$
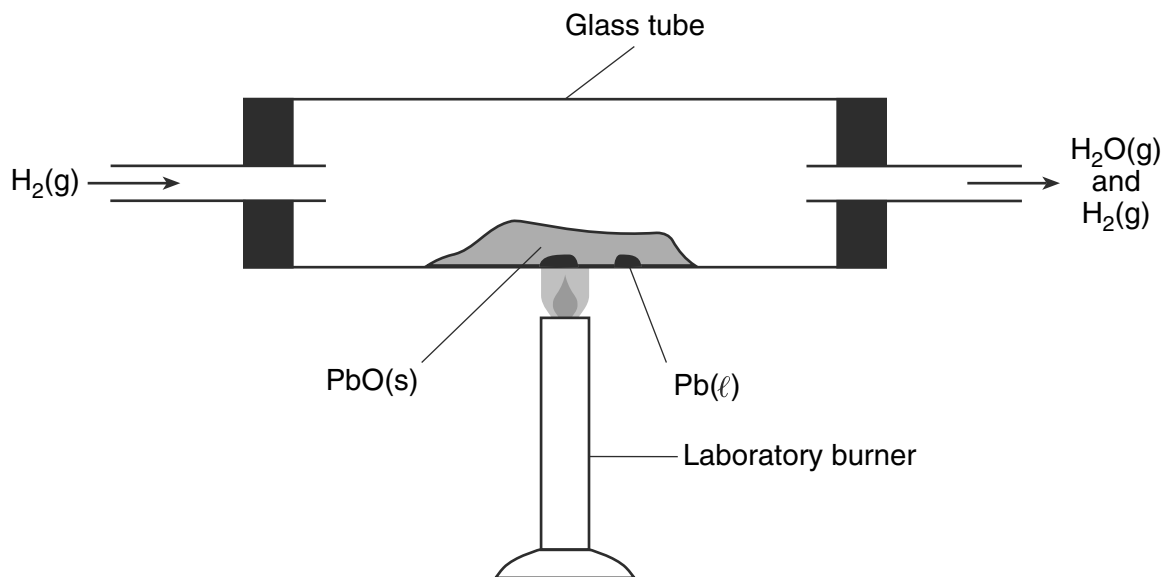
70 Determine the change in oxidation number for the hydrogen that reacts. [1]

71 Write a balanced half-reaction equation for the reduction of the Pb^{2+} ions in this reaction. [1]

72 Explain why the reaction that occurs in this glass tube can *not* reach equilibrium. [1]

73 State *one* change in reaction conditions, other than adding a catalyst, that would cause the rate of this reaction to increase. [1]

Base your answers to questions 74 through 77 on the information below and on your knowledge of chemistry.

In the late 19th century, the Hall-Herroult process was invented as an inexpensive way to produce aluminum. In this process, $Al_2O_3(\ell)$ extracted from bauxite is dissolved in $Na_3AlF_6(\ell)$ in a graphite-lined tank, as shown in the diagram below. The products are carbon dioxide and molten aluminum metal.

Hall-Heroult Process
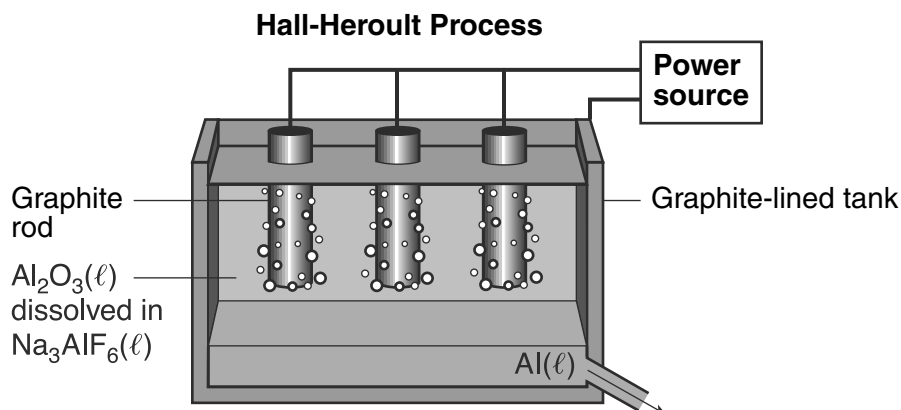
74 Compare the chemical properties of a 300.-kilogram sample of $Al_2O_3(\ell)$ with the chemical properties of a 600.-kilogram sample of $Al_2O_3(\ell)$. [1]

75 Write the chemical name for the liquid compound dissolved in the $Na_3AlF_6(\ell)$. [1]

76 What is the melting point of the substance that collects at the bottom of the tank? [1]

77 Compare the density of the $Al(\ell)$ with the density of the mixture of $Al_2O_3(\ell)$ and $Na_3AlF_6(\ell)$. [1]

Base your answers to questions 78 through 80 on the information below and on your knowledge of chemistry.

One process used to manufacture sulfuric acid is called the contact process. One step in this process, the reaction between sulfur dioxide and oxygen, is represented by the forward reaction in the system at equilibrium shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + 394 \text{ kJ}$$
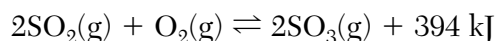
A mixture of platinum and vanadium(V) oxide may be used as a catalyst for this reaction. The sulfur trioxide produced is then used to make sulfuric acid.

78 Determine the amount of energy released when 1.00 mole of sulfur trioxide is produced. [1]

79 Write the chemical formula for vanadium(V) oxide. [1]

80 On the labeled axes *in your answer booklet*, complete the potential energy diagram for the forward reaction represented by this equation. [1]

Base your answers to questions 81 and 82 on the information below and on your knowledge of chemistry.

Two very stable compounds, Freon-12 and Freon-14, are used as liquid refrigerants. A Freon-12 molecule consists of one carbon atom, two chlorine atoms, and two fluorine atoms. A Freon-14 molecule consists of one carbon atom and four fluorine atoms.

81 In the space *in your answer booklet*, draw a structural formula for Freon-12. [1]

82 To which class of organic compounds do Freon-12 and Freon-14 belong? [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Chemical concepts are applied in candy making. A recipe for making lollipops is shown below.

Hard-Candy Lollipops Recipe

Ingredients:

414 grams of sugar
177 grams of water
158 milliliters of light corn syrup

Step 1: In a saucepan, mix the sugar and water. Heat this mixture, while stirring, until all of the sugar dissolves.
Step 2: Add the corn syrup and heat the mixture until it boils.
Step 3: Continue boiling the mixture until the temperature reaches 143°C at standard pressure.
Step 4: Remove the pan from the heat and allow it to stand until the bubbling stops. Pour the mixture into lollipop molds that have been coated with cooking oil spray.

83 Explain, in terms of the polarity of sugar molecules, why the sugar dissolves in water. [1]

84 Determine the concentration, expressed as percent by mass, of the sugar dissolved in the mixture produced in step 1. [1]

85 Explain, in terms of the concentration of sugar molecules, why the boiling point of the mixture in step 3 increases as water evaporates from the mixture. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING

CHEMISTRY

Tuesday, June 24, 2014 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Compared to the charge of a proton, the charge of an electron has

(1) a greater magnitude and the same sign
(2) a greater magnitude and the opposite sign
(3) the same magnitude and the same sign
(4) the same magnitude and the opposite sign

2 Which atom has the largest atomic radius?

(1) potassium   (3) francium
(2) rubidium   (4) cesium

3 In the wave-mechanical model of the atom, an orbital is defined as

(1) a region of the most probable proton location
(2) a region of the most probable electron location
(3) a circular path traveled by a proton around the nucleus
(4) a circular path traveled by an electron around the nucleus

4 When an excited electron in an atom moves to the ground state, the electron

(1) absorbs energy as it moves to a higher energy state
(2) absorbs energy as it moves to a lower energy state
(3) emits energy as it moves to a higher energy state
(4) emits energy as it moves to a lower energy state

5 Which polyatomic ion is found in the compound represented by the formula $NaHCO_3$?

(1) acetate   (3) hydrogen sulfate
(2) hydrogen carbonate (4) oxalate

6 The atomic mass of magnesium is the weighted average of the atomic masses of

(1) all of the artificially produced isotopes of Mg
(2) all of the naturally occurring isotopes of Mg
(3) the two most abundant artificially produced isotopes of Mg
(4) the two most abundant naturally occurring isotopes of Mg

7 Which element has atoms that can form halide ions?

(1) iodine   (3) strontium
(2) silver   (4) xenon

8 Two forms of solid carbon, diamond and graphite, differ in their physical properties due to the differences in their

(1) atomic numbers
(2) crystal structures
(3) isotopic abundances
(4) percent compositions

9 Which quantity can be calculated for a solid compound, given only the formula of the compound and the Periodic Table of the Elements?

(1) the density of the compound
(2) the heat of fusion of the compound
(3) the melting point of each element in the compound
(4) the percent composition by mass of each element in the compound

10 Which terms identify types of chemical reactions?

(1) decomposition and sublimation
(2) decomposition and synthesis
(3) deposition and sublimation
(4) deposition and synthesis

11 The greatest amount of energy released per gram of reactants occurs during a

(1) redox reaction
(2) fission reaction
(3) substitution reaction
(4) neutralization reaction

12 Which element has atoms with the strongest attraction for electrons in a chemical bond?

(1) chlorine
(2) nitrogen
(3) fluorine
(4) oxygen

13 Compared to the physical and chemical properties of the compound NO_2, the compound N_2O has

(1) different physical properties and different chemical properties
(2) different physical properties and the same chemical properties
(3) the same physical properties and different chemical properties
(4) the same physical properties and the same chemical properties

14 Which phrase describes a molecule of CH_4, in terms of molecular polarity and distribution of charge?

(1) polar with an asymmetrical distribution of charge
(2) polar with a symmetrical distribution of charge
(3) nonpolar with an asymmetrical distribution of charge
(4) nonpolar with a symmetrical distribution of charge

15 Which sample of copper has atoms with the *lowest* average kinetic energy?

(1) 10. g at 45°C
(2) 20. g at 35°C
(3) 30. g at 25°C
(4) 40. g at 15°C

16 Which change results in the formation of different substances?

(1) burning of propane
(2) melting of NaCl(s)
(3) deposition of CO_2(g)
(4) solidification of water

17 Which substance can *not* be broken down by a chemical change?

(1) ammonia
(2) ethanol
(3) propanal
(4) zirconium

18 According to Table *I*, which equation represents a change resulting in the greatest quantity of energy released?

(1) $2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$
(2) $2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$
(3) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
(4) $N_2(g) + O_2(g) \rightarrow 2NO(g)$

19 Which element is a liquid at STP?

(1) bromine
(2) cesium
(3) francium
(4) iodine

20 Which statement describes a reversible reaction at equilibrium?

(1) The activation energy of the forward reaction must equal the activation energy of the reverse reaction.
(2) The rate of the forward reaction must equal the rate of the reverse reaction.
(3) The concentration of the reactants must equal the concentration of the products.
(4) The potential energy of the reactants must equal the potential energy of the products.

21 Given the balanced equation representing a reaction:

$$O_2 \rightarrow O + O$$

What occurs during this reaction?

(1) Energy is absorbed as bonds are broken.
(2) Energy is absorbed as bonds are formed.
(3) Energy is released as bonds are broken.
(4) Energy is released as bonds are formed.

22 In terms of entropy and energy, systems in nature tend to undergo changes toward

(1) lower entropy and lower energy
(2) lower entropy and higher energy
(3) higher entropy and lower energy
(4) higher entropy and higher energy

23 Which term is defined as the difference between the potential energy of the products and the potential energy of the reactants in a chemical reaction?

(1) activation energy
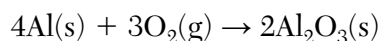(2) thermal energy
(3) heat of fusion
(4) heat of reaction

24 What is the atomic number of the element whose atoms bond to each other in chains, rings, and networks?

(1) 10
(2) 8
(3) 6
(4) 4

25 How many pairs of electrons are shared between two adjacent carbon atoms in a saturated hydrocarbon?

(1) 1
(2) 2
(3) 3
(4) 4

26 Given the balanced equation representing a reaction:

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

As the aluminum loses 12 moles of electrons, the oxygen

(1) gains 4 moles of electrons
(2) gains 12 moles of electrons
(3) loses 4 moles of electrons
(4) loses 12 moles of electrons

27 Which compound is an electrolyte?

(1) CH_3CHO
(2) CH_3OCH_3
(3) CH_3COOH
(4) $CH_3CH_2CH_3$

28 Which statement describes one acid-base theory?

(1) An acid is an H^+ acceptor, and a base is an H^+ donor.
(2) An acid is an H^+ donor, and a base is an H^+ acceptor.
(3) An acid is an H^- acceptor, and a base is an H^- donor.
(4) An acid is an H^- donor, and a base is an H^- acceptor.

29 Which compounds are classified as Arrhenius acids?

(1) HCl and NaOH
(2) HNO_3 and NaCl
(3) NH_3 and H_2CO_3
(4) HBr and H_2SO_4

30 Which statement describes the stability of the nuclei of potassium atoms?

(1) All potassium atoms have stable nuclei that spontaneously decay.
(2) All potassium atoms have unstable nuclei that do not spontaneously decay.
(3) Some potassium atoms have unstable nuclei that spontaneously decay.
(4) Some potassium atoms have unstable nuclei that do not spontaneously decay.

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 Which notations represent different isotopes of the element sodium?

(1) ^{32}S and ^{34}S
(2) S^{2-} and S^{6+}
(3) Na$^+$ and Na^0
(4) ^{22}Na and ^{23}Na

32 Which electron configuration represents the electrons in an atom of Ga in an excited state?

(1) 2-8-17-3
(2) 2-8-17-4
(3) 2-8-18-3
(4) 2-8-18-4

33 Which statement describes the general trends in electronegativity and first ionization energy as the elements in Period 3 are considered in order from Na to Cl?

(1) Electronegativity increases, and first ionization energy decreases.
(2) Electronegativity decreases, and first ionization energy increases.
(3) Electronegativity and first ionization energy both increase.
(4) Electronegativity and first ionization energy both decrease.

34 What is the gram-formula mass of Fe(NO$_3$)$_3$?

(1) 146 g/mol
(2) 194 g/mol
(3) 214 g/mol
(4) 242 g/mol

35 Given the balanced equation representing a reaction:

$$Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3Na_2SO_4$$
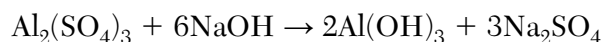
The mole ratio of NaOH to Al(OH)$_3$ is

(1) 1:1
(2) 1:3
(3) 3:1
(4) 3:7

36 Which equation represents a single replacement reaction?

(1) $2H_2O_2 \rightarrow 2H_2O + O_2$
(2) $2H_2 + O_2 \rightarrow 2H_2O$
(3) $H_2SO_4 + Mg \rightarrow H_2 + MgSO_4$
(4) $HCl + KOH \rightarrow KCl + H_2O$

37 The accepted value for the percent by mass of water in a hydrate is 36.0%. In a laboratory activity, a student determined the percent by mass of water in the hydrate to be 37.8%. What is the percent error for the student's measured value?

(1) 5.0%
(2) 4.8%
(3) 1.8%
(4) 0.05%

38 The boiling points, at standard pressure, of four compounds are given in the table below.

Boiling Points of Four Compounds

| Compound	Boiling Point (°C)
H$_2$O	100.0
H$_2$S	−59.6
H$_2$Se	−41.3
H$_2$Te	−2.0

Which type of attraction can be used to explain the unusually high boiling point of H$_2$O?

(1) ionic bonding
(2) hydrogen bonding
(3) polar covalent bonding
(4) nonpolar covalent bonding

39 Which formula represents a molecule with the most polar bond?

(1) CO
(2) NO
(3) HI
(4) HCl

40 The graph below represents the uniform heating of a substance from the solid to the gas phase.

Time
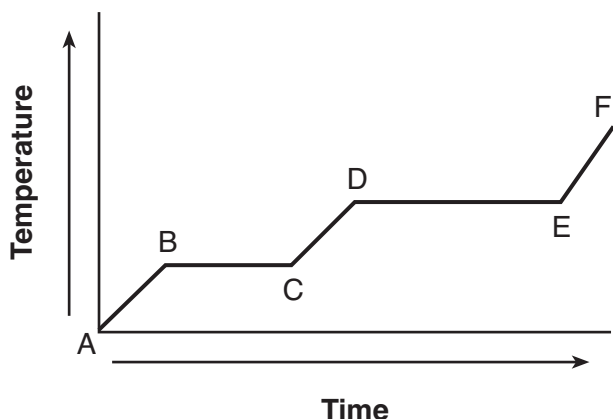
Which line segment of the graph represents boiling?

(1) $\overline{AB}$ (3) $\overline{CD}$
(2) $\overline{BC}$ (4) $\overline{DE}$

41 A 1-gram sample of a compound is added to 100 grams of $H_2O(\ell)$ and the resulting mixture is then thoroughly stirred. Some of the compound is then separated from the mixture by filtration. Based on Table *F*, the compound could be

(1) AgCl   (3) NaCl
(2) $CaCl_2$ (4) $NiCl_2$

42 At standard pressure, the total amount of heat required to completely vaporize a 100.-gram sample of water at its boiling point is

(1) 2.26×10 J   (3) 2.26×10^3 J
(2) 2.26×10^2 J   (4) 2.26×10^5 J

43 A sample of helium gas is in a sealed, rigid container. What occurs as the temperature of the sample is increased?

(1) The mass of the sample decreases.
(2) The number of moles of gas increases.
(3) The volume of each atom decreases.
(4) The frequency of collisions between atoms increases.

44 Given the equation representing a reaction at equilibrium:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + \text{heat}$$
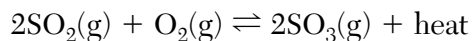
Which change causes the equilibrium to shift to the right?
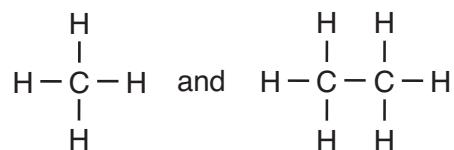
(1) adding a catalyst
(2) adding more $O_2(g)$
(3) decreasing the pressure
(4) increasing the temperature

45 Given the formula representing a compound:
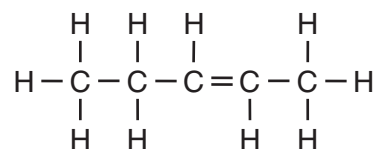
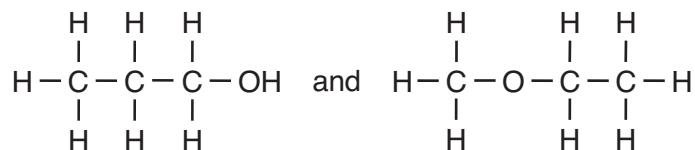

What is a chemical name of this compound?

(1) 2-pentene   (3) 3-pentene
(2) 2-pentyne   (4) 3-pentyne

46 What is the oxidation number of manganese in $KMnO_4$?

(1) $+7$ (3) $+3$
(2) $+2$ (4) $+4$

47 When the pH of an aqueous solution is changed from 1 to 2, the concentration of hydronium ions in the solution is

(1) decreased by a factor of 2
(2) decreased by a factor of 10
(3) increased by a factor of 2
(4) increased by a factor of 10

48 What is the color of the indicator thymol blue in a solution that has a pH of 11?
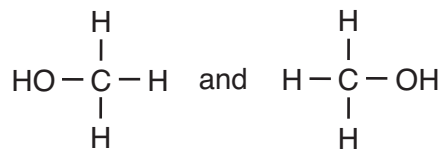
(1) red   (3) pink
(2) blue   (4) yellow

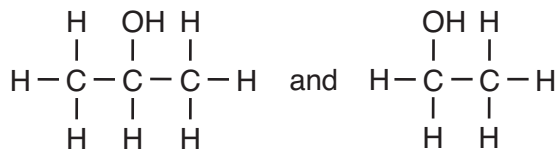49 Which formulas represent compounds that are isomers of each other?

$$H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H \quad \text{and} \quad H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H$$

(1)

$$H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-OH \quad \text{and} \quad H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-O-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H$$

(3)

$$HO-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H \quad \text{and} \quad H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-OH$$

(2)

$$H-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle OH}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H \quad \text{and} \quad H-\overset{\overset{\displaystyle OH}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-H$$

(4)

50 One beneficial use of radioisotopes is
(1) detection of disease
(2) neutralization of an acid spill
(3) decreasing the dissolved $O_2(g)$ level in seawater
(4) increasing the concentration of $CO_2(g)$ in the atmosphere

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Draw a Lewis electron-dot diagram for a molecule of bromomethane, CH_3Br.   [1]

52 Explain, in terms of atomic structure, why Group 18 elements on the Periodic Table rarely form compounds.   [1]

53 Explain, in terms of electrons, why the radius of a potassium atom is larger than the radius of a potassium ion in the ground state.   [1]

54 Identify the type of bonding in solid potassium.   [1]

Base your answers to questions 55 and 56 on the information below and on your knowledge of chemistry.

A 2.50-liter aqueous solution contains 1.25 moles of dissolved sodium chloride. The dissolving of $NaCl(s)$ in water is represented by the equation below.

$$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$$
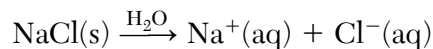
55 Determine the molarity of this solution.   [1]

56 Compare the freezing point of this solution to the freezing point of a solution containing 0.75 mole NaCl per 2.50 liters of solution.   [1]

Base your answers to questions 57 and 58 on the information below and on your knowledge of chemistry.

A 1.00-mole sample of glucose, $C_6H_{12}O_6$, completely reacts with oxygen, as represented by the balanced equation below.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(\ell) + energy$$

57 Write the empirical formula for glucose.   [1]

58 Using the axes *in your answer booklet*, complete the potential energy curve for the reaction of glucose with oxygen.   [1]

Base your answers to questions 59 through 61 on the information below and on your knowledge of chemistry.

Ethane, C_2H_6, has a boiling point of $-89°C$ at standard pressure. Ethanol, C_2H_5OH, has a much higher boiling point than ethane at standard pressure. At STP, ethane is a gas and ethanol is a liquid.

59 Identify the class of organic compounds to which ethanol belongs. [1]

60 A liquid boils when the vapor pressure of the liquid equals the atmospheric pressure on the surface of the liquid. Based on Table H, what is the boiling point of ethanol at standard pressure? [1]

61 Compare the intermolecular forces of the two substances at STP. [1]

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

An operating voltaic cell has zinc and iron electrodes. The cell and the unbalanced ionic equation representing the reaction that occurs in the cell are shown below.

Voltaic Cell

$$Zn(s) + Fe^{3+}(aq) \longrightarrow Zn^{2+}(aq) + Fe(s)$$
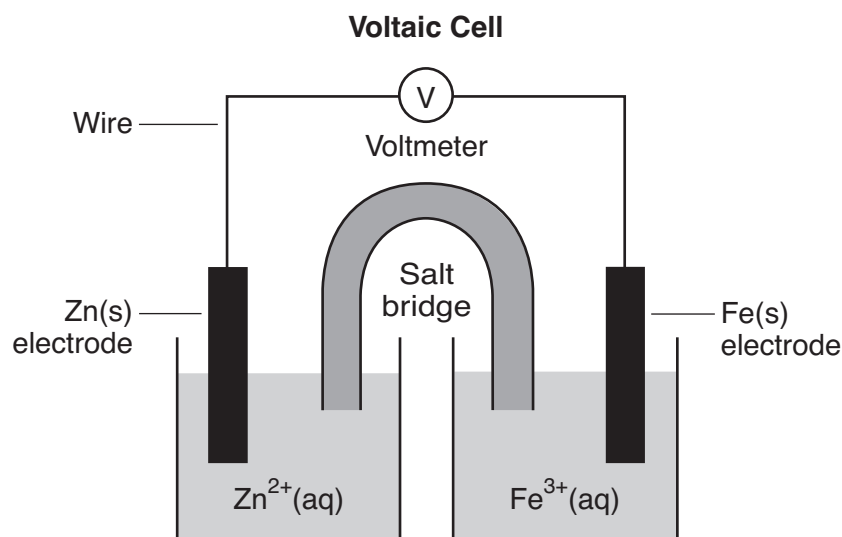
62 Identify the subatomic particles that flow through the wire as the cell operates. [1]

63 Balance the equation *in your answer booklet* for the redox reaction that occurs in this cell, using the smallest whole-number coefficients. [1]

64 Identify *one* metal from Table J that is more easily oxidized than Zn. [1]

65 Explain, in terms of Zn atoms and Zn ions, why the mass of the Zn electrode *decreases* as the cell operates. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

A student compares some models of the atom. These models are listed in the table below in order of development from top to bottom.

Models of the Atom

Model	Observation	Conclusion
Dalton model	Matter is conserved during a chemical reaction.	Atoms are hard, indivisible spheres of different sizes.
Thomson model	Cathode rays are deflected by magnetic/electric fields.	Atoms have small, negatively charged particles as part of their internal structure.
Rutherford model	Most alpha particles pass straight through gold foil but a few are deflected.	An atom is mostly empty space with a small, dense, positively charged nucleus.
Bohr model	Unique spectral lines are emitted by excited gaseous elements.	Packets of energy are absorbed or emitted by atoms when an electron changes shells.

66 State the model that first included electrons as subatomic particles. [1]

67 State *one* conclusion about the internal structure of the atom that resulted from the gold foil experiment. [1]

68 Using the conclusion from the Rutherford model, identify the charged subatomic particle that is located in the nucleus. [1]

69 State *one* way in which the Bohr model agrees with the Thomson model. [1]

Base your answers to questions 70 through 72 on the information below and on your knowledge of chemistry.

Paintball is a popular recreational activity that uses a metal tank of compressed carbon dioxide or nitrogen to launch small capsules of paint. A typical tank has a volume of 508 cubic centimeters. A 340.-gram sample of carbon dioxide is added to the tank before it is used for paintball. At 20.°C, this tank contains both $CO_2(g)$ and $CO_2(\ell)$. After a paintball game, the tank contains only $CO_2(g)$.

70 Determine the total number of moles of CO_2 added to the tank before it is used for paintball. [1]

71 In the box *in your answer booklet*, use the key to draw a particle diagram to represent the two phases of CO_2 in a newly filled tank. Your response must include *at least six* molecules of CO_2 in *each* phase. [1]

72 After the paintball game, the tank has a gas pressure of 6.1 atmospheres and is at 293 K. If the tank is heated to 313 K, the pressure in the tank will change. Show a numerical setup for calculating the pressure of the gas in the tank at 313 K. [1]

Base your answers to questions 73 through 75 on the information below and on your knowledge of chemistry.

Many breads are made by adding yeast to dough, causing the dough to rise. Yeast is a type of microorganism that produces the catalyst zymase, which converts glucose, $C_6H_{12}O_6$, to ethanol and carbon dioxide gas. The balanced equation for this reaction is shown below.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{zymase}} 2C_2H_5OH(aq) + 2CO_2(g)$$
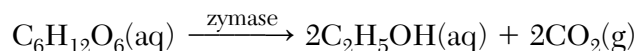
73 Draw a structural formula for the ethanol formed during this reaction. [1]

74 Describe how the catalyst, zymase, speeds up this reaction. [1]

75 Determine the total mass of ethanol produced when 270. grams of glucose reacts completely to form ethanol and 132 grams of carbon dioxide. [1]

Base your answers to questions 76 through 79 on the information below and on your knowledge of chemistry.

During a laboratory activity, a student places 25.0 mL of HCl(aq) of unknown concentration into a flask. The student adds four drops of phenolphthalein to the solution in the flask. The solution is titrated with 0.150 M KOH(aq) until the solution appears faint pink. The volume of KOH(aq) added is 18.5 mL.

76 What number of significant figures is used to express the concentration of the KOH(aq)? [1]

77 Complete the equation *in your answer booklet* for the neutralization reaction that occurs during the titration. [1]

78 Determine the concentration of the HCl(aq) solution, using the titration data. [1]

79 Describe *one* laboratory safety procedure that should be used if a drop of the KOH(aq) is spilled on the arm of the student. [1]

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

A few pieces of dry ice, $CO_2(s)$, at $-78°C$ are placed in a flask that contains air at 21°C. The flask is sealed by placing an uninflated balloon over the mouth of the flask. As the balloon inflates, the dry ice disappears and no liquid is observed in the flask.

80 State the direction of heat flow that occurs between the dry ice and the air in the flask. [1]

81 Write the name of the process that occurs as the dry ice undergoes a phase change in the flask. [1]

82 Compare the entropy of the CO_2 molecules in the dry ice to the entropy of the CO_2 molecules in the inflated balloon. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Illuminated **EXIT** signs are used in public buildings such as schools. If the word **EXIT** is green, the sign may contain the radioisotope tritium, hydrogen-3. The tritium is a gas sealed in glass tubes. The emissions from the decay of the tritium gas cause a coating on the inside of the tubes to glow.

83 State, in terms of neutrons, how an atom of tritium *differs* from an atom of hydrogen-1. [1]

84 Determine the fraction of an original sample of tritium that remains unchanged after 24.62 years. [1]

85 Complete the nuclear equation *in your answer booklet* for the radioactive decay of tritium, by writing a notation for the missing product. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING

CHEMISTRY

Tuesday, June 23, 2015 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

1 Compared to an electron, which particle has a charge that is equal in magnitude but opposite in sign?

  (1) an alpha particle   (3) a neutron
  (2) a beta particle   (4) a proton

2 The mass of a proton is approximately equal to

  (1) 1 atomic mass unit
  (2) 12 atomic mass units
  (3) the mass of 1 mole of carbon atoms
  (4) the mass of 12 moles of electrons

3 Which property *decreases* when the elements in Group 17 are considered in order of increasing atomic number?

  (1) atomic mass   (3) melting point
  (2) atomic radius   (4) electronegativity

4 Any substance composed of two or more elements that are chemically combined in a fixed proportion is

  (1) an isomer   (3) a solution
  (2) an isotope   (4) a compound

5 Which term refers to how strongly an atom of an element attracts electrons in a chemical bond with an atom of a different element?

  (1) entropy
  (2) electronegativity
  (3) activation energy
  (4) first ionization energy

6 At STP, which substance has metallic bonding?

  (1) ammonium chloride (3) iodine
  (2) barium oxide   (4) silver

7 What is the number of electrons shared between the carbon atoms in a molecule of ethyne?

  (1) 6   (3) 8
  (2) 2   (4) 4

8 Which atom in the ground state has a stable valence electron configuration?

  (1) Ar   (3) Si
  (2) Al   (4) Na

9 What occurs when two fluorine atoms react to produce a fluorine molecule?

  (1) Energy is absorbed as a bond is broken.
  (2) Energy is absorbed as a bond is formed.
  (3) Energy is released as a bond is broken.
  (4) Energy is released as a bond is formed.

10 Which gas sample at STP has the same number of molecules as a 2.0-liter sample of $Cl_2(g)$ at STP?

  (1) 1.0 L of $NH_3(g)$ (3) 3.0 L of $CO_2(g)$
  (2) 2.0 L of $CH_4(g)$ (4) 4.0 L of $NO(g)$

11 All atoms of uranium have the same

  (1) mass number
  (2) atomic number
  (3) number of neutrons plus protons
  (4) number of neutrons plus electrons

12 The concentration of a solution can be expressed in

  (1) kelvins
  (2) milliliters
  (3) joules per kilogram
  (4) moles per liter

13 Compared to the boiling point and the freezing point of water at 1 atmosphere, a 1.0 M $CaCl_2$(aq) solution at 1 atmosphere has a

(1) lower boiling point and a lower freezing point
(2) lower boiling point and a higher freezing point
(3) higher boiling point and a lower freezing point
(4) higher boiling point and higher freezing point

14 According to the kinetic molecular theory, which statement describes an ideal gas?

(1) The gas particles are diatomic.
(2) Energy is created when the gas particles collide.
(3) There are no attractive forces between the gas particles.
(4) The distance between the gas particles is small, compared to their size.

15 Which physical change is endothermic?

(1) CO_2(s) → CO_2(g)   (3) CO_2(g) → CO_2(ℓ)
(2) CO_2(ℓ) → CO_2(s)   (4) CO_2(g) → CO_2(s)

16 Which Group 16 element combines with hydrogen to form a compound that has the strongest hydrogen bonding between its molecules?

(1) oxygen   (3) sulfur
(2) selenium   (4) tellurium

17 Hydrocarbons are composed of the elements

(1) carbon and hydrogen, only
(2) carbon and oxygen, only
(3) carbon, hydrogen, and oxygen
(4) carbon, nitrogen, and oxygen

18 Which atom is bonded to the carbon atom in the functional group of a ketone?

(1) fluorine   (3) nitrogen
(2) hydrogen   (4) oxygen

19 Two types of organic reactions are

(1) addition and sublimation
(2) deposition and saponification
(3) decomposition and evaporation
(4) esterification and polymerization

20 The isomers butane and methylpropane have

(1) the same molecular formula and the same properties
(2) the same molecular formula and different properties
(3) different molecular formulas and the same properties
(4) different molecular formulas and different properties

21 In a redox reaction, which particles are lost and gained in equal numbers?

(1) electrons   (3) hydroxide ions
(2) neutrons   (4) hydronium ions

22 What is the oxidation state for a Mn atom?

(1) 0   (3) +3
(2) +7   (4) +4

23 Which compounds are classified as electrolytes?

(1) KNO_3 and H_2SO_4
(2) KNO_3 and CH_3OH
(3) CH_3OCH_3 and H_2SO_4
(4) CH_3OCH_3 and CH_3OH

24 Which compound is an Arrhenius base?

(1) CO_2 (3) $Ca(OH)_2$
(2) $CaSO_4$ (4) C_2H_5OH

25 According to one acid-base theory, a water molecule acts as a base when it accepts

(1) an H^+ ion   (3) a neutron
(2) an OH^- ion   (4) an electron

26 Given the equation representing a system at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$
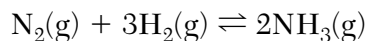
Which statement describes this reaction at equilibrium?

(1) The concentration of $N_2(g)$ decreases.
(2) The concentration of $N_2(g)$ is constant.
(3) The rate of the reverse reaction decreases.
(4) The rate of the reverse reaction increases.

27 The acidity or alkalinity of an unknown aqueous solution is indicated by its

(1) pH value
(2) electronegativity value
(3) percent by mass concentration
(4) percent by volume concentration

28 The laboratory process in which the volume of a solution of known concentration is used to determine the concentration of another solution is called

(1) distillation   (3) titration
(2) fermentation   (4) transmutation

29 Which list of nuclear emissions is arranged in order from the greatest penetrating power to the least penetrating power?

(1) alpha particle, beta particle, gamma ray
(2) alpha particle, gamma ray, beta particle
(3) gamma ray, alpha particle, beta particle
(4) gamma ray, beta particle, alpha particle

30 Given the diagram representing a reaction:
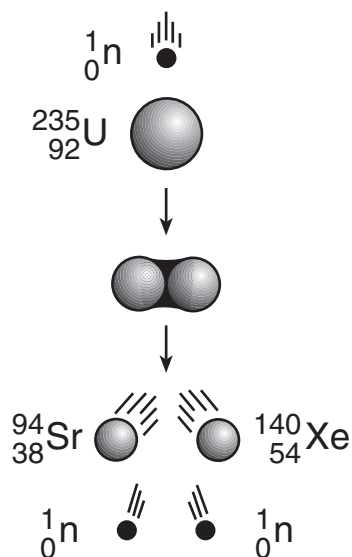
Which type of change is represented?

(1) fission   (3) deposition
(2) fusion   (4) evaporation

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which electron shell contains the valence electrons of a radium atom in the ground state?

(1) the sixth shell   (3) the seventh shell
(2) the second shell   (4) the eighteenth shell

32 Each diagram below represents the nucleus of an atom.
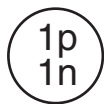
How many different elements are represented by the diagrams?

(1) 1   (3) 3
(2) 2   (4) 4

33 Chlorine and element X have similar chemical properties. An atom of element X could have an electron configuration of

(1) 2-2   (3) 2-8-8
(2) 2-8-1   (4) 2-8-18-7

34 Which group of elements contains a metalloid?

(1) Group 8   (3) Group 16
(2) Group 2   (4) Group 18

35 Which Lewis electron-dot diagram represents a fluoride ion?

36 In the formula for the compound XCl_4, the X could represent

(1) C   (3) Mg
(2) H   (4) Zn

37 The formula C_2H_4 can be classified as

(1) a structural formula, only
(2) a molecular formula, only
(3) both a structural formula and an empirical formula
(4) both a molecular formula and an empirical formula

38 Given the balanced equation representing a reaction:

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$
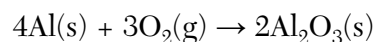
How many moles of $Al(s)$ react completely with 4.50 moles of $O_2(g)$ to produce 3.00 moles of $Al_2O_3(s)$?

(1) 1.50 mol   (3) 6.00 mol
(2) 2.00 mol   (4) 4.00 mol

39 What is the percent composition by mass of oxygen in $Ca(NO_3)_2$ (gram-formula mass = 164 g/mol)?

(1) 9.8%   (3) 48%
(2) 29%   (4) 59%

40 Given the balanced equation representing a reaction:

$$6Li + N_2 \rightarrow 2Li_3N$$
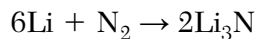
Which type of chemical reaction is represented by this equation?

(1) synthesis   (3) single replacement
(2) decomposition   (4) double replacement

41 Which elements can react to produce a molecular compound?

(1) calcium and chlorine
(2) hydrogen and sulfur
(3) lithium and fluorine
(4) magnesium and oxygen

42 Compared to a 1.0-mole sample of NaCl(s), a 1.0-mole sample of NaCl(ℓ) has a *different*

(1) number of ions
(2) empirical formula
(3) gram-formula mass
(4) electrical conductivity

43 Which property of an unsaturated solution of sodium chloride in water remains the same when more water is added to the solution?

(1) density of the solution
(2) boiling point of the solution
(3) mass of sodium chloride in the solution
(4) percent by mass of water in the solution

44 Which ion combines with Ba^{2+} to form a compound that is most soluble in water?

(1) S^{2-} (3) $CO_3{}^{2-}$
(2) OH^- (4) $SO_4{}^{2-}$

45 When a sample of gas is cooled in a sealed, rigid container, the pressure the gas exerts on the walls of the container will decrease because the gas particles hit the walls of the container

(1) less often and with less force
(2) less often and with more force
(3) more often and with less force
(4) more often and with more force

46 A rigid cylinder with a movable piston contains 50.0 liters of a gas at 30.0°C with a pressure of 1.00 atmosphere. What is the volume of the gas in the cylinder at STP?

(1) 5.49 L   (3) 55.5 L
(2) 45.0 L   (4) 455 L

47 Given the potential energy diagram for a chemical reaction:
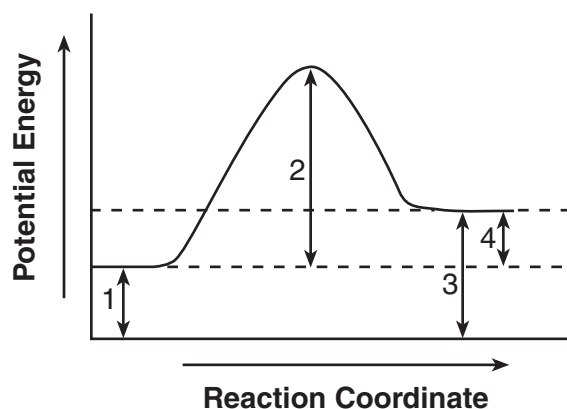
Which numbered interval represents the heat of reaction?

(1) 1   (3) 3
(2) 2   (4) 4

Base your answers to questions 48 and 49 on the graph below and on your knowledge of chemistry.

Boiling Points of Selected Alcohols at 101.3 kPa
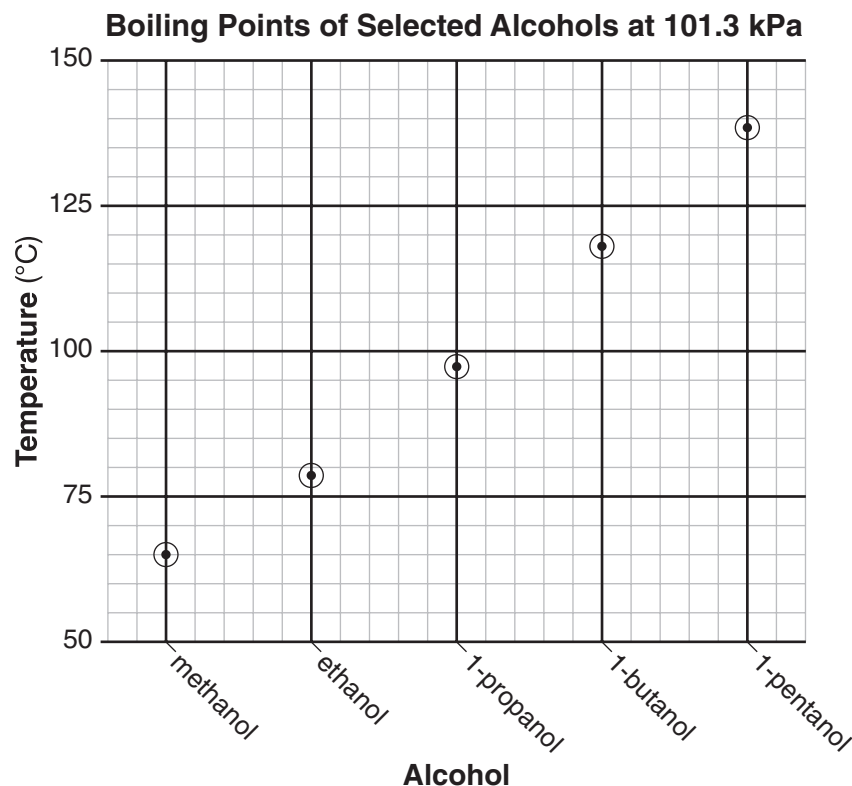
48 What is represented by the number "1" in the IUPAC name for three of these alcohols?
- (1) the number of isomers for each alcohol
- (2) the number of −OH groups for each carbon atom in each alcohol molecule
- (3) the location of an −OH group on one end of the carbon chain in each alcohol molecule
- (4) the location of an −OH group in the middle of the carbon chain in each alcohol molecule

49 What can be concluded from this graph?
- (1) At 101.3 kPa, water has a higher boiling point than 1-butanol.
- (2) At 101.3 kPa, water has a lower boiling point than ethanol.
- (3) The greater the number of carbon atoms per alcohol molecule, the lower the boiling point of the alcohol.
- (4) The greater the number of carbon atoms per alcohol molecule, the higher the boiling point of the alcohol.

50 In the laboratory, a student investigates the effect of concentration on the reaction between HCl(aq) and Mg(s), changing only the concentration of HCl(aq). Data for two trials in the investigation are shown in the table below.

Data Table

Trial	Volume of HCl(aq) (mL)	Concentration of HCl(aq) (M)	Mass of Mg(s) (g)	Reaction Time (s)
1	50.0	0.2	0.1	48
2	50.0	0.4	0.1	?

Compared to trial 1, what is the expected reaction time for trial 2 and the explanation for that result?

(1) less than 48 s, because there are fewer effective particle collisions per second
(2) less than 48 s, because there are more effective particle collisions per second
(3) more than 48 s, because there are fewer effective particle collisions per second
(4) more than 48 s, because there are more effective particle collisions per second

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Determine the volume of 2.00 M HCl(aq) solution required to completely neutralize 20.0 milliliters of 1.00 M NaOH(aq) solution. [1]

52 Determine the mass of KNO_3 that dissolves in 100. grams of water at 40.°C to produce a saturated solution. [1]

53 State, in terms of molecular polarity, why ethanol is soluble in water. [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

Three elements, represented by *D*, *E*, and *Q*, are located in Period 3. Some properties of these elements are listed in the table below. A student's experimental result indicates that the density of element *Q* is 2.10 g/cm³, at room temperature and standard pressure.

**Properties of Samples of Three Elements
at Room Temperature and Standard Pressure**

Element	Phase	Mass (g)	Density (g/cm³)	Oxide Formula
D	solid	50.0	0.97	D_2O
E	solid	50.0	1.74	EO
Q	solid	50.0	2.00	QO_2 *or* QO_3

54 Identify the physical property in the table that could be used to differentiate the samples of the three elements from each other. [1]

55 Identify the group on the Periodic Table to which element *D* belongs. [1]

56 Determine the percent error between the student's experimental density and the accepted density of element *Q*. [1]

Base your answers to questions 57 through 59 on the information below and on your knowledge of chemistry.

The equation below represents an equilibrium system of $SO_2(g)$, $O_2(g)$, and $SO_3(g)$. The reaction can be catalyzed by vanadium or platinum.
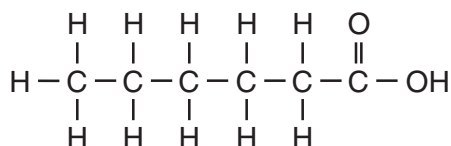
$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + energy$$
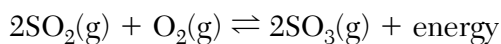
57 Compare the rates of the forward and reverse reactions at equilibrium. [1]

58 State how the equilibrium shifts when $SO_3(g)$ is removed from the system. [1]

59 A potential energy diagram for the forward reaction is shown *in your answer booklet.* On this diagram, draw a dashed line to show how the potential energy changes when the reaction occurs by the catalyzed pathway. [1]

_____

Base your answers to questions 60 and 61 on the information below and on your knowledge of chemistry.

The formulas for two compounds are shown below.
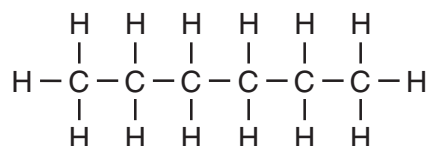
```
    H  H  H  H  H  H              H  H  H  H  H  O
    |  |  |  |  |  |              |  |  |  |  |  ||
H — C — C — C — C — C — C — H    H — C — C — C — C — C — C — OH
    |  |  |  |  |  |              |  |  |  |  |
    H  H  H  H  H  H              H  H  H  H  H
       Compound A                     Compound B
```

60 Explain, in terms of bonding, why compound *A* is saturated. [1]

61 Explain, in terms of molecular structure, why the chemical properties of compound *A* are different from the chemical properties of compound *B*. [1]

_____

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

Some isotopes of potassium are K-37, K-39, K-40, K-41, and K-42. The natural abundance and the atomic mass for the naturally occurring isotopes of potassium are shown in the table below.

Naturally Occurring Isotopes of Potassium

Isotope Notation	Natural Abundance (%)	Atomic Mass (u)
K-39	93.26	38.96
K-40	0.01	39.96
K-41	6.73	40.96

62 Identify the decay mode of K-37. [1]

63 Complete the nuclear equation *in your answer booklet* for the decay of K-40 by writing a notation for the missing nuclide. [1]

64 Determine the fraction of an original sample of K-42 that remains unchanged after 24.72 hours. [1]

65 Show a numerical setup for calculating the atomic mass of potassium. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

The Bohr model of the atom was developed in the early part of the twentieth century. A diagram of the Bohr model for one atom, in the ground state, of a specific element is shown below. The nucleus of this atom contains 4 protons and 5 neutrons.

Bohr Model

Nucleus

Second shell

First shell
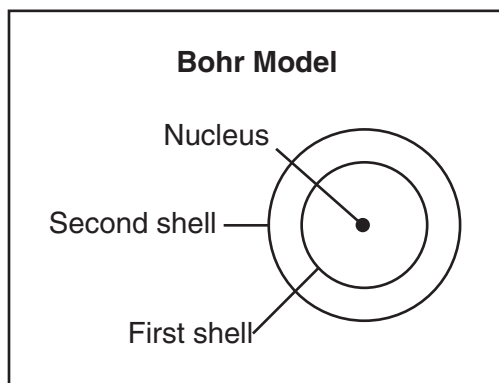
66 State the atomic number and the mass number of this element.   [1]

67 State the number of electrons in *each* shell in this atom in the ground state.   [1]

68 Using the Bohr model, describe the changes in electron energy and electron location when an atom changes from the ground state to an excited state.   [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

In 1828, Friedrich Wöhler produced urea when he heated a solution of ammonium cyanate. This reaction is represented by the balanced equation below.

Ammonium cyanate   Urea
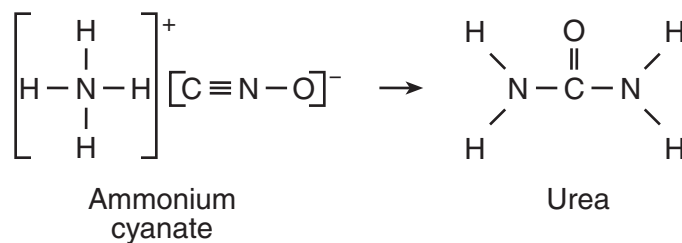
69 Identify the element in urea that makes it an organic compound. [1]

70 Determine the gram-formula mass of the product. [1]

71 Write an empirical formula for the product. [1]

72 Explain why this balanced equation represents a conservation of atoms. [1]

Base your answers to questions 73 through 75 on the information below and on your knowledge of chemistry.

Rubbing alcohol sold in stores is aqueous 2-propanol, $CH_3CHOHCH_3$(aq). Rubbing alcohol is available in concentrations of 70.% and 91% 2-propanol by volume.
To make 100. mL of 70.% aqueous 2-propanol, 70. mL of 2-propanol is diluted with enough water to produce a total volume of 100. mL. In a laboratory investigation, a student is given a 132-mL sample of 91% aqueous 2-propanol to separate using the process of distillation.

73 State evidence that indicates the proportions of the components in rubbing alcohol can vary. [1]

74 Identify the property of the components that makes it possible to use distillation to separate the 2-propanol from water. [1]

75 Determine the maximum volume of 2-propanol in the 132-mL sample. [1]

Base your answers to questions 76 through 79 on the information below and on your knowledge of chemistry.

A sample of seawater is analyzed. The table below gives the concentration of some ions in the sample.

**Concentration of Some Ions
in a Seawater Sample**

Ion	Concentration (M)
Cl^-	0.545
Na^+	0.468
Mg^{2+}	0.054
SO_4^{2-}	0.028
Ca^{2+}	0.010
K^+	0.010

76 Write a chemical formula of *one* compound formed by the combination of K^+ ions with one of these ions as water completely evaporates from the seawater sample. [1]

77 Determine the number of moles of the SO_4^{2-} ion in a 1400.-liter sample of the seawater. [1]

78 Compare the radius of an Mg^{2+} ion in the seawater to the radius of an Mg atom. [1]

79 Using the key *in your answer booklet*, draw *two* water molecules in the box, showing the orientation of *each* water molecule toward the calcium ion. [1]

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

A scientist bubbled HCl(g) through a sample of $H_2O(\ell)$. This process is represented by the balanced equation below.

$$H_2O(\ell) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$$
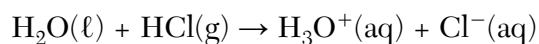
The scientist measured the pH of the liquid in the flask before and after the gas was bubbled through the water. The initial pH value of the water was 7.0 and the final pH value of the solution was 3.0.

80 Explain, in terms of ions, why the gaseous reactant in the equation is classified as an Arrhenius acid. [1]

81 What would be the color of bromcresol green if it had been added to the water in the flask before any of the HCl(g) was bubbled through the water? [1]

82 Compare the hydronium ion concentration of the solution that has the pH value of 3.0 to the hydronium ion concentration of the water. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

A small digital clock can be powered by a battery made from two potatoes and some household materials. The "potato clock" battery consists of two cells connected in a way to produce enough electricity to allow the clock to operate. In each cell, zinc atoms react to form zinc ions. Hydrogen ions from phosphoric acid in the potatoes react to form hydrogen gas. The labeled diagram and balanced ionic equation below show the reaction, the materials, and connections necessary to make a "potato clock" battery.

$$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$
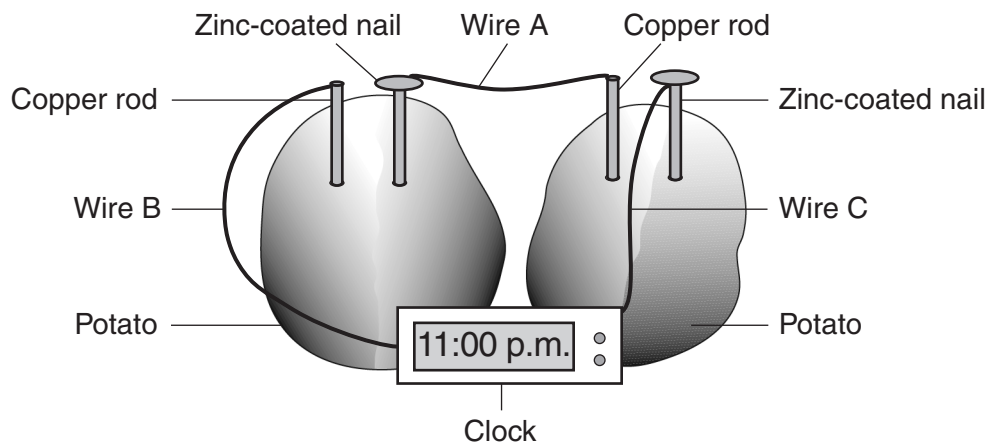
83 State the direction of electron flow in wire *A* as the two cells operate. [1]

84 Write a balanced half-reaction equation for the oxidation that occurs in the "potato clock" battery. [1]

85 Explain why phosphoric acid is needed for the battery to operate. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Tuesday, June 21, 2016 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which statement describes the charge of an electron and the charge of a proton?
   (1) An electron and a proton both have a charge of +1.
   (2) An electron and a proton both have a charge of −1.
   (3) An electron has a charge of +1, and a proton has a charge of −1.
   (4) An electron has a charge of −1, and a proton has a charge of +1.

2 Which subatomic particles are found in the nucleus of an atom of beryllium?
   (1) electrons and protons
   (2) electrons and positrons
   (3) neutrons and protons
   (4) neutrons and electrons

3 The elements in Period 4 on the Periodic Table are arranged in order of increasing
   (1) atomic radius
   (2) atomic number
   (3) number of valence electrons
   (4) number of occupied shells of electrons

4 Which phrase describes two forms of solid carbon, diamond and graphite, at STP?
   (1) the same crystal structure and the same properties
   (2) the same crystal structure and different properties
   (3) different crystal structures and the same properties
   (4) different crystal structures and different properties

5 Which element has six valence electrons in each of its atoms in the ground state?
   (1) Se   (3) Kr
   (2) As   (4) Ga

6 What is the chemical name for $H_2SO_3(aq)$?
   (1) sulfuric acid
   (2) sulfurous acid
   (3) hydrosulfuric acid
   (4) hydrosulfurous acid

7 Which substance is most soluble in water?
   (1) $(NH_4)_3PO_4$ (3) Ag_2SO_4
   (2) $Cu(OH)_2$ (4) $CaCO_3$

8 Which type of bonding is present in a sample of an element that is malleable?
   (1) ionic   (3) nonpolar covalent
   (2) metallic   (4) polar covalent

9 Which atom has the greatest attraction for the electrons in a chemical bond?
   (1) hydrogen   (3) silicon
   (2) oxygen   (4) sulfur

10 Which type of reaction involves the transfer of electrons?
   (1) alpha decay
   (2) double replacement
   (3) neutralization
   (4) oxidation-reduction

11 A 10.0-gram sample of nitrogen is at STP. Which property will increase when the sample is cooled to 72 K at standard pressure?
   (1) mass   (3) density
   (2) volume   (4) temperature

12 Which element is a gas at STP?
   (1) sulfur   (3) potassium
   (2) xenon   (4) phosphorus

13 A 5.0-gram sample of Fe(s) is to be placed in 100. milliliters of HCl(aq). Which changes will result in the fastest rate of reaction?

(1) increasing the surface area of Fe(s) and increasing the concentration of HCl(aq)

(2) increasing the surface area of Fe(s) and decreasing the concentration of HCl(aq)

(3) decreasing the surface area of Fe(s) and increasing the concentration of HCl(aq)

(4) decreasing the surface area of Fe(s) and decreasing the concentration of HCl(aq)

14 Which process is commonly used to separate a mixture of ethanol and water?

(1) distillation   (3) filtration
(2) ionization   (4) titration

15 A sample of hydrogen gas will behave most like an ideal gas under the conditions of

(1) low pressure and low temperature
(2) low pressure and high temperature
(3) high pressure and low temperature
(4) high pressure and high temperature

16 The collision theory states that a reaction is most likely to occur when the reactant particles collide with the proper

(1) formula masses
(2) molecular masses
(3) density and volume
(4) energy and orientation

17 At STP, which sample contains the same number of molecules as 3.0 liters of $H_2(g)$?

(1) 1.5 L of $NH_3(g)$ (3) 3.0 L of $CH_4(g)$
(2) 2.0 L of $CO_2(g)$ (4) 6.0 L of $N_2(g)$

18 The addition of a catalyst to a chemical reaction provides an alternate pathway that

(1) increases the potential energy of reactants
(2) decreases the potential energy of reactants
(3) increases the activation energy
(4) decreases the activation energy

19 A sample of water is boiling as heat is added at a constant rate. Which statement describes the potential energy and the average kinetic energy of the water molecules in this sample?

(1) The potential energy decreases and the average kinetic energy remains the same.

(2) The potential energy decreases and the average kinetic energy increases.

(3) The potential energy increases and the average kinetic energy remains the same.

(4) The potential energy increases and the average kinetic energy increases.

20 Entropy is a measure of the

(1) acidity of a sample
(2) disorder of a system
(3) concentration of a solution
(4) chemical activity of an element

21 Which element has atoms that can bond with each other to form ring, chain, and network structures?

(1) aluminum   (3) carbon
(2) calcium   (4) argon

22 What is the number of electrons shared in the multiple carbon-carbon bond in one molecule of 1-pentyne?

(1) 6   (3) 3
(2) 2   (4) 8

23 Butanal, butanone, and diethyl ether have different properties because the molecules of each compound differ in their

(1) numbers of carbon atoms
(2) numbers of oxygen atoms
(3) types of functional groups
(4) types of radioactive isotopes

24 What occurs when a magnesium atom becomes a magnesium ion?
   (1) Electrons are gained and the oxidation number increases.
   (2) Electrons are gained and the oxidation number decreases.
   (3) Electrons are lost and the oxidation number increases.
   (4) Electrons are lost and the oxidation number decreases.

25 Energy is required to produce a chemical change during
   (1) chromatography   (3) boiling
   (2) electrolysis   (4) melting

26 The reaction of an Arrhenius acid with an Arrhenius base produces water and
   (1) a salt   (3) an aldehyde
   (2) an ester   (4) a halocarbon

27 One acid-base theory defines an acid as an
   (1) H^- acceptor   (3) H^+ acceptor
   (2) H^- donor   (4) H^+ donor

28 Which phrase describes the decay modes and the half-lives of K-37 and K-42?
   (1) the same decay mode but different half-lives
   (2) the same decay mode and the same half-life
   (3) different decay modes and different half-lives
   (4) different decay modes but the same half-life

29 Which particle has a mass that is approximately equal to the mass of a proton?
   (1) an alpha particle   (3) a neutron
   (2) a beta particle   (4) a positron

30 Which change occurs during a nuclear fission reaction?
   (1) Covalent bonds are converted to ionic bonds.
   (2) Isotopes are converted to isomers.
   (3) Temperature is converted to mass.
   (4) Matter is converted to energy.

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which notations represent hydrogen isotopes?

(1) $_1^1H$ and $_1^2H$

(2) $_1^1H$ and $_2^4H$

(3) $_2^1H$ and $_3^1H$

(4) $_1^2H$ and $_2^7H$

32 Naturally occurring gallium is a mixture of isotopes that contains 60.11% of Ga-69 (atomic mass = 68.93 u) and 39.89% of Ga-71 (atomic mass = 70.92 u). Which numerical setup can be used to determine the atomic mass of naturally occurring gallium?

(1) $\dfrac{(68.93\ u\ +\ 70.92\ u)}{2}$

(2) $\dfrac{(68.93\ u)(0.6011)}{(70.92\ u)(0.3989)}$

(3) $(68.93\ u)(0.6011) + (70.92\ u)(0.3989)$

(4) $(68.93\ u)(39.89) + (70.92\ u)(60.11)$

33 Which list of symbols represents nonmetals, only?

(1) B, Al, Ga

(2) Li, Be, B

(3) C, Si, Ge

(4) P, S, Cl

34 In the formula XSO_4, the symbol X could represent the element

(1) Al

(2) Ar

(3) Mg

(4) Na

35 What is the chemical formula for lead(IV) oxide?

(1) PbO_2

(2) PbO_4

(3) Pb_2O

(4) Pb_4O

36 Which statement describes the general trends in electronegativity and atomic radius as the elements in Period 2 are considered in order from left to right?

(1) Both electronegativity and atomic radius increase.

(2) Both electronegativity and atomic radius decrease.

(3) Electronegativity increases and atomic radius decreases.

(4) Electronegativity decreases and atomic radius increases.

37 What is the percent composition by mass of nitrogen in $(NH_4)_2CO_3$ (gram-formula mass = 96.0 g/mol)?

(1) 14.6%

(2) 29.2%

(3) 58.4%

(4) 87.5%

38 Given the balanced equation:

$$2KI + F_2 \rightarrow 2KF + I_2$$
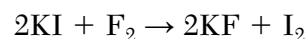
Which type of chemical reaction does this equation represent?

(1) synthesis

(2) decomposition

(3) single replacement

(4) double replacement

39 Which formula represents a nonpolar molecule containing polar covalent bonds?

H—H   O=C=O

(1)   (2)   (3)   (4)
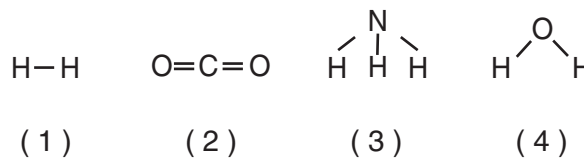
40 A reaction reaches equilibrium at 100.°C. The equation and graph representing this reaction are shown below.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

Concentration Versus Time
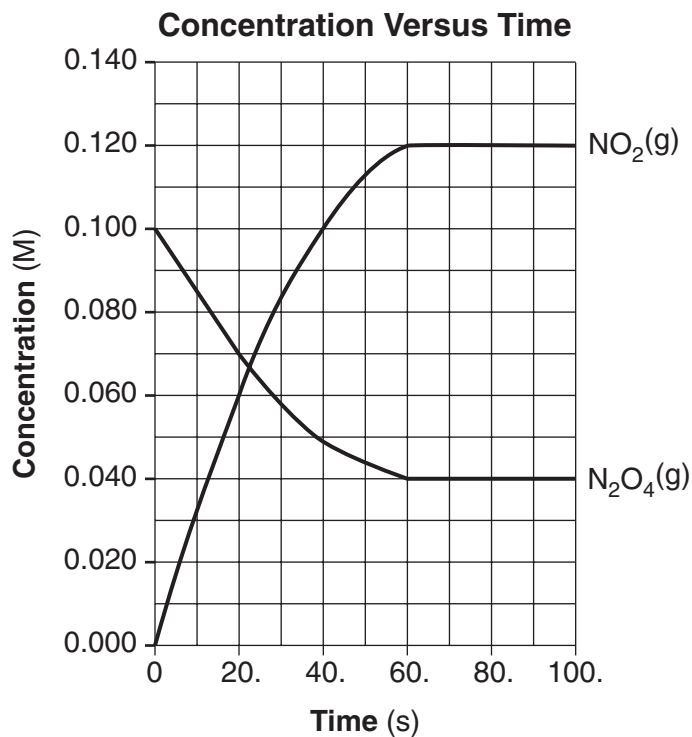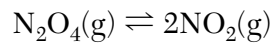
The graph shows that the reaction is at equilibrium after 60. seconds because the concentrations of both $NO_2(g)$ and $N_2O_4(g)$ are

(1) increasing   (3) constant
(2) decreasing   (4) zero

41 Given the balanced equation representing a reaction:

$$2H_2O + \text{energy} \rightarrow 2H_2 + O_2$$
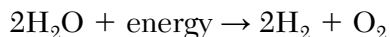
Which statement describes the changes in energy and bonding for the reactant?

(1) Energy is absorbed as bonds in H_2O are formed.
(2) Energy is absorbed as bonds in H_2O are broken.
(3) Energy is released as bonds in H_2O are formed.
(4) Energy is released as bonds in H_2O are broken.

42 At standard pressure, what is the temperature at which a saturated solution of NH_4Cl has a concentration of 60. g $NH_4Cl/100.$ g H_2O?

(1) 66°C   (3) 22°C
(2) 57°C   (4) 17°C

43 Which aqueous solution has the highest boiling point at standard pressure?

(1) 1.0 M KCl(aq)   (3) 2.0 M KCl(aq)
(2) 1.0 M $CaCl_2$(aq)   (4) 2.0 M $CaCl_2$(aq)

44 Given the equation representing a system at equilibrium:

$$KNO_3(s) + \text{energy} \xrightleftharpoons{\;H_2O\;} K^+(aq) + NO_3{}^-(aq)$$

Which change causes the equilibrium to shift?

(1) increasing pressure
(2) increasing temperature
(3) adding a noble gas
(4) adding a catalyst

45 Which hydrocarbon is saturated?

(1) C_2H_2 (3) C_4H_6
(2) C_3H_4 (4) C_4H_{10}

46 Which volume of 0.600 M H_2SO_4(aq) exactly neutralizes 100. milliliters of 0.300 M $Ba(OH)_2$(aq)?

(1) 25.0 mL   (3) 100. mL
(2) 50.0 mL   (4) 200. mL

47 Given the formula for an organic compound:
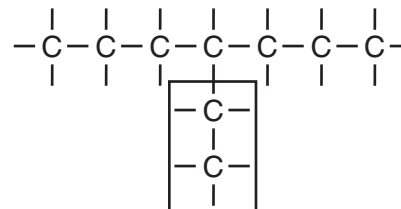
What is the name given to the group in the box?

(1) butyl   (3) methyl
(2) ethyl   (4) propyl

48 Given the particle diagram:

Key
○ = atom of an element
● = atom of a different element
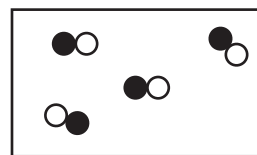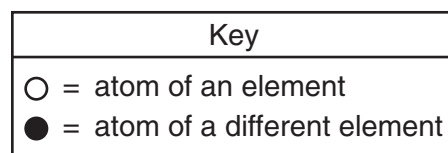
Which type of matter is represented by the particle diagram?

(1) an element
(2) a compound
(3) a homogeneous mixture
(4) a heterogeneous mixture

49 Which substance is an electrolyte?

(1) O_2 (3) C_3H_8
(2) Xe   (4) KNO_3

50 Which type of organic reaction produces both water and carbon dioxide?

(1) addition   (3) esterification
(2) combustion   (4) fermentation

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Draw a Lewis electron-dot diagram for a chloride ion, Cl^-.   [1]

Base your answers to questions 52 and 53 on the information below and on your knowledge of chemistry.

At STP, Cl_2 is a gas and I_2 is a solid. When hydrogen reacts with chlorine, the compound hydrogen chloride is formed. When hydrogen reacts with iodine, the compound hydrogen iodide is formed.

52 Balance the equation *in your answer booklet* for the reaction between hydrogen and chlorine, using the smallest whole-number coefficients.   [1]

53 Explain, in terms of intermolecular forces, why iodine is a solid at STP but chlorine is a gas at STP.   [1]

Base your answers to questions 54 and 55 on the information below and on your knowledge of chemistry.

Some properties of the element sodium are listed below.
• is a soft, silver-colored metal
• melts at a temperature of 371 K
• oxidizes easily in the presence of air
• forms compounds with nonmetallic elements in nature
• forms sodium chloride in the presence of chlorine gas

54 Identify *one* chemical property of sodium from this list.   [1]

55 Convert the melting point of sodium to degrees Celsius.   [1]

Base your answers to questions 56 through 58 on the information below and on your knowledge of chemistry.

At standard pressure, water has unusual properties that are due to both its molecular structure and intermolecular forces. For example, although most liquids contract when they freeze, water expands, making ice less dense than liquid water. Water has a much higher boiling point than most other molecular compounds having a similar gram-formula mass.

56 Explain why $H_2O(s)$ floats on $H_2O(\ell)$ when both are at 0ºC.   [1]

57 State the type of intermolecular force responsible for the unusual boiling point of $H_2O(\ell)$ at standard pressure.   [1]

58 Determine the total amount of heat, in joules, required to completely vaporize a 50.0-gram sample of $H_2O(\ell)$ at its boiling point at standard pressure.   [1]

Base your answers to questions 59 and 60 on the information below and on your knowledge of chemistry.

At 1023 K and 1 atm, a 3.00-gram sample of $SnO_2(s)$ (gram-formula mass = 151 g/mol) reacts with hydrogen gas to produce tin and water, as shown in the balanced equation below.

$$SnO_2(s) + 2H_2(g) \rightarrow Sn(\ell) + 2H_2O(g)$$
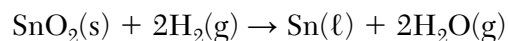
59 Show a numerical setup for calculating the number of moles of $SnO_2(s)$ in the 3.00-gram sample. [1]

60 Determine the number of moles of $Sn(\ell)$ produced when 4.0 moles of $H_2(g)$ is completely consumed. [1]

Base your answers to questions 61 and 62 on the information below and on your knowledge of chemistry.

The incomplete data table below shows the pH value of solutions A and B and the hydrogen ion concentration of solution A.

Hydrogen Ion and pH Data for HCl(aq) Solutions

HCl(aq) Solution	Hydrogen Ion Concentration (M)	pH
A	1.0×10^{-2}	2.0
B	?	5.0

61 State the color of methyl orange in a sample of solution A. [1]

62 Determine the hydrogen ion concentration of solution B. [1]

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

A sample of helium gas is placed in a rigid cylinder that has a movable piston. The volume of the gas is varied by moving the piston, while the temperature is held constant at 273 K. The volumes and corresponding pressures for three trials are measured and recorded in the data table below. For each of these trials, the product of pressure and volume is also calculated and recorded. For a fourth trial, only the volume is recorded.

**Pressure and Volume Data for
a Sample of Helium Gas at 273 K**

Trial Number	Pressure (atm)	Volume (L)	P × V (L•atm)
1	1.000	0.412	0.412
2	0.750	0.549	0.412
3	0.600	0.687	0.412
4	?	1.373	?

63 State evidence found in the data table that allows the product of pressure and volume for the fourth trial to be predicted.   [1]

64 Determine the pressure of the helium gas in trial 4.   [1]

65 Compare the average distances between the helium atoms in trial 1 to the average distances between the helium atoms in trial 3.   [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

Potassium phosphate, K_3PO_4, is a source of dietary potassium found in a popular cereal. According to the Nutrition-Facts label shown on the boxes of this brand of cereal, the accepted value for a one-cup serving of this cereal is 170. milligrams of potassium. The minimum daily requirement of potassium is 3500 milligrams for an adult human.

66 Identify *two* types of chemical bonding in the source of dietary potassium in this cereal. [1]

67 Identify the noble gas whose atoms have the same electron configuration as a potassium ion. [1]

68 Compare the radius of a potassium ion to the radius of a potassium atom. [1]

69 The mass of potassium in a one-cup serving of this cereal is determined to be 172 mg. Show a numerical setup for calculating the percent error for the mass of potassium in this serving. [1]

_____

Base your answers to questions 70 and 71 on the information below and on your knowledge of chemistry.

During photosynthesis, plants use carbon dioxide, water, and light energy to produce glucose, $C_6H_{12}O_6$, and oxygen. The reaction for photosynthesis is represented by the balanced equation below.

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$
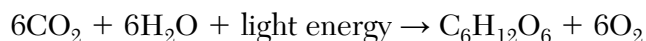
70 Write the empirical formula for glucose. [1]

71 State evidence that indicates photosynthesis is an endothermic reaction. [1]

_____

Base your answers to questions 72 through 74 on the information below and on your knowledge of chemistry.

Fireworks that contain metallic salts such as sodium, strontium, and barium can generate bright colors. A technician investigates what colors are produced by the metallic salts by performing flame tests. During a flame test, a metallic salt is heated in the flame of a gas burner. Each metallic salt emits a characteristic colored light in the flame.

72 Explain why the electron configuration of 2-7-1-1 represents a sodium atom in an excited state. [1]

73 Explain, in terms of electrons, how a strontium salt emits colored light. [1]

74 State how bright-line spectra viewed through a spectroscope can be used to identify the metal ions in the salts used in the flame tests. [1]

Base your answers to questions 75 through 77 on the information below and on your knowledge of chemistry.

The unique odors and flavors of many fruits are primarily due to small quantities of a certain class of organic compounds. The equation below represents the production of one of these compounds.

| Reactant 1 | Reactant 2 | Product 1 | Product 2 |
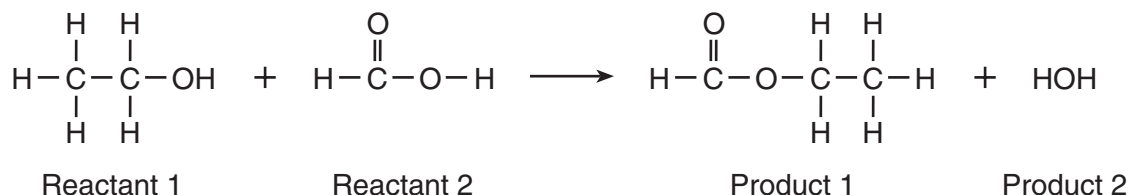
75 Show a numerical setup for calculating the gram-formula mass for reactant 1. [1]

76 Explain, in terms of molecular polarity, why reactant 2 is soluble in water. [1]

77 State the class of organic compounds to which product 1 belongs. [1]

Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

A student develops the list shown below that includes laboratory equipment and materials for constructing a voltaic cell.

Laboratory Equipment and Materials
- a strip of zinc
- a strip of copper
- a 250-mL beaker containing 150 mL of 0.1 M zinc nitrate
- a 250-mL beaker containing 150 mL of 0.1 M copper(II) nitrate
- wires
- a voltmeter
- a switch
- a salt bridge

78 State the purpose of the salt bridge in the voltaic cell. [1]

79 Complete and balance the half-reaction equation *in your answer booklet* for the oxidation of the Zn(s) that occurs in the voltaic cell. [1]

80 Compare the activities of the two metals used by the student for constructing the voltaic cell. [1]

81 Identify *one* item of laboratory equipment required to build an electrolytic cell that is *not* included in the list. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

In 1896, Antoine H. Becquerel discovered that a uranium compound could expose a photographic plate wrapped in heavy paper in the absence of light. It was shown that the uranium compound was spontaneously releasing particles and high-energy radiation. Further tests showed the emissions from the uranium that exposed the photographic plate were *not* deflected by charged plates.

82 Identify the highly penetrating radioactive emission that exposed the photographic plates. [1]

83 Complete the nuclear equation *in your answer booklet* for the alpha decay of U-238. [1]

84 Determine the number of neutrons in an atom of U-233. [1]

85 Identify the type of nuclear reaction that occurs when an alpha or a beta particle is spontaneously emitted by a radioactive isotope. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Tuesday, June 20, 2017 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

1 Which statement describes the structure of an atom?

(1) The nucleus contains positively charged electrons.
(2) The nucleus contains negatively charged protons.
(3) The nucleus has a positive charge and is surrounded by negatively charged electrons.
(4) The nucleus has a negative charge and is surrounded by positively charged electrons.

2 Which term is defined as the region in an atom where an electron is most likely to be located?

(1) nucleus   (3) quanta
(2) orbital   (4) spectra

3 What is the number of electrons in an atom of scandium?

(1) 21   (3) 45
(2) 24   (4) 66

4 Which particle has the *least* mass?

(1) a proton   (3) a helium atom
(2) an electron   (4) a hydrogen atom

5 Which electron transition in an excited atom results in a release of energy?

(1) first shell to the third shell
(2) second shell to the fourth shell
(3) third shell to the fourth shell
(4) fourth shell to the second shell

6 On the Periodic Table, the number of protons in an atom of an element is indicated by its

(1) atomic mass
(2) atomic number
(3) selected oxidation states
(4) number of valence electrons

7 Which type of formula shows an element symbol for each atom and a line for each bond between atoms?

(1) ionic   (3) empirical
(2) structural   (4) molecular

8 What is conserved during all chemical reactions?

(1) charge   (3) vapor pressure
(2) density   (4) melting point

9 In which type of reaction can two compounds exchange ions to form two different compounds?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

10 At STP, two 5.0-gram solid samples of different ionic compounds have the same density. These solid samples could be differentiated by their

(1) mass   (3) temperature
(2) volume   (4) solubility in water

11 What is the number of electrons shared between the atoms in an I_2 molecule?

(1) 7   (3) 8
(2) 2   (4) 4

12 Which substance has nonpolar covalent bonds?

(1) Cl_2 (3) SiO_2
(2) SO_3 (4) CCl_4

13 Compared to a potassium atom, a potassium ion has

(1) a smaller radius (3) fewer protons
(2) a larger radius   (4) more protons

14 Which form of energy is associated with the random motion of particles in a gas?

(1) chemical   (3) nuclear
(2) electrical   (4) thermal

15 The average kinetic energy of water molecules *decreases* when

(1) $H_2O(\ell)$ at 337 K changes to $H_2O(\ell)$ at 300. K
(2) $H_2O(\ell)$ at 373 K changes to $H_2O(g)$ at 373 K
(3) $H_2O(s)$ at 200. K changes to $H_2O(s)$ at 237 K
(4) $H_2O(s)$ at 273 K changes to $H_2O(\ell)$ at 273 K

16 The joule is a unit of

(1) concentration   (3) pressure
(2) energy   (4) volume

17 Compared to a sample of helium at STP, the same sample of helium at a higher temperature and a lower pressure

(1) condenses to a liquid
(2) is more soluble in water
(3) forms diatomic molecules
(4) behaves more like an ideal gas

18 A sample of a gas is in a sealed, rigid container that maintains a constant volume. Which changes occur between the gas particles when the sample is heated?

(1) The frequency of collisions increases, and the force of collisions decreases.
(2) The frequency of collisions increases, and the force of collisions increases.
(3) The frequency of collisions decreases, and the force of collisions decreases.
(4) The frequency of collisions decreases, and the force of collisions increases.

19 At STP, which gaseous sample has the same number of molecules as 3.0 liters of $N_2(g)$?

(1) 6.0 L of $F_2(g)$ (3) 3.0 L of $H_2(g)$
(2) 4.5 L of $N_2(g)$ (4) 1.5 L of $Cl_2(g)$

20 Distillation of crude oil from various parts of the world yields different percentages of hydrocarbons. Which statement explains these different percentages?

(1) Each component in a mixture has a different solubility in water.
(2) Hydrocarbons are organic compounds.
(3) The carbons in hydrocarbons may be bonded in chains or rings.
(4) The proportions of components in a mixture can vary.

21 In which 1.0-gram sample are the particles arranged in a crystal structure?

(1) $CaCl_2(s)$ (3) $CH_3OH(\ell)$
(2) $C_2H_6(g)$ (4) $CaI_2(aq)$

22 When a reversible reaction is at equilibrium, the concentration of products and the concentration of reactants must be

(1) decreasing   (3) constant
(2) increasing   (4) equal

23 In chemical reactions, the difference between the potential energy of the products and the potential energy of the reactants is equal to the

(1) activation energy
(2) ionization energy
(3) heat of reaction
(4) heat of vaporization

24 What occurs when a catalyst is added to a chemical reaction?

(1) an alternate reaction pathway with a lower activation energy
(2) an alternate reaction pathway with a higher activation energy
(3) the same reaction pathway with a lower activation energy
(4) the same reaction pathway with a higher activation energy

25 What is the name of the compound with the formula $CH_3CH_2CH_2NH_2$?

(1) 1-propanol   (3) propanal
(2) 1-propanamine   (4) propanamide

26 Which compound is an isomer of $C_2H_5OC_2H_5$?

(1) CH_3COOH (3) $C_3H_7COCH_3$
(2) $C_2H_5COOCH_3$ (4) C_4H_9OH

27 Ethanoic acid and 1-butanol can react to produce water and a compound classified as an

(1) aldehyde   (3) ester
(2) amide   (4) ether

28 During an oxidation-reduction reaction, the number of electrons gained is

(1) equal to the number of electrons lost
(2) equal to the number of protons gained
(3) less than the number of electrons lost
(4) less than the number of protons gained

29 Which process requires energy for a nonspontaneous redox reaction to occur?

(1) deposition   (3) alpha decay
(2) electrolysis   (4) chromatography

30 Which pair of compounds represents one Arrhenius acid and one Arrhenius base?

(1) CH_3OH and $NaOH$ (3) HNO_3 and $NaOH$
(2) CH_3OH and HCl (4) HNO_3 and HCl

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which electron configuration represents the electrons of an atom of neon in an excited state?

(1) 2-7   (3) 2-7-1
(2) 2-8   (4) 2-8-1

32 Some information about the two naturally occurring isotopes of gallium is given in the table below.

**Natural Abundance of
Two Gallium Isotopes**

Isotope	Natural Abundance (%)	Atomic Mass (u)
Ga-69	60.11	68.926
Ga-71	39.89	70.925

Which numerical setup can be used to calculate the atomic mass of gallium?

(1) (0.6011)(68.926 u) + (0.3989)(70.925 u)
(2) (60.11)(68.926 u) + (39.89)(70.925 u)
(3) (0.6011)(70.925 u) + (0.3989)(68.926 u)
(4) (60.11)(70.925 u) + (39.89)(68.926 u)

33 A student measures the mass and volume of a sample of copper at room temperature and 101.3 kPa. The mass is 48.9 grams and the volume is 5.00 cubic centimeters. The student calculates the density of the sample. What is the percent error of the student's calculated density?

(1) 7.4%   (3) 9.2%
(2) 8.4%   (4) 10.2%

34 What is the chemical formula for sodium sulfate?

(1) Na_2SO_4 (3) $NaSO_4$
(2) Na_2SO_3 (4) $NaSO_3$

35 Given the balanced equation representing a reaction:

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s) + energy$$

If 46 grams of Na and 71 grams of Cl_2 react completely, what is the total mass of NaCl produced?

(1) 58.5 g   (3) 163 g
(2) 117 g   (4) 234 g

36 Given the balanced equation representing a reaction:

$$2NO + O_2 \rightarrow 2NO_2 + energy$$

The mole ratio of NO to NO_2 is

(1) 1 to 1   (3) 3 to 2
(2) 2 to 1   (4) 5 to 2

37 The particle diagram below represents a solid sample of silver.

Which type of bonding is present when valence electrons move within the sample?

(1) metallic bonding   (3) covalent bonding
(2) hydrogen bonding   (4) ionic bonding

38 Given the formula representing a molecule:

$$H - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - H$$

Which statement explains why the molecule is nonpolar?

(1) Electrons are shared between the carbon atoms and the hydrogen atoms.
(2) Electrons are transferred from the carbon atoms to the hydrogen atoms.
(3) The distribution of charge in the molecule is symmetrical.
(4) The distribution of charge in the molecule is asymmetrical.

39 A solid sample of a compound and a liquid sample of the same compound are each tested for electrical conductivity. Which test conclusion indicates that the compound is ionic?

(1) Both the solid and the liquid are good conductors.
(2) Both the solid and the liquid are poor conductors.
(3) The solid is a good conductor, and the liquid is a poor conductor.
(4) The solid is a poor conductor, and the liquid is a good conductor.

40 Which statement explains why 10.0 mL of a 0.50 M H_2SO_4(aq) solution exactly neutralizes 5.0 mL of a 2.0 M NaOH(aq) solution?

(1) The moles of H^+(aq) equal the moles of OH^-(aq).
(2) The moles of H_2SO_4(aq) equal the moles of NaOH(aq).
(3) The moles of H_2SO_4(aq) are greater than the moles of NaOH(aq).
(4) The moles of H^+(aq) are greater than the moles of OH^-(aq).

41 Which particle diagram represents *one* substance in the gas phase?

Key
◯ = atom of one element
● = atom of another element

(1)

(2)

(3)
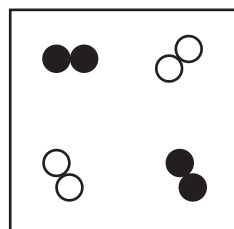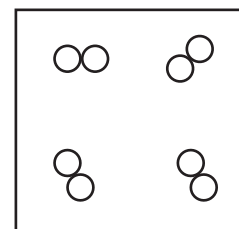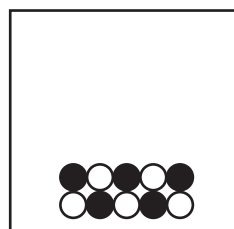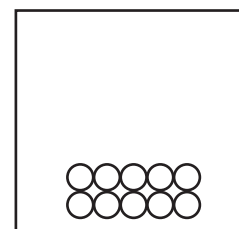
(4)

42 Given the equation representing a chemical reaction at equilibrium in a sealed, rigid container:

$$H_2(g) + I_2(g) + energy \rightleftharpoons 2HI(g)$$
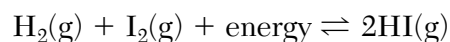
When the concentration of H_2(g) is increased by adding more hydrogen gas to the container at constant temperature, the equilibrium shifts

(1) to the right, and the concentration of HI(g) decreases
(2) to the right, and the concentration of HI(g) increases
(3) to the left, and the concentration of HI(g) decreases
(4) to the left, and the concentration of HI(g) increases

43 Which diagram represents the potential energy changes during an exothermic reaction?

Reaction Coordinate

(1)

Reaction Coordinate

(3)

Reaction Coordinate

(2)

Reaction Coordinate
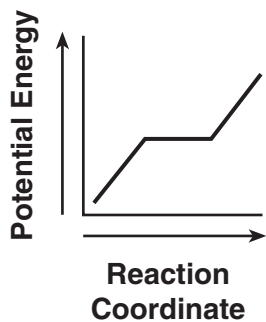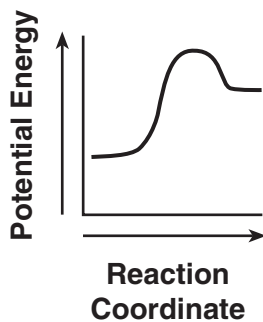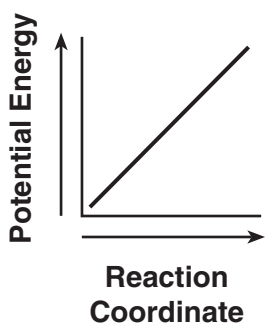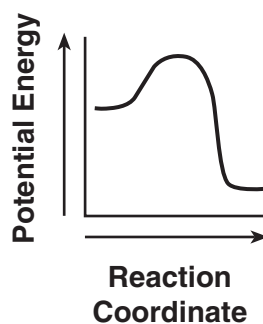
(4)

44 Which compound is classified as an ether?

(1) CH_3CHO (3) CH_3COCH_3

(2) CH_3OCH_3 (4) CH_3COOCH_3

45 Given the equation representing a reversible reaction:

$$HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$$
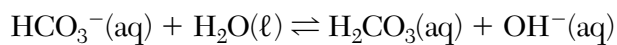
Which formula represents the H^+ acceptor in the forward reaction?

(1) $HCO_3^-(aq)$ (3) $H_2CO_3(aq)$

(2) $H_2O(\ell)$ (4) $OH^-(aq)$

46 What is the mass of an original 5.60-gram sample of iron-53 that remains unchanged after 25.53 minutes?

(1) 0.35 g (3) 1.40 g

(2) 0.70 g (4) 2.80 g

47 Given the equation representing a nuclear reaction:

$$_1^1H + X \rightarrow {}_3^6Li + {}_2^4He$$
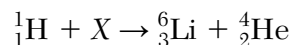
The particle represented by X is

(1) ${}_4^9Li$ (3) ${}_5^{10}Be$
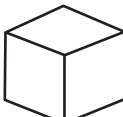
(2) ${}_4^9Be$ (4) ${}_6^{10}C$

48 Fission and fusion reactions both release energy. However, only fusion reactions

(1) require elements with large atomic numbers

(2) create radioactive products

(3) use radioactive reactants

(4) combine light nuclei

49 The chart below shows the crystal shapes and melting points of two forms of solid phosphorus.

Two Forms of Phosphorus

Form of Phosphorus	Crystal Shape	Melting Point (°C)
white	cubic	44
black	orthorhombic	610

Which phrase describes the two forms of phosphorus?

(1) same crystal structure and same properties
(2) same crystal structure and different properties
(3) different crystal structures and different properties
(4) different crystal structures and same properties

50 Which graph shows the relationship between pressure and Kelvin temperature for an ideal gas at constant volume?
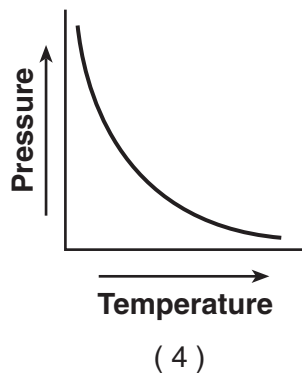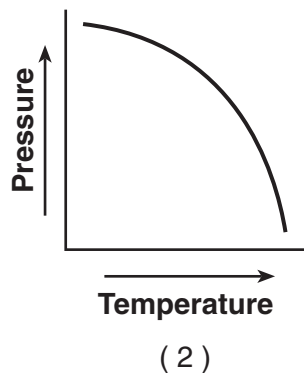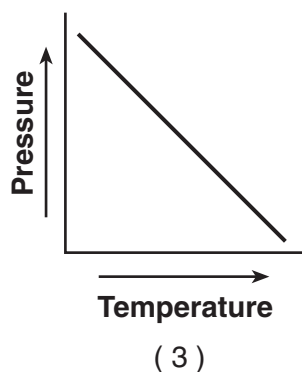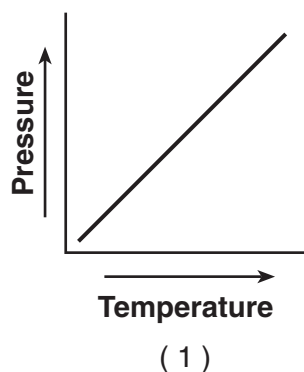
Temperature
(1)

Temperature
(3)

Temperature
(2)

Temperature
(4)

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 51 through 53 on the information below and on your knowledge of chemistry.

The elements in Group 17 are called halogens. The word "halogen" is derived from Greek and means "salt former."

51 State the trend in electronegativity for the halogens as these elements are considered in order of increasing atomic number. [1]

52 Identify the type of chemical bond that forms when potassium reacts with bromine to form a salt. [1]

53 Based on Table *F*, identify *one* ion that reacts with iodide ions in an aqueous solution to form an insoluble compound. [1]

Base your answers to questions 54 through 57 on the information below and on your knowledge of chemistry.

The diagrams below represent four different atomic nuclei.

Four Atomic Nuclei

| Nucleus 1 | Nucleus 2 | Nucleus 3 | Nucleus 4 |
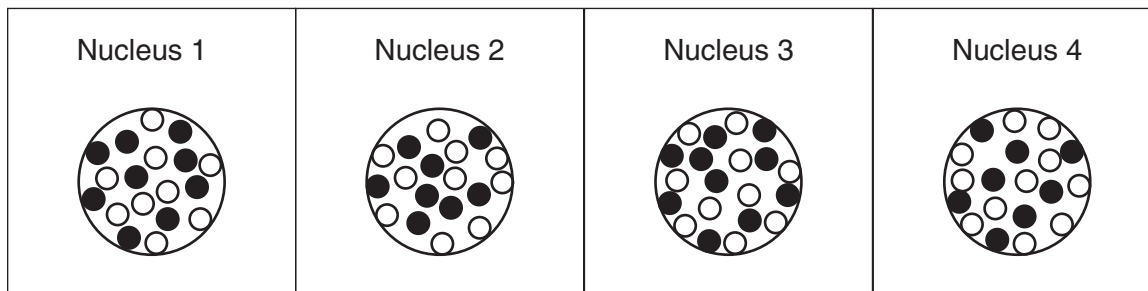
Key

● = proton
○ = neutron

54 Identify the element that has atomic nuclei represented by nucleus 1. [1]

55 Determine the mass number of the nuclide represented by nucleus 2. [1]

56 Explain why nucleus 2 and nucleus 4 represent the nuclei of two different isotopes of the same element. [1]

57 Identify the nucleus above that is found in an atom that has a stable valence electron configuration. [1]

Base your answers to questions 58 through 60 on the information below and on your knowledge of chemistry.

The equation below represents a chemical reaction at 1 atm and 298 K.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$
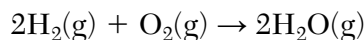
58 State the change in energy that occurs in order to break the bonds in the hydrogen molecules. [1]

59 In the space *in your answer booklet,* draw a Lewis electron-dot diagram for a water molecule. [1]

60 Compare the strength of attraction for electrons by a hydrogen atom to the strength of attraction for electrons by an oxygen atom within a water molecule. [1]

Base your answers to questions 61 through 63 on the information below and on your knowledge of chemistry.

- A test tube contains a sample of solid stearic acid, an organic acid.
- Both the sample and the test tube have a temperature of 22.0°C.
- The stearic acid melts after the test tube is placed in a beaker with 320. grams of water at 98.0°C.
- The temperature of the liquid stearic acid and water in the beaker reaches 74.0°C.

61 Identify the element in stearic acid that makes it an organic compound. [1]

62 State the direction of heat transfer between the test tube and the water when the test tube was placed in the water. [1]

63 Show a numerical setup for calculating the amount of thermal energy change for the water in the beaker. [1]

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

A nuclear reaction is represented by the equation below.

$$^3_1H \rightarrow ^3_2He + ^0_{-1}e$$
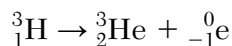
64 Identify the decay mode of hydrogen-3. [1]

65 Explain why the equation represents a transmutation. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

A technician recorded data for two properties of Period 3 elements. The data are shown in the table below.

Two Properties of Period 3 Elements

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Ionic Radius (pm)	95	66	51	41	212	184	181	—
Reaction with Cold Water	reacts vigorously	reacts very slowly	no observable reaction	no observable reaction	no observable reaction	no observable reaction	reacts slowly	no observable reaction

66 Identify the element in this table that is classified as a metalloid. [1]

67 State the phase of chlorine at 281 K and 101.3 kPa. [1]

68 State evidence from the technician's data which indicates that sodium is more active than aluminum. [1]

Base your answers to questions 69 through 71 on the information below and on your knowledge of chemistry.

Ammonia, $NH_3(g)$, can be used as a substitute for fossil fuels in some internal combustion engines. The reaction between ammonia and oxygen in an engine is represented by the unbalanced equation below.

$$NH_3(g) + O_2(g) \rightarrow N_2(g) + H_2O(g) + energy$$
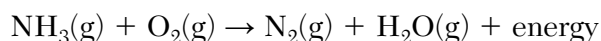
69 Balance the equation *in your answer booklet* for the reaction of ammonia and oxygen, using the smallest whole-number coefficients. [1]

70 Show a numerical setup for calculating the mass, in grams, of a 4.2-mole sample of O_2. Use 32 g/mol as the gram-formula mass of O_2. [1]

71 Determine the new pressure of a 6.40-L sample of oxygen gas at 300. K and 100. kPa after the gas is compressed to 2.40 L at 900. K. [1]

Base your answers to questions 72 through 76 on the information below and on your knowledge of chemistry.

Fruit growers in Florida protect oranges when the temperature is near freezing by spraying water on them. It is the freezing of the water that protects the oranges from frost damage. When $H_2O(\ell)$ at 0°C changes to $H_2O(s)$ at 0°C, heat energy is released. This energy helps to prevent the temperature inside the orange from dropping below freezing, which could damage the fruit. After harvesting, oranges can be exposed to ethene gas, C_2H_4, to improve their color.

72 Write the empirical formula for ethene. [1]

73 Explain, in terms of bonding, why the hydrocarbon ethene is classified as unsaturated. [1]

74 Determine the gram-formula mass of ethene. [1]

75 Explain, in terms of particle arrangement, why the entropy of the water *decreases* when the water freezes. [1]

76 Determine the quantity of heat released when 2.00 grams of $H_2O(\ell)$ freezes at 0°C. [1]

Base your answers to questions 77 through 80 on the information below and on your knowledge of chemistry.

A student constructs an electrochemical cell during a laboratory investigation. When the switch is closed, electrons flow through the external circuit. The diagram and ionic equation below represent this cell and the reaction that occurs.

$$Cu^{2+}(aq) + Zn(s) \longrightarrow Cu(s) + Zn^{2+}(aq)$$
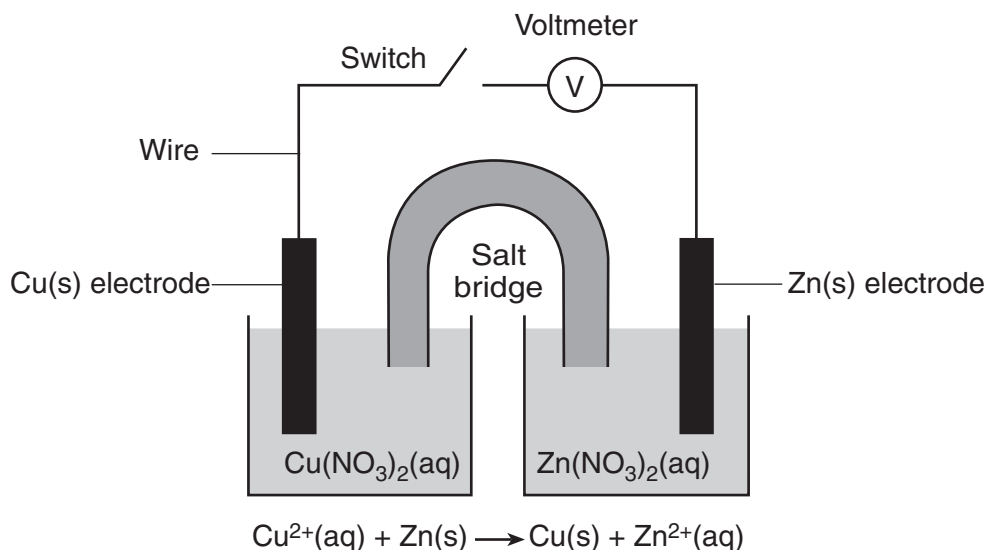
77 State the form of energy that is converted to electrical energy in the operating cell. [1]

78 State, in terms of the Cu(s) electrode and the Zn(s) electrode, the direction of electron flow in the external circuit when the cell operates. [1]

79 Write a balanced equation for the half-reaction that occurs in the Cu half-cell when the cell operates. [1]

80 State what happens to the mass of the Cu electrode and the mass of the Zn electrode in the operating cell. [1]

Base your answers to questions 81 and 82 on the information below and on your knowledge of chemistry.

A solution is made by dissolving 70.0 grams of $KNO_3(s)$ in 100. grams of water at 50.°C and standard pressure.

81 Show a numerical setup for calculating the percent by mass of KNO_3 in the solution.   [1]

82 Determine the number of additional grams of KNO_3 that must dissolve to make this solution saturated.   [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Vinegar is a commercial form of acetic acid, $HC_2H_3O_2(aq)$. One sample of vinegar has a pH value of 2.4.

83 Explain, in terms of particles, why $HC_2H_3O_2(aq)$ can conduct an electric current.   [1]

84 State the color of bromthymol blue indicator in a sample of the commercial vinegar.   [1]

85 State the pH value of a sample that has ten times *fewer* hydronium ions than an equal volume of a vinegar sample with a pH value of 2.4.   [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, June 20, 2018 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which statement describes the charge and location of an electron in an atom?

(1) An electron has a positive charge and is located outside the nucleus.
(2) An electron has a positive charge and is located in the nucleus.
(3) An electron has a negative charge and is located outside the nucleus.
(4) An electron has a negative charge and is located in the nucleus.

2 Which statement explains why a xenon atom is electrically neutral?

(1) The atom has fewer neutrons than electrons.
(2) The atom has more protons than electrons.
(3) The atom has the same number of neutrons and electrons.
(4) The atom has the same number of protons and electrons.

3 If two atoms are isotopes of the same element, the atoms must have

(1) the same number of protons and the same number of neutrons
(2) the same number of protons and a different number of neutrons
(3) a different number of protons and the same number of neutrons
(4) a different number of protons and a different number of neutrons

4 Which electrons in a calcium atom in the ground state have the greatest effect on the chemical properties of calcium?

(1) the two electrons in the first shell
(2) the two electrons in the fourth shell
(3) the eight electrons in the second shell
(4) the eight electrons in the third shell

5 The weighted average of the atomic masses of the naturally occuring isotopes of an element is the

(1) atomic mass of the element
(2) atomic number of the element
(3) mass number of each isotope
(4) formula mass of each isotope

6 Which element is classified as a metalloid?

(1) Cr   (3) Sc
(2) Cs   (4) Si

7 Which statement describes a chemical property of iron?

(1) Iron oxidizes.
(2) Iron is a solid at STP.
(3) Iron melts.
(4) Iron is attracted to a magnet.

8 Graphite and diamond are two forms of the same element in the solid phase that differ in their

(1) atomic numbers
(2) crystal structures
(3) electronegativities
(4) empirical formulas

9 Which ion has the largest radius?

(1) Br^- (3) F^-
(2) Cl^- (4) I^-

10 Carbon monoxide and carbon dioxide have

(1) the same chemical properties and the same physical properties
(2) the same chemical properties and different physical properties
(3) different chemical properties and the same physical properties
(4) different chemical properties and different physical properties

11 Based on Table *S*, which group on the Periodic Table has the element with the highest electronegativity?

(1) Group 1   (3) Group 17
(2) Group 2   (4) Group 18

12 What is represented by the chemical formula $PbCl_2(s)$?

(1) a substance
(2) a solution
(3) a homogeneous mixture
(4) a heterogeneous mixture

13 What is the vapor pressure of propanone at 50.°C?

(1) 37 kPa   (3) 83 kPa
(2) 50. kPa   (4) 101 kPa

14 Which statement describes the charge distribution and the polarity of a CH_4 molecule?

(1) The charge distribution is symmetrical and the molecule is nonpolar.
(2) The charge distribution is asymmetrical and the molecule is nonpolar.
(3) The charge distribution is symmetrical and the molecule is polar.
(4) The charge distribution is asymmetrical and the molecule is polar.

15 In a laboratory investigation, a student separates colored compounds obtained from a mixture of crushed spinach leaves and water by using paper chromatography. The colored compounds separate because of differences in

(1) molecular polarity
(2) malleability
(3) boiling point
(4) electrical conductivity

16 Which phrase describes the motion and attractive forces of ideal gas particles?

(1) random straight-line motion and no attractive forces
(2) random straight-line motion and strong attractive forces
(3) random curved-line motion and no attractive forces
(4) random curved-line motion and strong attractive forces

17 At which temperature will $Hg(\ell)$ and $Hg(s)$ reach equilibrium in a closed system at 1.0 atmosphere?

(1) 234 K   (3) 373 K
(2) 273 K   (4) 630. K

18 A molecule of any organic compound has at least one

(1) ionic bond   (3) oxygen atom
(2) double bond   (4) carbon atom

19 A chemical reaction occurs when reactant particles

(1) are separated by great distances
(2) have no attractive forces between them
(3) collide with proper energy and proper orientation
(4) convert chemical energy into nuclear energy

20 Systems in nature tend to undergo changes toward

(1) lower energy and lower entropy
(2) lower energy and higher entropy
(3) higher energy and lower entropy
(4) higher energy and higher entropy

21 Which formula can represent an alkyne?

(1) C_2H_4 (3) C_3H_4
(2) C_2H_6 (4) C_3H_6

22 Given the formula representing a compound:

```
            H
            |
         H—C—H
         H  |  H
         |  |  |
      H—C—C—C—H
         |  |  |
         H  H  H
```
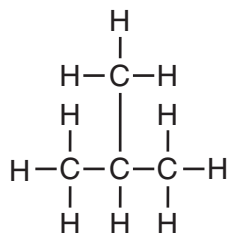
Which formula represents an isomer of this compound?

```
  H    H  H  H
   \   |  |  |
    C=C—C—C—H
   /      |  |
  H       H  H

      ( 1 )
```

```
      H  H
      |  |
   H—C≡C—C—C—H
         |  |
         H  H

      ( 3 )
```

```
      H  H  H  H
      |  |  |  |
   H—C—C—C—C—H
      |  |  |  |
      H  H  H  H

      ( 2 )
```
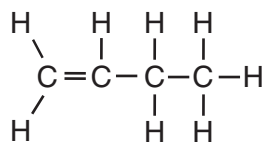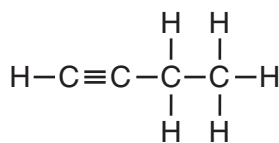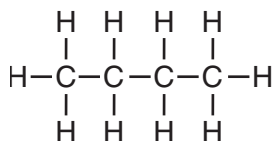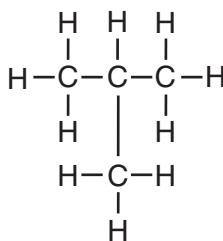
```
         H  H  H
         |  |  |
      H—C—C—C—H
         |  |  |
         H  |  H
         H—C—H
            |
            H

      ( 4 )
```

23 Which energy conversion occurs in an operating voltaic cell?

(1) chemical energy to electrical energy
(2) chemical energy to nuclear energy
(3) electrical energy to chemical energy
(4) electrical energy to nuclear energy

24 Which process requires energy to decompose a substance?

(1) electrolysis   (3) sublimation
(2) neutralization   (4) synthesis

25 The concentration of which ion is increased when LiOH is dissolved in water?

(1) hydroxide ion   (3) hydronium ion
(2) hydrogen ion   (4) halide ion

26 Which equation represents neutralization?

(1) $6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$

(2) $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

(3) $2KOH(aq) + H_2SO_4(aq) \rightarrow$
$K_2SO_4(aq) + 2H_2O(\ell)$

(4) $Pb(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow$
$2KNO_3(aq) + PbCrO_4(s)$

27 The stability of an isotope is related to its ratio of

(1) neutrons to positrons
(2) neutrons to protons
(3) electrons to positrons
(4) electrons to protons

28 Which particle has the *least* mass?

(1) alpha particle   (3) neutron
(2) beta particle   (4) proton

29 The energy released during a nuclear reaction is a result of

(1) breaking chemical bonds
(2) forming chemical bonds
(3) mass being converted to energy
(4) energy being converted to mass

30 The use of uranium-238 to determine the age of a geological formation is a beneficial use of

(1) nuclear fusion
(2) nuclear fission
(3) radioactive isomers
(4) radioactive isotopes

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 31 and 32 on your knowledge of chemistry and the bright-line spectra produced by four elements and the spectrum of a mixture of elements represented in the diagram below.

Bright-Line Spectra

Wavelength (nm)

Wavelength (nm)
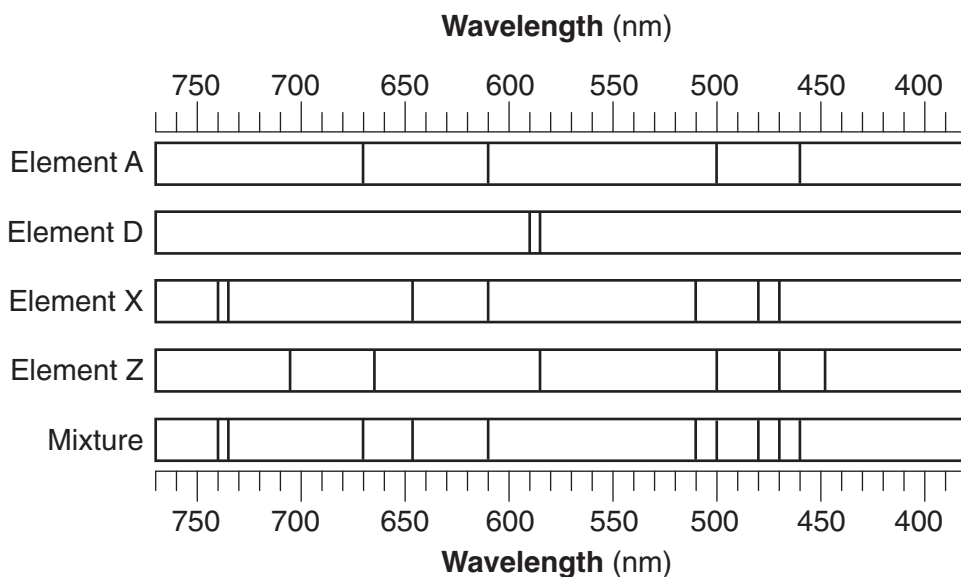
31 Which elements are present in this mixture?

(1) D and A   (3) X and A
(2) D and Z   (4) X and Z

32 Each line in the spectra represents the energy

(1) absorbed as an atom loses an electron
(2) absorbed as an atom gains an electron
(3) released as an electron moves from a lower energy state to a higher energy state
(4) released as an electron moves from a higher energy state to a lower energy state

---

33 The table below shows the number of protons, neutrons, and electrons in four ions.

Four Ions

Ion	Number of Protons	Number of Neutrons	Number of Electrons
A	8	10	10
E	9	10	10
G	11	12	10
J	12	12	10

Which ion has a charge of 2−?

(1) A   (3) G
(2) E   (4) J

34 What is the approximate mass of an atom that contains 26 protons, 26 electrons and 19 neutrons?

(1) 26 u   (3) 52 u
(2) 45 u   (4) 71 u

35 Which electron configuration represents a potassium atom in an excited state?

(1) 2-7-6   (3) 2-8-8-1
(2) 2-8-5   (4) 2-8-7-2

36 What is the total number of neutrons in an atom of K-42?

(1) 19   (3) 23
(2) 20   (4) 42

37 Given the equation representing a reaction:

$$2C + 3H_2 \rightarrow C_2H_6$$
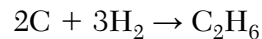
What is the number of moles of C that must completely react to produce 2.0 moles of C_2H_6?

(1) 1.0 mol   (3) 3.0 mol
(2) 2.0 mol   (4) 4.0 mol

38 Given the equation representing a reaction:
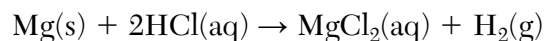
$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

Which type of chemical reaction is represented by the equation?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

39 The table below lists properties of selected elements at room temperature.

Properties of Selected Elements at Room Temperature

Element	Density (g/cm³)	Malleability	Conductivity
sodium	0.97	yes	good
gold	19.3	yes	good
iodine	4.933	no	poor
tungsten	19.3	yes	good

Based on this table, which statement describes how two of these elements can be differentiated from each other?

(1) Gold can be differentiated from tungsten based on density.
(2) Gold can be differentiated from sodium based on malleability.
(3) Sodium can be differentiated from tungsten based on conductivity.
(4) Sodium can be differentiated from iodine based on malleability.

40 Which particle diagram represents a mixture?

Key
● = an atom of an element
○ = an atom of a different element
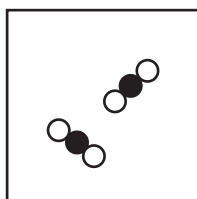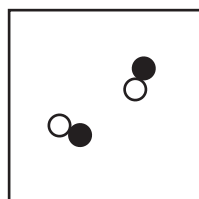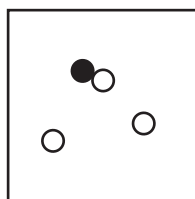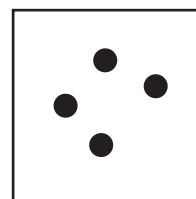
(1)　　　　(2)　　　　(3)　　　　(4)

41 An atom of which element reacts with an atom of hydrogen to form a bond with the greatest degree of polarity?

(1) carbon (3) nitrogen
(2) fluorine (4) oxygen

42 What is the concentration of an aqueous solution that contains 1.5 moles of NaCl in 500. milliliters of this solution?

(1) 0.30 M (3) 3.0 M
(2) 0.75 M (4) 7.5 M

43 The table below shows data for the temperature, pressure, and volume of four gas samples.

Data for Four Gases

Gas Sample	Temperature (K)	Pressure (atm)	Volume (L)
I	600.	2.0	5.0
II	300.	1.0	10.0
III	600.	3.0	5.0
IV	300.	1.0	10.0

Which two gas samples contain the same number of molecules?

(1) I and II (3) II and III
(2) I and III (4) II and IV

44 Based on Table I, what is the ΔH value for the production of 1.00 mole of $NO_2(g)$ from its elements at 101.3 kPa and 298 K?

(1) +33.2 kJ (3) +132.8 kJ
(2) −33.2 kJ (4) −132.8 kJ

45 Which equation represents an addition reaction?

(1) $C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$
(2) $C_3H_6 + Cl_2 \rightarrow C_3H_6Cl_2$
(3) $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$
(4) $CaCO_3 \rightarrow CaO + CO_2$

46 Given the balanced equation representing a reaction:

$$Ni(s) + 2HCl(aq) \rightarrow NiCl_2(aq) + H_2(g)$$
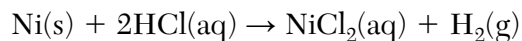
In this reaction, each Ni atom

(1) loses 1 electron (3) gains 1 electron
(2) loses 2 electrons (4) gains 2 electrons

47 Which equation represents a reduction half-reaction?

(1) $Fe \rightarrow Fe^{3+} + 3e^-$ (3) $Fe^{3+} \rightarrow Fe + 3e^-$
(2) $Fe + 3e^- \rightarrow Fe^{3+}$ (4) $Fe^{3+} + 3e^- \rightarrow Fe$

48 Given the balanced ionic equation representing a reaction:

$$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$
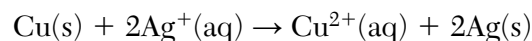
During this reaction, electrons are transferred from

(1) $Cu(s)$ to $Ag^+(aq)$
(2) $Cu^{2+}(aq)$ to $Ag(s)$
(3) $Ag(s)$ to $Cu^{2+}(aq)$
(4) $Ag^+(aq)$ to $Cu(s)$

49 Which metal reacts spontaneously with Sr^{2+} ions?

(1) Ca(s) (3) Cs(s)
(2) Co(s) (4) Cu(s)

50 Given the balanced equation representing a reaction:

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$
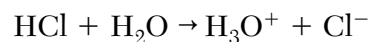
The water molecule acts as a base because it

(1) donates an H^+ (3) donates an OH^-
(2) accepts an H^+ (4) accepts an OH^-

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 State the general trend in first ionization energy as the elements in Period 3 are considered from left to right.   [1]

52 Identify a type of strong intermolecular force that exists between water molecules, but does *not* exist between carbon dioxide molecules.   [1]

53 Draw a structural formula for 2-butanol.   [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

Some compounds of silver are listed with their chemical formulas in the table below.

Silver Compounds

Name	Chemical Formula
silver carbonate	Ag_2CO_3
silver chlorate	$AgClO_3$
silver chloride	$AgCl$
silver sulfate	Ag_2SO_4

54 Explain, in terms of element classification, why silver chloride is an ionic compound.   [1]

55 Show a numerical setup for calculating the percent composition by mass of silver in silver carbonate (gram-formula mass = 276 g/mol).   [1]

56 Identify the silver compound in the table that is most soluble in water.   [1]

Base your answers to questions 57 through 59 on the information below and on your knowledge of chemistry.

When a cobalt-59 atom is bombarded by a subatomic particle, a radioactive cobalt-60 atom is produced. After 21.084 years, 1.20 grams of an original sample of cobalt-60 produced remains unchanged.

57 Complete the nuclear equation by writing a notation for the missing particle.   [1]

58 Based on Table *N*, identify the decay mode of cobalt-60.   [1]

59 Determine the mass of the original sample of cobalt-60 produced.   [1]

Base your answers to questions 60 through 62 on the information below and on your knowledge of chemistry.

A sample of a molecular substance starting as a gas at 206°C and 1 atm is allowed to cool for 16 minutes. This process is represented by the cooling curve below.

Cooling Curve for a Substance
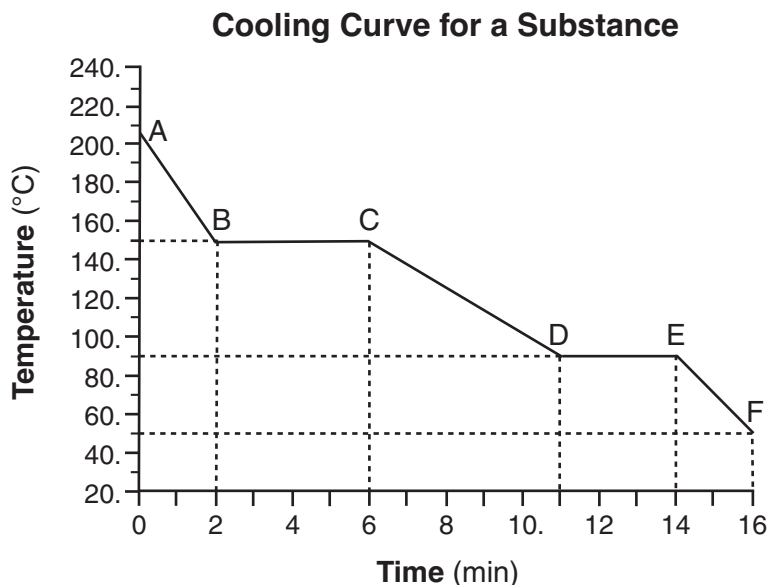
60 Determine the number of minutes that the substance was in the liquid phase, only. [1]

61 Compare the strength of the intermolecular forces within this substance at 180.°C to the strength of the intermolecular forces within this substance at 120.°C. [1]

62 Describe what happens to the potential energy and the average kinetic energy of the molecules in the sample during interval *DE*. [1]

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

The diagram below represents a cylinder with a moveable piston containing 16.0 g of $O_2(g)$. At 298 K and 0.500 atm, the $O_2(g)$ has a volume of 24.5 liters.

$O_2(g)$
$P = 0.500$ atm
$V = 24.5$ L
$T = 298$ K
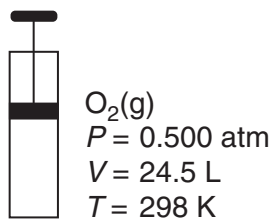
63 Determine the number of moles of $O_2(g)$ in the cylinder. The gram-formula mass of $O_2(g)$ is 32.0 g/mol. [1]

64 State the changes in *both* pressure and temperature of the gas in the cylinder that would increase the frequency of collisions between the $O_2(g)$ molecules. [1]

65 Show a numerical setup for calculating the volume of $O_2(g)$ in the cylinder at 265 K and 1.00 atm. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

In the late 1800s, Dmitri Mendeleev developed a periodic table of the elements known at that time. Based on the pattern in his periodic table, he was able to predict properties of some elements that had not yet been discovered. Information about two of these elements is shown in the table below.

Some Element Properties Predicted by Mendeleev

Predicted Elements	Property	Predicted Value	Actual Value
eka-aluminum (Ea)	density at STP	5.9 g/cm^3	5.91 g/cm^3
	melting point	low	30.°C
	oxide formula	Ea$_2$O$_3$	
	approximate molar mass	68 g/mol	
eka-silicon (Es)	density at STP	5.5 g/cm^3	5.3234 g/cm^3
	melting point	high	938°C
	oxide formula	EsO$_2$	
	approximate molar mass	72 g/mol	

66 Identify the phase of Ea at 310. K. [1]

67 Write a chemical formula for the compound formed between Ea and Cl. [1]

68 Identify the element that Mendeleev called eka-silicon, Es. [1]

69 Show a numerical setup for calculating the percent error of Mendeleev's predicted density of Es. [1]

Base your answers to questions 70 through 73 on the information below and your knowledge of chemistry.

Methanol can be manufactured by a reaction that is reversible. In the reaction, carbon monoxide gas and hydrogen gas react using a catalyst. The equation below represents this system at equilibrium.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) + energy$$
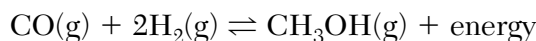
70 State the class of organic compounds to which the product of the forward reaction belongs. [1]

71 Compare the rate of the forward reaction to the rate of the reverse reaction in this equilibrium system. [1]

72 Explain, in terms of collision theory, why increasing the concentration of $H_2(g)$ in this system will increase the concentration of $CH_3OH(g)$. [1]

73 State the effect on the rates of both the forward and reverse reactions if no catalyst is used in the system. [1]

Base your answers to questions 74 through 76 on the information below and on your knowledge of chemistry.

Fatty acids, a class of compounds found in living things, are organic acids with long hydrocarbon chains. Linoleic acid, an unsaturated fatty acid, is essential for human skin flexibility and smoothness. The formula below represents a molecule of linoleic acid.

```
     H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   O
     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   ||
 H — C — C — C — C — C — C = C — C — C = C — C — C — C — C — C — C — C — C — O — H
     |   |   |   |   |       |           |   |   |   |   |   |   |
     H   H   H   H   H       H           H   H   H   H   H   H   H
```
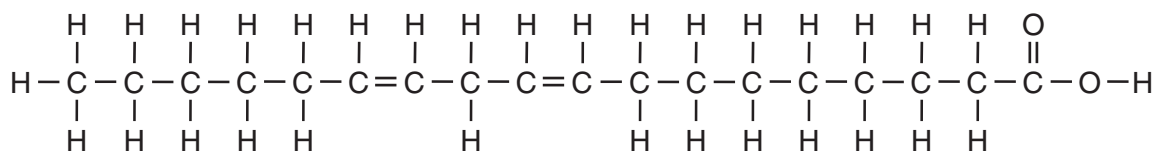
74 Write the molecular formula of linoleic acid. [1]

75 Identify the type of chemical bond between the oxygen atom and the hydrogen atom in the linoleic acid molecule. [1]

76 On the diagram *in your answer booklet*, circle the organic acid functional group. [1]

Base your answers to questions 77 through 79 on the information below and on your knowledge of chemistry.

Fuel cells are voltaic cells. In one type of fuel cell, oxygen gas, $O_2(g)$, reacts with hydrogen gas, $H_2(g)$, producing water vapor, $H_2O(g)$, and electrical energy. The unbalanced equation for this redox reaction is shown below.

$$H_2(g) + O_2(g) \rightarrow H_2O(g) + energy$$
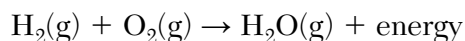
A diagram of the fuel cell is shown below. During operation of the fuel cell, hydrogen gas is pumped into one compartment and oxygen gas is pumped into the other compartment. Each compartment has an inner wall that is a porous carbon electrode through which ions flow. Aqueous potassium hydroxide, $KOH(aq)$, and the porous electrodes serve as the salt bridge.
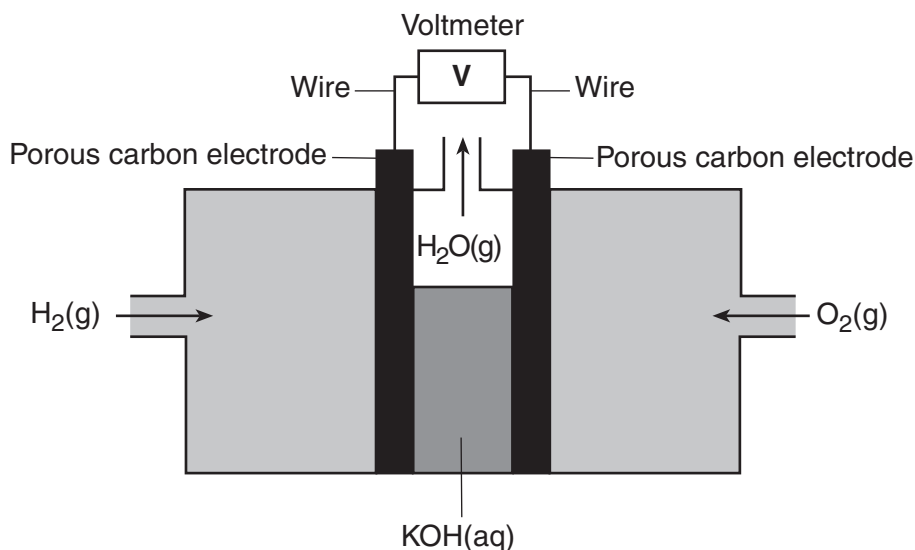
77 Balance the equation *in your answer booklet* for the reaction in this fuel cell, using the smallest whole-number coefficients.   [1]

78 Determine the change in oxidation number for oxygen in this operating fuel cell.   [1]

79 State the number of moles of electrons that are gained when 5.0 moles of electrons are lost in this reaction.   [1]

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

In a laboratory investigation, a student compares the concentration and pH value of each of four different solutions of hydrochloric acid, HCl(aq), as shown in the table below.

Data for HCl(aq) Solutions

Solution	Concentration of HCl(aq) (M)	pH Value
W	1.0	0
X	0.10	1
Y	0.010	2
Z	0.0010	3

80 State the number of significant figures used to express the concentration of solution Z. [1]

81 Determine the concentration of an HCl(aq) solution that has a pH value of 4. [1]

82 Determine the volume of 0.25 M NaOH(aq) that would exactly neutralize 75.0 milliliters of solution X. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Carbon dioxide is slightly soluble in seawater. As carbon dioxide levels in the atmosphere increase, more CO_2 dissolves in seawater, making the seawater more acidic because carbonic acid, $H_2CO_3(aq)$, is formed.

Seawater also contains aqueous calcium carbonate, $CaCO_3(aq)$, which is used by some marine organisms to make their hard exoskeletons. As the acidity of the sea water changes, the solubility of $CaCO_3$ also changes, as shown in the graph below.

Solubility of CaCO₃ vs. pH of Seawater
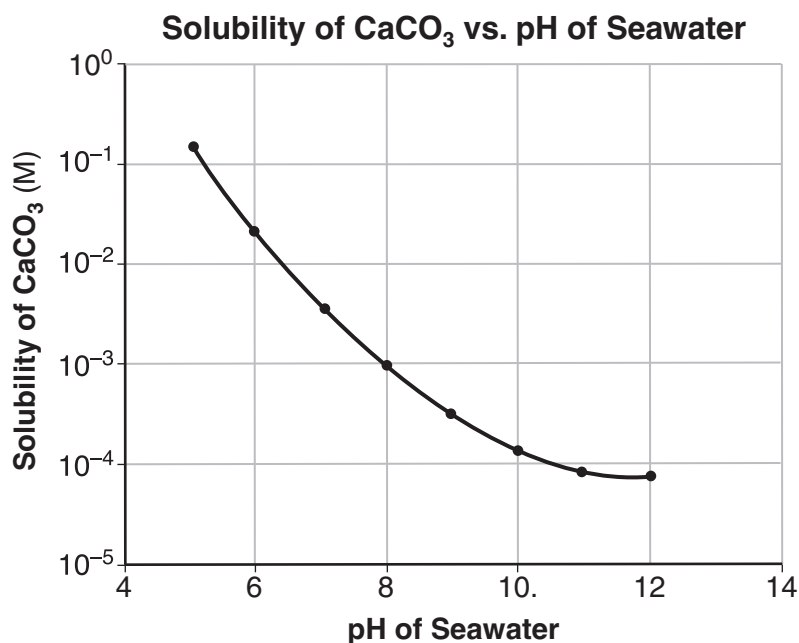
83 State the trend in the solubility of $CaCO_3$ as seawater becomes more acidic. [1]

84 State the color of bromcresol green in a sample of seawater in which the $CaCO_3$ solubility is 10^{-2} M. [1]

85 A sample of seawater has a pH of 8. Determine the new pH of the sample if the hydrogen ion concentration is increased by a factor of 100. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Tuesday, June 25, 2019 — 9:15 a.m to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.* You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which particles are found in the nucleus of an argon atom?

(1) protons and electrons
(2) positrons and neutrons
(3) protons and neutrons
(4) positrons and electrons

2 The diagram below represents a particle traveling through an electric field.

Positively charged plate

Particle

Negatively charged plate
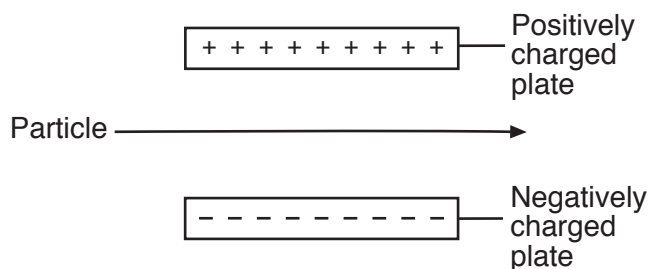
An electric field exists between the two plates.

Which particle remains undeflected when passing through this electric field?

(1) proton   (3) neutron
(2) electron   (4) positron

3 The mass of an electron is

(1) equal to the mass of a proton
(2) equal to the mass of a neutron
(3) greater than the mass of a proton
(4) less than the mass of a neutron

4 Compared to the energy of an electron in the second shell of an atom of sulfur, the energy of an electron in the

(1) first shell is lower
(2) first shell is the same
(3) third shell is lower
(4) third shell is the same

5 In the ground state, an atom of which element has seven valence electrons?

(1) sodium   (3) nitrogen
(2) phosphorus   (4) fluorine

6 Which information is sufficient to differentiate a sample of sodium from a sample of silver?

(1) the mass of each sample
(2) the volume of each sample
(3) the reactivity of each sample with water
(4) the phase of each sample at room temperature

7 Graphite and diamond are two forms of solid carbon at STP. These forms have

(1) different molecular structures and different properties
(2) different molecular structures and the same properties
(3) the same molecular structures and different properties
(4) the same molecular structures and the same properties

8 As the first five elements in Group 14 are considered in order from top to bottom, there are changes in both the

(1) number of valence shell electrons and number of first shell electrons
(2) electronegativity values and number of first shell electrons
(3) number of valence shell electrons and atomic radii
(4) electronegativity values and atomic radii

9 Which statement explains why NaBr is classified as a compound?

(1) Na and Br are chemically combined in a fixed proportion.
(2) Na and Br are both nonmetals.
(3) NaBr is a solid at 298 K and standard pressure.
(4) NaBr dissolves in H_2O at 298 K.

10 Which two terms represent types of chemical formulas?

(1) fission and fusion
(2) oxidation and reduction
(3) empirical and structural
(4) endothermic and exothermic

11 During all chemical reactions, charge, mass and energy are

(1) condensed   (3) decayed
(2) conserved   (4) decomposed

12 The degree of polarity of a covalent bond between two atoms is determined by calculating the difference in their

(1) atomic radii   (3) electronegativities
(2) melting points   (4) ionization energies

13 Which substance can *not* be broken down by a chemical change?

(1) ammonia   (3) methane
(2) magnesium   (4) water

14 Which statement describes the components of a mixture?

(1) Each component gains new properties.
(2) Each component loses its original properties.
(3) The proportions of components can vary.
(4) The proportions of components cannot vary.

15 Table sugar can be separated from a mixture of table sugar and sand at STP by adding

(1) sand, stirring, and distilling at 100.°C
(2) sand, stirring, and filtering
(3) water, stirring, and distilling at 100.°C
(4) water, stirring, and filtering

16 Which statement describes the particles of an ideal gas, based on the kinetic molecular theory?

(1) The volume of the particles is considered negligible.
(2) The force of attraction between the particles is strong.
(3) The particles are closely packed in a regular, repeating pattern.
(4) The particles are separated by small distances, relative to their size.

17 During which two processes does a substance release energy?

(1) freezing and condensation
(2) freezing and melting
(3) evaporation and condensation
(4) evaporation and melting

18 Based on Table *I*, which compound dissolves in water by an exothermic process?

(1) NaCl   (3) NH_4Cl
(2) NaOH   (4) NH_4NO_3

19 At STP, which property of a molecular substance is determined by the arrangement of its molecules?

(1) half-life
(2) molar mass
(3) physical state
(4) percent composition

20 Equilibrium can be reached by

(1) physical changes, only
(2) nuclear changes, only
(3) both physical changes and chemical changes
(4) both nuclear changes and chemical changes

21 Which value is defined as the difference between the potential energy of the products and the potential energy of the reactants during a chemical change?

(1) heat of fusion
(2) heat of reaction
(3) heat of deposition
(4) heat of vaporization

22 The effect of a catalyst on a chemical reaction is to provide a new reaction pathway that results in a different

(1) potential energy of the products
(2) heat of reaction
(3) potential energy of the reactants
(4) activation energy

23 Chemical systems in nature tend to undergo changes toward

(1) lower energy and lower entropy
(2) lower energy and higher entropy
(3) higher energy and lower entropy
(4) higher energy and higher entropy

24 The atoms of which element bond to one another in chains, rings, and networks?

(1) barium   (3) iodine
(2) carbon   (4) mercury

25 What is the general formula for the homologous series that includes ethene?

(1) C_nH_{2n} (3) C_nH_{2n-2}
(2) C_nH_{2n-6} (4) C_nH_{2n+2}

26 When an F atom becomes an F^- ion, the F atom

(1) gains a proton   (3) gains an electron
(2) loses a proton   (4) loses an electron

27 Which substance is an Arrhenius base?

(1) HNO_3 (3) $Ca(OH)_2$
(2) H_2SO_3 (4) CH_3COOH

28 In which type of nuclear reaction do two light nuclei combine to produce a heavier nucleus?

(1) positron emission   (3) fission
(2) gamma emission   (4) fusion

29 Using equal masses of reactants, which statement describes the relative amounts of energy released during a chemical reaction and a nuclear reaction?

(1) The chemical and nuclear reactions release equal amounts of energy.
(2) The nuclear reaction releases half the amount of energy of the chemical reaction.
(3) The chemical reaction releases more energy than the nuclear reaction.
(4) The nuclear reaction releases more energy than the chemical reaction.

30 The ratio of the mass of U-238 to the mass of Pb-206 can be used to

(1) diagnose thyroid disorders
(2) diagnose kidney function
(3) date geological formations
(4) date once-living things

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 The bright-line spectra of four elements, *G, J, L*, and *M*, and a mixture of *at least two* of these elements is given below.

Bright-Line Spectra

Wavelength (nm)
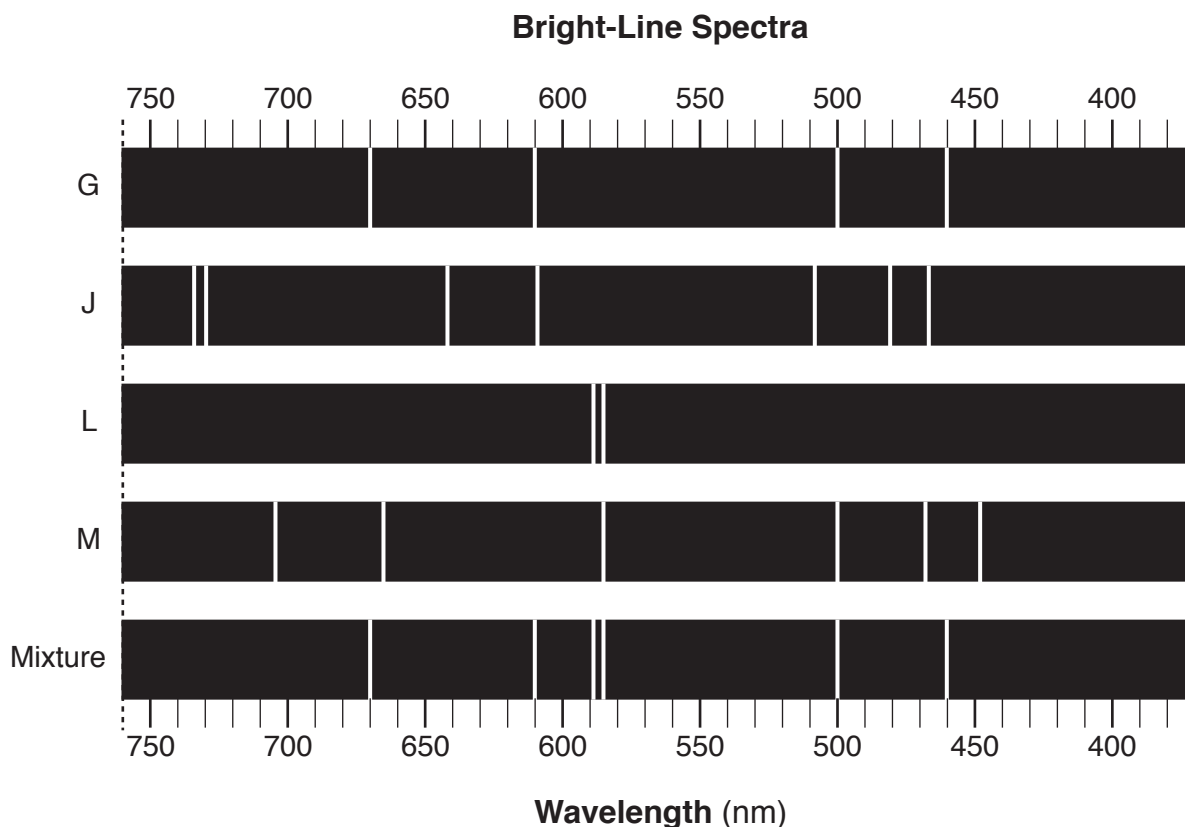
Which elements are present in the mixture?

(1) *G* and *J*   (3) *M, J*, and *G*
(2) *G* and *L*   (4) *M, J*, and *L*

32 Which electron configuration represents an atom of chlorine in an excited state?

(1) 2-8-7-2   (3) 2-8-8
(2) 2-8-7   (4) 2-7-8

33 A student measures the mass and volume of a sample of aluminum at room temperature, and calculates the density of Al to be 2.85 grams per cubic centimeter. Based on Table *S*, what is the percent error for the student's calculated density of Al?

(1) 2.7%   (3) 5.6%
(2) 5.3%   (4) 95%

34 Magnesium and calcium have similar chemical properties because their atoms in the ground state have

(1) equal numbers of protons and electrons
(2) equal numbers of protons and neutrons
(3) two electrons in the first shell
(4) two electrons in the outermost shell

35 As the elements in Period 2 of the Periodic Table are considered in order from left to right, which property generally *decreases*?

(1) atomic radius   (3) ionization energy
(2) electronegativity   (4) nuclear charge

36 Given the balanced equation for the reaction of butane and oxygen:

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O + energy$$

How many moles of carbon dioxide are produced when 5.0 moles of butane react completely?

(1) 5.0 mol   (3) 20. mol
(2) 10. mol   (4) 40. mol

37 What is the percent composition by mass of nitrogen in the compound N_2H_4 (gram-formula mass = 32 g/mol)?

(1) 13%   (3) 88%
(2) 44%   (4) 93%

38 Which ion in the ground state has the same electron configuration as an atom of neon in the ground state?

(1) Ca^{2+} (3) Li^+
(2) Cl^- (4) O^{2-}

39 The molar masses and boiling points at standard pressure for four compounds are given in the table below.

Compound	Molar Mass (g/mol)	Boiling Point (K)
HF	20.01	293
HCl	36.46	188
HBr	80.91	207
HI	127.91	237

Which compound has the strongest intermolecular forces?

(1) HF   (3) HBr
(2) HCl   (4) HI

40 Which particle model diagram represents xenon at STP?
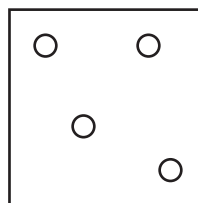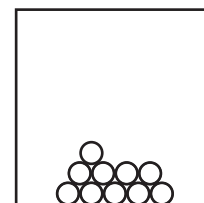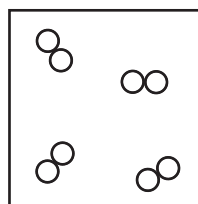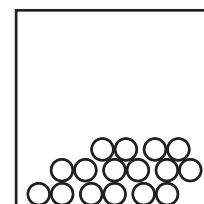
41 What is the amount of heat absorbed when the temperature of 75 grams of water increases from 20.°C to 35°C?

(1) 1100 J   (3) 6300 J
(2) 4700 J   (4) 11 000 J

42 Which sample of HCl(aq) reacts at the fastest rate with a 1.0-gram sample of iron filings?

  (1) 10. mL of 1 M HCl(aq) at 10.°C
  (2) 10. mL of 1 M HCl(aq) at 25°C
  (3) 10. mL of 3 M HCl(aq) at 10.°C
  (4) 10. mL of 3 M HCl(aq) at 25°C

43 Given the equation representing a system at equilibrium:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$
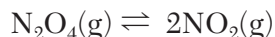
Which statement describes the concentration of the two gases in this system?

  (1) The concentration of $N_2O_4(g)$ must be less than the concentration of $NO_2(g)$.

  (2) The concentration of $N_2O_4(g)$ must be greater than the concentration of $NO_2(g)$.

  (3) The concentration of $N_2O_4(g)$ and the concentration of $NO_2(g)$ must be equal.

  (4) The concentration of $N_2O_4(g)$ and the concentration of $NO_2(g)$ must be constant.

44 Given the equation representing a system at equilibrium:

$$PCl_5(g) + \text{energy} \rightleftharpoons PCl_3(g) + Cl_2(g)$$
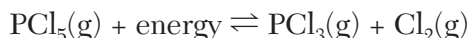
Which change will cause the equilibrium to shift to the right?

  (1) adding a catalyst
  (2) adding more $PCl_3(g)$
  (3) increasing the pressure
  (4) increasing the temperature

45 Given the formula representing a molecule:
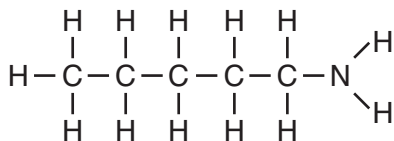
A chemical name for this compound is

  (1) pentanone   (3) 1-pentanamine
  (2) 1-pentanol   (4) pentanamide

46 Given the formula of a compound:
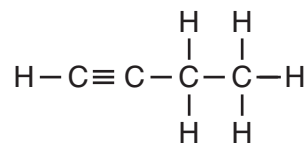
This compound is classified as an

  (1) aldehyde   (3) alkyne
  (2) alkene   (4) alcohol

47 Which equation represents fermentation?

  (1) $C_2H_4 + H_2O \rightarrow CH_3CH_2OH$
  (2) $C_2H_4 + HCl \rightarrow CH_3CH_2Cl$
  (3) $C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$
  (4) $2CH_3CHO \rightarrow C_3H_5CHO + H_2O$

48 Given the equation representing a reaction:

$$3CuCl_2(aq) + 2Al(s) \rightarrow 3Cu(s) + 2AlCl_3(aq)$$
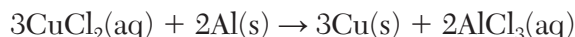
The oxidation number of copper changes from

  (1) +1 to 0   (3) +2 to +1
  (2) +2 to 0   (4) +6 to +3

49 Given the equation representing a reversible reaction:

$$CH_3COOH(aq) + H_2O(\ell) \rightleftharpoons$$
$$CH_3COO^-(aq) + H_3O^+(aq)$$
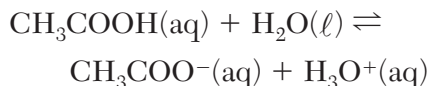
According to one acid-base theory, the two H^+ donors in the equation are

  (1) CH_3COOH and H_2O
  (2) CH_3COOH and H_3O^+
  (3) CH_3COO^- and H_2O
  (4) CH_3COO^- and H_3O^+

50 Which nuclear equation represents a spontaneous decay?

  (1) $^{222}_{86}Rn \rightarrow \, ^{218}_{84}Po + \, ^{4}_{2}He$

  (2) $^{27}_{13}Al + \, ^{4}_{2}He \rightarrow \, ^{30}_{15}P + \, ^{1}_{0}n$

  (3) $^{235}_{92}U + \, ^{1}_{0}n \rightarrow \, ^{139}_{56}Ba + \, ^{94}_{36}Kr + 3^{1}_{0}n$

  (4) $^{7}_{3}Li + \, ^{1}_{1}H \rightarrow \, ^{4}_{2}He + \, ^{4}_{2}He$

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

51 Draw a structural formula for methanal. [1]

Base your answers to questions 52 through 54 on the information below and on your knowledge of chemistry.

The atomic mass and natural abundance of the naturally occuring isotopes of hydrogen are shown in the table below.

Naturally Occuring Isotopes of Hydrogen

Isotope	Common Name of Isotope	Atomic Mass (u)	Natural Abundance (%)
H-1	protium	1.0078	99.9885
H-2	deuterium	2.0141	0.0115
H-3	tritium	3.0160	negligible

The isotope H-2, also called deuterium, is usually represented by the symbol "D." Heavy water forms when deuterium reacts with oxygen, producing molecules of D_2O.

52 Explain, in terms of subatomic particles, why atoms of H-1, H-2, and H-3 are each electrically neutral. [1]

53 Determine the formula mass of heavy water, D_2O. [1]

54 Based on Table *N*, identify the decay mode of tritium. [1]

Base your answers to questions 55 through 57 on the information below and on your knowledge of chemistry.

At 23°C, 85.0 grams of $NaNO_3(s)$ are dissolved in 100. grams of $H_2O(\ell)$.

55 Convert the temperature of the $NaNO_3(s)$ to kelvins. [1]

56 Based on Table G, determine the additional mass of $NaNO_3(s)$ that must be dissolved to saturate the solution at 23°C. [1]

57 State what happens to the boiling point and freezing point of the solution when the solution is diluted with an additional 100. grams of $H_2O(\ell)$. [1]

Base your answers to questions 58 through 61 on the information below and on your knowledge of chemistry.

A 200.-milliliter sample of $CO_2(g)$ is placed in a sealed, rigid cylinder with a movable piston at 296 K and 101.3 kPa.

58 State a change in temperature and a change in pressure of the $CO_2(g)$ that would cause it to behave more like an ideal gas. [1]

59 Determine the volume of the sample of $CO_2(g)$ if the temperature and pressure are changed to 336 K and 152.0 kPa. [1]

60 State, in terms of *both* the frequency and force of collisions, what would result from decreasing the temperature of the original sample of $CO_2(g)$, at constant volume. [1]

61 Compare the mass of the original 200.-milliliter sample of $CO_2(g)$ to the mass of the $CO_2(g)$ sample when the cylinder is adjusted to a volume of 100. milliliters. [1]

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

Cobalt-60 is an artificial isotope of Co-59. The incomplete equation for the decay of cobalt-60, including beta and gamma emissions, is shown below.

$$^{60}_{27}\text{Co} \rightarrow X + {}^{0}_{-1}\text{e} + {}^{0}_{0}\gamma$$
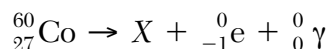
62 Explain, in terms of *both* protons and neutrons, why Co-59 and Co-60 are isotopes of cobalt.   [1]

63 Compare the penetrating power of the beta and gamma emissions.   [1]

64 Complete the nuclear equation, *in your answer booklet*, for the decay of cobalt-60 by writing a notation for the missing product.   [1]

65 Based on Table *N*, determine the total time required for an 80.00-gram sample of cobalt-60 to decay until only 10.00 grams of the sample remain unchanged.   [1]

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

During a laboratory activity, appropriate safety equipment was used and safety procedures were followed. A laboratory technician heated a sample of solid $KClO_3$ in a crucible to determine the percent composition by mass of oxygen in the compound. The unbalanced equation and the data for the decomposition of solid $KClO_3$ are shown below.

$$KClO_3(s) \rightarrow KCl(s) + O_2(g)$$

Lab Data and Calculated Results

Object or Material	Mass (g)
empty crucible and cover	22.14
empty crucible, cover, and $KClO_3$	24.21
$KClO_3$	2.07
crucible, cover, and KCl after heating	23.41
KCl	?
O_2	0.80

66 Write a chemical name for the compound that decomposed. [1]

67 Based on the lab data, show a numerical setup to determine the number of moles of O_2 produced. Use 32 g/mol as the gram-formula mass of O_2. [1]

68 Based on the lab data, determine the mass of KCl produced in the reaction. [1]

69 Balance the equation *in your answer booklet* for the decomposition of $KClO_3$, using the smallest whole-number coefficients. [1]

Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

A bottled water label lists the ions dissolved in the water. The table below lists the mass of some ions dissolved in a 500.-gram sample of the bottled water.

Ions in 500. g of Bottled Water

Ion Formula	Mass (g)
Ca^{2+}	0.040
Mg^{2+}	0.013
Na^+	0.0033
SO_4^{2-}	0.0063
HCO_3^-	0.180

70 State the number of significant figures used to express the mass of hydrogen carbonate ions in the table above. [1]

71 Based on Table *F*, write the formula of the ion in the bottled water table that would form the *least* soluble compound when combined with the sulfate ion. [1]

72 Show a numerical setup for calculating the parts per million of the Na^+ ions in the 500.-gram sample of the bottled water. [1]

73 Compare the radius of a Mg^{2+} ion to the radius of a Mg atom. [1]

Base your answers to questions 74 through 77 on the information below and on your knowledge of chemistry.

Ethyl ethanoate is used as a solvent for varnishes and in the manufacture of artificial leather. The formula below represents a molecule of ethyl ethanoate.

$$\begin{array}{c} \text{H} \quad\ \text{O} \qquad\ \ \text{H} \ \ \text{H} \\ | \qquad || \qquad\quad | \quad\ | \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{C}-\text{C}-\text{H} \\ | \qquad\qquad\qquad\ | \quad\ | \\ \text{H} \qquad\qquad\quad\ \text{H} \ \ \text{H} \end{array}$$
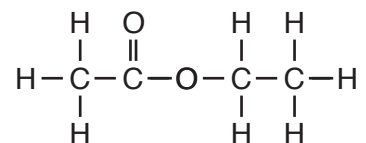
74 Identify the element in ethyl ethanoate that makes it an organic compound. [1]

75 Write the empirical formula for this compound. [1]

76 Write the name of the class of organic compounds to which this compound belongs. [1]

77 Determine the number of electrons shared in the bond between a hydrogen atom and a carbon atom in the molecule. [1]

Base your answers to questions 78 through 80 on the information below and on your knowledge of chemistry.

An operating voltaic cell has magnesium and silver electrodes. The cell and the ionic equation representing the reaction that occurs in the cell are shown below.

Voltaic Cell

$$Mg(s) + 2Ag^+(aq) \longrightarrow Mg^{2+}(aq) + 2Ag(s)$$
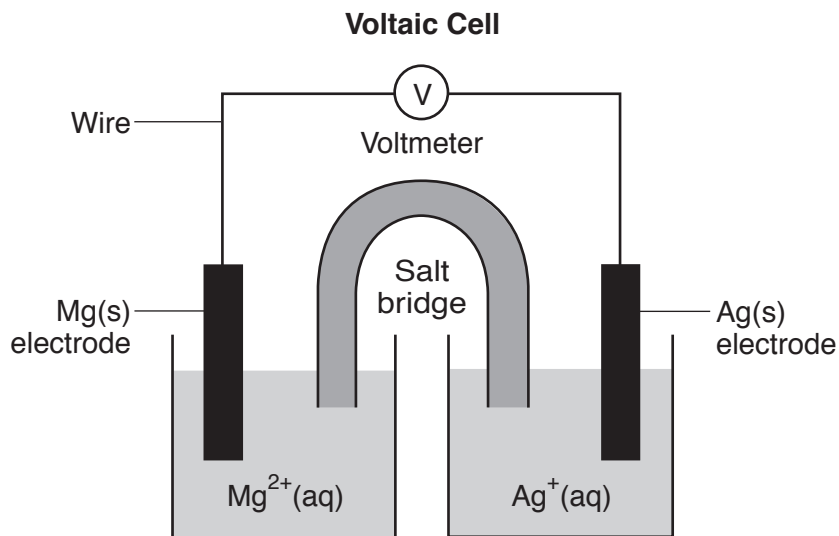
78 State the purpose of the salt bridge in this cell. [1]

79 Write a balanced equation for the half-reaction that occurs at the magnesium electrode in this cell. [1]

80 Explain, in terms of electrical energy, how electrolysis reactions differ from voltaic cell reactions. [1]

Base your answers to questions 81 through 85 on the information below and on your knowledge of chemistry.

In a laboratory investigation, an HCl(aq) solution with a pH value of 2 is used to determine the molarity of a KOH(aq) solution. A 7.5-milliliter sample of the KOH(aq) is exactly neutralized by 15.0 milliliters of the 0.010 M HCl(aq). During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

81 Determine the pH value of a solution that is ten times *less* acidic than the HCl(aq) solution. [1]

82 State the color of the indicator bromcresol green if it is added to a sample of the KOH(aq) solution. [1]

83 Complete the equation *in your answer booklet* by writing the chemical formula for *each* product. [1]

84 Show a numerical setup for calculating the molarity of the KOH solution. [1]

85 Explain, in terms of aqueous ions, why 15.0 mL of a 1.0 M HCl(aq) solution is a better conductor of electricity than 15.0 mL of a 0.010 M HCl(aq) solution. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, June 16, 2022 — 1:15 to 4:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.* You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which subatomic particles are matched with their charges?
  (1) Protons are positive and neutrons are negative.
  (2) Protons are positive and electrons are negative.
  (3) Protons are negative and neutrons have no charge.
  (4) Protons are negative and electrons have no charge.

2 Which conclusion directly resulted from the "gold foil experiment"?
  (1) Atoms are mostly empty space.
  (2) Atoms are hard, indivisible spheres.
  (3) Electrons are located in shells.
  (4) Electrons have a small mass.

3 The bright-line spectrum of an element is produced when excited-state electrons
  (1) absorb energy and move to higher energy states
  (2) absorb energy and move to lower energy states
  (3) release energy and move to higher energy states
  (4) release energy and move to lower energy states

4 The elements on the Periodic Table of the Elements are arranged in order of increasing
  (1) atomic mass   (3) mass number
  (2) atomic number   (4) oxidation state

5 Atoms of which element in Group 15 have the greatest electronegativity?
  (1) As   (3) N
  (2) Bi   (4) P

6 Which term represents the simplest whole-number ratio of atoms of the elements in a compound?
  (1) atomic mass   (3) empirical formula
  (2) formula mass   (4) structural formula

7 How many electrons are shared in a triple bond between two atoms?
  (1) 6   (3) 3
  (2) 2   (4) 4

8 Given the equation representing a reaction:

$$Cl_2 \rightarrow Cl + Cl$$

What occurs during this reaction?
  (1) Energy is released as a bond is broken.
  (2) Energy is released as a bond is formed.
  (3) Energy is absorbed as a bond is broken.
  (4) Energy is absorbed as a bond is formed.

9 Krypton atoms in the ground state tend *not* to bond with other atoms because their
  (1) second electron shell contains eight electrons
  (2) third electron shell contains eighteen electrons
  (3) innermost electron shell contains two electrons
  (4) outermost electron shell contains eight electrons

10 All matter can be classified as
  (1) an element
  (2) a compound
  (3) a mixture or an element
  (4) a mixture or a substance

11 Which sample at STP has the same chemical properties as 10. grams of Al(s) at STP?

(1) 10. grams of Si(s) (3) 5 grams of Al(s)
(2) 10. grams of Na(s) (4) 5 grams of Mg(s)

12 Which sample of matter can *not* be broken down by a chemical change?

(1) antimony (3) methane
(2) ethanol (4) water

13 Based on Table *F*, which 10.-gram sample, when thoroughly mixed with 1 liter of water at room temperature, forms a heterogeneous mixture?

(1) ammonium chloride, NH_4Cl
(2) potassium iodide, KI
(3) silver bromide, AgBr
(4) sodium nitrate, $NaNO_3$

14 Compared to a 1.0 M NaCl(aq) solution at 1.0 atm, a 2.0 M NaCl(aq) solution at 1.0 atm has

(1) a lower boiling point and a lower freezing point
(2) a lower boiling point and a higher freezing point
(3) a higher boiling point and a lower freezing point
(4) a higher boiling point and a higher freezing point

15 Which list includes three forms of energy?

(1) temperature, chemical, thermal
(2) temperature, thermal, alkalinity
(3) electromagnetic, nuclear, chemical
(4) electromagnetic, alkalinity, nuclear

16 Under which conditions of pressure and temperature is a real gas most like an ideal gas?

(1) low pressure and low temperature
(2) low pressure and high temperature
(3) high pressure and low temperature
(4) high pressure and high temperature

17 Which sample of argon gas has the same number of atoms as a 100.-milliliter sample of helium gas at 1.0 atm and 300. K?

(1) 50. mL at 1.0 atm and 300. K
(2) 50. mL at 0.5 atm and 300. K
(3) 100. mL at 0.5 atm and 300. K
(4) 100. mL at 1.0 atm and 300. K

18 Which process is a chemical change?

(1) condensation of $H_2O(g)$
(2) synthesis of MgO(s)
(3) evaporation of $C_2H_5OH(\ell)$
(4) sublimation of $CO_2(s)$

19 Which property is determined by the structure, arrangement, and interactions of the molecules of a substance at a given temperature and pressure?

(1) atomic radius (3) formula mass
(2) half-life (4) physical state

20 A collision between reactant particles is most likely to result in a reaction when the particles have proper orientation and proper

(1) charge (3) mass
(2) energy (4) radius

21 Given the equation representing a system at equilibrium:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Which statement describes this reaction at equilibrium?

(1) The concentration of the reactant and the product must be equal.
(2) The concentration of the reactant and the product must be constant.
(3) The rates of the forward and reverse reactions are increasing.
(4) The rates of the forward and reverse reactions are decreasing.

22 Which phrase describes the effect of adding a catalyst to a chemical reaction in order to increase the reaction rate?

(1) provides a different reaction pathway with a lower activation energy
(2) provides a different reaction pathway with a higher activation energy
(3) uses the same reaction pathway with a higher activation energy
(4) uses the same reaction pathway with a lower activation energy

23 Systems in nature tend to undergo changes toward

(1) lower energy and less disorder
(2) lower energy and greater disorder
(3) higher energy and less disorder
(4) higher energy and greater disorder

24 Which element must be present in an organic compound?

(1) carbon   (3) nitrogen
(2) sulfur   (4) oxygen

25 Which formula represents a saturated hydrocarbon?

(1) C_2H_2 (3) C_6H_{10}
(2) C_2H_4 (4) C_6H_{14}

26 Which reaction occurs at the anode in an electrochemical cell?

(1) saponification   (3) esterification
(2) oxidation   (4) reduction

27 Which statement describes the two types of reactions that occur in operating electrochemical cells?

(1) Nonspontaneous reactions occur in voltaic cells, and spontaneous reactions occur in electrolytic cells.
(2) Nonspontaneous reactions occur in electrolytic cells, and nonspontaneous reactions occur in voltaic cells.
(3) Spontaneous reactions occur in voltaic cells, and nonspontaneous reactions occur in electrolytic cells.
(4) Spontaneous reactions occur in electrolytic cells, and spontaneous reactions occur in voltaic cells.

28 Which term describes an acid according to one acid-base theory?

(1) H^+ acceptor   (3) H_2 acceptor
(2) H^+ donor   (4) H_2 donor

29 Which emission will be released from an unstable Fe-53 nucleus?

(1) an alpha particle   (3) a positron
(2) a beta particle   (4) a proton

30 What is a potential risk associated with radioactive isotopes?

(1) biological exposure
(2) curing of diseases
(3) industrial measurements
(4) tracing chemical processes

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which electron configuration represents the electrons of a phosphorus atom in an excited state?

(1) 2−8−5   (3) 2−7−6
(2) 2−8−6   (4) 2−7−4

32 A 26.7-gram sample of which element has a volume of 3.00 cubic centimeters at room temperature?

(1) Cr   (3) Nb
(2) Cd   (4) Ni

33 Which element is a nonmetal and solid at STP?

(1) lead   (3) sodium
(2) nitrogen   (4) sulfur

34 What is the molecular formula for $CH_3CH_2COOCH_3$?

(1) C_2H_4O (3) C_4H_8O
(2) $C_2H_4O_2$ (4) $C_4H_8O_2$

35 A substance conducts electricity in the liquid phase but *not* in the solid phase. This substance can be classified as

(1) covalent   (3) metallic
(2) ionic   (4) molecular

36 A student measured the melting point of a sample of gallium to be 309 K. Based on Table *S*, which numerical setup can be used to calculate the student's percent error?

(1) $\dfrac{309\,\text{K} - 303\,\text{K}}{303\,\text{K}} \times 100$ (3) $\dfrac{303\,\text{K}}{309\,\text{K}} \times 100$

(2) $\dfrac{309\,\text{K} - 303\,\text{K}}{309\,\text{K}} \times 100$ (4) $\dfrac{309\,\text{K}}{303\,\text{K}} \times 100$

37 Which chemical bond is most polar?

(1) a O–H bond in H_2O
(2) a S–H bond in H_2S
(3) a Se–H bond in H_2Se
(4) a Te–H bond in H_2Te

38 What is the amount of heat required to melt 43 grams of solid magnesium oxide at its melting point? The heat of fusion is 1.9×10^3 J/g.

(1) 2.3×10^{-2} J   (3) 8.2×10^4 J
(2) 4.4×10^1 J   (4) 3.4×10^5 J

39 Given the diagram of a laboratory apparatus:
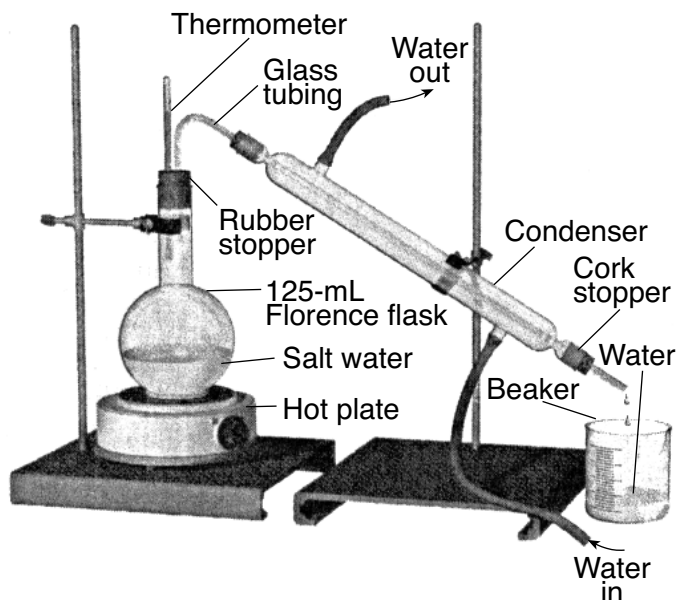
This apparatus is used for which process?

(1) filtration   (3) chromatography
(2) distillation   (4) electrolysis

40 Solid aluminum has a specific heat capacity of 0.90 J/g•K. How many joules of heat are absorbed to raise the temperature of 24.0 grams of aluminum from 300. K to 350. K?

(1) 22 J   (3) 1100 J
(2) 45 J   (4) 1200 J

41 Based on Table *G*, which solute sample in 100.g of water at 40.°C can produce a solution equilibrium in a closed system?

(1) 10. g $KClO_3$ (3) 45 g KCl
(2) 25 g NaCl   (4) 55 g KNO_3

42 Given the equation representing a system at equilibrium:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + energy$$
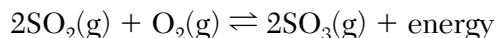
Which change favors the forward reaction?
(1) increasing the concentration of $O_2(g)$
(2) increasing the temperature
(3) decreasing the pressure
(4) decreasing the concentration of $SO_2(g)$

43 When ice, $H_2O(s)$, melts at 0°C, entropy increases because the

(1) average kinetic energy of the particles increases
(2) average kinetic energy of the particles decreases
(3) particle arrangement is more random
(4) particle arrangement is less random

44 At STP, propanal and propanone have different chemical properties due to their different

(1) molecular masses
(2) empirical formulas
(3) percent compositions
(4) functional groups

45 Given the formula for a compound:
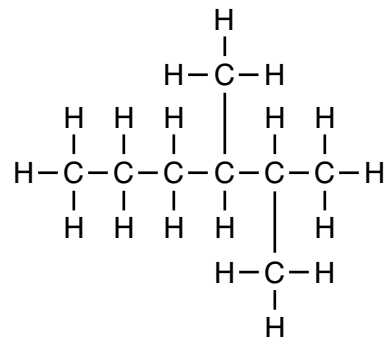
What is the IUPAC name of the compound?
(1) 2,3-dimethyloctane
(2) 2,3-dimethylhexane
(3) 4,5-dimethyloctane
(4) 4,5-dimethylhexane

46 Given the formula representing a compound:
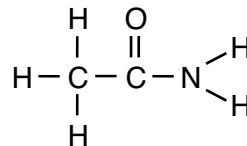
This compound is classified as an
(1) amide   (3) ester
(2) amine   (4) ether

47 Which substance is an electrolyte?
(1) H_2 (3) C_6H_{14}
(2) HCl   (4) $C_6H_{12}O_6$

48 An indicator is added to an aqueous solution with a pH value of 5.6. Which indicator is paired with its observed color in this solution?

(1) Methyl orange is yellow.
(2) Phenolphthalein is pink.
(3) Bromcresol green is yellow.
(4) Thymol blue is blue.

49 Solution A has a pH value of 2.0 and solution B has a pH value of 4.0. How many times greater is the hydronium ion concentration in solution A than the hydronium ion concentration in solution B?

(1) 10 (3) 100
(2) 2   (4) 4

50 Which net change occurs in both nuclear fission and nuclear fusion reactions?

(1) Mass is converted to energy.
(2) Energy is converted to mass.
(3) Small nuclei form a larger nucleus.
(4) A large nucleus forms smaller nuclei.

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 51 through 53 on the information below and on your knowledge of chemistry.

The two naturally occuring isotopes of lithium are Li-6 and Li-7. The table below shows the atomic mass and percent natural abundance for these isotopes.

Naturally Occurring Isotopes of Lithium

Isotope	Atomic Mass (u)	Natural Abundance (%)
Li-6	6.015	7.59
Li-7	7.016	92.41

51 State the number of electrons in an atom of Li-7. [1]

52 Compare the energy of an electron in the first shell of a lithium atom to the energy of an electron in the second shell of the same atom. [1]

53 Show a numerical setup for calculating the atomic mass of the element lithium. [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

The graph below represents the atomic radii of the elements in Period 3 on the Periodic Table of the Elements.

**Atomic Radii of
Period 3 Elements**
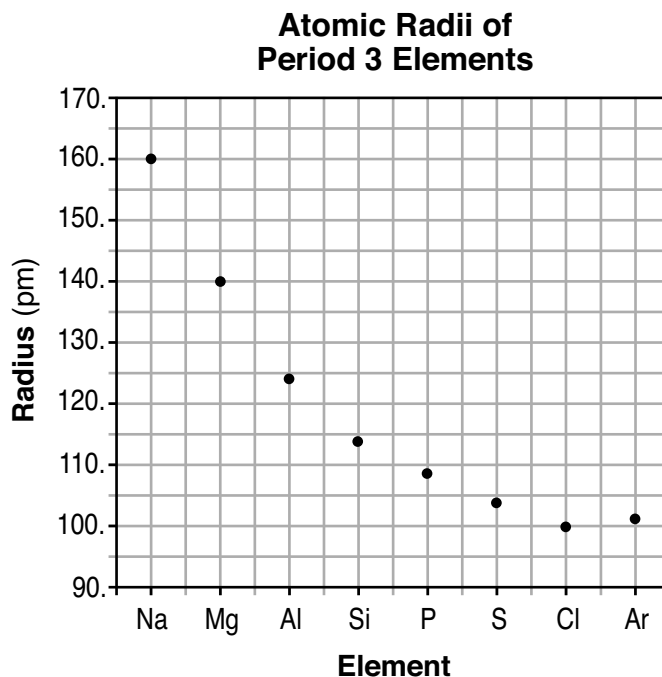
54 State the general trend for the atomic radius of the first seven elements in Period 3 when considered in order from left to right. [1]

55 State, in terms of valence electrons, why aluminum and sulfur have different chemical properties. [1]

56 Identify the element in Period 3 that reacts with oxygen to form an ionic compound represented by X in the formula X_2O. [1]

_____

Base your answers to questions 57 and 58 on the information below and on your knowledge of chemistry.

Lithium, beryllium, boron, and fluorine are four elements in Period 2 on the Periodic Table.

57 State, in terms of electrons, why the radius of a Be^{2+} ion is smaller than the radius of a Be atom. [1]

58 Draw a Lewis electron-dot diagram for an atom of boron. [1]

_____

Base your answers to questions 59 and 60 on the information below and on your knowledge of chemistry.

The incomplete equation below represents a reaction between 2-butene and hydrogen in the presence of a catalyst, producing one compound, X.

$$
\begin{array}{c}
\text{H} \quad \text{H} \qquad\; \text{H} \\
|\quad\;\; | \qquad\quad | \\
\text{H}-\text{C}-\text{C}=\text{C}-\text{C}-\text{H} \;+\; \text{H}_2 \xrightarrow{\text{catalyst}} X \\
|\quad\;\; \qquad\;\; |\quad | \\
\text{H} \qquad\quad \text{H}\;\, \text{H}
\end{array}
$$
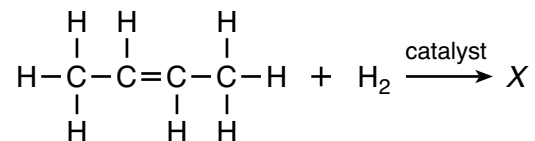
59 Explain, in terms of molecular formulas and structural formulas, why 1-butene is an isomer of 2-butene. [1]

60 Draw a structural formula for the missing product, X, in the equation. [1]

___

Base your answers to questions 61 through 65 on the information below and on your knowledge of chemistry.

In a titration using a pH meter, 16.0 milliliters of 0.18 M NaOH(aq) exactly neutralizes a 24.0-milliliter sample of HCl(aq) in a flask. During this laboratory activity, appropriate safety equipment was used and safety procedures were followed.

61 State the number of significant figures used to express the volume of the HCl(aq) solution. [1]

62 Identify the negative ion in the NaOH(aq) used in the titration. [1]

63 Compare the number of moles of hydronium ions to the number of moles of hydroxide ions in the titration mixture when the HCl(aq) is exactly neutralized by the NaOH(aq). [1]

64 Complete the equation *in your answer booklet* for the neutralization reaction by writing a formula for each product. [1]

65 Determine the molarity of the HCl(aq) sample based on the titration data. [1]

___

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 70 on the information below and on your knowledge of chemistry.

An average person on board the International Space Station (ISS) requires 840 grams of oxygen per day. To produce the oxygen needed on the ISS, water undergoes an electrolysis reaction. The oxygen produced is vented into the ISS cabin, and the hydrogen is vented into outer space. The reaction is represented by the balanced equation below.

$$2H_2O(\ell) + energy \rightarrow 2H_2(g) + O_2(g)$$
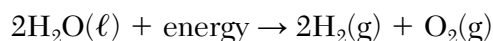
Some gases in the ISS must be removed from the air the astronauts breathe. Carbon dioxide can be removed using solid lithium hydroxide.

66 Show a numerical setup for calculating the number of moles of oxygen gas required for the average person per day. The gram-formula mass of $O_2(g)$ is 32 g/mol.   [1]

67 State the change in oxidation number for oxygen during the electrolysis reaction represented by the equation.   [1]

68 Determine the number of moles of oxygen vented into the cabin when 120 moles of water undergoes electrolysis.   [1]

69 Determine the percent composition by mass of hydrogen in water.   [1]

70 Balance the equation for the reaction between $LiOH$ and CO_2 *in your answer booklet*, using the *smallest* whole-number coefficients.   [1]

Base your answers to questions 71 through 73 on the information below and on your knowledge of chemistry.

One sample of tap water contains dissolved ions such as $Ca^{2+}(aq)$, $Mg^{2+}(aq)$, and $CO_3^{2-}(aq)$. A 150.-gram sample of this tap water contains 0.000 75 gram of $CaCO_3(aq)$. When these ions in the tap water are present in greater concentrations, the water is called hard water. The hard water can damage water pipes and water heaters by producing large deposits of solid calcium carbonate, known as scale. Some homeowners have a water softener to replace positive ions, such as $Ca^{2+}(aq)$ and $Mg^{2+}(aq)$, in hard water with sodium ions, $Na^+(aq)$.

71 Determine the parts per million of $CaCO_3$ in the tap water sample. [1]

72 State, in terms of aqueous ions, why this tap water can conduct an electric current. [1]

73 Using the key *in your answer booklet*, draw *at least two* water molecules in the box, showing the orientation of each water molecule toward the Ca^{2+} ion. [1]

_____

Base your answers to questions 74 through 77 on the information below and on your knowledge of chemistry.

A 3% hydrogen peroxide solution, $H_2O_2(aq)$, is commonly used as a disinfectant. Hydrogen peroxide, H_2O_2, decomposes as represented by the balanced equation below.

$$2H_2O_2 \rightarrow 2H_2O + O_2 + heat$$

74 State evidence, from the equation, that the reaction is exothermic. [1]

75 Explain, in terms of substances, why the reaction is a decomposition reaction. [1]

76 State how increasing the temperature of the H_2O_2 affects the rate of the reaction. [1]

77 On the potential energy diagram *in your answer booklet*, draw a double-headed arrow (↕) to indicate the interval that represents the heat of reaction. [1]

_____

Base your answers to questions 78 through 82 on the information below and on your knowledge of chemistry.

During a laboratory activity, appropriate safety equipment is used and safety procedures are followed. A student constructs a voltaic cell with magnesium and copper electrodes. The diagram and net ionic equation below represent this cell and the reaction that occurs.

Voltaic Cell

$$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$$
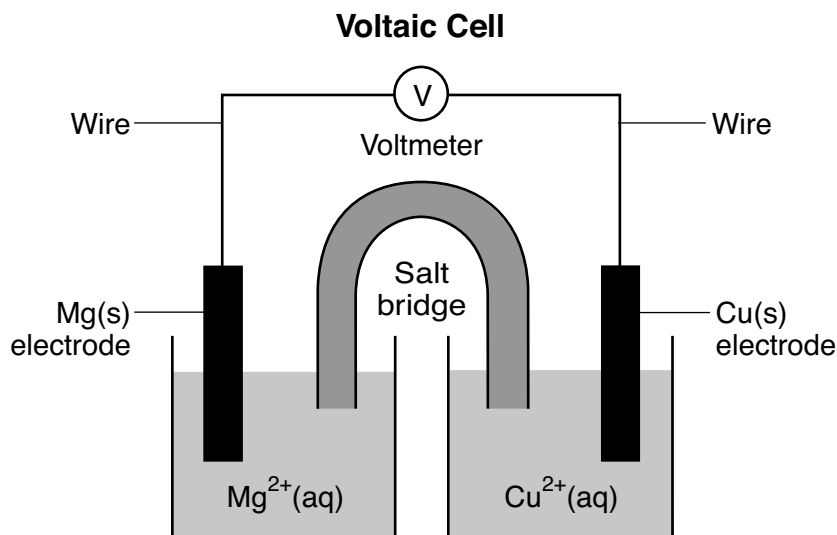
78 Identify the subatomic particles that flow through the wire as the cell operates. [1]

79 Compare the number of electrons lost to the number of electrons gained during the reaction in the operating cell. [1]

80 State the form of energy that is converted to electrical energy in the operating cell. [1]

81 Write a balanced equation for the half-reaction that occurs in the copper half-cell when the cell operates. [1]

82 Identify one metal from Table *J* that is more easily oxidized than Mg. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Element 117, Uus, has been synthesized and has at least two isotopes, Uus-293 and Uus-294. Atoms of Uus-293 can be made by bombarding Bk-249 with Ca-48 in a reaction represented by the nuclear equation below.

$$^{48}_{20}\text{Ca} + {}^{249}_{97}\text{Bk} \rightarrow {}^{293}_{117}\text{Uus} + 4{}^{1}_{0}\text{n}$$
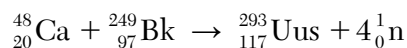
The Bk-249 has a half-life of 320. days, decays by beta emission, and also emits gamma rays.

83 Determine the fraction of Bk-249 that remains unchanged after 960. days.   [1]

84 State, in terms of *both* protons and neutrons, why Uus-293 and Uus-294 are isotopes of the same element.   [1]

85 Complete the nuclear equation *in your answer booklet* for the alpha decay of Uus-294 by writing a notation for the missing product.   [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Friday, June 16, 2023 — 1:15 to 4:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which phrase describes the nucleus of any atom?
  (1) has an overall positive charge
  (2) has an overall negative charge
  (3) contains negative electrons
  (4) contains positive electrons

2 Which two particles each have a mass of approximately one atomic mass unit?
  (1) an electron and a proton
  (2) an electron and a positron
  (3) a neutron and a proton
  (4) a neutron and a positron

3 The wave-mechanical model of the atom describes the location of electrons
  (1) as loosely packed in the nucleus of an atom
  (2) as densely packed in the nucleus of an atom
  (3) in circular paths around the nucleus
  (4) in orbitals outside the nucleus

4 When a ground state electron in an atom moves to an excited state, the electron
  (1) absorbs energy as it moves to a higher energy state
  (2) absorbs energy as it moves to a lower energy state
  (3) releases energy as it moves to a higher energy state
  (4) releases energy as it moves to a lower energy state

5 Which statement describes a chemical property of iron?
  (1) Iron is malleable.
  (2) Iron conducts electricity.
  (3) Iron reacts with nitric acid.
  (4) Iron has a high melting point.

6 Diamond and graphite are two forms of solid carbon. These two forms of carbon have
  (1) different crystal structures and different properties
  (2) different crystal structures and the same properties
  (3) the same crystal structure and different properties
  (4) the same crystal structure and the same properties

7 Which substance can be broken down by a chemical change?
  (1) cobalt   (3) krypton
  (2) ethane   (4) manganese

8 Based on Table *I*, which equation represents conservation of mass and energy?
  (1) $CH_4(g) + O_2(g) + 890.4\,kJ \rightarrow CO_2(g) + H_2O(\ell)$
  (2) $CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(\ell) + 890.4\,kJ$
  (3) $CH_4(g) + 2O_2(g) + 890.4\,kJ \rightarrow CO_2(g) + 2H_2O(\ell)$
  (4) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell) + 890.4\,kJ$

9 At STP, which property can be used to differentiate a 10.-gram sample of NaCl(s) from a 10.-gram sample of $NaNO_3(s)$?
  (1) mass of the sample
  (2) temperature of the sample
  (3) solubility in water
  (4) phase at STP

10 What is the number of electrons shared between the two atoms in an O_2 molecule?
  (1) 6   (3) 3
  (2) 2   (4) 4

11 Which changes in *both* charge and radius occur when an atom loses an electron?

(1) A negative ion is formed with a smaller radius than the atom.
(2) A negative ion is formed with a larger radius than the atom.
(3) A positive ion is formed with a smaller radius than the atom.
(4) A positive ion is formed with a larger radius than the atom.

12 Which statement describes what occurs when two iodine atoms react to produce an iodine molecule?

(1) A bond forms and energy is absorbed.
(2) A bond forms and energy is released.
(3) A bond breaks and energy is absorbed.
(4) A bond breaks and energy is released.

13 Which process can be used to separate a mixture of two liquids having different boiling points?

(1) deposition   (3) filtration
(2) distillation   (4) sublimation

14 Which statement describes a solution of sodium chloride in water?

(1) The mixture is heterogeneous, the solute is NaCl and the solvent is H_2O.
(2) The mixture is heterogeneous, the solute is H_2O and the solvent is NaCl.
(3) The mixture is homogeneous, the solute is NaCl and the solvent is H_2O.
(4) The mixture is homogeneous, the solute is H_2O and the solvent is NaCl.

15 At STP, which property would be the same for 1.0 liter of helium and 1.0 liter of argon?

(1) boiling point   (3) mass
(2) density   (4) number of atoms

16 The melting of an ice cube is an example of an

(1) endothermic, chemical change
(2) endothermic, physical change
(3) exothermic, chemical change
(4) exothermic, physical change

17 Which statement explains the low boiling point of hydrogen, H_2, at standard pressure?

(1) Hydrogen has strong covalent bonds.
(2) Hydrogen has weak covalent bonds.
(3) Hydrogen has strong intermolecular forces.
(4) Hydrogen has weak intermolecular forces.

18 In chemical reactions, which term is defined as the difference between the potential energy of the products and the potential energy of the reactants?

(1) heat of fusion
(2) heat of reaction
(3) thermal conductivity
(4) electrical conductivity

19 Which phrase describes what happens to the reaction pathway and activation energy of a reaction to which a catalyst is added?

(1) the same pathway with the same activation energy
(2) the same pathway with a lower activation energy
(3) a different pathway with the same activation energy
(4) a different pathway with a lower activation energy

20 An atom of which element is bonded to the carbon atom in the amide functional group?

(1) iodine   (3) phosphorus
(2) nitrogen   (4) sulfur

21 Which statement describes the two isomers of butane?

(1) They have the same molecular formula but different structural formulas.
(2) They have the same molecular formula and the same structural formula.
(3) They have different molecular formulas and different structural formulas.
(4) They have different molecular formulas but the same structural formula.

22 Which term represents an organic reaction that produces soap?

(1) esterification   (3) saponification
(2) fermentation   (4) solidification

23 In which part of an electrochemical cell does reduction occur?

(1) anode   (3) wire
(2) cathode   (4) voltmeter

24 Which energy change occurs in an operating voltaic cell?

(1) chemical energy to electrical energy
(2) chemical energy to nuclear energy
(3) electrical energy to chemical energy
(4) electrical energy to nuclear energy

25 Which substance is an Arrhenius base?

(1) HNO_3 (3) LiOH
(2) KNO_3 (4) CH_3COOH

26 Which statement represents neutralization?

(1) An Arrhenius acid and an Arrhenius base react to produce water and a salt.
(2) An Arrhenius acid and a salt react to produce water and an Arrhenius base.
(3) Water and an Arrhenius acid react to produce an Arrhenius base and a salt.
(4) Water and a salt react to produce an Arrhenius base and an Arrhenius acid.

27 A tenfold increase in hydronium ion concentration is represented by

(1) a decrease of one unit of pH
(2) a decrease of 10 units of pH
(3) an increase of one unit of pH
(4) an increase of 10 units of pH

28 Based on Table N, which particle is emitted by the radioactive decay of francium-220?

(1) an alpha particle   (3) a positron
(2) a beta particle   (4) a neutron

29 Which type of reaction releases the greatest amount of energy per kilogram of reactant?

(1) acid-base reaction   (3) organic reaction
(2) fission reaction   (4) redox reaction

30 Which risk is related to the radioactive isotopes used to generate electricity?

(1) depletion of fossil fuels
(2) depletion of atmospheric ozone
(3) exposure to acid rain
(4) exposure to nuclear emissions

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which Lewis electron-dot diagram represents an atom of nitrogen in the ground state?

$\ddot{N}$ $\quad$ $\cdot\ddot{N}\colon$ $\quad$ $\colon\ddot{N}\colon$ $\quad$ $\colon\ddot{N}\colon$

(1) $\qquad$ (2) $\qquad$ (3) $\qquad$ (4)

32 The atomic masses and natural abundances of the two naturally occurring isotopes of silver are shown in the table below.

Silver Isotopes

Isotope	Atomic Mass (u)	Natural Abundance (%)
Ag-107	106.905	51.8
Ag-109	108.905	48.2

Which numerical setup can be used to calculate the atomic mass of silver?

(1) (106.905 u)(51.8) + (108.905 u)(48.2)
(2) (106.905 u)(51.8%) + (108.905 u)(48.2%)
(3) (106.905 u)(48.2) + (108.905 u)(51.8)
(4) (106.905 u)(48.2%) + (108.905 u)(51.8%)

33 A potassium atom has a mass number of 37. What is the number of neutrons in this atom?

(1) 15 $\qquad$ (3) 22
(2) 18 $\qquad$ (4) 37

34 At room temperature, a student determines the density of a sample of nickel to be 9.79 g/cm³. Based on Table *S*, what is the student's percent error for the density of nickel?

(1) 0.091% $\qquad$ (3) 9.1%
(2) 0.10% $\qquad$ (4) 10.%

35 Compared to the metals in Period 2, the nonmetals in Period 2 have

(1) lower first ionization energies and lower electronegativity values
(2) lower first ionization energies and higher electronegativity values
(3) higher first ionization energies and lower electronegativity values
(4) higher first ionization energies and higher electronegativity values

36 Which formula represents calcium hydride?

(1) CaH $\qquad$ (3) CaOH
(2) CaH$_2$ $\qquad$ (4) Ca(OH)$_2$

37 What is the number of moles in a 78.8-gram sample of MgCO$_3$ (gram-formula mass = 84.3 g/mol)?

(1) 0.949 mol $\qquad$ (3) 0.843 mol
(2) 0.935 mol $\qquad$ (4) 1.070 mol

38 Given the equation representing a reaction:
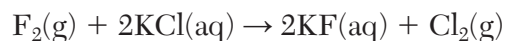
$$F_2(g) + 2KCl(aq) \rightarrow 2KF(aq) + Cl_2(g)$$

Which type of chemical reaction is represented by the equation?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

39 Based on Table *H*, which compound has the strongest intermolecular forces at 60 kPa?

(1) ethanoic acid $\qquad$ (3) propanone
(2) ethanol $\qquad$ (4) water

40 Which particle diagram represents a sample of xenon at STP?

Key

○ = atom of xenon
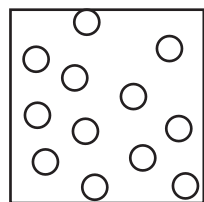
(1)
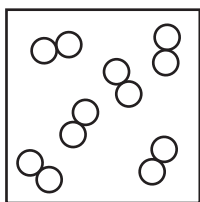
(3)
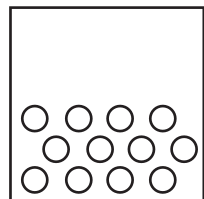
(2)
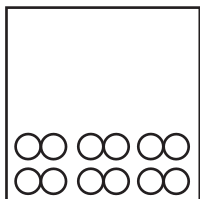
(4)

41 Based on Table *G*, which compound is *less* soluble in water as the temperature increases from 0°C to 100°C?

(1) KNO_3
(2) NH_3
(3) $KClO_3$
(4) NH_4Cl

42 How many moles of KI are needed to make 0.50 L of a 0.20 M aqueous solution?

(1) 0.10 mol
(2) 0.25 mol
(3) 0.40 mol
(4) 0.70 mol

43 A solution is prepared using 9.80 grams of $NaHCO_3$ in enough water to make 1500. grams of total solution. What is the concentration of the solution expressed in parts per million?

(1) 6.49×10^{-3} ppm
(2) 6.53×10^{-3} ppm
(3) 6.49×10^3 ppm
(4) 6.53×10^3 ppm

44 A potential energy diagram for a chemical reaction is given below. Each interval on the potential energy axis represents 100. kilojoules of potential energy.

Reaction Coordinate
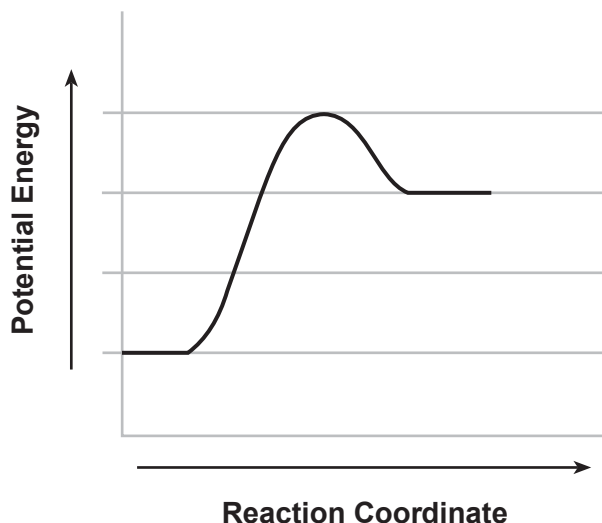
What can be concluded from the diagram?
(1) The reaction is endothermic, and the heat of reaction is −200. kJ.
(2) The reaction is endothermic, and the heat of reaction is +200. kJ.
(3) The reaction is exothermic, and the heat of reaction is −200. kJ.
(4) The reaction is exothermic, and the heat of reaction is +200. kJ.

45 Given the formula representing a compound:
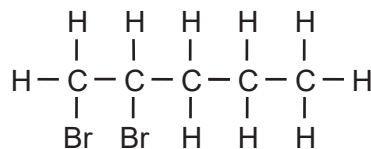
What is a chemical name of this compound?
(1) 1,1-dibromopentane
(2) 2,2-dibromopentane
(3) 1,2-dibromopentane
(4) 4,5-dibromopentane

46 The diagram and equation below represent an electrochemical cell.
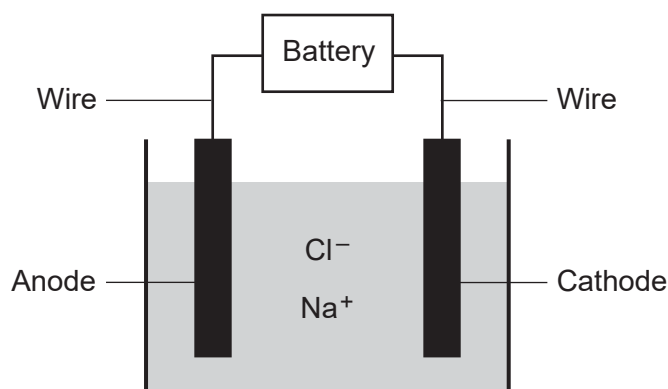
$$2NaCl(\ell) \longrightarrow 2Na(\ell) + Cl_2(g)$$

Which process is represented by this diagram?

(1) chromatography (3) electrolysis
(2) distillation (4) polymerization

47 Which aqueous solution has the greatest ability to conduct an electric current?

(1) 0.10 M NaCl(aq)
(2) 0.010 M NaCl(aq)
(3) 0.10 M $C_6H_{12}O_6$ (aq)
(4) 0.010 M $C_6H_{12}O_6$ (aq)

48 What fraction of an original sample of ^{131}I remains unchanged after 24.063 days?

(1) 1/8 (3) 1/3
(2) 1/2 (4) 1/4

49 Given the equation representing a reaction:

$$^2_1H + ^3_1H \rightarrow ^4_2He + ^1_0n + energy$$

Which type of reaction is represented by the equation?

(1) nuclear fission (3) combustion
(2) nuclear fusion (4) substitution

50 Given the nuclear equation and isotopic masses:

$$^6_3Li \quad + \quad ^2_1H \quad \rightarrow \quad 2(^4_2He) \quad + \quad energy$$
$$6.0151\ u \quad 2.0140\ u \quad 2(4.0026\ u)$$
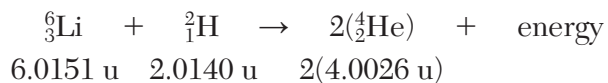
What is the amount of mass converted to energy as a result of the reaction between the two reactant nuclei?

(1) 0.0239 u (3) 8.0052 u
(2) 4.0265 u (4) 16.0343 u

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 51 and 52 on the information below and on your knowledge of chemistry.

The element technetium, Tc, has several isotopes. The bright-line spectrum of technetium has been observed in the spectra of some stars.

51 Compare the energy of an electron in the first shell of a technetium atom to the energy of an electron in the third shell of the same atom. [1]

52 State, in terms of protons and neutrons, why the various nuclides of technetium are isotopes of each other. [1]

Base your answers to questions 53 and 54 on the information below and on your knowledge of chemistry.

A sample of a gas in a sealed, rigid cylinder with a movable piston has a volume of 0.250 liter at STP.

53 Show a numerical setup for calculating the volume of this sample of gas at 298 K and 1.00 atm. [1]

54 State a change in pressure that will cause the gas in the cylinder to behave more like an ideal gas. [1]

Base your answers to questions 55 through 57 on the information below and on your knowledge of chemistry.

During a laboratory activity, a student heats a beaker containing 120.0 grams of water as shown in the diagram below.
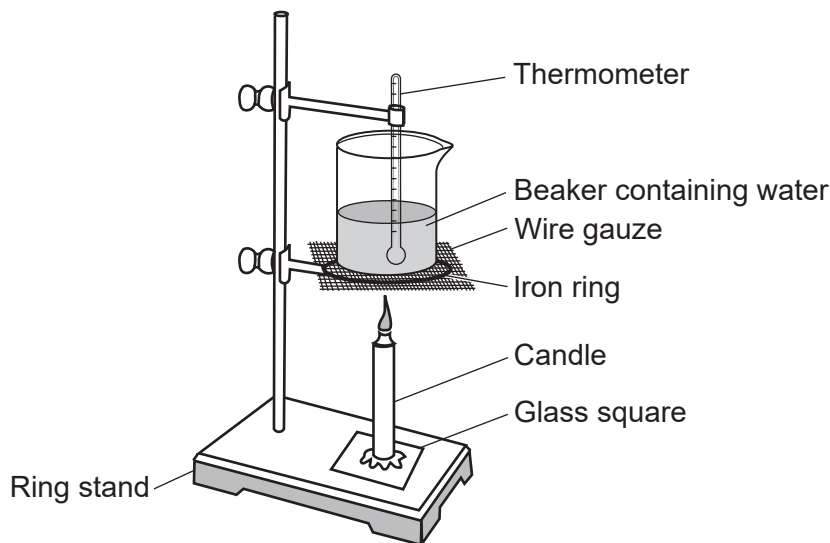
The table below shows the mass of the water and the temperature of the water before and after heating. During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

Data for Heating Water

Mass of 120.0 mL of water	120.0 g
Temperature of water before heating	23.0°C
Temperature of water after heating 20.0 min	86.0°C

55 State the direction of heat flow between the candle flame and the beaker of water during the time the candle is lit. [1]

56 Show a numerical setup for calculating the amount of heat, in joules, absorbed by the water in the beaker as a result of the burning candle. [1]

57 State how the molecular motion of the water molecules in the beaker changes as the temperature increases. [1]

Base your answers to questions 58 through 60 on the information below and on your knowledge of chemistry.

Nitrogen dioxide gas, $NO_2(g)$, can reach equilibrium with dinitrogen tetroxide gas, $N_2O_4(g)$, in a closed system. At 1.0 atmosphere, the boiling point of N_2O_4 is 21°C. The equation below represents this system.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) + energy$$

58 Compare the rate of the forward reaction to the rate of the reverse reaction when the system is at equilibrium. [1]

59 State how the equilibrium shifts when the pressure on the equilibrium system is increased at constant temperature. [1]

60 Compare the entropy of a sample of dinitrogen tetroxide gas at 25°C and 1.0 atmosphere to the entropy of the same sample of dinitrogen tetroxide liquid at 15°C and 1.0 atmosphere. [1]

_____

Base your answers to questions 61 through 63 on the information below and on your knowledge of chemistry.

When solid copper is placed in an aqueous silver nitrate solution, a reaction occurs, as represented by the equation below.

$$Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$
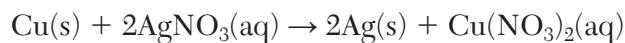
61 State the change in oxidation state of copper in this reaction. [1]

62 Based on Table J, state why Cu(s) reacts spontaneously with $Ag^+(aq)$. [1]

63 Write a balanced half-reaction equation to represent the reduction of the silver ions to silver atoms. [1]

_____

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

During a laboratory activity, 15.0 mL of hydrochloric acid, HCl(aq), is exactly neutralized by 18.2 mL of 0.11 M sodium hydroxide, NaOH(aq). During the laboratory activity, appropriate safety equipment is used and safety procedures are followed.

64 Write the name of the laboratory procedure used in this activity. [1]

65 Show a numerical setup for calculating the molarity of the HCl(aq) solution. [1]

_____

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

Several elements are considered endangered because there is a risk of these elements becoming unavailable for commercial uses in the next 100 years. Helium, zinc, gallium, indium, and tellurium are included in the list of these endangered elements.

66 Identify the *three* endangered elements listed in the passage that are classified as metals. [1]

67 Explain, in terms of electrons, why gallium and indium have similar chemical properties. [1]

68 Compare the density of a sample of helium at STP with the density of a sample of tellurium at STP. [1]

69 Explain, in terms of electron shells, why the atomic radius of an atom of indium is greater than the atomic radius of an atom of gallium when both atoms are in the ground state. [1]

Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

The Ostwald process is an industrial method to produce nitric acid, $HNO_3(aq)$, used in the manufacture of fertilizers. Several steps are involved in this process. In the first step, ammonia and oxygen react in the presence of a catalyst, as represented by unbalanced equation 1.

Equation 1: $NH_3(g) + O_2(g) \rightarrow NO(g) + H_2O(g) + $ heat
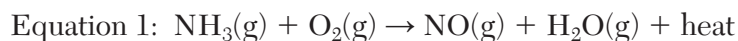
In the second step, nitrogen(II) oxide reacts with oxygen to produce nitrogen(IV) oxide, represented by balanced equation 2 below.

Equation 2: $2NO(g) + O_2(g) \rightarrow 2NO_2(g) + $ heat
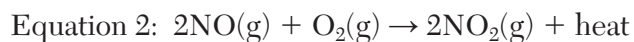
70 Determine the percent composition by mass of nitrogen in HNO_3 (gram-formula mass = 63.0 g/mol). [1]

71 Balance equation 1 *in your answer booklet*, using the smallest whole-number coefficients. [1]

72 Show a numerical setup for calculating the gram-formula mass of the $NO_2(g)$ produced in equation 2. [1]

73 Determine the number of moles of oxygen required to completely react with 4.0 moles of $NO(g)$ in equation 2. [1]

Base your answers to questions 74 through 78 on the information below and on your knowledge of chemistry.

As plants grow, light energy is converted into chemical energy during the process of photosynthesis. The reaction produces glucose and oxygen. The balanced equation below represents photosynthesis.

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

74 State the molecular polarity for each of the reactants in the equation. [1]

75 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for a molecule of water. [1]

76 Based on Table S, compare the strength of attraction of a carbon atom for electrons with the strength of attraction of an oxygen atom for the electrons in a bond between them. [1]

77 State, in terms of element classification, why CO_2 is a molecular compound. [1]

78 Write the empirical formula for glucose. [1]

Base your answers to questions 79 through 81 on the information below and on your knowledge of chemistry.

In the United States, nearly all fuel for automobiles is a mixture of gasoline and ethanol, C_2H_5OH. The equation below represents a reaction between ethene and water to produce ethanol.
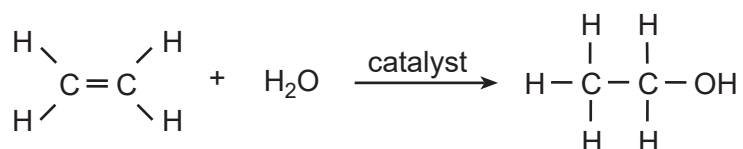
79 State the class of organic compound to which the product in the equation belongs. [1]

80 State, in terms of carbon-to-carbon bonds, why the hydrocarbon in the equation is unsaturated. [1]

81 Identify the element in the product of the reaction that allows it to be classified as an organic compound. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

In a laboratory activity, a student measures the pH values of four household liquids and distilled water, as shown in the table below. During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

Measured pH Value of Liquids Tested

Liquid Tested	Measured pH Value
aqueous ammonia	11.9
black coffee	4.9
lemon juice	2.1
vinegar	3.3
distilled water	7.0

82 Identify the liquid tested by the student that is most acidic. [1]

83 State the color of bromcresol green after the indicator is added to a sample of lemon juice. [1]

84 Complete the equation *in your answer booklet* by writing the formula of the missing product in the reaction of aqueous potassium hydroxide with the vinegar, acetic acid. [1]

85 Based on the pH value in the table, compare the concentration of hydronium ions to the concentration of hydroxide ions in the distilled water. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING

CHEMISTRY

Thursday, August 13, 2015 — 12:30 to 3:30 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, select the word or expression that, of those given, best completes the statement or answers the question. Record your answer on the separate answer sheet in accordance with the directions on the front page of this booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which subatomic particles are paired with their charges?

(1) electron–positive, neutron–negative, proton–neutral
(2) electron–negative, neutron–neutral, proton–positive
(3) electron–negative, neutron–positive, proton–neutral
(4) electron–neutral, neutron–positive, proton–negative

2 In the ground state, an atom of which element has two valence electrons?

(1) Cr   (3) Ni
(2) Cu   (4) Se

3 The atoms in a sample of an element are in excited states. A bright-line spectrum is produced when these atoms

(1) absorb energy   (3) emit energy
(2) absorb positrons   (4) emit positrons

4 Which statement describes a concept included in the wave-mechanical model of the atom?

(1) Positrons are located in shells outside the nucleus.
(2) Neutrons are located in shells outside the nucleus.
(3) Protons are located in orbitals outside the nucleus.
(4) Electrons are located in orbitals outside the nucleus.

5 All elements on the modern Periodic Table are arranged in order of increasing

(1) atomic mass
(2) molar mass
(3) number of neutrons per atom
(4) number of protons per atom

6 At STP, which substance is a noble gas?

(1) ammonia   (3) neon
(2) chlorine   (4) nitrogen

7 At STP, oxygen exists in two forms, $O_2(g)$ and $O_3(g)$. These two forms of oxygen have

(1) different molecular structures and different properties
(2) different molecular structures and the same properties
(3) the same molecular structure and different properties
(4) the same molecular structure and the same properties

8 Which statement describes a chemical property of sodium?

(1) Sodium has a melting point of 371 K.
(2) Sodium has a molar mass of 23 grams.
(3) Sodium can conduct electricity in the liquid phase.
(4) Sodium can combine with chlorine to produce a salt.

9 Which term identifies a type of chemical reaction?

(1) decomposition   (3) sublimation
(2) distillation   (4) vaporization

10 Based on Table S, an atom of which element has the *weakest* attraction for electrons in a chemical bond?

(1) polonium   (3) selenium
(2) sulfur   (4) tellurium

11 Given the balanced equation:

$$F_2 + energy \rightarrow F + F$$

Which statement describes what occurs during this reaction?

(1) Energy is absorbed as a bond is formed.
(2) Energy is absorbed as a bond is broken.
(3) Energy is released as a bond is formed.
(4) Energy is released as a bond is broken.

12 Which atoms will bond when valence electrons are transferred from one atom to the other?

(1) O and Se   (3) O and H
(2) O and Sr   (4) O and P

13 Which sample of matter is a mixture?

(1) $Br_2(\ell)$ (3) $KBr(s)$
(2) $K(s)$ (4) $KBr(aq)$

14 According to kinetic molecular theory, collisions between gas particles in a sample of an ideal gas

(1) increase the energy content of the gas sample
(2) produce strong attractive forces between the gas particles
(3) result in a net loss of energy by the gas sample
(4) transfer energy between the gas particles

15 Which substance can *not* be broken down by a chemical change?

(1) ethane   (3) silicon
(2) propanone   (4) water

16 The temperature of a sample of matter is a measure of the

(1) average potential energy of the particles of the sample
(2) average kinetic energy of the particles of the sample
(3) total nuclear energy of the sample
(4) total thermal energy of the sample

17 Under which conditions of temperature and pressure does a real gas behave most like an ideal gas?

(1) 37 K and 1 atm   (3) 347 K and 1 atm
(2) 37 K and 8 atm   (4) 347 K and 8 atm

18 The ratio of chromium to iron to carbon varies among the different types of stainless steel. Therefore, stainless steel is classified as

(1) a compound   (3) a mixture
(2) an element   (4) a substance

19 Which statement explains why increasing the temperature increases the rate of a chemical reaction, while other conditions remain the same?

(1) The reacting particles have less energy and collide less frequently.
(2) The reacting particles have less energy and collide more frequently.
(3) The reacting particles have more energy and collide less frequently.
(4) The reacting particles have more energy and collide more frequently.

20 An open flask is half filled with water at 25°C. Phase equilibrium can be reached after

(1) more water is added to the flask
(2) the flask is stoppered
(3) the temperature is decreased to 15°C
(4) the temperature is increased to 35°C

21 Which formula represents an unsaturated organic compound?

(1) CH_4 (3) C_3H_8
(2) C_2H_4 (4) C_4H_{10}

22 All isomers of octane have the same

(1) molecular formula   (3) physical properties
(2) structural formula   (4) IUPAC name

23 Which formula represents a hydrocarbon?

(1) CH_3I (3) CH_3CH_3
(2) CH_3NH_2 (4) CH_3OH

24 In a redox reaction, the number of electrons lost is equal to the number of

(1) protons lost   (3) neutrons gained

(2) neutrons lost   (4) electrons gained

25 At which electrode does oxidation occur in a voltaic cell and in an electrolytic cell?

(1) the anode in a voltaic cell and the cathode in an electrolytic cell

(2) the cathode in a voltaic cell and the anode in an electrolytic cell

(3) the anode in both a voltaic cell and an electrolytic cell

(4) the cathode in both a voltaic cell and an electrolytic cell

26 Based on the Arrhenius theory, when potassium hydroxide dissolves in water, the only negative ion in the aqueous solution is

(1) O^{2-} (aq)   (3) H^- (aq)

(2) OH^{2-} (aq)   (4) OH^- (aq)

27 Compared to distilled water, an aqueous salt solution has

(1) better electrical conductivity

(2) poorer electrical conductivity

(3) a lower boiling point at standard pressure

(4) a higher freezing point at standard pressure

28 According to one acid-base theory, water can act as a base because a water molecule can

(1) donate an H^+ ion   (3) donate an H^- ion

(2) accept an H^+ ion   (4) accept an H^- ion

29 Compared to the half-life and decay mode of the nuclide ^{90}Sr, the nuclide ^{226}Ra has

(1) a longer half-life and the same decay mode

(2) a longer half-life and a different decay mode

(3) a shorter half-life and the same decay mode

(4) a shorter half-life and a different decay mode

30 Which net change occurs in a nuclear fusion reaction?

(1) Ionic bonds are broken.

(2) Ionic bonds are formed.

(3) Energy is converted to mass.

(4) Mass is converted to energy.

Directions (31–50): For each statement or question, select the word or expression that, of those given, best completes the statement or answers the question. Record your answer in the separate answer sheet in accordance with the directions on the front page of this booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 Which conclusion was drawn from the results of the gold foil experiment?

(1) An atom is electrically neutral.
(2) An atom is mostly empty space.
(3) The nucleus of an atom is negatively charged.
(4) The electrons in an atom are located in specific shells.

32 Which electron configuration represents an atom of magnesium in an excited state?

(1) 2–7–3   (3) 2–8–2
(2) 2–7–6   (4) 2–8–5

33 Which group on the Periodic Table has elements with atoms that tend *not* to bond with atoms of other elements?

(1) Group 1   (3) Group 17
(2) Group 2   (4) Group 18

34 Which group on the Periodic Table has at least one element in each of the three phases of matter at STP?

(1) 1   (3) 17
(2) 2   (4) 18

35 Rubidium and cesium have similar chemical properties because, in the ground state, the atoms of both elements each have

(1) one electron in the outermost shell
(2) two electrons in the outermost shell
(3) one neutron in the nucleus
(4) two neutrons in the nucleus

36 As the first five elements in Group 15 are considered in order of increasing atomic number, first ionization energy

(1) decreases
(2) increases
(3) decreases, then increases
(4) increases, then decreases

37 Which substance in the table below has the strongest intermolecular forces?

Substance	Molar Mass (g/mol)	Boiling Point (kelvins)
HF	20.01	293
HCl	36.46	188
HBr	80.91	207
HI	127.91	237

(1) HF   (3) HBr
(2) HCl   (4) HI

38 Which ion in the ground state has the same electron configuration as an atom of argon in the ground state?

(1) Al^{3+} (3) K^+
(2) O^{2-} (4) F^-

39 What is the number of pairs of electrons shared in a molecule of N_2?

(1) 1   (3) 3
(2) 2   (4) 6

40 Which statement explains why a C–O bond is more polar than a F–O bond?

(1) At STP, carbon has a greater density than fluorine.

(2) A carbon atom has more valence electrons than a fluorine atom.

(3) The difference in electronegativity between carbon and oxygen is greater than that between fluorine and oxygen.

(4) The difference in first ionization energy between carbon and oxygen is greater than that between fluorine and oxygen.

41 A mixture consists of sand and an aqueous salt solution. Which procedure can be used to separate the sand, salt, and water from each other?

(1) Evaporate the water, then filter out the salt.

(2) Evaporate the water, then filter out the sand.

(3) Filter out the salt, then evaporate the water.

(4) Filter out the sand, then evaporate the water.

42 An aqueous solution has a mass of 490 grams containing 8.5×10^{-3} gram of calcium ions. The concentration of calcium ions in this solution is

(1) 4.3 ppm   (3) 17 ppm

(2) 8.5 ppm   (4) 34 ppm

43 A sample of hydrogen gas at 2.0 atmospheres and 273 K occupies a volume of 5.0 liters. The gas sample is completely transferred to a 10.0-liter sealed, rigid container. What is the new pressure of the gas sample when the temperature returns to 273 K?

(1) 1.0 atm   (3) 3.0 atm

(2) 2.0 atm   (4) 4.0 atm

44 Given the equation for a system at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{energy}$$
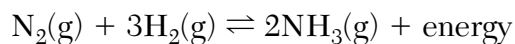
If only the concentration of $N_2(g)$ is increased, the concentration of

(1) $NH_3(g)$ increases

(2) $NH_3(g)$ remains the same

(3) $H_2(g)$ increases

(4) $H_2(g)$ remains the same

45 A hydrocarbon molecule has seven carbon atoms in a straight chain. There is a double bond between the third carbon atom and the fourth carbon atom in the chain. The IUPAC name for this hydrocarbon is

(1) 3-heptyne   (3) 3-heptene

(2) 4-heptyne   (4) 4-heptene

46 Given the balanced equation representing a reaction:
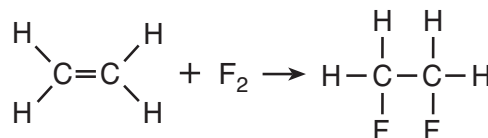
Which type of reaction is represented by this equation?

(1) addition   (3) polymerization

(2) fermentation   (4) substitution

47 Given the diagram representing an incomplete electrochemical cell:
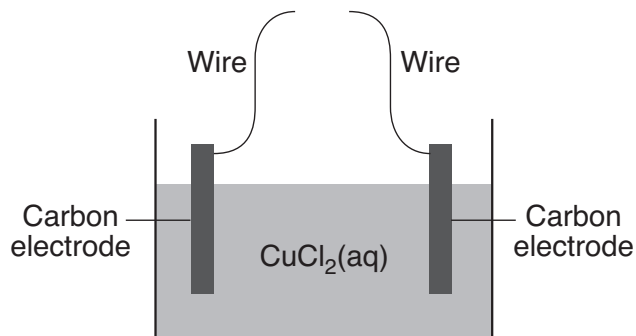
Solid copper will be deposited on one of the carbon electrodes when the wires are connected to

(1) each other   (3) a switch

(2) a battery   (4) a voltmeter

48 What is the volume of 0.30 M NaOH(aq) needed to completely neutralize 15.0 milliliters of 0.80 M HCl(aq)?

(1) 3.6 mL   (3) 20. mL

(2) 5.6 mL   (4) 40. mL

49 Which equation represents a spontaneous transmutation?

(1) $Ca(s) + 2H_2O(\ell) \rightarrow Ca(OH)_2(aq) + H_2(g)$

(2) $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$

(3) $^{239}_{94}Pu + 2^{1}_{0}n \rightarrow {}^{241}_{95}Am + {}^{0}_{-1}e$

(4) $^{37}_{20}Ca \rightarrow {}^{37}_{19}K + {}^{0}_{+1}e$
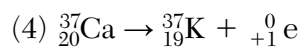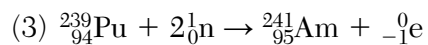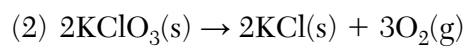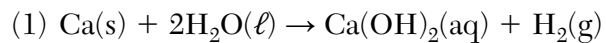
50 Which particle has two neutrons?
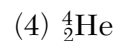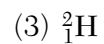
(1) $^{1}_{0}n$

(2) $^{1}_{1}H$

(3) $^{2}_{1}H$

(4) $^{4}_{2}He$

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in the separate answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

51 Determine the vapor pressure of ethanol at 90.°C. [1]

52 Explain, in terms of particle arrangement, why a sample of solid NaCl has *less* entropy than a sample of aqueous NaCl. [1]

53 Determine the molecular formula for a compound that has the empirical formula CH_2O and a molar mass of 120. grams per mole. [1]

54 A student drew the Lewis electron-dot diagram below to represent sodium chloride.

$$\text{Na} \; :\!\overset{\displaystyle\cdot\cdot}{\underset{\displaystyle\cdot\cdot}{\text{Cl}}}\!:$$

Explain why this diagram is *not* an accurate representation for the bonding in NaCl. [1]

55 Given the formula for heptanal:

```
      H   H   H   H   H   H   O
      |   |   |   |   |   |   ‖
  H − C − C − C − C − C − C − C − H
      |   |   |   |   |   |
      H   H   H   H   H   H
```
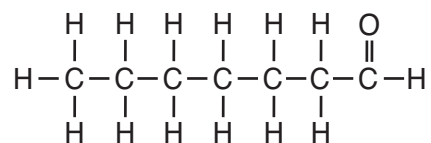
Determine the gram-formula mass of heptanal. [1]

56 Compare the mass of a proton to the mass of an electron. [1]

57 In nature, 1.07% of the atoms in a carbon sample are C-13 atoms. In the space *in your answer booklet*, show a numerical setup for calculating the number of C-13 atoms in a sample containing 3.28×10^{24} atoms of carbon. [1]

Base your answers to questions 58 and 59 on the information below and on your knowledge of chemistry.

A sample of a substance is a liquid at 65°C. The sample is heated uniformly to 125°C. The heating curve for the sample at standard pressure is shown below.

Heating Curve
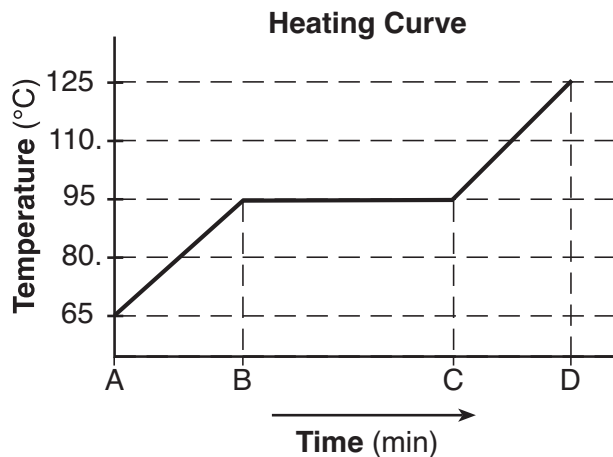
58 Determine the boiling point of the sample at standard pressure. [1]

59 State what happens to the potential energy of the particles of the sample during time interval BC. [1]

_____

Base your answers to questions 60 and 61 on the information below and on your knowledge of chemistry.

A sample of nitric acid contains both H_3O^+ ions and NO_3^- ions. This sample has a pH value of 1.

60 Write a name of the positive ion present in this sample. [1]

61 What is the color of methyl orange after it is added to this sample? [1]

_____

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

One fission reaction for U-235 is represented by the balanced nuclear equation below.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n$$
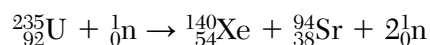
Both radioisotopes produced by this fission reaction undergo beta decay. The half-life of Xe-140 is 13.6 seconds and the half-life of Sr-94 is 1.25 minutes.

62 Explain, in terms of *both* reactants and products, why the reaction represented by the nuclear equation is a fission reaction.   [1]

63 Complete the equation *in your answer booklet* for the decay of Xe-140 by writing a notation for the missing product.   [1]

64 Determine the time required for an original 24.0-gram sample of Sr-94 to decay until only 1.5 grams of the sample remains unchanged.   [1]

65 On the diagram *in your answer booklet*, draw an arrow to represent the path of an emitted beta particle in the electric field between two oppositely charged metal plates.   [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in the separate answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

The two naturally occurring isotopes of antimony are Sb-121 and Sb-123. The table below shows the atomic mass and percent natural abundance for these isotopes.

Naturally Occurring Isotopes of Antimony

Isotope	Atomic Mass (u)	Natural Abundance (%)
Sb-121	120.90	57
Sb-123	122.90	43

Antimony and sulfur are both found in the mineral stibnite, Sb_2S_3. To obtain antimony, stibnite is roasted (heated in air), producing oxides of antimony and sulfur. The unbalanced equation below represents one of the reactions that occurs during the roasting.

$$Sb_2S_3(s) + O_2(g) \rightarrow Sb_2O_3(s) + SO_2(g)$$
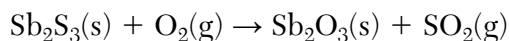
66 Determine the percent composition by mass of antimony in stibnite (gram-formula mass = 340. g/mol).   [1]

67 In the space *in your answer booklet*, show a correct numerical setup for calculating the atomic mass of antimony.   [1]

68 Complete the balancing of the equation *in your answer booklet* for the roasting of stibnite, using the smallest whole-number coefficients.   [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

In a laboratory investigation, ammonium chloride was dissolved in water. Laboratory procedures and corresponding observations made by a student during the investigation are shown in the table below.

Dissolving NH$_4$Cl(s) in H$_2$O(ℓ)

Procedure	Observation
1. Measure the temperature of 10.0 milliliters (10.0 grams) of H$_2$O(ℓ) in a test tube.	1. The temperature of the H$_2$O(ℓ) was 25.8°C.
2. Add 5.0 grams of the solute, NH$_4$Cl(s), to the H$_2$O(ℓ).	2. The NH$_4$Cl(s) settled to the bottom of the test tube.
3. Stir the contents of the test tube for 4 minutes.	3. A small amount of NH$_4$Cl(s) remained at the bottom of the test tube.
4. Measure the temperature of the NH$_4$Cl(aq) solution.	4. The temperature of the solution was 11.2°C.

69 Identify *two* types of bonds in the solute. [1]

70 State evidence from the investigation that indicates the NH$_4$Cl(aq) solution is saturated. [1]

71 State evidence from the investigation that indicates the process of dissolving the NH$_4$Cl(s) in water is endothermic. [1]

72 State the observation that would be made if procedure 3 is repeated with the original temperature of the H$_2$O(ℓ) at 98°C. [1]

Base your answers to questions 73 and 74 on the information below and on your knowledge of chemistry.

Coal is a fuel consisting primarily of carbon. In an open system, the carbon that burns completely in air produces carbon dioxide and heat. This reaction is represented by the balanced equation below.

$$C(s) + O_2(g) \rightarrow CO_2(g) + heat$$
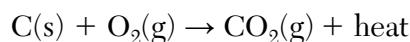
73 *In your answer booklet*, use the key to draw *at least five* particles in the box to represent the phase of the product. [1]

74 On the potential energy diagram *in your answer booklet*, draw a double-headed arrow (↕) to indicate the interval that represents the heat of reaction. [1]

Base your answers to questions 75 and 76 on the information below and on your knowledge of chemistry.

During the winter months, icy roads pose a threat to motorists and can lead to accidents. A mixture of sand and sodium chloride, NaCl, can be spread on roads to make winter driving safer.
One New York town requires that a mixture of sand and salt used on residential roads should contain 25% or less of NaCl by mass. A 10.0-gram sample of a mixture of sand and NaCl was analyzed and found to contain 3.3 grams of NaCl.

75 State, in terms of freezing point, why sodium chloride is part of the mixture put on icy roads. [1]

76 Explain, in terms of composition by mass, why the mixture from which the analyzed sample was taken should *not* be used on residential roads of the town. [1]

Base your answers to questions 77 and 78 on the information below and on your knowledge of chemistry.

In a laboratory investigation, a solution that contains 13.2 grams of $Pb(NO_3)_2$ reacts completely with a solution that contains 12.0 grams of NaI, producing 18.4 grams of PbI_2 and an undetermined mass of a second product, $NaNO_3$. This reaction is represented by the balanced equation below.

$$Pb(NO_3)_2 + 2NaI \rightarrow PbI_2 + 2NaNO_3$$
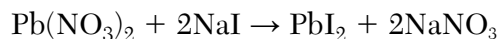
77 Identify the compound produced that is insoluble in water. [1]

78 Determine the mass of $NaNO_3$ produced. [1]

Base your answers to questions 79 and 80 on the information below and on your knowledge of chemistry.

Two organic compounds, geraniol and linalool, can be represented by the molecular formula $C_{10}H_{18}O$. Geraniol has an odor similar to the scent of roses and linalool has an odor similar to the scent of citrus fruits. Both compounds are nearly insoluble in water. The structural formulas of geraniol and linalool are shown below.
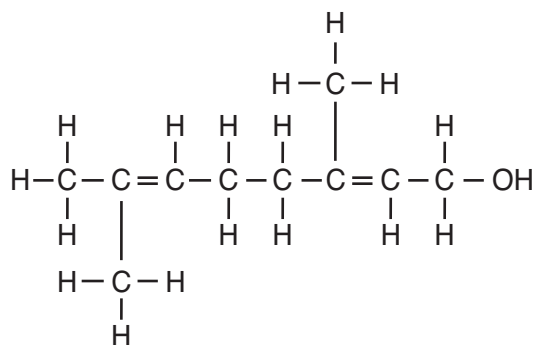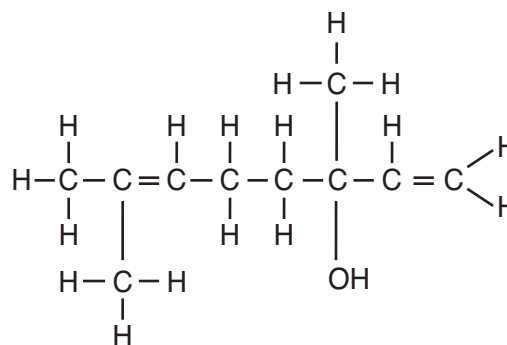
Geraniol   **Linalool**

79 Write the name of the class of organic compound to which both geraniol and linalool belong. [1]

80 Explain, in terms of molecular polarity, why geraniol and linalool are nearly insoluble in water. [1]

_____

Base your answers to questions 81 and 82 on the information below and on your knowledge of chemistry.

The gastric juice of the human stomach has a pH value of approximately 1.5. Hydrochloric acid in the gastric juice is necessary for the digestion process. However, excess hydrochloric acid may harm the stomach lining. One type of antacid uses $Mg(OH)_2(s)$ to neutralize excess hydrochloric acid in the stomach. This neutralization is represented by the incomplete equation below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow \underline{\quad} (aq) + 2H_2O(\ell)$$
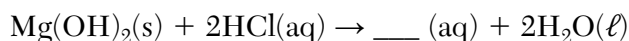
81 Complete the equation *in your answer booklet* by writing the formula of the missing product. [1]

82 Describe the changes in *both* the hydrogen ion concentration and the pH of the gastric juice of a human after ingesting this type of antacid. [1]

_____

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Early scientists defined oxidation as a chemical reaction in which oxygen combined with another element to produce an oxide of the element. An example of oxidation based on this definition is the combustion of methane. This reaction is represented by the balanced equation below.

Equation 1: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
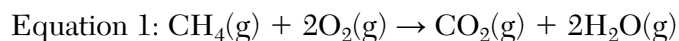
The definition of oxidation has since been expanded to include many reactions that do not involve oxygen. An example of oxidation based on this expanded definition is the reaction between magnesium ribbon and powdered sulfur when heated in a crucible. This reaction is represented by the balanced equation below.

Equation 2: $Mg(s) + S(s) \rightarrow MgS(s)$
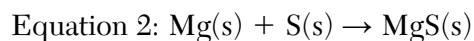
83 State why early scientists classified the reaction represented by equation 1 as oxidation. [1]

84 Determine the change in oxidation number of carbon in equation 1. [1]

85 Write a balanced half-reaction equation for the oxidation that occurs in the reaction represented by equation 2. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, August 17, 2016 — 8:30 to 11:30 a.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

1 Which change occurs when an atom in an excited state returns to the ground state?

(1) Energy is emitted.
(2) Energy is absorbed.
(3) The number of electrons decreases.
(4) The number of electrons increases.

2 The valence electrons in an atom of phosphorus in the ground state are all found in

(1) the first shell   (3) the third shell
(2) the second shell   (4) the fourth shell

3 Which two elements have the most similar chemical properties?

(1) beryllium and magnesium
(2) hydrogen and helium
(3) phosphorus and sulfur
(4) potassium and strontium

4 Which phrase describes a compound that consists of two elements?

(1) a mixture in which the elements are in a variable proportion

(2) a mixture in which the elements are in a fixed proportion

(3) a substance in which the elements are chemically combined in a variable proportion

(4) a substance in which the elements are chemically combined in a fixed proportion

5 The formula mass of a compound is the

(1) sum of the atomic masses of its atoms
(2) sum of the atomic numbers of its atoms
(3) product of the atomic masses of its atoms
(4) product of the atomic numbers of its atoms

6 The arrangement of the elements from left to right in Period 4 on the Periodic Table is based on

(1) atomic mass
(2) atomic number
(3) the number of electron shells
(4) the number of oxidation states

7 Which diatomic molecule is formed when the two atoms share six electrons?

(1) H_2 (3) O_2
(2) N_2 (4) F_2

8 Which formula represents a polar molecule?

(1) O_2 (3) NH_3
(2) CO_2 (4) CH_4

9 Which element is *least* likely to undergo a chemical reaction?

(1) lithium   (3) fluorine
(2) carbon   (4) neon

10 Which element has a melting point higher than the melting point of rhenium?

(1) iridium   (3) tantalum
(2) osmium   (4) tungsten

11 Which property can be defined as the ability of a substance to be hammered into thin sheets?

(1) conductivity   (3) melting point
(2) malleability   (4) solubility

12 Which list of elements consists of a metal, a metalloid, and a noble gas?

(1) aluminum, sulfur, argon
(2) magnesium, sodium, sulfur
(3) sodium, silicon, argon
(4) silicon, phosphorus, chlorine

13 Which sample of matter has a crystal structure?

(1) Hg(ℓ) (3) NaCl(s)
(2) H$_2$O(ℓ) (4) CH$_4$(g)

14 One mole of liquid water and one mole of solid water have *different*

(1) masses
(2) properties
(3) empirical formulas
(4) gram-formula masses

15 Which substance can *not* be broken down by a chemical change?

(1) butanal (3) gold
(2) propene (4) water

16 Which statement describes particles of an ideal gas, based on the kinetic molecular theory?

(1) Gas particles are separated by distances smaller than the size of the gas particles.
(2) Gas particles do not transfer energy to each other when they collide.
(3) Gas particles have no attractive forces between them.
(4) Gas particles move in predictable, circular motion.

17 Which expression could represent the concentration of a solution?

(1) 3.5 g (3) 3.5 mL
(2) 3.5 M (4) 3.5 mol

18 Which form of energy is associated with the random motion of the particles in a sample of water?

(1) chemical energy (3) nuclear energy
(2) electrical energy (4) thermal energy

19 Which change is most likely to occur when a molecule of H$_2$ and a molecule of I$_2$ collide with proper orientation and sufficient energy?

(1) a chemical change, because a compound is formed
(2) a chemical change, because an element is formed
(3) a physical change, because a compound is formed
(4) a physical change, because an element is formed

20 Which changes can reach dynamic equilibrium?

(1) nuclear changes, only
(2) chemical changes, only
(3) nuclear and physical changes
(4) chemical and physical changes

21 What occurs when a reaction reaches equilibrium?

(1) The concentration of the reactants increases.
(2) The concentration of the products increases.
(3) The rate of the forward reaction is equal to the rate of the reverse reaction.
(4) The rate of the forward reaction is slower than the rate of the reverse reaction.

22 In terms of potential energy, *PE*, which expression defines the heat of reaction for a chemical change?

(1) $PE_{products} - PE_{reactants}$

(2) $PE_{reactants} - PE_{products}$

(3) $\dfrac{PE_{products}}{PE_{reactants}}$

(4) $\dfrac{PE_{reactants}}{PE_{products}}$

23 Systems in nature tend to undergo changes that result in

(1) lower energy and lower entropy
(2) lower energy and higher entropy
(3) higher energy and lower entropy
(4) higher energy and higher entropy

24 What occurs when Cr^{3+} ions are reduced to Cr^{2+} ions?

(1) Electrons are lost and the oxidation number of chromium increases.
(2) Electrons are lost and the oxidation number of chromium decreases.
(3) Electrons are gained and the oxidation number of chromium increases.
(4) Electrons are gained and the oxidation number of chromium decreases.

25 Where do reduction and oxidation occur in an electrolytic cell?

(1) Both occur at the anode.
(2) Both occur at the cathode.
(3) Reduction occurs at the anode, and oxidation occurs at the cathode.
(4) Reduction occurs at the cathode, and oxidation occurs at the anode.

26 Which compound is an electrolyte?

(1) H_2O (3) H_3PO_4
(2) C_2H_6 (4) CH_3OH

27 When the hydronium ion concentration of an aqueous solution is increased by a factor of 10, the pH value of the solution

(1) decreases by 1   (3) decreases by 10
(2) increases by 1   (4) increases by 10

28 The stability of isotopes is related to the ratio of which particles in the atoms?

(1) electrons and protons
(2) electrons and positrons
(3) neutrons and protons
(4) neutrons and positrons

29 Which radioisotope has the fastest rate of decay?

(1) ^{14}C (3) ^{53}Fe
(2) ^{37}Ca (4) ^{42}K

30 The atomic mass of an element is the weighted average of the atomic masses of

(1) the least abundant isotopes of the element
(2) the naturally occurring isotopes of the element
(3) the artificially produced isotopes of the element
(4) the natural and artificial isotopes of the element

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which list of elements is arranged in order of increasing electronegativity?

(1) Be, Mg, Ca   (3) K, Ca, Sc
(2) F, Cl, Br   (4) Li, Na, K

32 The table below gives the masses of two different subatomic particles found in an atom.

Subatomic Particles and Their Masses

Subatomic Particle	Mass (g)
X	1.67×10^{-24}
Z	9.11×10^{-28}

Which of the subatomic particles are each paired with their corresponding name?

(1) *X*, proton and Z, electron
(2) *X*, proton and Z, neutron
(3) *X*, neutron and Z, proton
(4) *X*, electron and Z, proton

33 Which electron configuration represents an excited state for an atom of calcium?

(1) 2-8-7-1   (3) 2-8-7-3
(2) 2-8-7-2   (4) 2-8-8-2

34 At STP, graphite and diamond are two solid forms of carbon. Which statement explains why these two forms of carbon differ in hardness?

(1) Graphite and diamond have different ionic radii.
(2) Graphite and diamond have different molecular structures.
(3) Graphite is a metal, but diamond is a nonmetal.
(4) Graphite is a good conductor of electricity, but diamond is a poor conductor of electricity.

35 Which equation shows conservation of charge?

(1) $Cu + Ag^+ \rightarrow Cu^{2+} + Ag$
(2) $Mg + Zn^{2+} \rightarrow 2Mg^{2+} + Zn$
(3) $2F_2 + Br^- \rightarrow 2F^- + Br_2$
(4) $2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$

36 What occurs when potassium reacts with chlorine to form potassium chloride?

(1) Electrons are shared and the bonding is ionic.
(2) Electrons are shared and the bonding is covalent.
(3) Electrons are transferred and the bonding is ionic.
(4) Electrons are transferred and the bonding is covalent.

37 Given the balanced equation representing a reaction:

$$H_2 + energy \rightarrow H + H$$

What occurs as bonds are broken in one mole of H_2 molecules during this reaction?

(1) Energy is absorbed and one mole of unbonded hydrogen atoms is produced.
(2) Energy is absorbed and two moles of unbonded hydrogen atoms are produced.
(3) Energy is released and one mole of unbonded hydrogen atoms is produced.
(4) Energy is released and two moles of unbonded hydrogen atoms are produced.

38 Which pair of atoms has the most polar bond?

(1) H–Br   (3) I–Br
(2) H–Cl   (4) I–Cl

39 Which two notations represent isotopes of the same element?

(1) $^{14}_{7}$N and $^{18}_{7}$N   (3) $^{14}_{7}$N and $^{17}_{10}$Ne

(2) $^{20}_{7}$N and $^{20}_{10}$Ne   (4) $^{19}_{7}$N and $^{16}_{10}$Ne

40 The graph below shows the volume and the mass of four different substances at STP.
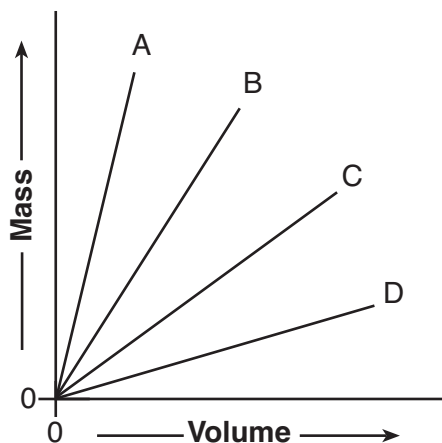
Which of the four substances has the *lowest* density?

(1) A   (3) C

(2) B   (4) D

41 What is the total amount of heat required to completely melt 347 grams of ice at its melting point?

(1) 334 J   (3) 116 000 J

(2) 1450 J   (4) 784 000 J

42 As the temperature of a reaction increases, it is expected that the reacting particles collide

(1) more often and with greater force
(2) more often and with less force
(3) less often and with greater force
(4) less often and with less force

43 Given the formula representing a compound:
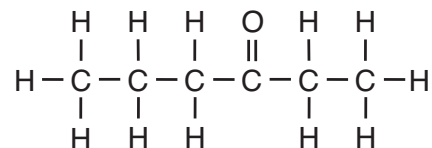
What is an IUPAC name for this compound?

(1) ethyl propanoate   (3) 3-hexanone
(2) propyl ethanoate   (4) 4-hexanone

44 A voltaic cell converts chemical energy to

(1) electrical energy with an external power source
(2) nuclear energy with an external power source
(3) electrical energy without an external power source
(4) nuclear energy without an external power source

45 Which acid and base react to form water and sodium sulfate?

(1) sulfuric acid and sodium hydroxide
(2) sulfuric acid and potassium hydroxide
(3) sulfurous acid and sodium hydroxide
(4) sulfurous acid and potassium hydroxide

46 Given the equation representing a reaction:

$$H_2CO_3 + NH_3 \rightarrow NH_4^+ + HCO_3^-$$
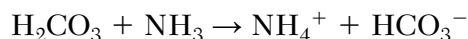
According to one acid-base theory, the compound NH_3 acts as a base because it

(1) accepts a hydrogen ion
(2) donates a hydrogen ion
(3) accepts a hydroxide ion
(4) donates a hydroxide ion

47 Which statement describes characteristics of a 0.01 M KOH(aq) solution?

(1) The solution is acidic with a pH less than 7.
(2) The solution is acidic with a pH greater than 7.
(3) The solution is basic with a pH less than 7.
(4) The solution is basic with a pH greater than 7.

48 Four statements about the development of the atomic model are shown below.

A: Electrons have wavelike properties.
B: Atoms have small, negatively charged particles.
C: The center of an atom is a small, dense nucleus.
D: Atoms are hard, indivisible spheres.

Which order of statements represents the historical development of the atomic model?

(1) $C \rightarrow D \rightarrow A \rightarrow B$
(2) $C \rightarrow D \rightarrow B \rightarrow A$
(3) $D \rightarrow B \rightarrow A \rightarrow C$
(4) $D \rightarrow B \rightarrow C \rightarrow A$

49 Five cubes of iron are tested in a laboratory. The tests and the results are shown in the table below.

Iron Tests and the Results

Test	Procedure	Result
1	A cube of Fe is hit with a hammer.	The cube is flattened.
2	A cube of Fe is placed in 3 M HCl(aq).	Bubbles of gas form.
3	A cube of Fe is heated to 1811 K.	The cube melts.
4	A cube of Fe is left in damp air.	The cube rusts.
5	A cube of Fe is placed in water.	The cube sinks.

Which tests demonstrate chemical properties?

(1) 1, 3, and 4   (3) 2 and 4
(2) 1, 3, and 5   (4) 2 and 5

50 A rigid cylinder with a movable piston contains a sample of helium gas. The temperature of the gas is held constant as the piston is pulled outward. Which graph represents the relationship between the volume of the gas and the pressure of the gas?
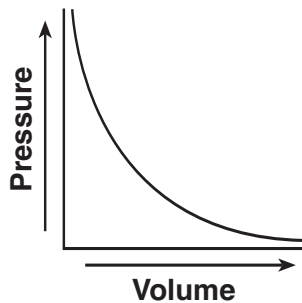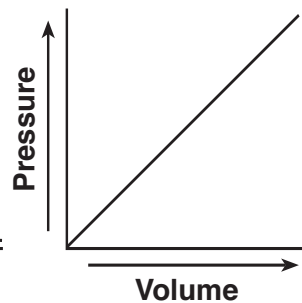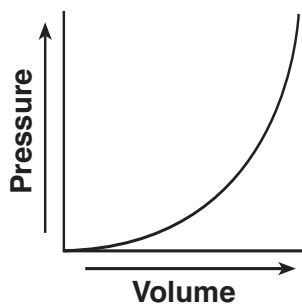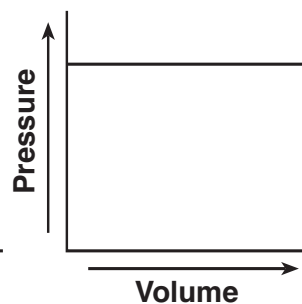
Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 What is the empirical formula for C_6H_{12}?   [1]

52 Using Table *G*, determine the minimum mass of NaCl that must be dissolved in 200. grams of water to produce a saturated solution at 90.°C.   [1]

53 State the physical property that makes it possible to separate a solution by distillation.   [1]

Base your answers to questions 54 and 55 on the information below and on your knowledge of chemistry.

A beaker contains a liquid sample of a molecular substance. Both the beaker and the liquid are at 194 K. The graph below represents the relationship between temperature and time as the beaker and its contents are cooled for 12 minutes in a refrigerated chamber.

Cooling Curve for a Substance
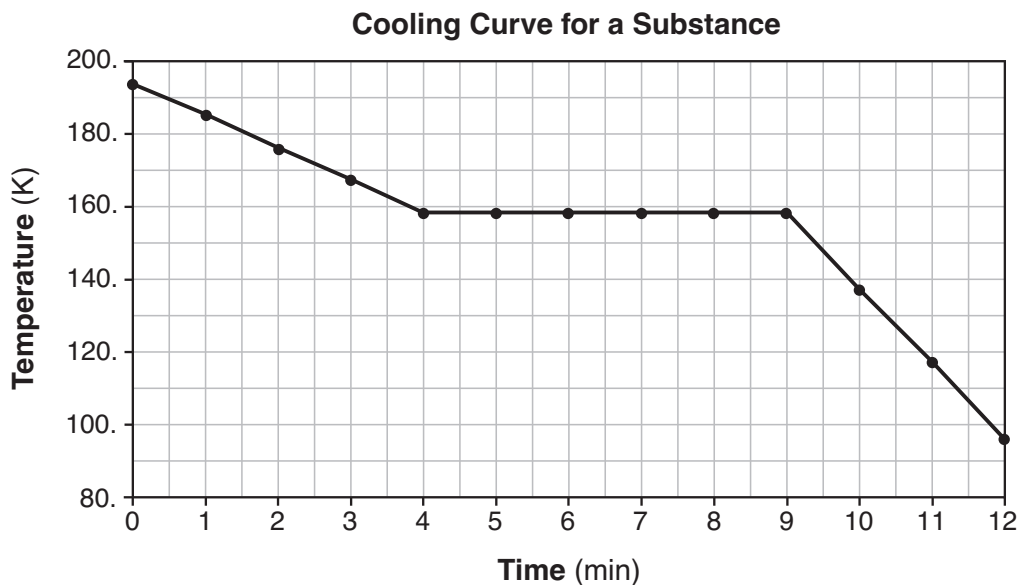
54 State what happens to the average kinetic energy of the molecules in the sample during the first 3 minutes.   [1]

55 Identify the physical change occurring during the time interval, minute 4 to minute 9.   [1]

Base your answers to questions 56 through 59 on the information below and on your knowledge of chemistry.

The equation below represents a reaction between propene and hydrogen bromide.
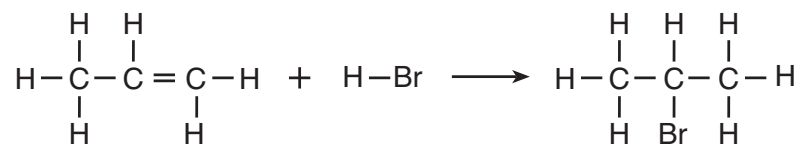
Cyclopropane, an isomer of propene, has a boiling point of –33ºC at standard pressure and is represented by the formula below.
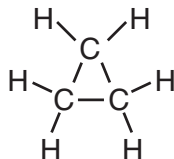
56 Explain why this reaction can be classified as a synthesis reaction. [1]

57 Identify the class of organic compounds to which the product of this reaction belongs. [1]

58 Explain, in terms of molecular formulas and structural formulas, why cyclopropane is an isomer of propene. [1]

59 Convert the boiling point of cyclopropane at standard pressure to kelvins. [1]

Base your answers to questions 60 through 63 on the information below and on your knowledge of chemistry.

The radius of a lithium atom is 130. picometers, and the radius of a fluorine atom is 60. picometers. The radius of a lithium ion, Li^+, is 59 picometers, and the radius of a fluoride ion, F^-, is 133 picometers.

60 Compare the radius of a fluoride ion to the radius of a fluorine atom. [1]

61 Explain, in terms of subatomic particles, why the radius of a lithium ion is smaller than the radius of a lithium atom. [1]

62 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for a fluoride ion. [1]

63 Describe the general trend in atomic radius as each element in Period 2 is considered in order from left to right. [1]

Base your answers to questions 64 and 65 on the information below and on your knowledge of chemistry.

Nuclear fission reactions can produce different radioisotopes. One of these radioisotopes is Te-137, which has a half-life of 2.5 seconds. The diagram below represents one of the many nuclear fission reactions.
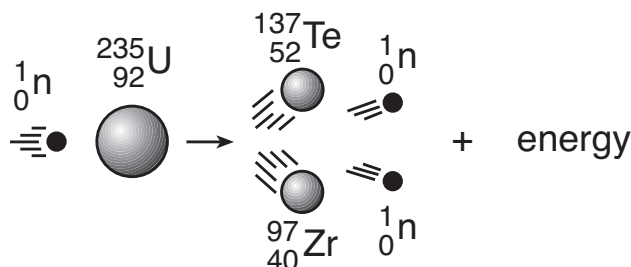
64 State evidence that this nuclear reaction represents transmutation. [1]

65 Complete the nuclear equation *in your answer booklet* for the beta decay of Zr-97, by writing an isotopic notation for the missing product. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

Stamping an identification number into the steel frame of a bicycle compresses the crystal structure of the metal. If the number is filed off, there are scientific ways to reveal the number.

One method is to apply aqueous copper(II) chloride to the number area. The Cu^{2+} ions react with some iron atoms in the steel frame, producing copper atoms that show the pattern of the number. The ionic equation below represents this reaction.

$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$
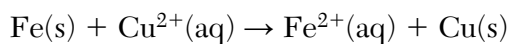
Another method is to apply hydrochloric acid to the number area. The acid reacts with the iron, producing bubbles of hydrogen gas. The bubbles form faster where the metal was compressed, so the number becomes visible. The equation below represents this reaction.

$$2HCl(aq) + Fe(s) \rightarrow FeCl_2(aq) + H_2(g)$$
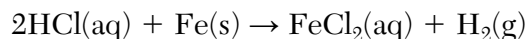
66 Explain why the Fe atoms in the bicycle frame react with the Cu^{2+} ions.   [1]

67 Determine the number of moles of hydrogen gas produced when 0.001 mole of HCl(aq) reacts completely with the iron metal.   [1]

68 Write a balanced half-reaction equation for the reduction of the hydrogen ions to hydrogen gas. [1]

69 Describe *one* change in the HCl(aq) that will increase the rate at which hydrogen bubbles are produced when the acid is applied to the steel frame.   [1]

Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

In an investigation, aqueous solutions are prepared by completely dissolving a different amount of NaCl(s) in each of four beakers containing 100.00 grams of $H_2O(\ell)$ at room temperature. Each solution is heated and the temperature at which boiling occurred is measured. The data are recorded in the table below.

Boiling Point Data for Four NaCl(aq) Solutions

Beaker Number	Mass of $H_2O(\ell)$ (g)	Mass of NaCl(s) Dissolved (g)	Boiling Point of Solution (°C)
1	100.00	8.76	101.5
2	100.00	17.52	103.1
3	100.00	26.28	104.6
4	100.00	35.04	106.1

70 Identify the solute and the solvent used in this investigation.   [1]

71 Show a numerical setup for calculating the percent by mass of NaCl in the solution in beaker 4.   [1]

72 Explain, in terms of ions, why the ability to conduct an electric current is greater for the solution in beaker 4 than for the solution in beaker 1.   [1]

73 State the relationship between the concentration of ions and the boiling point for these solutions.   [1]

Base your answers to questions 74 through 76 on the information below and on your knowledge of chemistry.

One type of voltaic cell, called a mercury battery, uses zinc and mercury(II) oxide to generate an electric current. Mercury batteries were used because of their miniature size, even though mercury is toxic. The overall reaction for a mercury battery is given in the equation below.

$$Zn(s) + HgO(s) \rightarrow ZnO(s) + Hg(\ell)$$
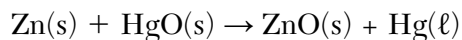
74 Determine the change in the oxidation number of zinc during the operation of the cell. [1]

75 Compare the number of moles of electrons lost to the number of moles of electrons gained during the reaction. [1]

76 Using information in the passage, state *one* risk and *one* benefit of using a mercury battery. [1]

Base your answers to questions 77 through 80 on the information below and on your knowledge of chemistry.

A company produces a colorless vinegar that is 5.0% $HC_2H_3O_2$ in water. Using thymol blue as an indicator, a student titrates a 15.0-milliliter sample of the vinegar with 43.1 milliliters of a 0.30 M NaOH(aq) solution until the acid is neutralized.

77 Based on Table *M*, what is the color of the indicator in the vinegar solution before any base is added? [1]

78 Identify the negative ion in the NaOH(aq) used in this titration. [1]

79 The concentration of the base used in this titration is expressed to what number of significant figures? [1]

80 Determine the molarity of the $HC_2H_3O_2$ in the vinegar sample, using the titration data. [1]

Base your answers to questions 81 through 85 on the information below and on your knowledge of chemistry.

In industry, ethanol is primarily produced by two different reactions. One process involves the reaction of glucose in the presence of an enzyme that acts as a catalyst. The equation below represents this reaction.

$$\text{Equation 1: } C_6H_{12}O_6 \xrightarrow{\text{enzyme}} 2CH_3CH_2OH + 2CO_2$$
$$\text{glucose} \qquad\qquad \text{ethanol}$$
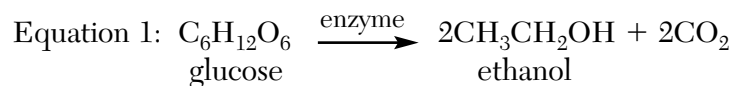
In another reaction, ethanol is produced from ethene and water. The equation below represents this reaction in which H_2SO_4 is a catalyst.

$$\text{Equation 2: } CH_2CH_2 + H_2O \xrightarrow{H_2SO_4} CH_3CH_2OH$$
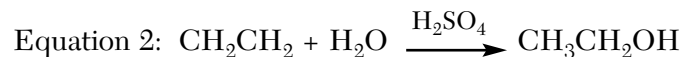
Industrial ethanol can be oxidized using a catalyst to produce ethanal. The equation representing this oxidation is shown below.

$$\text{Equation 3: } CH_3CH_2OH \xrightarrow{\text{catalyst}} CH_3CHO + H_2$$
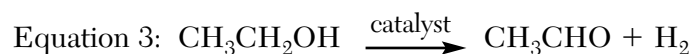
81 Identify the element that causes the reactant in equation 1 to be classified as an organic compound. [1]

82 Identify the type of organic reaction represented by equation 1. [1]

83 Explain why the hydrocarbon in equation 2 is unsaturated. [1]

84 Explain, in terms of intermolecular forces, why ethanol has a much higher boiling point than ethene, at standard pressure. [1]

85 Draw a structural formula for the organic product in equation 3. [1]

_____

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, August 16, 2017 — 8:30 to 11:30 a.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which phrase describes an Al atom?

(1) a negatively charged nucleus, surrounded by negatively charged electrons
(2) a negatively charged nucleus, surrounded by positively charged electrons
(3) a positively charged nucleus, surrounded by negatively charged electrons
(4) a positively charged nucleus, surrounded by positively charged electrons

2 What is the number of electrons in an atom that has 20 protons and 17 neutrons?

(1) 37   (3) 3
(2) 20   (4) 17

3 The mass of a proton is approximately equal to the mass of

(1) an electron   (3) an alpha particle
(2) a neutron   (4) a beta particle

4 When a sample of $CO_2(s)$ becomes $CO_2(g)$, there is a change in

(1) bond type
(2) gram-formula mass
(3) molecular polarity
(4) particle arrangement

5 Which properties are characteristic of Group 2 elements at STP?

(1) good electrical conductivity and electro-negativities less than 1.7
(2) good electrical conductivity and electro-negativities greater than 1.7
(3) poor electrical conductivity and electro-negativities less than 1.7
(4) poor electrical conductivity and electro-negativities greater than 1.7

6 Compared to an atom of C-12, an atom of C-14 has a greater

(1) number of electrons
(2) number of protons
(3) atomic number
(4) mass number

7 Elements that have atoms with stable valence electron configurations in the ground state are found in

(1) Group 1   (3) Group 11
(2) Group 8   (4) Group 18

8 A magnesium atom that loses two electrons becomes a

(1) positive ion with a smaller radius
(2) negative ion with a smaller radius
(3) positive ion with a larger radius
(4) negative ion with a larger radius

9 An atom of which element has the strongest attraction for the electrons in a bond?

(1) aluminum   (3) chlorine
(2) carbon   (4) lithium

10 Which type of matter can *not* be broken down into simpler substances by a chemical change?

(1) an element   (3) a mixture
(2) a solution   (4) a compound

11 According to Table *F*, which substance is most soluble in water?

(1) AgCl   (3) Na_2CO_3
(2) $CaCO_3$ (4) $SrSO_4$

12 Given the equation representing a reaction:

$$H + H \rightarrow H_2$$

Which statement describes the energy change in this reaction?

(1) A bond is broken as energy is absorbed.
(2) A bond is broken as energy is released.
(3) A bond is formed as energy is absorbed.
(4) A bond is formed as energy is released.

13 Which sample of matter is a mixture?

(1) air   (3) manganese
(2) ammonia   (4) water

14 Paper chromatography can separate the components of a mixture of colored dyes because the components have differences in

(1) decay mode
(2) thermal conductivity
(3) ionization energy
(4) molecular polarity

15 At standard pressure, the boiling point of an unsaturated $NaNO_3(aq)$ solution increases when

(1) the solution is diluted with water
(2) some of the $NaNO_3(aq)$ solution is removed
(3) the solution is stirred
(4) more $NaNO_3(s)$ is dissolved in the solution

16 Which term identifies a form of energy?

(1) combustion   (3) thermal
(2) exothermic   (4) electrolytic

17 According to kinetic molecular theory, which statement describes one characteristic of an ideal gas system?

(1) The distance between gas molecules is smaller than the diameter of one gas molecule.
(2) The attractive force between two gas molecules is strong.
(3) The energy of the system decreases as gas molecules collide.
(4) The straight-line motion of the gas molecules is constant and random.

18 The temperature of a substance is a measure of the

(1) average kinetic energy of its particles
(2) average potential energy of its particles
(3) ionization energy of its particles
(4) activation energy of its particles

19 A real gas behaves most like an ideal gas at

(1) low pressure and high temperature
(2) low pressure and low temperature
(3) high pressure and high temperature
(4) high pressure and low temperature

20 A reaction is most likely to occur when the colliding particles have proper orientation and

(1) mass   (3) half-life
(2) volume   (4) energy

21 At STP, a 12.0-liter sample of $CH_4(g)$ has the same total number of molecules as

(1) 6.0 L of $H_2(g)$ at STP
(2) 12.0 L of $CO_2(g)$ at STP
(3) 18.0 L of $HCl(g)$ at STP
(4) 24.0 L of $O_2(g)$ at STP

22 At standard pressure, during which physical change does the potential energy decrease?

(1) liquid to gas   (3) solid to gas
(2) liquid to solid   (4) solid to liquid

23 Which equation represents a chemical equilibrium?

(1) $N_2(\ell) \rightleftharpoons N_2(g)$
(2) $2NO_2(g) \rightleftharpoons N_2O_4(g)$
(3) $CO_2(s) \rightleftharpoons CO_2(g)$
(4) $NH_3(\ell) \rightleftharpoons NH_3(g)$

24 The amount of randomness of the atoms in a system is an indication of the

(1) entropy of the system
(2) polarity of the system
(3) excited state of the atoms
(4) ground state of the atoms

25 When a sample of Ca(s) loses 1 mole of electrons in a reaction with a sample of $O_2(g)$, the oxygen

(1) loses 1 mole of electrons
(2) loses 2 moles of electrons
(3) gains 1 mole of electrons
(4) gains 2 moles of electrons

26 Which reaction occurs at the anode of an electrochemical cell?

(1) oxidation   (3) neutralization
(2) reduction   (4) transmutation

27 Which substance is an electrolyte?

(1) CCl_4 (3) SiO_2
(2) $C_6H_{12}O_6$ (4) H_2SO_4

28 In which process does a heavy nucleus split into two lighter nuclei?

(1) titration   (3) electrolysis
(2) fission   (4) neutralization

29 Which process converts mass into energy?

(1) distillation of ethanol
(2) filtration of a mixture
(3) fusion of hydrogen atoms
(4) ionization of cesium atoms

30 Which radioisotope is used to determine the age of once-living organisms?

(1) carbon-14   (3) iodine-131
(2) cobalt-60   (4) uranium-238

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 Which electron configuration represents the electrons in an atom of calcium in an excited state?

(1) 2–8–8
(2) 2–8–8–2
(3) 2–7–8–1
(4) 2–7–8–3

32 The table below gives the atomic mass and the abundance of the two naturally occurring isotopes of bromine.

Naturally Occurring Isotopes of Bromine

Isotopes	Atomic Mass (u)	Natural Abundance (%)
Br-79	78.92	50.69
Br-81	80.92	49.31

Which numerical setup can be used to calculate the atomic mass of the element bromine?

(1) (78.92 u)(50.69) + (80.92 u)(49.31)
(2) (78.92 u)(49.31) + (80.92 u)(50.69)
(3) (78.92 u)(0.5069) + (80.92 u)(0.4931)
(4) (78.92 u)(0.4931) + (80.92 u)(0.5069)

33 Given the formulas of two substances:

These diagrams represent substances that have

(1) the same molecular structure and the same physical properties
(2) the same molecular structure and different physical properties
(3) different molecular structures and the same physical properties
(4) different molecular structures and different physical properties

34 What is the chemical formula of titanium(II) oxide?

(1) TiO
(2) Ti_2O
(3) TiO_2
(4) Ti_2O_3

35 Which equation shows conservation of mass and energy for a reaction at 101.3 kPa and 298 K?

(1) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + 483.6$ kJ
(2) $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell) + 285.8$ kJ
(3) $H_2(g) + O_2(g) \rightarrow H_2O(g) + 483.6$ kJ
(4) $H_2(g) + O_2(g) \rightarrow H_2O(\ell) + 285.8$ kJ

36 Which two particle diagrams each represent a sample of one substance?

(1) I and II
(2) I and III
(3) II and III
(4) II and IV

37 According to Table *G*, which substance forms an unsaturated solution when 80. grams of the substance are stirred into 100. grams of H_2O at 10.°C?

(1) KNO_3 (3) NH_3
(2) KI   (4) NaCl

38 What is the concentration of AgCl in an aqueous solution that contains 1.2×10^{-3} gram of AgCl in 800. grams of the solution?

(1) 1.2 ppm   (3) 7.2 ppm
(2) 1.5 ppm   (4) 9.6 ppm

39 A sample of gas is in a rigid cylinder with a movable piston. The pressure of the gas is kept constant. If the Kelvin temperature of the gas is doubled, the volume of the gas is

(1) halved   (3) tripled
(2) doubled   (4) unchanged

40 What is the amount of heat required to completely melt a 200.-gram sample of $H_2O(s)$ at STP?

(1) 334 J   (3) 66 800 J
(2) 836 J   (4) 452 000 J

41 As a 15.1-gram sample of a metal absorbs 48.75 J of heat, its temperature increases 25.0 K. What is the specific heat capacity of the metal?

(1) 0.129 J/g•K   (3) 3.23 J/g•K
(2) 1.95 J/g•K   (4) 7.74 J/g•K

42 Given the formula:

```
      H   H   O
      |   |   ||
  H − C − C − C − H
      |   |
      H   H
```
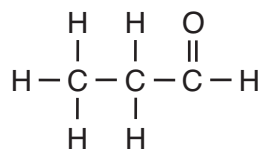
What is a chemical name of this compound?

(1) propane   (3) propanol
(2) propanal   (4) propanone

43 Given the equation representing a reaction:

```
      H                       H
      |                       |
  H − C − H  +  Cl − Cl  →  H − C − H  +  H − Cl
      |                       |
      H                       Cl
```
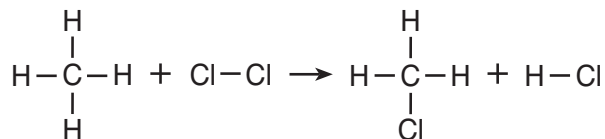
Which type of reaction is represented by this equation?

(1) addition   (3) polymerization
(2) esterification   (4) substitution

44 Atoms of which element react spontaneously with $Mg^{2+}(aq)$?

(1) chromium   (3) iron
(2) barium   (4) zinc

45 In a titration, 5.0 mL of a 2.0 M NaOH(aq) solution exactly neutralizes 10.0 mL of an HCl(aq) solution. What is the concentration of the HCl(aq) solution?

(1) 1.0 M   (3) 10. M
(2) 2.0 M   (4) 20. M

46 Given the equation representing a reaction at equilibrium:

$$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$
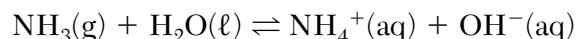
If an acid is defined as an H^+ donor, what is the acid in the forward reaction?

(1) $OH^-(aq)$ (3) $NH_3(g)$
(2) $H_2O(\ell)$ (4) $NH_4^+(aq)$

47 Compared to a solution with a pH value of 7, a solution with a thousand times greater hydronium ion concentration has a pH value of

(1) 10   (3) 3
(2) 7   (4) 4

48 Which Lewis electron-dot diagram represents the bonding in potassium iodide?

$K^+ \left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{I}}: \right]^-$ $\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{K}}: \right]^- I^+$ $K:\overset{\cdot\cdot}{\underset{\cdot\cdot}{I}}:$ $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{K}}:I$

 (1)   (2)   (3)   (4)
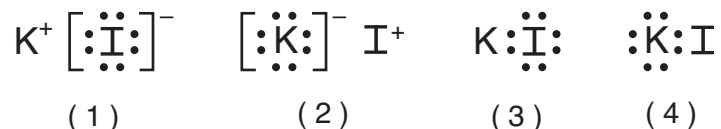
49 The table below shows properties of two compounds at standard pressure.

Selected Properties of Two Compounds

Compound	Melting Point (°C)	Boiling Point (°C)	Electrical Conductivity
1	775	1935	good as a liquid or in an aqueous solution
2	−112.1	46	poor as a liquid

Which statement classifies the two compounds?

(1) Both compounds are ionic.
(2) Both compounds are molecular.
(3) Compound 1 is ionic, and compound 2 is molecular.
(4) Compound 1 is molecular, and compound 2 is ionic.

50 Given two balanced equations, each representing a reaction:

Equation 1: $^{226}_{88}Ra \rightarrow\ ^{222}_{86}Rn +\ ^{4}_{2}He + 4.8 \times 10^8$ kJ

Equation 2: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + 2.2 \times 10^3$ kJ
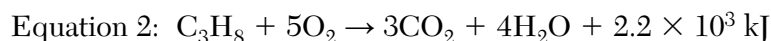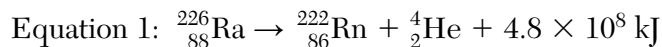
Which statement compares the energy terms in these two equations?

(1) Equation 1 shows 2.2×10^5 times more energy being absorbed.
(2) Equation 2 shows 2.2×10^5 times more energy being absorbed.
(3) Equation 1 shows 2.2×10^5 times more energy being released.
(4) Equation 2 shows 2.2×10^5 times more energy being released.

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

Base your answers to questions 51 and 52 on the information below and on your knowledge of chemistry.

The formula below represents a molecule of butanamide.

$$\begin{array}{ccccccc} & H & H & H & O & & H \\ & | & | & | & \| & & \diagup \\ H- & C- & C- & C- & C- & N & \\ & | & | & | & & & \diagdown \\ & H & H & H & & & H \end{array}$$
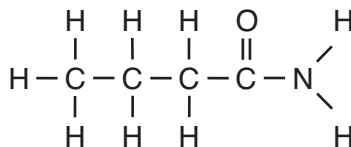
51 State the type of chemical bond between a hydrogen atom and the nitrogen atom in the molecule. [1]

52 Explain, in terms of charge distribution, why a molecule of butanamide is polar. [1]

Base your answers to questions 53 and 54 on the information below and on your knowledge of chemistry.

An equilibrium system in a sealed, rigid container is represented by the equation below.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$
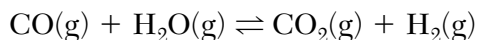
53 Compare the rate of the forward reaction to the rate of the reverse reaction at equilibrium. [1]

54 State the effect on the concentrations of $H_2O(g)$ and $CO_2(g)$ when more $H_2(g)$ is added to the system. [1]

Base your answers to questions 55 through 58 on the information below and on your knowledge of chemistry.

The table below contains selected information about chlorine and two compounds containing chlorine. One piece of information is missing for each of the substances in the table.

Chlorine and Two Compounds Containing Chlorine

Name	Formula	Molar Mass (g/mol)	Phase at STP
chlorine	Cl_2	71	?
calcium chloride	$CaCl_2$	?	solid
1,2-dichloroethene	?	97	liquid

55 Identify the phase of the chlorine at STP.   [1]

56 Determine the molar mass for calcium chloride.   [1]

57 The liquid compound has an empirical formula of CHCl. Write the molecular formula for this compound.   [1]

58 Explain, in terms of electrons, why the compound containing calcium and chlorine is classified as an ionic compound.   [1]

_____

Base your answers to questions 59 and 60 on the information below and on your knowledge of chemistry.

The equation below represents the reaction between 2-methylpropene and hydrogen chloride gas.
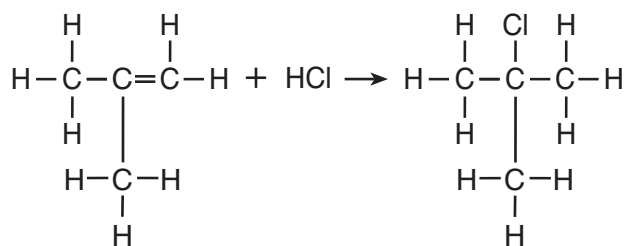
59 Explain, in terms of chemical bonds, why the hydrocarbon is unsaturated.   [1]

60 Identify the class of organic compounds to which the product belongs.   [1]

_____

Base your answers to questions 61 through 65 on the information below and on your knowledge of chemistry.

Many scientists made observations of the elements that led to the modern Periodic Table. In 1829, Dobereiner found groups of three elements that have similar properties and called each of these groups a triad. Dobereiner noticed a relationship between the atomic masses of the elements in each triad. Triad 1, shown in the table below, consists of sulfur, selenium, and tellurium. The middle element, selenium, has an atomic mass that is close to the sum of the atomic masses of sulfur and tellurium, divided by 2.

For example: $\dfrac{32 \text{ u} + 128 \text{ u}}{2}$ = 80. u, which is close to the 79 u value in the table.

The other triads shown in the table below demonstrate the same mathematical relationship.

Dobereiner's Triads

Triad	Triad	Dobereiner's Atomic Masses (u)
1	sulfur selenium tellurium	32 79 128
2	calcium strontium barium	40. 88 137
3	chlorine bromine iodine	35.5 80. 127
4	lithium sodium potassium	7 23 39

61 Identify the triad that contains a metalloid. [1]

62 Explain, in terms of electrons, why the elements in triad 2 have similar chemical properties. [1]

63 State the trend in first ionization energy as the elements in triad 3 are considered in order of increasing atomic number. [1]

64 Compare the volume of a 100.-gram sample of the first element in triad 4 to the volume of a 100.-gram sample of the third element in triad 4 when both samples are at room temperature. [1]

65 Show a numerical setup that demonstrates Dobereiner's mathematical relationship for triad 2. [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

Wood is mainly cellulose, a polymer produced by plants. One use of wood is as a fuel in campfires, fireplaces, and wood furnaces. The molecules of cellulose are long chains of repeating units. Each unit of the chain can be represented as $C_6H_{10}O_5$. The balanced equation below represents a reaction that occurs when $C_6H_{10}O_5$ is burned in air.

$$C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O + \text{heat}$$

66 State evidence from the equation that this reaction is exothermic. [1]

67 Explain, in terms of substances in the reaction, why the equation represents a chemical change. [1]

68 Show a numerical setup for calculating the percent composition by mass of carbon in $C_6H_{10}O_5$ (gram-formula mass = 162.1 g/mol). [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

Millions of tons of ammonia are produced each year for use as fertilizer to increase food production. Most of the hydrogen needed to produce ammonia comes from methane gas reacting with steam. This reaction, which occurs in a container under controlled conditions, is shown below in unbalanced equation 1.

Equation 1: $CH_4(g) + H_2O(g) + energy \rightarrow CO(g) + H_2(g)$
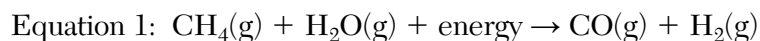
The reaction that produces ammonia is represented by balanced equation 2, shown below. A catalyst can be used to increase the rate of the reaction.

Equation 2: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + energy$
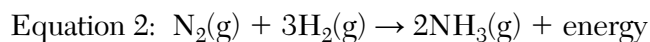
A potential energy diagram for equation 2 is shown below.
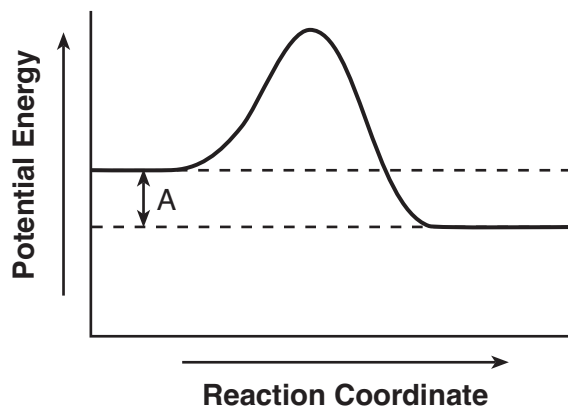
69 Balance equation 1 *in your answer booklet*, using the smallest whole-number coefficients. [1]

70 Explain, in terms of collision theory, why an increase in temperature increases the rate of reaction between methane gas and steam. [1]

71 State what is represented by interval *A* on the potential energy diagram. [1]

72 Determine the number of moles of hydrogen gas required to react completely with 50.0 moles of nitrogen gas in the production of ammonia. [1]

Base your answers to questions 73 through 77 on the information below and on your knowledge of chemistry.

Diethyl ether is used as a laboratory and industrial solvent. The boiling point of diethyl ether at standard pressure is 34.6°C. The equation below represents a reaction that produces diethyl ether.

$$\underset{H}{\overset{H}{\diagdown}}C=C\underset{H}{\overset{H}{\diagup}} \;+\; \underset{H}{\overset{H}{\diagdown}}C=C\underset{H}{\overset{H}{\diagup}} \;+\; H_2O \;\xrightarrow{\text{catalyst}}\; H-\underset{H}{\overset{H}{\underset{|}{\overset{|}{C}}}}-\underset{H}{\overset{H}{\underset{|}{\overset{|}{C}}}}-O-\underset{H}{\overset{H}{\underset{|}{\overset{|}{C}}}}-\underset{H}{\overset{H}{\underset{|}{\overset{|}{C}}}}-H$$
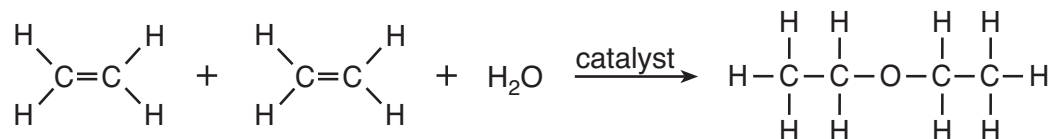
73 Identify the element in diethyl ether that allows it to be classified as an organic compound. [1]

74 State the number of electrons shared between the carbon atoms in one molecule of the organic reactant. [1]

75 State why the reaction is classified as a synthesis reaction. [1]

76 Explain, in terms of the strength of intermolecular forces, why the boiling point of diethyl ether at standard pressure is *lower* than the boiling point of water at standard pressure. [1]

77 Draw a structural formula for an isomer of the product that has the same functional group. [1]

Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

The electrolysis of brine, a concentrated aqueous sodium chloride solution, produces three important industrial chemicals: chlorine gas, hydrogen gas, and sodium hydroxide. The diagram and equation below represent a brine electrolysis cell. Before the battery is connected, the pH value of the brine solution is 7.0.

$$2NaCl(aq) + 2H_2O(\ell) \rightarrow Cl_2(g) + H_2(g) + 2NaOH(aq)$$
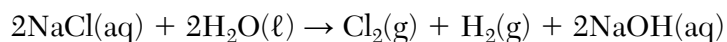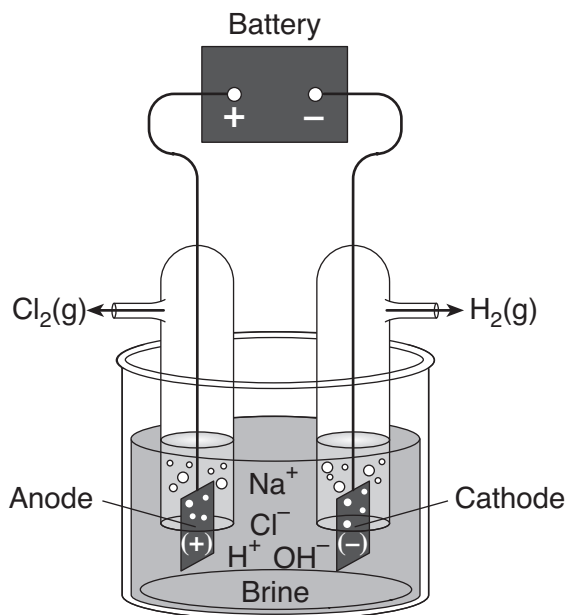
78 Explain, in terms of energy, why this cell is an electrolytic cell. [1]

79 Explain, in terms of ions, why the aqueous solution in the cell conducts an electric current. [1]

80 State the oxidation number of oxygen in the aqueous product. [1]

81 Compare the pH value of the solution before the battery is connected to the pH value of the solution after the cell operates for 20 minutes. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

The isotope Rn-222 is produced by the decay of uranium in Earth's crust. Some of this isotope leaks into basements of homes in areas where the ground is more porous. An atom of Rn-222 decays to an atom of Pb-206 through a series of steps as shown on the graph below.

Decay Series of Rn-222
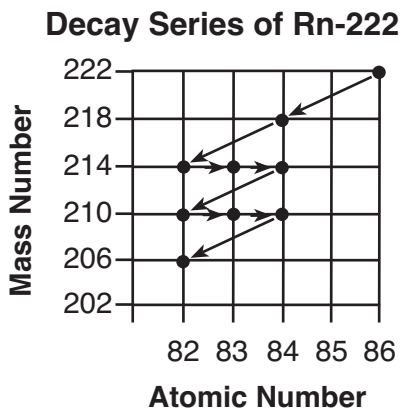
82 Determine the number of neutrons in an atom of Pb-214. [1]

83 Complete the nuclear equation *in your answer booklet* for the decay of Po-218 by writing a notation for the missing product. [1]

84 Determine the fraction of an original sample of Rn-222 that remains unchanged after 7.646 days. [1]

85 Explain, in terms of elements, why the decay of Bi-210 is considered a transmutation. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, August 16, 2018 — 8:30 to 11:30 a.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 According to the wave-mechanical model, an orbital is defined as the most probable location of

(1) a proton   (3) a positron
(2) a neutron   (4) an electron

2 The part of an atom that has an overall positive charge is called

(1) an electron   (3) the first shell
(2) the nucleus   (4) the valence shell

3 Which subatomic particles each have a mass of approximately 1 u?

(1) proton and electron
(2) proton and neutron
(3) neutron and electron
(4) neutron and positron

4 The discovery of the electron as a subatomic particle was a result of

(1) collision theory
(2) kinetic molecular theory
(3) the gold-foil experiment
(4) experiments with cathode ray tubes

5 The elements on the Periodic Table of the Elements are arranged in order of increasing

(1) atomic mass   (3) atomic number
(2) formula mass   (4) oxidation number

6 Which element is classified as a metalloid?

(1) Te   (3) Hg
(2) S   (4) I

7 At STP, $O_2(g)$ and $O_3(g)$ are two forms of the same element that have

(1) the same molecular structure and the same properties
(2) the same molecular structure and different properties
(3) different molecular structures and the same properties
(4) different molecular structures and different properties

8 Which substance can be broken down by chemical means?

(1) ammonia   (3) antimony
(2) aluminum   (4) argon

9 Which statement describes $H_2O(\ell)$ and $H_2O_2(\ell)$?

(1) Both are compounds that have the same properties.
(2) Both are compounds that have different properties.
(3) Both are mixtures that have the same properties.
(4) Both are mixtures that have different properties.

10 Which two terms represent major categories of compounds?

(1) ionic and nuclear
(2) ionic and molecular
(3) empirical and nuclear
(4) empirical and molecular

11 Which formula represents an asymmetrical molecule?

(1) CH_4 (3) N_2
(2) CO_2 (4) NH_3

12 Which statement describes the energy changes that occur as bonds are broken and formed during a chemical reaction?

(1) Energy is absorbed when bonds are both broken and formed.

(2) Energy is released when bonds are both broken and formed.

(3) Energy is absorbed when bonds are broken, and energy is released when bonds are formed.

(4) Energy is released when bonds are broken, and energy is absorbed when bonds are formed.

13 A solid sample of copper is an excellent conductor of electric current. Which type of chemical bonds are in the sample?

(1) ionic bonds

(2) metallic bonds

(3) nonpolar covalent bonds

(4) polar covalent bonds

14 Which list includes three forms of energy?

(1) thermal, nuclear, electronegativity

(2) thermal, chemical, electromagnetic

(3) temperature, nuclear, electromagnetic

(4) temperature, chemical, electronegativity

15 Based on Table *S*, an atom of which element has the strongest attraction for electrons in a chemical bond?

(1) chlorine   (3) oxygen

(2) nitrogen   (4) selenium

16 At which temperature and pressure would a sample of helium behave most like an ideal gas?

(1) 75 K and 500. kPa

(2) 150. K and 500. kPa

(3) 300. K and 50. kPa

(4) 600. K and 50. kPa

17 A cube of iron at 20.°C is placed in contact with a cube of copper at 60.°C. Which statement describes the initial flow of heat between the cubes?

(1) Heat flows from the copper cube to the iron cube.

(2) Heat flows from the iron cube to the copper cube.

(3) Heat flows in both directions between the cubes.

(4) Heat does not flow between the cubes.

18 Which sample at STP has the same number of atoms as 18 liters of $Ne(g)$ at STP?

(1) 18 moles of $Ar(g)$

(2) 18 liters of $Ar(g)$

(3) 18 grams of $H_2O(g)$

(4) 18 milliliters of $H_2O(g)$

19 Compared to H_2S, the higher boiling point of H_2O is due to the

(1) greater molecular size of water

(2) stronger hydrogen bonding in water

(3) higher molarity of water

(4) larger gram-formula mass of water

20 In terms of entropy and energy, systems in nature tend to undergo changes toward

(1) lower entropy and lower energy

(2) lower entropy and higher energy

(3) higher entropy and lower energy

(4) higher entropy and higher energy

21 Amines, amides, and amino acids are categories of

(1) isomers

(2) isotopes

(3) organic compounds

(4) inorganic compounds

22 A molecule of which compound has a multiple covalent bond?

(1) CH_4 (3) C_3H_8

(2) C_2H_4 (4) C_4H_{10}

23 Which type of reaction produces soap?

   (1) polymerization   (3) fermentation

   (2) combustion   (4) saponification

24 For a reaction system at equilibrium, LeChatelier's principle can be used to predict the

   (1) activation energy for the system
   (2) type of bonds in the reactants
   (3) effect of a stress on the system
   (4) polarity of the product molecules

25 Which value changes when a Cu atom becomes a Cu^{2+} ion?

   (1) mass number
   (2) oxidation number
   (3) number of protons
   (4) number of neutrons

26 Which reaction occurs at the anode in an electrochemical cell?

   (1) oxidation   (3) combustion

   (2) reduction   (4) substitution

27 What evidence indicates that the nuclei of strontium-90 atoms are unstable?

   (1) Strontium-90 electrons are in the excited state.
   (2) Strontium-90 electrons are in the ground state.
   (3) Strontium-90 atoms spontaneously absorb beta particles.
   (4) Strontium-90 atoms spontaneously emit beta particles.

28 Which nuclear emission is listed with its notation?

   (1) gamma radiation, $_{0}^{0}\gamma$
   (2) proton, $_{2}^{4}He$
   (3) neutron, $_{-1}^{0}\beta$
   (4) alpha particle, $_{1}^{1}H$

29 The energy released by a nuclear fusion reaction is produced when

   (1) energy is converted to mass
   (2) mass is converted to energy
   (3) heat is converted to temperature
   (4) temperature is converted to heat

30 Dating once-living organisms is an example of a beneficial use of

   (1) redox reactions
   (2) organic isomers
   (3) radioactive isotopes
   (4) neutralization reactions

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 What is the net charge of an ion that has 11 protons, 10 electrons, and 12 neutrons?
   (1) 1+   (3) 1–
   (2) 2+   (4) 2–

32 Which electron configuration represents the electrons of an atom in an excited state?
   (1) 2-5   (3) 2-5-1
   (2) 2-8-5   (4) 2-6

33 Which element is a liquid at 1000. K?
   (1) Ag   (3) Ca
   (2) Al   (4) Ni

34 Which formula represents ammonium nitrate?
   (1) NH_4NO_3 (3) $NH_4(NO_3)_2$
   (2) NH_4NO_2 (4) $NH_4(NO_2)_2$

35 The empirical formula for butene is
   (1) CH_2 (3) C_4H_6
   (2) C_2H_4 (4) C_4H_8

36 Which equation represents a conservation of charge?
   (1) $2Fe^{3+} + Al \rightarrow 2Fe^{2+} + Al^{3+}$
   (2) $2Fe^{3+} + 2Al \rightarrow 3Fe^{2+} + 2Al^{3+}$
   (3) $3Fe^{3+} + 2Al \rightarrow 2Fe^{2+} + 2Al^{3+}$
   (4) $3Fe^{3+} + Al \rightarrow 3Fe^{2+} + Al^{3+}$

37 Given the balanced equation representing a reaction:

$$2H_2 + O_2 \rightarrow 2H_2O + energy$$

Which type of reaction is represented by this equation?
   (1) decomposition
   (2) double replacement
   (3) single replacement
   (4) synthesis

38 When a Mg^{2+} ion becomes a Mg atom, the radius increases because the Mg^{2+} ion
   (1) gains 2 protons   (3) loses 2 protons
   (2) gains 2 electrons   (4) loses 2 electrons

39 The *least* polar bond is found in a molecule of
   (1) HI   (3) HCl
   (2) HF   (4) HBr

40 A solution is prepared using 0.125 g of glucose, $C_6H_{12}O_6$, in enough water to make 250. g of total solution. The concentration of this solution, expressed in parts per million, is
   (1) 5.00×10^1 ppm   (3) 5.00×10^3 ppm
   (2) 5.00×10^2 ppm   (4) 5.00×10^4 ppm

41 What is the amount of heat, in joules, required to increase the temperature of a 49.5-gram sample of water from 22°C to 66°C?
   (1) 2.2×10^3 J   (3) 9.1×10^3 J
   (2) 4.6×10^3 J   (4) 1.4×10^4 J

42 A sample of a gas in a rigid cylinder with a movable piston has a volume of 11.2 liters at STP. What is the volume of this gas at 202.6 kPa and 300. K?

(1) 5.10 L   (3) 22.4 L
(2) 6.15 L   (4) 24.6 L

43 The equation below represents a reaction between two molecules, X_2 and Z_2. These molecules form an "activated complex," which then forms molecules of the product.

Key
●● = a molecule of X_2
○○ = a molecule of Z_2

●● + ○○ → → ●○ + ●○

Reactants   Activated complex   Product
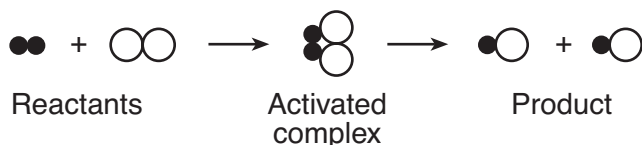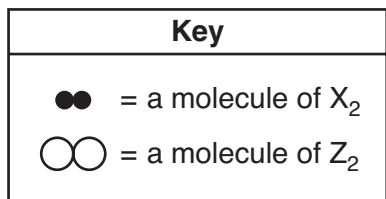
Which diagram represents the most likely orientation of X_2 and Z_2 when the molecules collide with proper energy, producing an activated complex?

(1)   (3)

(2)   (4)

44 What is the chemical name for the compound $CH_3CH_2CH_2CH_3$?

(1) butane   (3) decane
(2) butene   (4) decene

45 In a laboratory activity, the density of a sample of vanadium is determined to be 6.9 g/cm^3 at room temperature. What is the percent error for the determined value?

(1) 0.15%   (3) 13%
(2) 0.87%   (4) 15%

46 Given the equation representing a reaction:

$$Cd + NiO_2 + 2H_2O \rightarrow Cd(OH)_2 + Ni(OH)_2$$
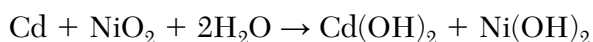
Which half-reaction equation represents the oxidation in the reaction?

(1) $Ni^{4+} + 2e^- \rightarrow Ni^{2+}$
(2) $Ni^{4+} \rightarrow Ni^{2+} + 2e^-$
(3) $Cd \rightarrow Cd^{2+} + 2e^-$
(4) $Cd + 2e^- \rightarrow Cd^{2+}$

47 Which metal reacts spontaneously with $NiCl_2(aq)$?

(1) Au(s)   (3) Sn(s)
(2) Cu(s)   (4) Zn(s)

48 Which solution is the best conductor of an electric current?

(1) 0.001 mole of NaCl dissolved in 1000. mL of water
(2) 0.005 mole of NaCl dissolved in 1000. mL of water
(3) 0.1 mole of NaCl dissolved in 1000. mL of water
(4) 0.05 mole of NaCl dissolved in 1000. mL of water

49 Compared to a 1.0-liter aqueous solution with a pH of 7.0, a 1.0-liter aqueous solution with a pH of 5.0 contains

(1) 10 times more hydronium ions
(2) 100 times more hydronium ions
(3) 10 times more hydroxide ions
(4) 100 times more hydroxide ions

50 Given the equation representing a reaction:

$$^{208}_{82}Pb + ^{70}_{30}Zn \rightarrow ^{277}_{112}Cn + ^{1}_{0}n$$
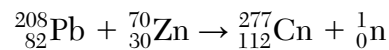
Which type of reaction is represented by this equation?

(1) neutralization   (3) substitution
(2) polymerization   (4) transmutation

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Show a numerical setup for calculating the percent composition by mass of oxygen in Al_2O_3 (gram-formula mass = 102 g/mol). [1]

52 Identify a laboratory process that can be used to separate a liquid mixture of methanol and water, based on the differences in their boiling points. [1]

Base your answers to questions 53 through 55 on the information below and on your knowledge of chemistry.

The table below shows data for three isotopes of the same element.

Data for Three Isotopes of an Element

Isotopes	Number of Protons	Number of Neutrons	Atomic Mass (u)	Natural Abundance (%)
Atom D	12	12	23.99	78.99
Atom E	12	13	24.99	10.00
Atom G	12	14	25.98	11.01

53 Explain, in terms of subatomic particles, why these three isotopes represent the same element. [1]

54 State the number of valence electrons in an atom of isotope *D* in the ground state. [1]

55 Compare the energy of an electron in the first electron shell to the energy of an electron in the second electron shell in an atom of isotope *E*. [1]

Base your answers to questions 56 through 58 on the information below and on your knowledge of chemistry.

The elements in Group 2 on the Periodic Table can be compared in terms of first ionization energy, electronegativity, and other general properties.

56 Describe the general trend in electronegativity as the metals in Group 2 on the Periodic Table are considered in order of increasing atomic number.   [1]

57 Explain, in terms of electron configuration, why the elements in Group 2 have similar chemical properties.   [1]

58 Explain, in terms of atomic structure, why barium has a lower first ionization energy than magnesium.   [1]

Base your answers to questions 59 through 61 on the information below and on your knowledge of chemistry.

A saturated solution of sulfur dioxide is prepared by dissolving $SO_2(g)$ in 100. g of water at 10.°C and standard pressure.

59 Determine the mass of SO_2 in this solution.   [1]

60 Based on Table G, state the general relationship between solubility and temperature of an aqueous SO_2 solution at standard pressure.   [1]

61 Describe what happens to the solubility of $SO_2(g)$ when the pressure is increased at constant temperature.   [1]

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

Starting as a solid, a sample of a molecular substance is heated, until the entire sample of the substance is a gas. The graph below represents the relationship between the temperature of the sample and the elapsed time.

Heating Curve
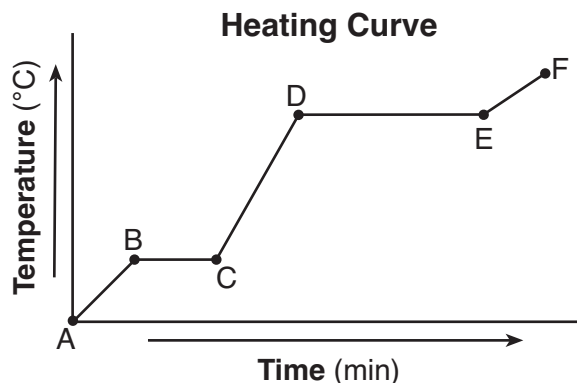
62 Using the key *in your answer booklet*, draw a particle diagram to represent the sample during interval *AB*. Your response must include *at least six* molecules.   [1]

63 Compare the average kinetic energy of the molecules of the sample during interval *BC* to the average kinetic energy of the molecules of the sample during interval *DE*.   [1]

64 On the graph *in your answer booklet*, mark an **X** on the axis labeled "Temperature (°C)" to indicate the boiling point of the substance.   [1]

65 State evidence that indicates the sample undergoes only physical changes during this heating.   [1]

Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your anwers to questions 66 through 68 on the information below and on your knowledge of chemistry.

"Water gas," a mixture of hydrogen and carbon monoxide, is an industrial fuel and source of commercial hydrogen. Water gas is produced by passing steam over hot carbon obtained from coal. The equation below represents this system at equilibrium:

$$C(s) + H_2O(g) + heat \rightleftharpoons CO(g) + H_2(g)$$

66 State, in terms of the rates of the forward and reverse reactions, what occurs when dynamic equilibrium is reached in this system.   [1]

67 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for a molecule of H_2O.   [1]

68 Explain, in terms of collisions, why increasing the surface area of the hot carbon increases the rate of the forward reaction.   [1]

Base your answers to questions 69 through 71 on the information below and on your knowledge of chemistry.

In a laboratory activity, each of four different masses of $KNO_3(s)$ is placed in a separate test tube that contains 10.0 grams of H_2O at 25°C.

When each sample is first placed in the water, the temperature of the mixture decreases. The mixture in each test tube is then stirred while it is heated in a hot water bath until all of the $KNO_3(s)$ is dissolved. The contents of each test tube are then cooled to the temperature at which KNO_3 crystals first reappear. The procedure is repeated until the recrystallization temperatures for each mixture are consistent, as shown in the table below.

Data Table for the Laboratory Activity

Mixture	Mass of KNO$_3$ (g)	Mass of H$_2$O (g)	Temperature of Recrystallization (°C)
1	4.0	10.0	24
2	5.0	10.0	32
3	7.5	10.0	45
4	10.0	10.0	58

69 Based on Table *I*, explain why there is a *decrease* in temperature when the $KNO_3(s)$ was first dissolved in the water. [1]

70 Determine the percent by mass concentration of KNO_3 in mixture 2 after heating. [1]

71 Compare the freezing point of mixture 4 at 1.0 atm to the freezing point of water at 1.0 atm. [1]

Base your answers to questions 72 through 74 on the information below and on your knowledge of chemistry.

The balanced equation below represents the reaction between carbon monoxide and oxygen to produce carbon dioxide.

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g) + energy$$
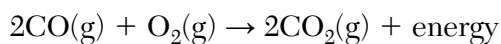
72 On the potential energy diagram *in your answer booklet*, draw a double-headed arrow ($\updownarrow$) to indicate the interval that represents the heat of reaction. [1]

73 Determine the number of moles of $O_2(g)$ needed to completely react with 8.0 moles of $CO(g)$. [1]

74 On the potential energy diagram *in your answer booklet*, draw a dashed line to show how the potential energy diagram changes when the reaction is catalyzed. [1]

Base your answers to questions 75 through 77 on the information below and on your knowledge of chemistry.

The equation below represents an industrial preparation of diethyl ether.

Compound A   **Compound B**
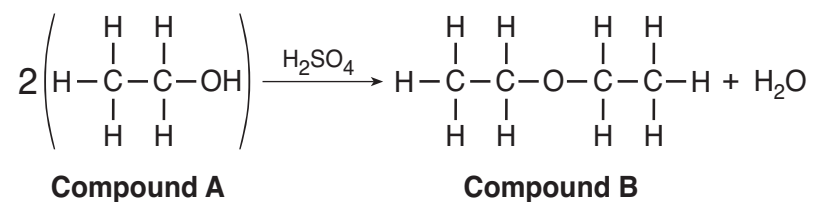
75 Write the name of the class of organic compounds to which compound *A* belongs. [1]

76 Identify the element in compound *B* that makes it an organic compound. [1]

77 Explain, in terms of elements, why compound *B* is *not* a hydrocarbon. [1]

Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

A student is to determine the concentration of an NaOH(aq) solution by performing two different titrations. In a first titration, the student titrates 25.0 mL of 0.100 M H_2SO_4(aq) with NaOH(aq) of unknown concentration.

In a second titration, the student titrates 25.0 mL of 0.100 M HCl(aq) with a sample of the NaOH(aq). During this second titration, the volume of the NaOH(aq) added and the corresponding pH value of the reaction mixture is measured. The graph below represents the relationship between pH and the volume of the NaOH(aq) added for this second titration.

pH versus Volume of NaOH(aq) Added to HCl(aq)
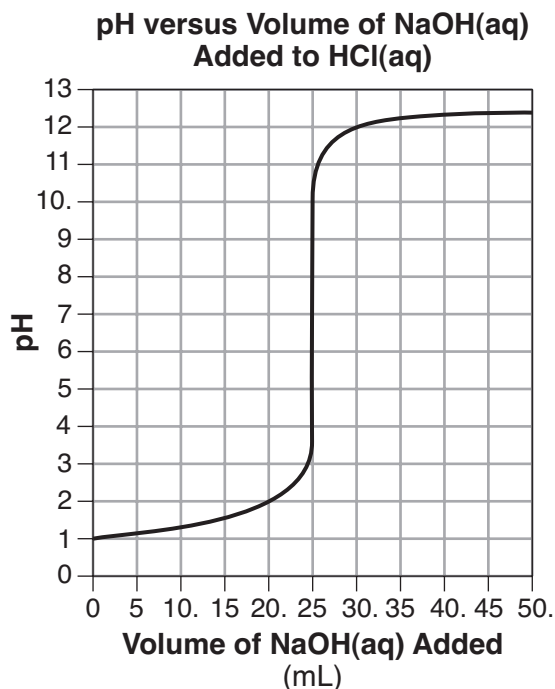
78 Identify the positive ion present in the H_2SO_4(aq) solution before the titration. [1]

79 Complete the equation *in your answer booklet* for the neutralization that occurs in the first titration by writing a formula of the missing product. [1]

80 Based on the graph, determine the volume of NaOH(aq) used to exactly neutralize the HCl(aq). [1]

81 State the color of phenolphthalein indicator if it were added after the HCl(aq) was titrated with 50. mL of NaOH(aq). [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

When uranium-235 nuclei are bombarded with neutrons, many different combinations of smaller nuclei can be produced. The production of neodymium-150 and germanium-81 in one of these reactions is represented by the equation below.

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{150}_{60}Nd + ^{81}_{32}Ge + 5^{1}_{0}n$$
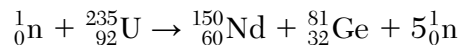
Germanium-81 and uranium-235 have different decay modes. Ge-81 emits beta particles and has a half-life of 7.6 seconds.

82 Explain, in terms of nuclides, why the reaction represented by the nuclear equation is a fission reaction. [1]

83 State the number of protons and number of neutrons in a neodymium-150 atom. [1]

84 Complete the equation *in your answer booklet* for the decay of Ge-81 by writing a notation for the missing nuclide. [1]

85 Determine the time required for a 16.00-gram sample of Ge-81 to decay until only 1.00 gram of the sample remains unchanged. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Tuesday, August 13, 2019 — 8:30 to 11:30 a.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.* You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

**DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.**

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which statement describes the earliest model of the atom?
  (1) An atom is an indivisible hard sphere.
  (2) An atom has a small, dense nucleus.
  (3) Electrons are negative particles in an atom.
  (4) Electrons in an atom have wave-like properties.

2 In all atoms of bismuth, the number of electrons must equal the
  (1) number of protons
  (2) number of neutrons
  (3) sum of the number of neutrons and protons
  (4) difference between the number of neutrons and protons

3 Which symbol represents a particle that has a mass approximately equal to the mass of a neutron?
  (1) α (3) β^-
  (2) β^+ (4) p

4 An orbital is a region in an atom where there is a high probability of finding
  (1) an alpha particle   (3) a neutron
  (2) an electron   (4) a positron

5 Which electron shell in an atom of calcium in the ground state has an electron with the greatest amount of energy?
  (1) 1   (3) 3
  (2) 2   (4) 4

6 As the elements in Period 2 are considered in order from lithium to fluorine, there is an increase in the
  (1) atomic radius
  (2) electronegativity
  (3) number of electron shells
  (4) number of electrons in the first shell

7 Which element is classified as a metalloid?
  (1) boron   (3) sulfur
  (2) potassium   (4) xenon

8 Strontium and barium have similar chemical properties because atoms of these elements have the same number of
  (1) protons   (3) electron shells
  (2) neutrons   (4) valence electrons

9 Which term represents the fixed proportion of elements in a compound?
  (1) atomic mass   (3) chemical formula
  (2) molar mass   (4) density formula

10 Which two terms represent types of chemical formulas?
  (1) mechanical and structural
  (2) mechanical and thermal
  (3) molecular and structural
  (4) molecular and thermal

11 Which element has metallic bonds at room temperature?
  (1) bromine   (3) krypton
  (2) cesium   (4) sulfur

12 What is the number of electrons shared between the atoms in a molecule of nitrogen, N_2?

(1) 8   (3) 3

(2) 2   (4) 6

13 Given the equation representing a reaction:

$$H + H \rightarrow H_2$$

What occurs during this reaction?

(1) A bond is broken and energy is absorbed.

(2) A bond is broken and energy is released.

(3) A bond is formed and energy is absorbed.

(4) A bond is formed and energy is released.

14 An atom of which element has the strongest attraction for electrons in a chemical bond?

(1) chlorine   (3) phosphorus

(2) carbon   (4) sulfur

15 At STP, a 50.-gram sample of $H_2O(\ell)$ and a 100.-gram sample of $H_2O(\ell)$ have

(1) the same chemical properties

(2) the same volume

(3) different temperatures

(4) different empirical formulas

16 Which statement describes a mixture of sand and water at room temperature?

(1) It is heterogeneous, and its components are in the same phase.

(2) It is heterogeneous, and its components are in different phases.

(3) It is homogeneous, and its components are in the same phase.

(4) It is homogeneous, and its components are in different phases.

17 Distillation is a process used to separate a mixture of liquids based on different

(1) boiling points   (3) freezing points

(2) densities   (4) solubilities

18 According to the kinetic molecular theory, which statement describes the particles in a sample of an ideal gas?

(1) The particles are constantly moving in circular paths.

(2) The particles collide, decreasing the total energy of the system.

(3) The particles have attractive forces between them.

(4) The particles are considered to have negligible volume.

19 Which sample of matter has the greatest distance between molecules at STP?

(1) $N_2(g)$ (3) $C_6H_{14}(\ell)$

(2) $NH_3(aq)$ (4) $C_6H_{12}O_6(s)$

20 For a chemical system at equilibrium, the concentrations of both the reactants and the products must

(1) decrease   (3) be constant

(2) increase   (4) be equal

21 In terms of disorder and energy, systems in nature have a tendency to undergo changes toward

(1) less disorder and lower energy

(2) less disorder and higher energy

(3) greater disorder and lower energy

(4) greater disorder and higher energy

22 The only two elements in alkenes and alkynes are

(1) carbon and nitrogen

(2) carbon and hydrogen

(3) oxygen and nitrogen

(4) oxygen and hydrogen

23 Which functional group contains a nitrogen atom and an oxygen atom?

(1) ester   (3) amide

(2) ether   (4) amine

24 When a sample of Mg(s) reacts completely with $O_2(g)$, the Mg(s) loses 5.0 moles of electrons. How many moles of electrons are gained by the $O_2(g)$?

(1) 1.0 mol   (3) 5.0 mol

(2) 2.5 mol   (4) 10.0 mol

25 Which statement describes the reactions in an electrochemical cell?

(1) Oxidation occurs at the anode, and reduction occurs at the cathode.

(2) Oxidation occurs at the cathode, and reduction occurs at the anode.

(3) Oxidation and reduction both occur at the cathode.

(4) Oxidation and reduction both occur at the anode.

26 A 0.050 M aqueous solution of which compound is the best conductor of electric current?

(1) C_3H_7OH (3) $MgSO_4$

(2) $C_6H_{12}O_6$ (4) K_2SO_4

27 What is the color of bromcresol green indicator in a solution with a pH value of 2.0?

(1) blue   (3) red

(2) green   (4) yellow

28 Which formula can represent hydrogen ions in an aqueous solution?

(1) $OH^-(aq)$ (3) $H_3O^+(aq)$

(2) $Hg_2^{2+}(aq)$ (4) $NH_4^+(aq)$

29 In which reaction is an atom of one element converted into an atom of another element?

(1) combustion

(2) fermentation

(3) oxidation-reduction

(4) transmutation

30 In which type of nuclear reaction do nuclei combine to form a nucleus with a greater mass?

(1) alpha decay   (3) fusion

(2) beta decay   (4) fission

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 The bright-line spectra produced by four elements are represented in the diagram below.

Bright-Line Spectra of Four Elements

Wavelength (nm)
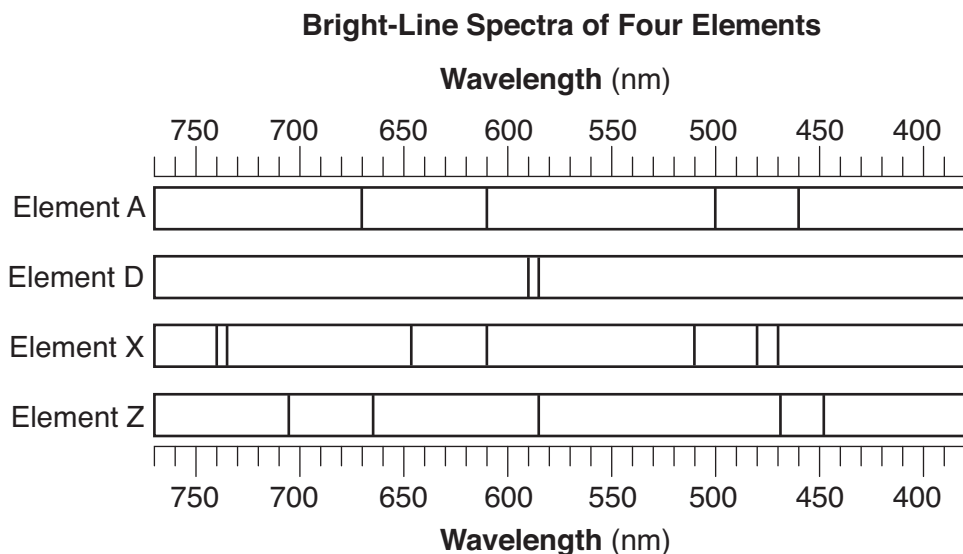
Given the bright-line spectrum of a mixture formed from two of these elements:
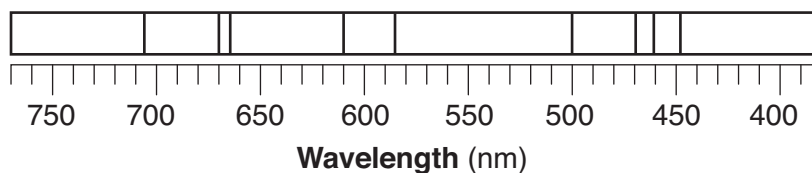
Which elements are present in this mixture?

(1) *A* and *X* (3) *D* and *X*
(2) *A* and *Z* (4) *D* and *Z*

32 Which electron configuration represents the electrons in an atom of sulfur in an excited state?

(1) 2 – 8 – 6 (3) 2 – 8 – 7
(2) 2 – 7 – 7 (4) 2 – 7 – 8

33 Which notations represent atoms that have the same number of protons but a different number of neutrons?

(1) H-3 and He-3 (3) Cl-35 and Cl-37
(2) S-32 and S-32 (4) Ga-70 and Ge-73

34 What is the chemical name of the compound NH_4SCN?

(1) ammonium thiocyanate
(2) ammonium cyanide
(3) nitrogen hydrogen cyanide
(4) nitrogen hydrogen sulfate

35 Which equation represents a conservation of atoms?

(1) $2Fe + 2O_2 \rightarrow Fe_2O_3$
(2) $2Fe + 3O_2 \rightarrow Fe_2O_3$
(3) $4Fe + 2O_2 \rightarrow 2Fe_2O_3$
(4) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

36 Which compound has covalent bonds?

(1) H_2O (3) Na_2O
(2) Li_2O (4) K_2O

37 Which particle diagram represents a sample of oxygen gas at STP?

Key
● = one atom of oxygen
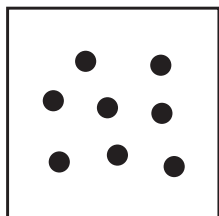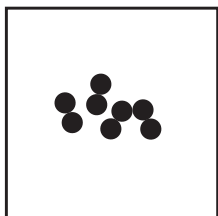
(1)   (3)
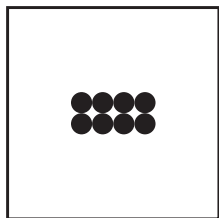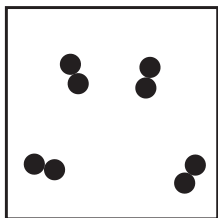
(2)   (4)

38 At which temperature and pressure will a sample of neon gas behave most like an ideal gas?

(1) 300. K and 2.0 atm   (3) 500. K and 2.0 atm
(2) 300. K and 4.0 atm   (4) 500. K and 4.0 atm

39 What is the molarity of 2.0 liters of an aqueous solution that contains 0.50 mole of potassium iodide, KI?

(1) 1.0 M   (3) 0.25 M
(2) 2.0 M   (4) 0.50 M

40 The volumes of four samples of gaseous compounds at 298 K and 101.3 kPa are shown in the table below.

Sample	Compounds	Volume (L)
1	$NH_3(g)$	44.0
2	$CO_2(g)$	33.0
3	$HF(g)$	44.0
4	$CH_4(g)$	22.0

Which two samples contain the same number of molecules?

(1) 1 and 2   (3) 2 and 3
(2) 1 and 3   (4) 2 and 4

41 Hydrochloric acid reacts faster with powdered zinc than with an equal mass of zinc strips because the greater surface area of the powdered zinc

(1) decreases the frequency of particle collisions
(2) decreases the activation energy of the reaction
(3) increases the frequency of particle collisions
(4) increases the activation energy of the reaction

42 Given the equation representing a system at equilibrium in a sealed, rigid container:

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) + \text{energy}$$
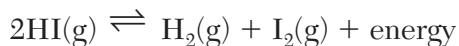
Increasing the temperature of the system causes the concentration of

(1) HI to increase
(2) H_2 to increase
(3) HI to remain constant
(4) H_2 to remain constant

43 Based on Table *I*, which equation represents a reaction with the greatest difference between the potential energy of the products and the potential energy of the reactants?

(1) $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

(2) $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$

(3) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$

(4) $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(\ell)$

44 Which phase change results in an increase in entropy?

(1) $I_2(g) \rightarrow I_2(s)$
(2) $CH_4(g) \rightarrow CH_4(\ell)$
(3) $Br_2(\ell) \rightarrow Br_2(g)$
(4) $H_2O(\ell) \rightarrow H_2O(s)$

45 Given the formula for a compound:

```
    H   H   H   O       H
    |   |   |   ||      |
H − C − C − C − C − O − C − H
    |   |   |           |
    H   H   H           H
```
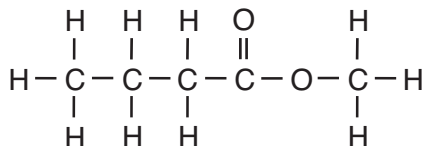
What is the name of this compound?

(1) methyl butanoate
(2) methyl butyl ether
(3) pentanone
(4) pentanoic acid

46 Given the equation representing a reaction:

$$2Ca(s) + O_2(g) \rightarrow 2CaO(s)$$
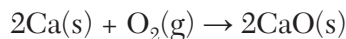
During this reaction, each element changes in

(1) atomic number
(2) oxidation number
(3) number of protons per atom
(4) number of neutrons per atom

47 Which equation represents a spontaneous reaction?

(1) $Ca + Ba^{2+} \rightarrow Ca^{2+} + Ba$
(2) $Co + Zn^{2+} \rightarrow Co^{2+} + Zn$
(3) $Fe + Mg^{2+} \rightarrow Fe^{2+} + Mg$
(4) $Mn + Ni^{2+} \rightarrow Mn^{2+} + Ni$

48 Which equation represents a neutralization reaction?

(1) $6HClO \rightarrow 4HCl + 2HClO_3$

(2) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

(3) $Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$

(4) $Ba(OH)_2 + Cu(NO_3)_2 \rightarrow Ba(NO_3)_2 + Cu(OH)_2$

49 Which radioisotope requires long-term storage as the method of disposal, to protect living things from radiation exposure over time?

(1) Pu-239
(2) Fr-220
(3) Fe-53
(4) P-32

50 Given the equation representing a reaction:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{140}_{56}Ba + ^{93}_{36}Kr + 3^{1}_{0}n + energy$$

total mass equals
236.053 u

total mass equals
235.868 u
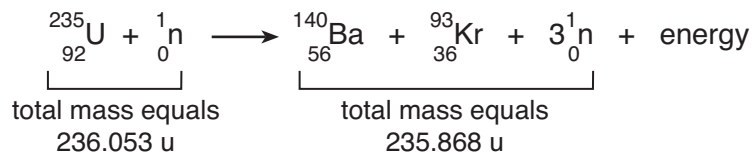
Which statement explains the energy term in this reaction?

(1) Mass is gained due to the conversion of mass to energy.
(2) Mass is gained due to the conversion of energy to mass.
(3) Mass is lost due to the conversion of mass to energy.
(4) Mass is lost due to the conversion of energy to mass.

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 51 through 53 on the information below and on your knowledge of chemistry.

The only naturally occurring isotopes of nitrogen are N-14 and N-15.

51 State the number of protons in an atom of N-15. [1]

52 State the number of electrons in each shell of a N-14 atom in the ground state. [1]

53 Based on the atomic mass of the element nitrogen on the Periodic Table, compare the relative abundances of the naturally occurring isotopes of nitrogen. [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

The melting points and boiling points of five substances at standard pressure are listed on the table below.

Melting Points and Boiling Points of Five Substances

Substance	Melting Point (K)	Boiling Point (K)
HCl	159	188
NO	109	121
F_2	53	85
Br_2	266	332
I_2	387	457

54 Identify the substance in this table that is a liquid at STP. [1]

55 State, in terms of the strength of intermolecular forces, why I_2 has a higher boiling point than F_2. [1]

56 State what happens to the potential energy of a sample of $NO(\ell)$ at 121 K as it changes to $NO(g)$ at constant temperature and standard pressure. [1]

Base your answers to questions 57 through 59 on the information below and on your knowledge of chemistry.

A 100.-gram sample of liquid water is heated from 20.0°C to 50.0°C. Enough $KClO_3(s)$ is dissolved in the sample of water at 50.0°C to form a saturated solution.

57 Using the information on Table B, determine the amount of heat absorbed by the water when the water is heated from 20.0°C to 50.0°C. [1]

58 Based on Table H, determine the vapor pressure of the water sample at its final temperature. [1]

59 Based on Table G, determine the mass of $KClO_3(s)$ that must dissolve to make a saturated solution in 100. g of H_2O at 50.0°C. [1]

Base your answers to questions 60 through 62 on the information below and on your knowledge of chemistry.

The diagram and ionic equation below represent an operating voltaic cell.

Voltaic Cell

$$3Cu^{2+}(aq) + 2Cr(s) \longrightarrow 3Cu(s) + 2Cr^{3+}(aq)$$
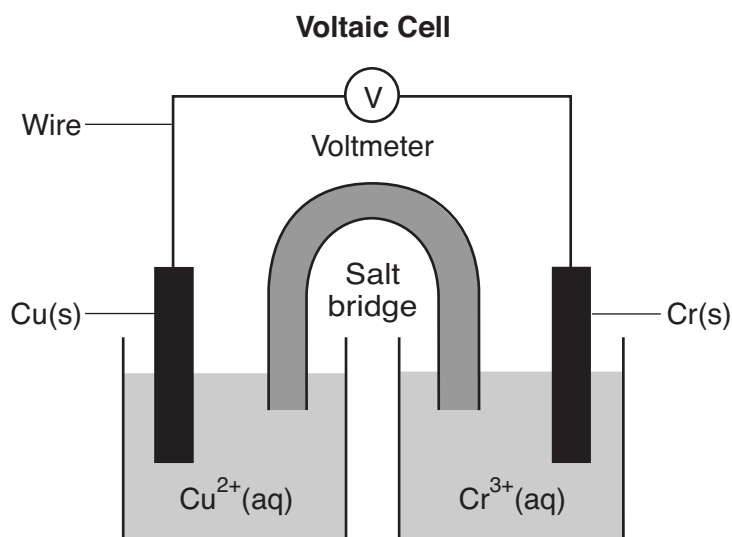
60 Identify the subatomic particles that flow through the wires as the cell operates. [1]

61 State the purpose of the salt bridge in completing the circuit in this cell. [1]

62 Write a balanced equation for the half-reaction that occurs in the copper half-cell when the cell operates. [1]

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

A NaOH(aq) solution with a pH value of 13 is used to determine the molarity of a HCl(aq) solution. A 10.0-mL sample of the HCl(aq) is exactly neutralized by 16.0 mL of 0.100 M NaOH(aq). During this laboratory activity, appropriate safety equipment was used and safety procedures were followed.

63 Determine the molarity of the HCl(aq) sample, using the titration data.   [1]

64 Compare the hydronium ion concentration to the hydroxide ion concentration when the HCl(aq) solution is exactly neutralized by the NaOH(aq) solution.   [1]

65 Determine the pH value of a solution that has a H^+(aq) ion concentration 10 times greater than the original NaOH(aq) solution.   [1]

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

A hydrate is a compound that has water molecules within its crystal structure. Magnesium sulfate heptahydrate, $MgSO_4 \bullet 7H_2O$, is a hydrated form of magnesium sulfate. The hydrated compound has 7 moles of H_2O for each mole of $MgSO_4$. When 5.06 grams of $MgSO_4 \bullet 7H_2O$ are heated to at least 300.°C in a crucible by using a laboratory burner, the water molecules are released. The sample was heated repeatedly, until the remaining $MgSO_4$ had a constant mass of 2.47 grams. During this laboratory activity, appropriate safety equipment was used and safety procedures were followed.

66 Explain why the sample in the crucible was heated repeatedly until the sample had a constant mass. [1]

67 Using the lab data, show a numerical setup for calculating the percent composition by mass of water in the hydrated compound. [1]

68 Determine the gram-formula mass of the magnesium sulfate heptahydrate. [1]

Base your answers to questions 69 through 71 on the information below and on your knowledge of chemistry.

Solid sodium chloride, also known as table salt, can be obtained by the solar evaporation of seawater and from underground mining. Liquid sodium chloride can be decomposed by electrolysis to produce liquid sodium and chlorine gas, as represented by the equation below.

$$2NaCl(\ell) \rightarrow 2Na(\ell) + Cl_2(g)$$

69 State, in terms of electrons, why the radius of a Na^+ ion in the table salt is smaller than the radius of a Na atom. [1]

70 Identify the noble gas that has atoms with the same number of electrons as a chloride ion in table salt. [1]

71 In the space *in your answer booklet*, draw a Lewis electron-dot diagram of a Cl_2 molecule. [1]

Base your answers to questions 72 through 75 on the information below and on your knowledge of chemistry.

The enclosed cabin of a submarine has a volume of 2.4×10^5 liters, a temperature of 312 K, and a pressure of 116 kPa. As people in the cabin breathe, carbon dioxide gas, $CO_2(g)$, can build up to unsafe levels. Air in the cabin becomes unsafe to breathe when the mass of $CO_2(g)$ in this cabin exceeds 2156 grams.

72 State what happens to the average kinetic energy of the gas molecules if the cabin temperature *decreases*. [1]

73 Show a numerical setup for calculating the pressure in the submarine cabin if the cabin temperature changes to 293 K. [1]

74 Determine the number of moles of $CO_2(g)$ in the submarine cabin at which the air becomes unsafe to breathe. The gram-formula mass of CO_2 is 44.0 g/mol. [1]

75 Convert the original air pressure in the cabin of the submarine to atmospheres. [1]

Base your answers to questions 76 through 78 on the information below and on your knowledge of chemistry.

Automobile catalytic converters use a platinum catalyst to reduce air pollution by changing emissions such as carbon monoxide, $CO(g)$, into carbon dioxide, $CO_2(g)$. The uncatalyzed reaction is represented by the balanced equation below.

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g) + heat$$
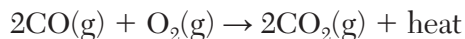
76 On the labeled axes *in your answer booklet*, draw a potential energy diagram for the reaction represented by this equation. [1]

77 Compare the activation energy of the catalyzed reaction to the activation energy of the uncatalyzed reaction. [1]

78 Determine the number of moles of $O_2(g)$ required to completely react with 28 moles of $CO(g)$ during this reaction. [1]

Base your answers to questions 79 through 81 on the information below and on your knowledge of chemistry.

The solvent 2-chloropropane can be made when chemists react propene with hydrogen chloride, as shown in the equation below.

$$
\begin{array}{c}
\text{H} \quad \text{H} \\
| \quad | \\
\text{H}-\text{C}-\text{C}=\text{C}-\text{H} \ + \ \text{HCl} \ \longrightarrow \\
| \quad \quad | \\
\text{H} \quad \quad \text{H}
\end{array}
\qquad
\begin{array}{c}
\text{H} \quad \text{H} \quad \text{H} \\
| \quad | \quad | \\
\text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\
| \quad | \quad | \\
\text{H} \quad \text{Cl} \quad \text{H}
\end{array}
$$
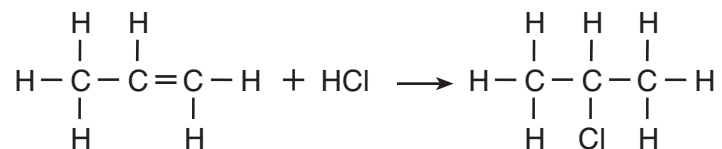
79 Identify the element in propene that is in all organic compounds. [1]

80 Explain, in terms of chemical bonds, why the hydrocarbon reactant is classified as unsaturated. [1]

81 Write the general formula for the homologous series to which propene belongs. [1]

Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

Radioactive emissions can be detected by a Geiger counter. When radioactive emissions enter the Geiger counter probe, which contains a noble gas such as argon or helium, some of the atoms are ionized. The ionized gas allows for a brief electric current. The current causes the speaker to make a clicking sound. To make sure that the Geiger counter is measuring radiation properly, the device is tested using the radioisotope Cs-137.

To detect gamma radiation, an aluminum shield can be placed over the probe window, to keep alpha and beta radiation from entering the probe. A diagram that represents the Geiger counter is shown below.

Probe containing
a noble gas

Window for
radiation to enter

Amplifier and speaker
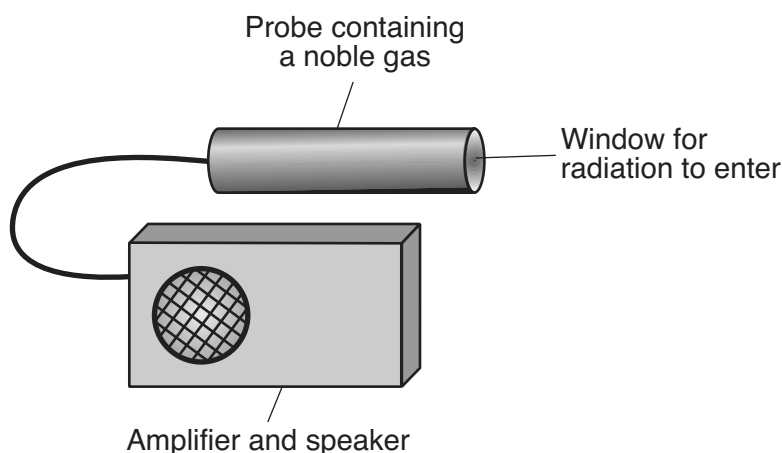
82 Compare the first ionization energy of argon to the first ionization energy of helium. [1]

83 State evidence from the passage that gamma radiation has greater penetrating power than alpha or beta radiation. [1]

84 Determine the time required for a sample of cesium-137 to decay until only $\frac{1}{8}$ of the original sample remains unchanged. [1]

85 Complete the nuclear equation *in your answer booklet* for the decay of Cs-137 by writing a notation for the missing product. [1]

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, August 17, 2022 — 8:30 to 11:30 a.m., only

> The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.* You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

> Notice. . .
> A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 What is the number of protons in an atom with the electron configuration of 2−5?

(1) 5   (3) 3
(2) 2   (4) 7

2 In the wave-mechanical model of an atom, an orbital is defined as

(1) a region of the most probable neutron location
(2) a region of the most probable electron location
(3) the straight-line path of a neutron
(4) the straight-line path of an electron

3 In the ground state, which shell of a potassium atom has an electron with the greatest amount of energy?

(1) first   (3) third
(2) second   (4) fourth

4 Which phrase describes two atoms that contain the same number of protons but a different number of neutrons?

(1) ions of the same element
(2) isotopes of the same element
(3) a mixture of different elements
(4) nuclides of different elements

5 All atoms of an element have the same

(1) mass number
(2) atomic mass
(3) number of neutrons
(4) number of protons

6 Which Group 15 element is classified as a metal?

(1) N   (3) As
(2) P   (4) Bi

7 Compared to the number of electron shells and radius of an aluminum atom in the ground state, a boron atom in the ground state has

(1) fewer electron shells and a smaller radius
(2) fewer electron shells and a larger radius
(3) more electron shells and a smaller radius
(4) more electron shells and a larger radius

8 Hydrogen sulfide, H_2S, is classified as a

(1) compound with atoms in a fixed proportion
(2) compound with atoms in a proportion that can vary
(3) mixture with atoms in a fixed proportion
(4) mixture with atoms in a proportion that can vary

9 A structural formula differs from a molecular formula in that a structural formula shows the

(1) arrangement of atoms
(2) number of atoms
(3) ratio of atoms
(4) types of atoms

10 Which type of reaction occurs when a compound is separated into its elements?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

11 Which terms represent two categories of compounds?

(1) chemical and physical
(2) chemical and molecular
(3) ionic and physical
(4) ionic and molecular

12 When an atom of hydrogen and an atom of chlorine combine to form a molecule of hydrogen chloride, a bond is

(1) formed as energy is absorbed
(2) formed as energy is released
(3) broken as energy is absorbed
(4) broken as energy is released

13 All atoms of the element vanadium must have the same

(1) atomic number
(2) mass number
(3) number of neutrons plus electrons
(4) number of protons plus neutrons

14 Which sample of matter can be separated into two different substances by physical means?

(1) liquid bromine
(2) gaseous propane
(3) solid sodium acetate
(4) aqueous magnesium sulfate

15 Two liquids can be separated by distillation due to a difference in

(1) concentration   (3) boiling point
(2) conductivity   (4) heat of fusion

16 Which unit can be used to express the concentration of a $PbCl_2$(aq) solution?

(1) kelvins   (3) pascals
(2) kilojoules per gram   (4) parts per million

17 Compared to the freezing point and boiling point of water at 1.0 atm, a 0.5 M aqueous solution of NaCl at 1.0 atm has

(1) a lower freezing point and a lower boiling point
(2) a lower freezing point and a higher boiling point
(3) a higher freezing point and a lower boiling point
(4) a higher freezing point and a higher boiling point

18 Which form of energy is converted to thermal energy when propane burns in air?

(1) chemical   (3) mechanical
(2) electrical   (4) nuclear

19 According to the kinetic molecular theory, which statement explains why an ideal gas can be compressed to a smaller volume?

(1) The motion of the gas particles is circular and orderly.
(2) The force of attraction between the gas particles is strong.
(3) As the gas particles collide, the total energy of the system decreases.
(4) The gas particles are separated by great distances relative to their size.

20 Under which conditions of temperature and pressure does a sample of propane behave *least* like an ideal gas?

(1) 250. K and 1.0 atm   (3) 500. K and 1.0 atm
(2) 250. K and 5.0 atm   (4) 500. K and 5.0 atm

21 Compared to a 1.0-L sample of CO_2(g) in a sealed, rigid container at STP, a 1.0-L sample of CH_4(g) in a sealed, rigid container at STP has the same

(1) density
(2) molar mass
(3) chemical properties
(4) number of molecules

22 A chemical reaction occurs when

(1) H_2O(g) forms H_2O(ℓ)
(2) H_2O(ℓ) forms H_2O(s)
(3) O_2(ℓ) forms O_2(s)
(4) O_2(g) forms O_3(g)

23 What is the purpose of adding a catalyst to a chemical reaction?

(1) to decrease the potential energy of the products
(2) to increase the potential energy of the reactants
(3) to convert solid reactants to liquid reactants
(4) to provide an alternate reaction pathway

24 Systems in nature tend to undergo changes toward

(1) lower energy and less disorder
(2) lower energy and greater disorder
(3) higher energy and less disorder
(4) higher energy and greater disorder

25 Which reaction occurs at the anode in an electrochemical cell?

(1) neutralization   (3) reduction
(2) oxidation   (4) substitution

26 As more $NaCl(s)$ is dissolved in a dilute, unsaturated $NaCl(aq)$ solution, the conductivity of the solution

(1) decreases as the ion concentration decreases
(2) decreases as the ion concentration increases
(3) increases as the ion concentration decreases
(4) increases as the ion concentration increases

27 Which substance always forms when an Arrhenius acid reacts with an Arrhenius base?

(1) CO_2 (3) CH_3OH
(2) H_2 (4) H_2O

28 Which symbol represents a nuclear emission with the greatest mass and the greatest ionizing power?

(1) α (3) β^-
(2) β^+ (4) γ

29 One potential benefit of nuclear fusion reactions is

(1) reactor meltdown
(2) uncontrolled chain reaction
(3) production of large amounts of energy
(4) production of radioactive waste materials

30 Determining the age of a wooden beam from a sunken ship is an example of a beneficial use of

(1) Lewis structures
(2) polyatomic ions
(3) radioactive nuclides
(4) homogeneous mixture

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

31 Given the bright-line spectra of four elements and the spectrum of a mixture formed from two of these elements:

Bright-Line Spectra
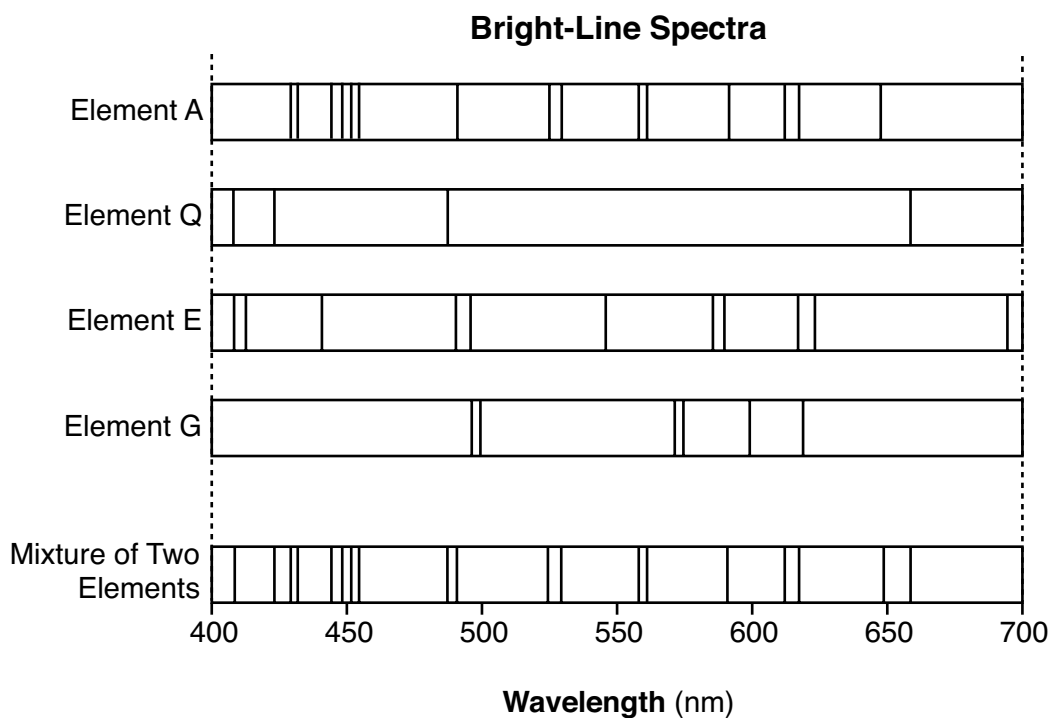
Which two elements are present in this mixture?

(1) *A* and *Q*   (3) *G* and *Q*
(2) *A* and *E*   (4) *G* and *E*

32 What is the approximate mass of an atom that has 10 electrons, 10 protons, and 9 neutrons?

(1) 10. u   (3) 20. u
(2) 19 u   (4) 29 u

33 Which electron configuration represents the electrons of an atom in an excited state?

(1) 2-7-3   (3) 2-8-8-1
(2) 2-8-2   (4) 2-8-9-2

34 Given information about the naturally occurring isotopes of bromine:

Naturally Occurring Isotopes of Bromine

Isotope Notation	Atomic Mass (u)	Natural Abundance (%)
Br-79	78.92	50.69
Br-81	80.92	49.31

Which numerical setup can be used to determine the atomic mass of bromine?

(1) (78.92 u)(50.69) + (80.92 u)(49.31)
(2) (80.92 u)(50.69) + (78.92 u)(49.31)
(3) (78.92 u)(0.5069) + (80.92 u)(0.4931)
(4) (80.92 u)(0.5069) + (78.92 u)(0.4931)

35 What is a chemical name of the compound CuS?

(1) copper(I) sulfide   (3) copper(II) sulfide
(2) copper(I) sulfate   (4) copper(II) sulfate

36 Given the equation representing a reaction:

$$2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O(g)$$
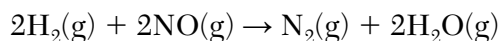
What is the mass of $N_2(g)$ produced when 1.0 gram of $H_2(g)$ completely reacts with 15.0 grams of NO(g) to produce 9.0 grams of $H_2O(g)$?

(1) 7.0 g   (3) 25.0 g
(2) 14.0 g   (4) 28.0 g

37 An atom of which element bonds with an atom of hydrogen to form the most polar bond?

(1) bromine   (3) fluorine
(2) chlorine   (4) iodine

38 Given the diagram representing a classification of matter:
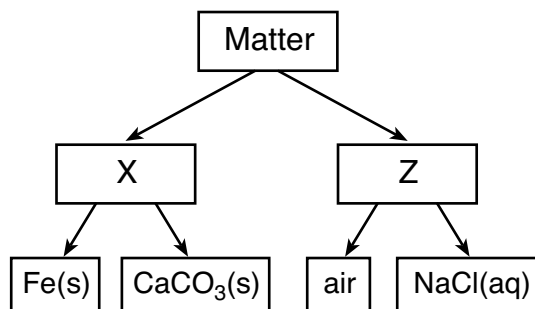
Which types of matter are represented by X and Z in the diagram?

(1) X is mixture, and Z is substance.
(2) X is substance, and Z is mixture.
(3) X is element, and Z is compound.
(4) X is compound, and Z is element.

39 Based on Table G, which sample, when added to 100. grams of water and thoroughly stirred, produces a heterogeneous mixture at 20.°C?

(1) 20. g of KCl   (3) 80. g of KCl
(2) 20. g of KI   (4) 80. g of KI

40 How many milliliters of 1 M HCl(aq) must be diluted with water to make exactly 500 mL of 0.1 M HCl(aq)?

(1) 10 mL   (3) 100 mL
(2) 50 mL   (4) 5000 mL

41 Which two particle diagrams represent two different phases of the same compound, only?

Key	
○	= atom of one element
●	= atom of a different element
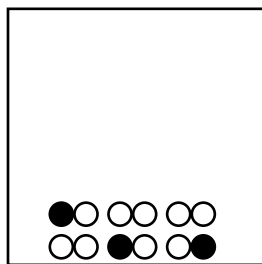
A   B   C   D
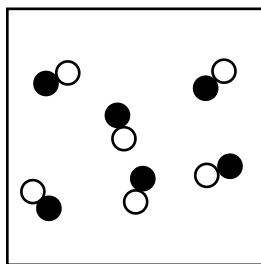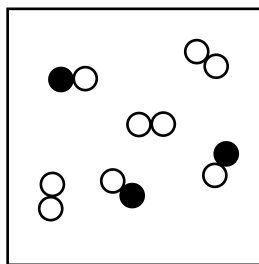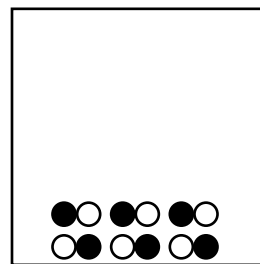
(1) A and B   (3) B and C
(2) A and C   (4) B and D

42 A sample of KCl(s) is dissolved in water to form KCl(aq). When the water in the KCl(aq) is completely evaporated, KCl(s) remains. Which statement describes a property of the KCl(s) after the water evaporated?

(1) The KCl(s) becomes a molecular compound.   (3) The melting point of the KCl(s) is unchanged.
(2) The molar mass of the KCl(s) decreases.   (4) The KCl(s) conducts an electric current.

43 Which statement describes ice and liquid water in a stoppered flask at 0°C at equilibrium?

(1) The rate of melting must equal the rate of freezing.
(2) The rate of freezing must be greater than the rate of melting.
(3) The mass of the ice must equal the mass of the liquid water.
(4) The mass of the ice must be greater than the mass of the liquid water.

44 Given the equation representing a system at equilibrium in a sealed, rigid container:

$$N_2(g) + O_2(g) + 182.6 \text{ kJ} \rightleftharpoons 2NO(g)$$
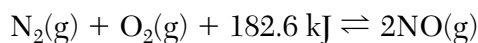
When heat is added to the system, the concentration of $N_2(g)$

(1) decreases and the concentration of NO(g) decreases
(2) decreases and the concentration of NO(g) increases
(3) increases and the concentration of NO(g) increases
(4) increases and the concentration of NO(g) decreases

45 Given the potential energy diagram for a reaction:

Reaction Coordinate
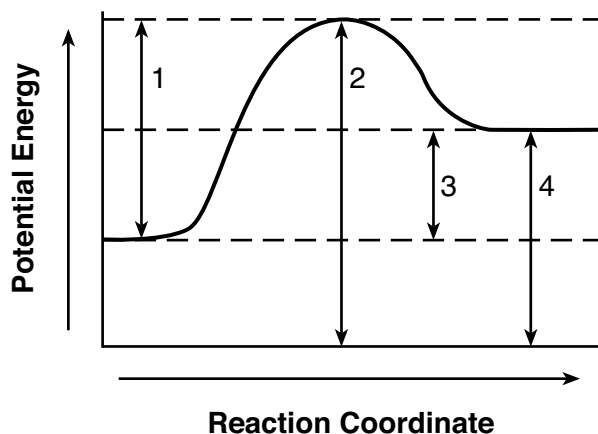
Which numbered interval represents the activation energy of the reaction?

(1) 1   (3) 3
(2) 2   (4) 4

46 Given the formula representing a compound:
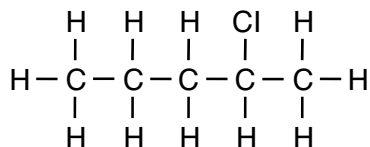
What is a chemical name for the compound?

(1) 2-chloropentene   (3) 4-chloropentene
(2) 2-chloropentane   (4) 4-chloropentane

47 Which formula represents a saturated organic compound?

(1) C_2H_2 (3) C_3H_4
(2) C_2H_4 (4) C_3H_8

48 The compounds $CH_3CH_2CH_2OH$ and $CH_3OCH_2CH_3$ have different

(1) numbers of carbon atoms per mole
(2) numbers of hydrogen atoms per mole
(3) functional groups
(4) molecular masses

49 The diagram and ionic equation below represent an operating voltaic cell.

$$Mg(s) + Ni^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Ni(s)$$
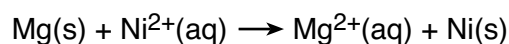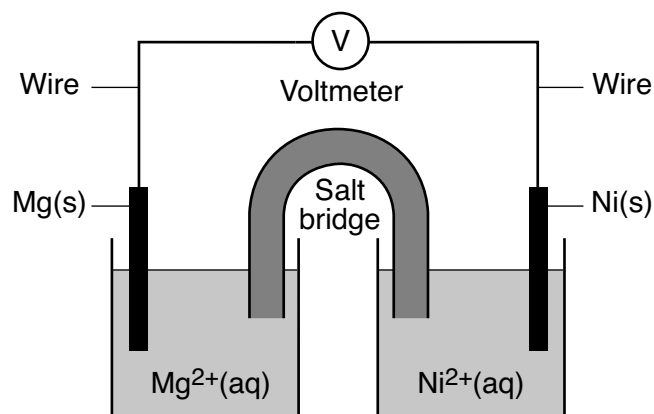
Which phrase describes the direction of electron flow in this cell?

(1) from Ni(s) through the wire to Mg(s)
(2) from Mg(s) through the wire to Ni(s)
(3) from $Ni^{2+}(aq)$ ions through the salt bridge to $Mg^{2+}(aq)$ ions
(4) from $Mg^{2+}(aq)$ ions through the salt bridge to $Ni^{2+}(aq)$ ions

50 Given the equation representing a reaction at equilibrium:

$$NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$
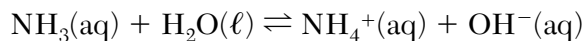
According to one acid-base theory, which pair are the H^+ donors?

(1) $NH_3(aq)$ and $H_2O(\ell)$
(2) $NH_3(aq)$ and $OH^-(aq)$
(3) $NH_4^+(aq)$ and $H_2O(\ell)$
(4) $NH_4^+(aq)$ and $OH^-(aq)$

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

51 Identify a metal from Table *J* that is *less* active than silver. [1]

Base your answers to questions 52 through 54 on the information below and on your knowledge of chemistry.

Fluorine, chlorine, bromine, and iodine are located in Group 17 and are called halogens.

52 State, in terms of electrons, why these halogens have similar chemical properties. [1]

53 Compare the radius of a chlorine atom to the radius of a Cl^- ion. [1]

54 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for an atom of fluorine in the ground state. [1]

Base your answers to questions 55 through 57 on the information below and on your knowledge of chemistry.

A sample of helium gas in a sealed, rigid container is at 240. K and 120. kPa. The temperature is increased to 360. K.

55 State the number of significant figures to which the given pressure is expressed. [1]

56 Determine the pressure of the helium at 360. K. [1]

57 Show a numerical setup for converting 120. kPa to atmospheres. [1]

Base your answers to questions 58 and 59 on the information below and on your knowledge of chemistry.

The table and graph below show information about five aldehydes.

**Names and Molar Masses
of Selected Aldehydes**

Name	Molar Mass (g/mol)
methanal	30.0
ethanal	44.1
propanal	58.1
butanal	72.1
pentanal	86.1

**Boiling Points at Standard Pressure
Versus Molar Mass of Some Aldehydes**
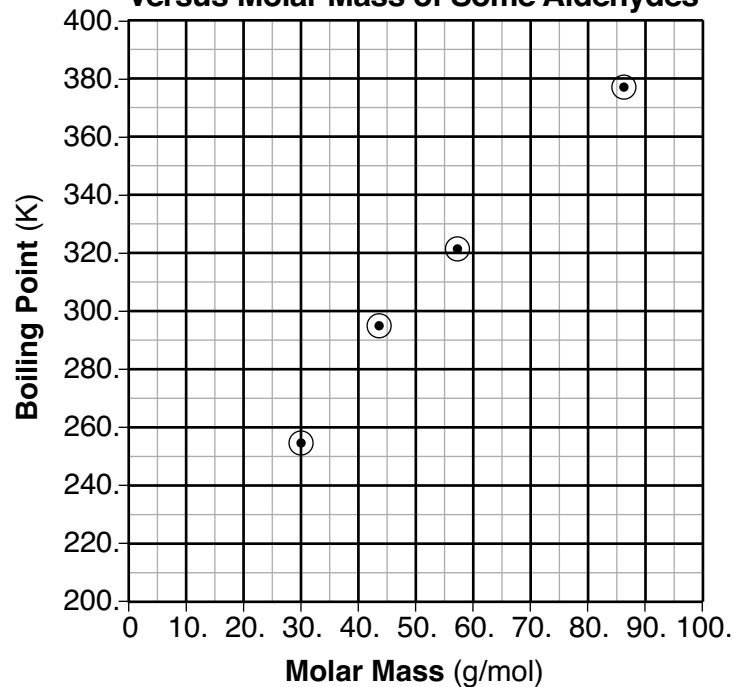
58 Based on the graph, determine the boiling point of butanal at standard pressure. [1]

59 Determine the mass of 3.00 moles of propanal using the molar mass given in the table. [1]

Base your answers to questions 60 through 62 on the information below and on your knowledge of chemistry.

A 100.-mL sample of liquid water is heated in a flask to boiling at 1 atm. As the water boils, some liquid water changes phase to water vapor. The equation below represents this change.

$$H_2O(\ell) + heat \rightarrow H_2O(g)$$

60 Describe the change in potential energy of the water molecules that vaporize during boiling. [1]

61 Compare the entropy of the $H_2O(\ell)$ to the $H_2O(g)$ that is formed. [1]

62 Determine the mass of liquid water that vaporizes if 7700 joules of energy is absorbed by the $H_2O(\ell)$ at 100.°C. [1]

_____

Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

Tritium, hydrogen-3, is a radioisotope.

63 State the number of neutrons in an atom of tritium. [1]

64 Complete the nuclear equation *in your answer booklet* for the decay of tritium by writing a notation for the missing nuclide. [1]

65 Based on Table *N*, identify a nuclide that has the same decay mode as tritium, but has a longer half-life. [1]

_____

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

Phosphorus combines with oxygen to form an oxide that reacts with water to produce phosphoric acid, which is an important industrial compound used to produce fertilizers. An unbalanced equation for the production of phosphoric acid is shown below.

$$P_4O_{10}(s) + H_2O(\ell) \rightarrow H_3PO_4(aq) + energy$$
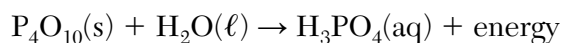
66 Balance the equation *in your answer booklet* for the production of phosphoric acid, using the *smallest* whole-number coefficients. [1]

67 Write the empirical formula of the solid reactant in the equation. [1]

68 Show a numerical setup for calculating the percent composition by mass of phosphorus in P_4O_{10} (formula mass = 283.89 u). [1]

69 Determine the oxidation state of phosphorus in the phosphoric acid. [1]

Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

Calcium oxide, CaO, also known as lime, is an important industrial chemical. Lime can be obtained by the heating of limestone, which is mainly calcium carbonate, $CaCO_3$. An equation representing the reaction for the production of lime is shown below.

$$CaCO_3(s) + heat \rightarrow CaO(s) + CO_2(g)$$
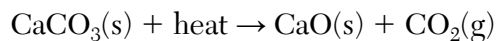
70 State the solubility of limestone in water. [1]

71 State evidence from the equation that the reaction to form lime is endothermic. [1]

72 Identify the noble gas that has atoms in the ground state with the same electron configuration as the calcium ion, in the ground state, in the $CaCO_3$. [1]

73 State the type of chemical bonding in a sample of CaO. [1]

Base your answers to questions 74 and 75 on the information below and on your knowledge of chemistry.

During a laboratory activity, a student places 20.0 mL of HCl(aq) of unknown concentration into a flask. The solution is titrated with 0.10 M KOH(aq) until the HCl(aq) is exactly neutralized. At the end of the titration, the volume of KOH(aq) added is 42.0 mL. During the laboratory activity appropriate safety equipment was used and safety procedures were followed.

74 Compare the number of moles of H^+(aq) ions to the number of moles of OH^-(aq) ions in the titration mixture when the HCl(aq) is exactly neutralized by the KOH(aq). [1]

75 Determine the concentration of the HCl(aq) solution using the titration data. [1]

_____

Base your answers to questions 76 and 77 on the information below and on your knowledge of chemistry.

A scientific sampling instrument landed on a comet. Four of the organic compounds detected on the comet are methyl isocyanate, propanone, propanal, and ethanamide. The structural formula for methyl isocyanate is shown below:

$$
\begin{array}{c}
\text{H} \\
| \\
\text{H}-\text{C}-\text{N}=\text{C}=\text{O} \\
| \\
\text{H}
\end{array}
$$
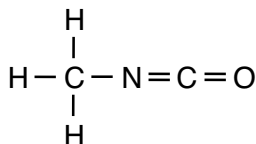
76 Identify the element in these four compounds that makes them organic compounds. [1]

77 Write the names of the two organic compounds detected on the comet that are isomers of each other. [1]

_____

Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

During a laboratory activity appropriate safety equipment is used and safety procedures are followed. A student tests samples of four different metals using 0.20 M aqueous metal ion solutions of the same four metals. The student uses a 24-well plate as the reaction container for the different metal and solution combinations.

Before placing a metal strip in each solution, the student cleans the surface of the metal strip with sandpaper. The 24-well plate diagram below shows the setup and results of the investigation. In each vertical column, the metal strips are all the same metal. For each horizontal row, all of the solutions contain the same type of metal ion.

24-Well Plate with Metal Strips and Aqueous Metal Ion Solutions

78 Using the results of the student's investigation, state evidence that zinc metal is more active than copper metal. [1]

79 Compare the number of electrons lost by the Mg(s) placed in the Zn^{2+}(aq) solution to the number of electrons gained by the Zn^{2+}(aq). [1]

80 Write a balanced, half-reaction equation for the reduction of the copper ions. [1]

81 State why the student was instructed to clean the surface of the metal strips with sandpaper before placing each strip into an aqueous metal ion solution. [1]

Base your answers to questions 82 and 83 on the information below and on your knowledge of chemistry.

Tetrachloromethane, CCl_4, was used as a dry cleaning solvent until it was banned for this use in the U.S. in 1970 due to its toxicity. This solvent was replaced in many dry cleaning processes by tetrachloroethene, C_2Cl_4. Another currently available alternative dry cleaning solvent is 1-bromopropane. The table below shows the boiling points of these solvents.

Boiling Points of Three Compounds at 1 atm

Name	Boiling Point (°C)
tetrachloromethane	76.8
tetrachloroethene	121.3
1-bromopropane	71.1

82 Explain, in terms of intermolecular forces, why tetrachloroethene has a higher boiling point than tetrachloromethane. [1]

83 Draw a structural formula for 1-bromopropane. [1]

_____

Base your answers to questions 84 and 85 on the information below and on your knowledge of chemistry.

When a neutron is absorbed by a uranium-235 nucleus, the nucleus can split. One possible nuclear reaction is represented by the balanced equation below.

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{90}_{38}Sr + {}^{142}_{54}Xe + 4{}^{1}_{0}n + energy$$
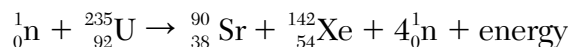
In this reaction, the products have a mass that is 0.180 u less than the mass of the reactants.

84 Compare the energy released per gram of reactant during this reaction to the energy released per gram of reactant in a chemical reaction. [1]

85 Determine the time required for an 8.00-mg sample of Sr-90 to decay until only 2.00 mg of the sample remains unchanged. [1]

_____

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, August 17, 2023 — 8:30 to 11:30 a.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.* You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .
A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Which proposal in the development of the modern model of the atom was made before the others?

(1) Atoms are hard, indivisible spheres of different sizes.
(2) Atoms are mostly empty space with a small dense nucleus.
(3) Atoms have electrons that have wavelike properties.
(4) Atoms have an internal structure that contains negative particles.

2 According to the wave-mechanical model, in the ground state, the 10 electrons of a neon atom would be located

(1) in the nucleus (3) in the first shell
(2) in orbitals (4) in the valence shell

3 Which statement describes two different isotopes of carbon?

(1) The isotopes contain the same number of neutrons and have the same atomic number.
(2) The isotopes contain the same number of neutrons but have a different atomic number.
(3) The isotopes contain a different number of neutrons but have the same atomic number.
(4) The isotopes contain a different number of neutrons and have a different atomic number.

4 An element that is a very reactive metal could have an atomic number of

(1) 9 (3) 19
(2) 2 (4) 79

5 Which element is listed with the number of protons in each of its atoms?

(1) nitrogen, 14 (3) oxygen, 16
(2) silicon, 14 (4) phosphorus, 16

6 What is the overall charge on the nucleus of a fluorine atom?

(1) -1 (3) $+9$
(2) -9 (4) $+19$

7 As the elements with atomic numbers 11 through 17 are considered in order of increasing atomic number, the classification of the elements changes from

(1) metal to metalloid to nonmetal
(2) metal to nonmetal to metalloid
(3) nonmetal to metalloid to metal
(4) nonmetal to metal to metalloid

8 At STP, which property can be used to differentiate one-mole samples of $Cl_2(g)$ and $Kr(g)$?

(1) phase (3) chemical reactivity
(2) pressure (4) temperature

9 Two gaseous forms of oxygen are diatomic oxygen, O_2, and ozone, O_3. These two forms of oxygen have

(1) the same molecular structure and the same properties
(2) the same molecular structure and different properties
(3) different molecular structures and the same properties
(4) different molecular structures and different properties

10 A compound consists of two or more different elements that are

(1) physically mixed in a fixed proportion
(2) physically mixed in a proportion that can vary
(3) chemically combined in a fixed proportion
(4) chemically combined in a proportion that can vary

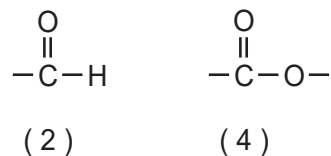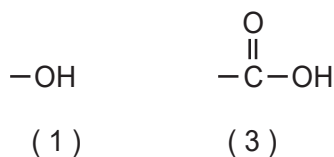11 Compared to the chemical and physical properties of the compound CO, the compound CO_2 has

(1) the same chemical properties and the same physical properties
(2) the same chemical properties and different physical properties
(3) different chemical properties and the same physical properties
(4) different chemical properties and different physical properties

12 Which phrase describes the molecular polarity of and the charge distribution in an HCl molecule?

(1) nonpolar with an asymmetrical charge distribution
(2) nonpolar with a symmetrical charge distribution
(3) polar with an asymmetrical charge distribution
(4) polar with a symmetrical charge distribution

13 Which atom forms an ion with a radius larger than the atomic radius?

(1) calcium atom   (3) lead atom
(2) oxygen atom   (4) tin atom

14 Which sample can be classified as a substance?

(1) air   (3) soil
(2) argon   (4) seawater

15 A 1.0-gram sample of NaCl(s) is dissolved in 100. grams of water at 25°C, and another 1.0-gram sample of NaCl(s) is dissolved in 50. grams of water at 25°C. Which property of the two resulting mixtures will be different?

(1) color of the components in the mixture
(2) particle size of the components in the mixture
(3) polarity of the components in the mixture
(4) proportion by mass of the components in the mixture

16 Based on Table G, which compound has the greatest solubility in 100. grams of water at 10.°C?

(1) HCl   (3) KCl
(2) NaCl   (4) NH_4Cl

17 According to the kinetic molecular theory, ideal gas particles

(1) are separated by small distances relative to their size
(2) do not transfer energy when they collide with each other
(3) have attractive forces between them
(4) move in random, constant, straight-line motion

18 A reaction is most likely to occur when the reacting particles collide with proper orientation and proper

(1) charge   (3) mass
(2) energy   (4) volume

19 A sample of $SO_2(g)$ and a sample of $NO_2(g)$ contain the same number of molecules when they have the same

(1) mass, temperature, and volume
(2) mass, temperature, and pressure
(3) pressure, volume, and temperature
(4) pressure, volume, and mass

20 Which term identifies the strong intermolecular forces found in a sample of liquid water?

(1) ionic bonding   (3) hydrogen bonding
(2) covalent bonding   (4) metallic bonding

21 Which mathematical expression represents the heat of reaction for a chemical change?

(1) (PE of the products) − (PE of the reactants)
(2) (PE of the products) + (PE of the reactants)
(3) (PE of the products) ÷ (PE of the reactants)
(4) (PE of the products) × (PE of the reactants)

22 Catalysts can increase the rate of a chemical reaction by providing

   (1) an alternate reaction pathway with a higher activation energy

   (2) the same reaction pathway with a higher activation energy

   (3) an alternate reaction pathway with a lower activation energy

   (4) the same reaction pathway with a lower activation energy

23 Which term represents the disorder of a system?

   (1) entropy   (3) quanta

   (2) mole   (4) pressure

24 Which element must be present in all organic compounds?

   (1) nitrogen   (3) carbon

   (2) hydrogen   (4) sulfur

25 Based on Table R, which functional group allows a compound to be classified as an organic acid?

$$-OH$$

  (1)

$$\overset{\displaystyle O}{\overset{\displaystyle \|}{-C-H}}$$

  (2)

$$\overset{\displaystyle O}{\overset{\displaystyle \|}{-C-OH}}$$

  (3)

$$\overset{\displaystyle O}{\overset{\displaystyle \|}{-C-O-}}$$

  (4)

26 In a voltaic cell, oxidation occurs

   (1) at the cathode

   (2) at the anode

   (3) in the salt bridge

   (4) in the external circuit

27 Which positive ion must be present in an aqueous solution of an Arrhenius acid?

   (1) H_3O^+ (3) NH_4^+

   (2) Na^+ (4) Rb^+

28 A change that converts an atom of one element to another element is called

   (1) neutralization   (3) sublimation

   (2) oxidation   (4) transmutation

29 Which radiation has the *least* ionizing power and greatest penetrating power?

   (1) alpha particles   (3) gamma emissions

   (2) beta particles   (4) positron emissions

30 Which nuclear emission is listed with its notation?

   (1) alpha particle, ^1_1p (3) neutron, $^0_0\gamma$

   (2) beta particle, $^0_{-1}e$ (4) proton, $^0_{+1}\beta$

Part B–1

Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Diagram 1 represents an atom of hydrogen, showing the nucleus and the electron in the first shell.
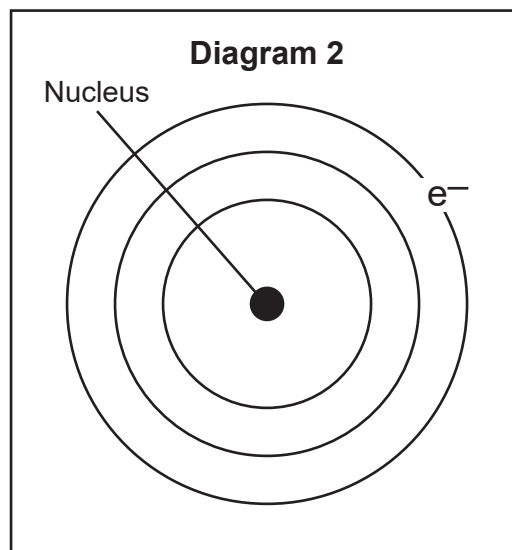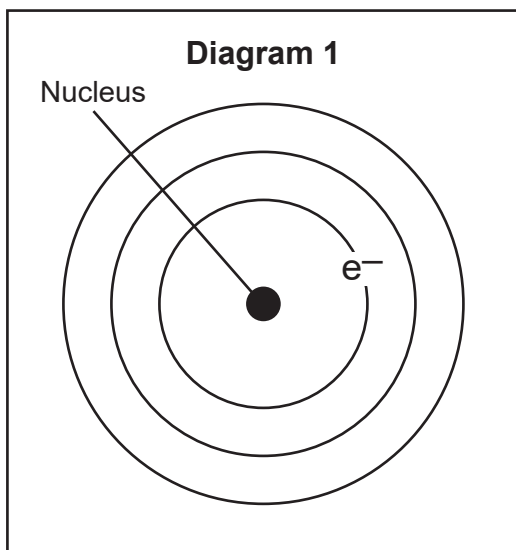
Diagram 1

Diagram 2

What is represented by diagram 2?

(1) a positive ion of hydrogen
(2) a negative ion of hydrogen
(3) an atom of hydrogen in an excited state
(4) an atom of hydrogen in the ground state

32 The table below gives the atomic mass and the abundance of the two naturally occurring isotopes of copper.

Naturally Occurring Isotopes of Copper

Isotope Notation	Atomic Mass of the Isotope (u)	Natural Abundance (%)
Cu-63	62.93	69.15
Cu-65	64.93	30.85

Which numerical setup can be used to calculate the atomic mass of the element copper?

(1) (62.93 u)(30.85) + (64.93 u)(69.15)
(2) (62.93 u)(69.15) + (64.93 u)(30.85)
(3) (62.93 u)(0.3085) + (64.93 u)(0.6915)
(4) (62.93 u)(0.6915) + (64.93 u)(0.3085)

33 Which subatomic particles were discovered as the result of experiments with cathode ray tubes?

(1) electrons   (3) positrons
(2) neutrons   (4) protons

34 Which change in electron location in an atom of calcium is accompanied by the greatest amount of energy emitted?

(1) from shell 1 to shell 2
(2) from shell 2 to shell 1
(3) from shell 1 to shell 4
(4) from shell 4 to shell 1

35 As the atomic number increases in Group 2 from Be to Ba, the first ionization energy

(1) decreases, and the atomic radius decreases
(2) decreases, and the atomic radius increases
(3) increases, and the atomic radius decreases
(4) increases, and the atomic radius increases

36 Given the equation representing a reaction:

$$3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$$
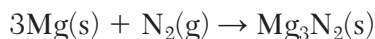
What is the mass of Mg_3N_2 that is produced when 14.58 grams of magnesium completely reacts with 5.60 grams of nitrogen?
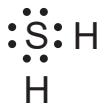
(1) 8.98 g   (3) 20.18 g
(2) 10.46 g   (4) 49.34 g

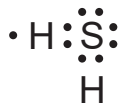37 Which Lewis electron-dot diagram represents a molecule of H_2S?

(1)

(2)

(3)
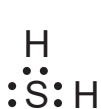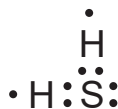
(4)

38 What is the vapor pressure of water at 90.°C?

(1) 40. kPa   (3) 94 kPa
(2) 68 kPa   (4) 150. kPa

39 A sample is composed of two different substances that can be separated by using filter paper. This sample is classified as

(1) a heterogeneous mixture
(2) a homogeneous mixture
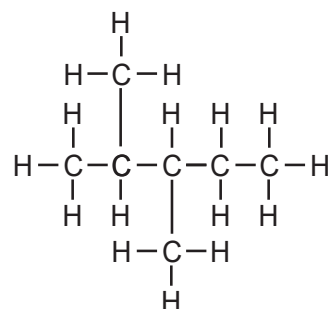(3) a single compound
(4) an unsaturated solution

40 Which solutions react to produce an insoluble compound?

(1) $KCl(aq) + LiCl(aq) \rightarrow$
(2) $LiCl(aq) + NaNO_3(aq) \rightarrow$
(3) $NaCl(aq) + AgClO_3(aq) \rightarrow$
(4) $KNO_3(aq) + AgClO_3(aq) \rightarrow$

41 What is the amount of heat energy absorbed when 40.0 grams of water is heated from 10.0°C to 30.0°C?

(1) 1.67×10^3 J   (3) 5.02×10^3 J
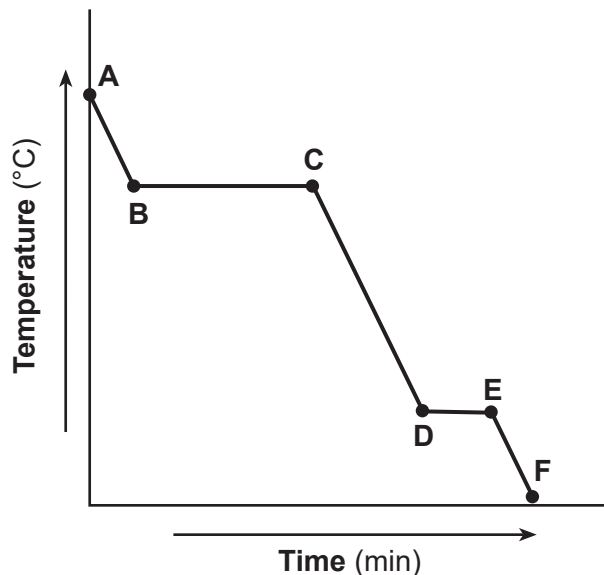(2) 3.34×10^3 J   (4) 2.67×10^5 J

42 Given the formula representing a compound:

What is a chemical name of this compound?

(1) 2,3,3-trimethylbutane
(2) 2-methyl-2-ethylbutane
(3) 2,3-dimethylpentane
(4) 2,3-ethylpentane

43 Given the cooling curve for a substance:

Temperature (°C) vs **Time** (min)

During which intervals is the potential energy decreasing while the average kinetic energy remains constant?

(1) *BC* and *AB*   (3) *EF* and *AB*
(2) *BC* and *DE*   (4) *EF* and *DE*

44 Which formula represents a hydrocarbon?

(1) CO_2 (3) $C_2H_4O_2$
(2) C_3H_8 (4) C_3H_8O

45 Which type of organic reaction produces carbon dioxide and water?

(1) combustion   (3) fermentation
(2) esterification   (4) saponification

46 Which half-reaction equation represents the oxidation of lithium?

(1) $Li^+ + e^- \rightarrow Li$ (3) $Li \rightarrow Li + e^-$
(2) $Li + e^- \rightarrow Li^+$ (4) $Li \rightarrow Li^+ + e^-$

47 Based on Table *J*, which ionic equation represents a spontaneous reaction that can occur in a voltaic cell?

(1) $Fe(s) + Mg^{2+}(aq) \rightarrow Fe^{2+}(aq) + Mg(s)$
(2) $Fe(s) + Mg(s) \rightarrow Fe^{2+}(aq) + Mg^{2+}(aq)$
(3) $Fe^{2+}(aq) + Mg^{2+}(aq) \rightarrow Fe(s) + Mg(s)$
(4) $Fe^{2+}(aq) + Mg(s) \rightarrow Fe(s) + Mg^{2+}(aq)$

48 Given the equation representing a system at equilibrium:

$$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$
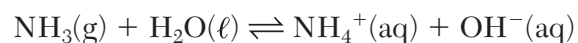
In this system, the $H_2O(\ell)$ acts as

(1) an acid, because it accepts an H^+
(2) an acid, because it donates an H^+
(3) a base, because it accepts an H^+
(4) a base, because it donates an H^+

49 Which indicator is blue in a solution that has a pH value of 7.0?

(1) bromcresol green   (3) phenolphthalein
(2) methyl orange   (4) thymol blue

50 Which radioisotope requires long-term storage to prevent the risk of biological exposure?

(1) N-16   (3) Pu-239
(2) K-42   (4) Au-198

Part B–2

Answer all questions in this part.

Directions (51-65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 51 and 52 on the information below and on your knowledge of chemistry.

The four naturally occurring isotopes of sulfur are sulfur-32, sulfur-33, sulfur-34, and sulfur-36.

51 State the number of valence electrons in an atom of sulfur-32 in the ground state. [1]

52 State the number of neutrons in an atom of sulfur-33. [1]

Base your answers to questions 53 through 55 on the information below and on your knowledge of chemistry.

The Group 1 elements below hydrogen are called alkali metals, and the first five Group 17 elements are called halogens.

53 Compare the electrical conductivity of an alkali metal at STP with the electrical conductivity of a halogen at STP. [1]

54 State the type of chemical bonds formed when an alkali metal and a halogen react to form a compound. [1]

55 Explain, in terms of electrons, why the halogens are all placed in the same group on the Periodic Table. [1]

Base your answers to questions 56 through 58 on the information below and on your knowledge of chemistry.

The unbalanced equation below represents the reaction between silver sulfide and aluminum.

$$Ag_2S + Al \rightarrow Ag + Al_2S_3$$
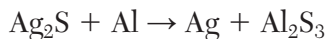
56 Balance the equation *in your answer booklet* for the reaction, using the *smallest* whole number coefficients. [1]

57 Determine the gram-formula mass of the aluminum sulfide product. [1]

58 Show a numerical setup for calculating the number of moles of silver sulfide in a 546-gram sample of Ag_2S (gram-formula mass = 248 g/mol). [1]

Base your answers to questions 59 through 61 on the information below and on your knowledge of chemistry.

Hydrogen gas and iodine gas can combine in a reversible reaction to form hydrogen iodide gas. The equation below represents this system at equilibrium in a sealed, rigid container.

$$H_2(g) + I_2(g) + 53.0 \text{ kJ} \rightleftharpoons 2HI(g)$$
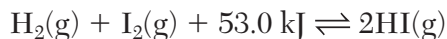
59 State evidence from the equation that the forward reaction is endothermic. [1]

60 State, in terms of reaction rates, why the concentration of $HI(g)$ remains constant when the system is at equilibrium. [1]

61 State how an increase in temperature affects the concentration of $HI(g)$. [1]

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

The equation below represents the reaction of straight-chain butane with chlorine.

$$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$$
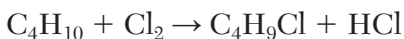
The reaction produces two different isomers of C_4H_9Cl: 1-chlorobutane and 2-chlorobutane. The table below shows the boiling point of each C_4H_9Cl isomer at standard pressure.

Name of Compound	Boiling Point (°C)
1-chlorobutane	78.4
2-chlorobutane	68.2

62 State, in terms of carbon-carbon bonds, why butane is saturated. [1]

63 Identify the class of organic compounds to which the organic product in the equation belongs. [1]

64 Based on the boiling point data, compare the strength of the intermolecular forces in 1-chlorobutane to the strength of the intermolecular forces in 2-chlorobutane. [1]

65 Draw a structural formula for the 2-chlorobutane. [1]

Part C

Answer all questions in this part.

Directions (66-85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

During a laboratory activity, appropriate safety equipment was used and safety procedures were followed, as two students worked with hydrated $CuSO_4$. A hydrate is a compound that has water within its crystal structure.

Student 1 and student 2 each heated their own 3.00-gram sample of hydrated $CuSO_4$. Student 2 determined the percent composition by mass of water in the hydrated $CuSO_4$ to be 37.0%. The accepted value for the percent of water in the hydrated $CuSO_4$ is 36.1%. The final mass values for each student sample are shown in the table below.

Mass Values for Lab Activity

Student	Mass of Hydrated $CuSO_4$ (g)	Mass of $CuSO_4$ After Final Heating (g)	Mass of H_2O in Hydrated $CuSO_4$ (g)
1	3.00	1.98	1.02
2	3.00	1.89	1.11

66 State the number of significant figures in the mass of the hydrated $CuSO_4$ sample used by student 1. [1]

67 Determine the percent composition by mass of water in the hydrated $CuSO_4$ sample, based on the data for student 1. [1]

68 Show a numerical setup for calculating the percent error for the percent composition by mass of water in the hydrated $CuSO_4$ sample as determined by student 2. [1]

Base your answers to questions 69 through 71 on the information below and on your knowledge of chemistry.

Ammonia, $NH_3(g)$, is a compound that is used to manufacture fertilizer for agriculture. This gas is produced by a reaction between nitrogen gas, $N_2(g)$, and hydrogen gas, $H_2(g)$. During this reaction, bonds are both broken and formed. Bond energy is the amount of energy required to break one mole of bonds between atoms in the gas phase. The bond energy of an H–H bond is 436 kilojoules per mole.

69 State the number of electrons shared between the nitrogen atom and one of the hydrogen atoms in an ammonia molecule. [1]

70 Identify the noble gas that has atoms in the ground state with the same electron configuration as the nitrogen atom in a molecule of ammonia. [1]

71 Determine the energy required to break all of the bonds in 0.250 mol of H–H bonds in the $H_2(g)$. [1]

Base your answers to questions 72 and 73 on the information below and on your knowledge of chemistry.

The diagram below represents a sealed, rigid cylinder with a movable piston containing helium gas at 296 K and 1.3 atm.


He(g)
P = 1.3 atm
V = 50.0 mL
T = 296 K
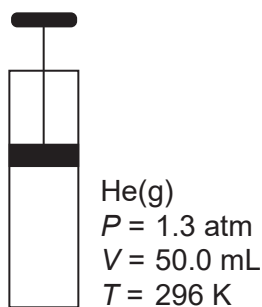
72 Compare the density of the helium in the cylinder when the volume is 50.0 mL to the density of the helium in the cylinder when the volume is decreased to 25.0 mL. [1]

73 State *one* change in temperature and *one* change in pressure that will cause the gas in the cylinder to behave more like an ideal gas. [1]

Base your answers to questions 74 through 76 on the information below and on your knowledge of chemistry.

Four different samples of $NaNO_3(aq)$ are each evaporated to dryness. The solution volume and mass of the dry $NaNO_3(s)$ of each sample are recorded in the table below.

Sample	Volume of $NaNO_3(aq)$ (L)	Mass of dry $NaNO_3(s)$ (g)
1	0.0524	3.56
2	0.0988	6.72
3	0.2017	13.71
4	0.2431	16.53

The number of moles of $NaNO_3(s)$ of each sample was then calculated and used to produce the graph below.

Moles of $NaNO_3$ Versus Volume of Solution Sample
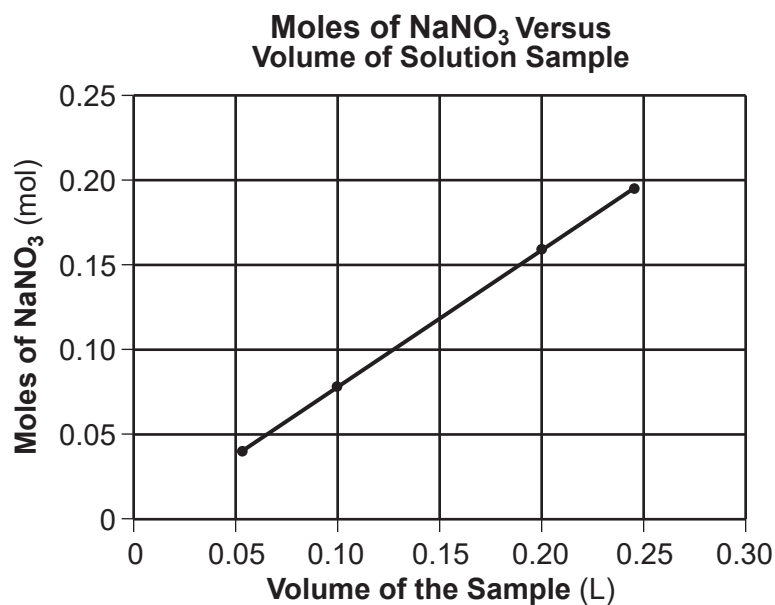

74 Determine the number of moles of $NaNO_3$ in 0.15 L of the solution. [1]

75 Write a chemical name for $NaNO_3$. [1]

76 Compare the boiling point of the solution in sample 1 at standard pressure to the boiling point of water at standard pressure. [1]

Base your answers to questions 77 through 79 on the information below and on your knowledge of chemistry.

Electroplating is an electrolytic process that can be used to coat metal objects with a less reactive metal. The diagram below shows an electroplating cell that includes a power source connected to a copper rod and a bracelet made from a different metal. The rod and bracelet are in an aqueous copper(II) sulfate solution.
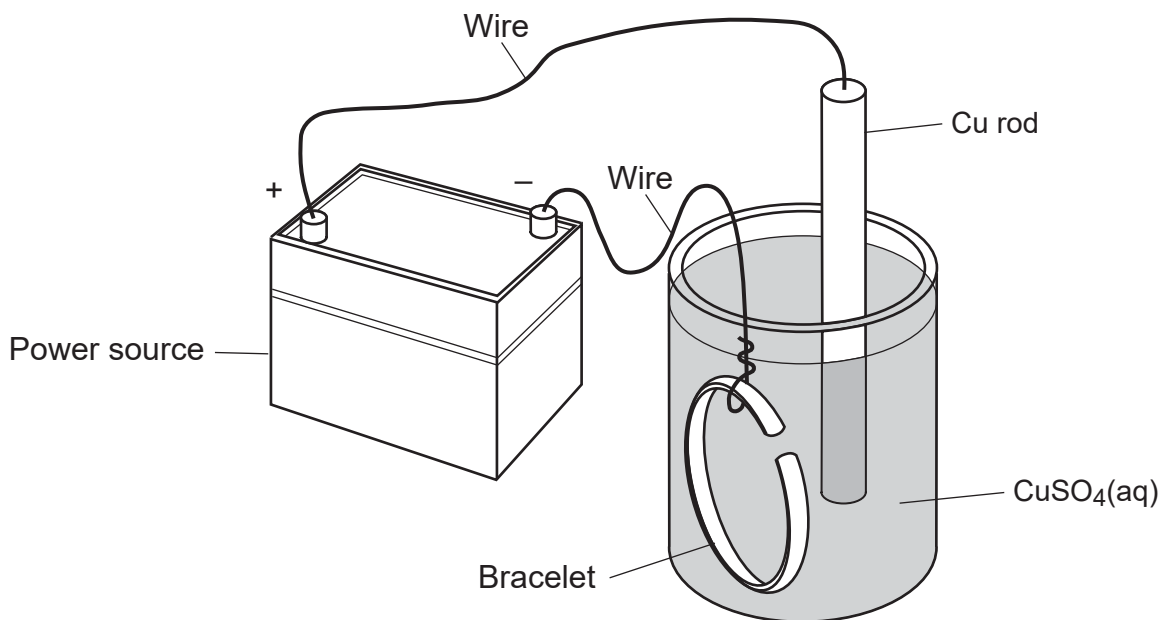
77 Identify the electrode that attracts the Cu^{2+} ions as the cell operates. [1]

78 Determine the oxidation state of sulfur in $CuSO_4$. [1]

79 Write a balanced half-reaction equation for the reduction of Cu^{2+} ions that occurs in this cell. [1]

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

In a titration, 15.0 mL of hydrochloric acid, HCl(aq), of unknown concentration is exactly neutralized by the addition of 8.0 mL of 0.15 M KOH(aq). The pH value of the HCl(aq) solution is 1.1 before the titration begins.
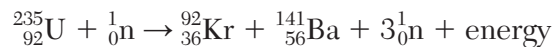
80 Complete the equation *in your answer booklet* for the reaction that occurs in this titration by writing the formula for *each* product. [1]

81 State the pH value of the solution when the $H^+(aq)$ ion concentration in the acid has *decreased* by a factor of 10 compared to its original value. [1]

82 Determine the molarity of the HCl(aq), by using the titration data. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

Nuclear fission is currently used to produce electricity in a nuclear power plant. One possible fission reaction is represented by the equation below.

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + 3^{1}_{0}\text{n} + \text{energy}$$

The barium-141 decays by beta emission and has a half-life of 18.3 minutes.

83 Based on Table *N*, state the decay mode for U-235. [1]

84 Complete the nuclear equation *in your answer booklet* for the decay of Ba-141, by writing a notation for the missing product. [1]

85 Compare the amount of energy released by the fission of one mole of uranium-235 to the amount of energy released by the combustion of one mole of octane fuel, C_8H_{18}. [1]