CHEMISTRY TEST

Note: For all questions involving solutions, assume that the solvent is water unless otherwise stated.

Throughout the test the following symbols have the definitions specified unless otherwise noted.

H	= enthalpy	atm	= atmosphere(s)
M	= molar	g	= gram(s)
n	= number of moles	J	= joule(s)
P	= pressure	kJ	= kilojoule(s)
R	= molar gas constant	L	= liter(s)
S	= entropy	mL	= milliliter(s)
T	= temperature	mm	= millimeter(s)
V	= volume	mol	= mole(s)
		V	= volt(s)

Part A

Directions: Each set of lettered choices below refers to the numbered statements or questions immediately following it. Select the one lettered choice that best fits each statement or answers each question and then fill in the corresponding circle on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1-3 refer to the following molecules.

(A) N_2
(B) C_2H_6
(C) NH_3
(D) CO_2
(E) CCl_4

1. A molecule that has atoms joined by a triple covalent bond
2. A molecule that is polar
3. A molecule having a 180° bond angle

Questions 4-7 refer to the following separation methods.

(A) Treatment with water followed by filtration
(B) Fractional distillation
(C) Evaporation
(D) Paper chromatography
(E) Gaseous diffusion

4. Most appropriate for separating several components of ink
5. Most appropriate for obtaining salt from salt-water solutions
6. Most appropriate for separating sand and sugar
7. Most appropriate for separating methyl alcohol and water

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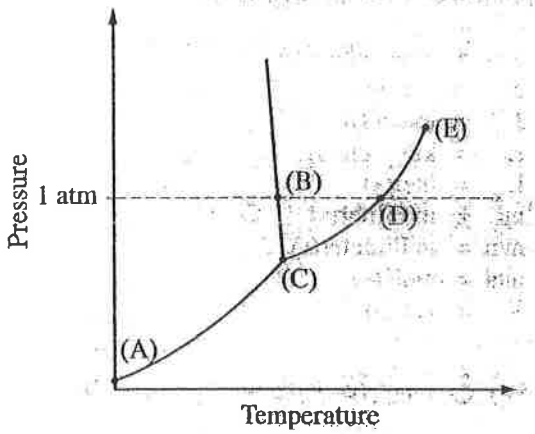
Questions 8-10 refer to the figure below, which represents the phase diagram of pure water.



For each of the following questions, select the letter corresponding to the appropriate point on the phase diagram.

8. The triple point

9. The critical point

10. The normal boiling point

Questions 11-13 refer to the atoms with the following electron configurations.

(A) $1s^2\ 2s^2\ 2p^6\ 3s^1$
(B) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
(C) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
(D) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$
(E) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$

11. Is a transition element that can exhibit several oxidation states

12. Forms a diatomic gas that is a halogen

13. Has the lowest first ionization energy (potential)

Questions 14-16 refer to the following types of substances.

(A) Hydride
(B) Halide
(C) Hydroxide
(D) Hydrate
(E) Hydrocarbon

14. A crystalline substance in which water is one of the structural units

15. A crystalline compound that contains only metal atoms and hydrogen atoms

16. An organic compound

Questions 17-18 refer to the following substances at room temperature.

(A) CO_2
(B) N_2O
(C) NO_2
(D) SiO_2
(E) CaO

17. Is an ionic solid

18. Is a gas in which each molecule has an unpaired electron

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Questions 19-21

(A) Oxidation
(B) Decomposition
(C) Precipitation
(D) Acid-base
(E) Reduction

Which of the above best describes the reaction represented by each of the following equations?

19. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

20. $Pb^{2+}(aq) + 2\,I^-(aq) \rightarrow PbI_2(s)$

21. $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

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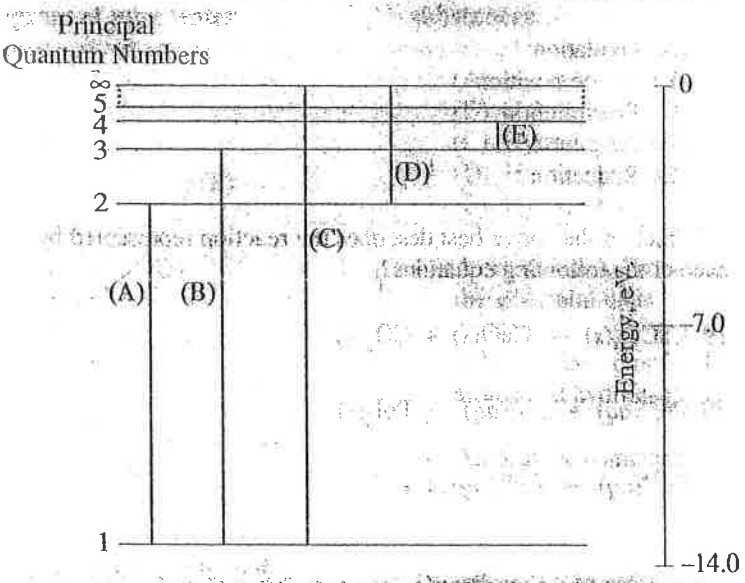
Questions 22-24 refer to the following energy diagram.



The diagram above is a plot of the energy levels for the electron of the hydrogen atom (roughly to scale) according to the Bohr theory. The vertical lines represent possible transitions (increases or decreases of energy) that can occur.

22. The transition from the ground state to the first excited state of hydrogen

23. Of the transitions shown, the one that involves the LEAST energy

24. The transition that represents the ionization energy (potential) of hydrogen

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PLEASE GO TO THE SPECIAL SECTION AT THE LOWER LEFT-HAND CORNER OF THE PAGE OF THE ANSWER SHEET YOU ARE WORKING ON AND ANSWER QUESTIONS 101-115 ACCORDING TO THE FOLLOWING DIRECTIONS.

Part B

Directions: Each question below consists of two statements, I in the left-hand column and II in the right-hand column. For each question, determine whether statement I is true or false and whether statement II is true or false and fill in the corresponding T or F circles on your answer sheet. Fill in circle CE only if statement II is a correct explanation of the true statement I.

EXAMPLES:

	I		II
EX 1.	H_2SO_4 is a strong acid.	**BECAUSE**	H_2SO_4 contains sulfur.
EX 2.	An atom of oxygen is electrically neutral	**BECAUSE**	an oxygen atom contains an equal number of protons and electrons.

SAMPLE ANSWERS

	I		II		CE*
EX1	●	Ⓕ	●	Ⓕ	Ⓒ
EX2	●	Ⓕ	●	Ⓕ	●

I II

101.	The volume of a gas at constant pressure increases with increasing temperature	BECAUSE	the average speed of gas molecules decreases with increasing temperature.
102.	HCl(*aq*) is a weak acid	BECAUSE	chlorine is a very electronegative element.

$$H_2(g) + I_2(g) \rightleftarrows 2\,HI(g)$$

103.	Equilibrium for the reaction represented above can be reached more quickly by increasing the temperature	BECAUSE	rates of reaction increase with increasing temperature.
104.	The covalent bond between O and H in H_2O is polar	BECAUSE	the H_2O molecule is linear.
105.	Mendeleev was able to predict correctly the physical properties of gallium, Ga, before its discovery	BECAUSE	on the basis of periodic relationships, gallium would be expected to have the same total number of electrons as aluminum.
106.	Metallic copper is an electrical conductor	BECAUSE	in metallic copper, the atoms of copper are covalently bonded.

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107. Acetic acid, $HC_2H_3O_2$, is a stronger acid than sulfuric acid	BECAUSE	acetic acid has more hydrogen atoms in its molecular structure than does sulfuric acid.
108. The decomposition of water by electrolysis to yield $H_2(g)$ and $O_2(g)$ is an endothermic process	BECAUSE	converting a pure liquid to its vapor phase increases the entropy of the system.
109. When some of the liquid in an insulated vessel evaporates, the temperature of the remaining liquid decreases	BECAUSE	the first molecules to leave the liquid are those with the higher kinetic energies and the remaining molecules have lower average kinetic energies.
110. The first ionization energy of K is greater than that of Li	BECAUSE	the Li atom has a smaller radius than the K atom.
111. Catalysts increase the rates of chemical reactions	BECAUSE	the activation energy of a reaction is lowered by a catalyst for the reaction.
112. The hydrogen carbonate ion, $HCO_3^-(aq)$, is both a Brønsted-Lowry acid and a Brønsted-Lowry base	BECAUSE	the hydrogen carbonate ion can either donate or accept a proton.
113. Lithium, sodium, and potassium have similar chemical properties	BECAUSE	lithium, sodium, and potassium all have the same number of valence electrons.
114. The CH_4 molecule has a square planar geometry	BECAUSE	all the bonds in the CH_4 molecule are equal in length.
115. At 25°C, the average speed of $H_2(g)$ molecules is less than the average speed of $O_2(g)$ molecules	BECAUSE	at 25°C, the average kinetic energy of $H_2(g)$ molecules is less than the average kinetic energy of $O_2(g)$ molecules.

RETURN TO THE SECTION OF YOUR ANSWER SHEET YOU STARTED FOR CHEMISTRY AND ANSWER QUESTIONS 25-70.

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Part C

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

25. Given solutions with the following pH values, which has the greatest concentration of H^+ ions?

(A) 1
(B) 5
(C) 7
(D) 9
(E) 11

26. In the compound $RbBrO_3$, the oxidation number of bromine is

(A) −1
(B) +1
(C) +3
(D) +5
(E) +7

$$C_3H_8(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(g)$$

27. How many moles of water would be produced if 11.0 g of propane (molar mass 44 g/mol) were burned completely to carbon dioxide and water according to the equation represented above?

(A) 1.0 mol
(B) 2.0 mol
(C) 3.0 mol
(D) 4.0 mol
(E) 5.0 mol

28. Ions of charge 2+ are formed readily from the elements whose atoms have which of the following electronic configurations?

I. $1s^2\ 2s^1$
II. $1s^2\ 2s^2$
III. $1s^2\ 2s^2 2p^6\ 3s^2$

(A) II only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

$$\ldots NH_3(g) + \ldots O_2(g) \rightarrow \ldots N_2(g) + \ldots H_2O(g)$$

29. When the equation for the reaction represented above is balanced with all the coefficients reduced to the lowest whole-number terms, the coefficient for $O_2(g)$ is

(A) 1
(B) 2
(C) 3
(D) 4
(E) 6

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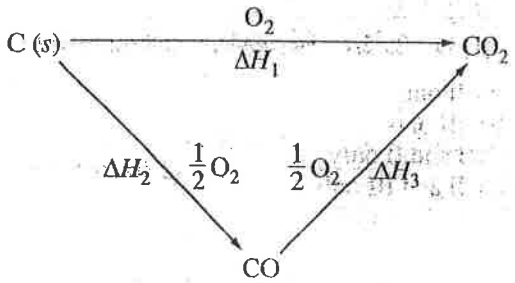
30. What is the number of moles of NaOH (molar mass 40. g/mol) present in 250 mL of 0.10 *M* NaOH(*aq*) ?

(A) 0.025 mol
(B) 0.10 mol
(C) 1.0 mol
(D) 4.0 mol
(E) 25 mol



31. Carbon dioxide may be prepared by the two processes above, where ΔH represents the energy change in the steps indicated. From the law of conservation of energy, one concludes that

(A) $\Delta H_1 = \Delta H_2 + \Delta H_3$

(B) $\Delta H_1 = \frac{1}{2}(\Delta H_2 + \Delta H_3)$

(C) $\Delta H_1 = \frac{1}{2}(\Delta H_2 - \Delta H_3)$

(D) $\Delta H_2 = \Delta H_1 + \Delta H_3$

(E) $\Delta H_2 = \Delta H_3 - \Delta H_1$

32. One isotope of an element contains 13 protons, 13 electrons, and 14 neutrons. Another isotope of this element is

(A) $^{26}_{12}Mg$

(B) $^{28}_{13}Al$

(C) $^{27}_{14}Si$

(D) $^{55}_{26}Fe$

(E) $^{59}_{27}Co$

33. Which of the following elements can be correctly represented by X in the chemical formula X_2O_3 ?

I. Fe
II. B
III. Ca

(A) I only
(B) II only
(C) III only
(D) I and II
(E) II and III

34. What is the maximum mass of Al (molar mass 27 g/mol) that can be obtained from 20.4 g of pure Al_2O_3 (molar mass 102 g/mol) ?

(A) 2.70 g
(B) 5.40 g
(C) 8.10 g
(D) 10.8 g
(E) 16.3 g

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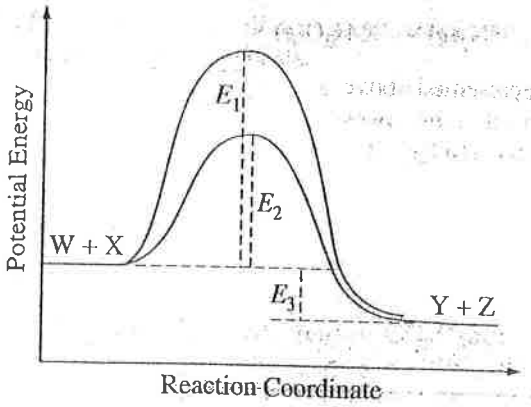

35. Consider the potential energy diagram above for the reaction W + X → Y + Z. Which of the following statements is correct?

(A) The reaction is endothermic.
(B) The reaction will not occur without a catalyst.
(C) E_1 and E_2 both represent activation energies.
(D) E_3 varies with the catalyst used.
(E) W and X represent a lower potential energy state than Y and Z.

$$2\,A(g) + B(g) \rightleftarrows C(g) + D(g)$$

36. All of the following can change equilibrium concentrations of reactants and products in the gas-phase reaction represented above EXCEPT

(A) decreasing the temperature of the system
(B) decreasing the volume of the system
(C) removing one of the products of the reaction from the system
(D) adding more of one of the reactants to the system
(E) adding a catalyst for the reaction to the system

37. Of the following, the conditions under which the molar volume of gaseous helium is greatest are

(A) 237 K and 1 atm
(B) 300 K and 1 atm
(C) 400 K and 1 atm
(D) 500 K and 2 atm
(E) 600 K and 2 atm

38. How many grams of $RbNO_3$ (molar mass 147 g/mol) are required to produce 0.500 L of a 0.200 *M* $RbNO_3$ solution?

(A) 73.5 g
(B) 29.6 g
(C) 14.7 g
(D) 2.96 g
(E) 1.47 g

39. The boiling points of NH_3, H_2O, and HF are all higher than would be expected on the basis of their molecular masses because of the

(A) low kinetic energy of the molecules
(B) unusual isotopic distribution of N, O, and F in nature
(C) high ionization energies of N, O, and F
(D) high potential energy of the molecules
(E) hydrogen bonding between the molecules

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$\ldots (NH_4)_2Cr_2O_7(s) \rightarrow \ldots Cr_2O_3(s) + \ldots N_2(g) + \ldots H_2O(g)$

40. When the equation for the reaction represented above is balanced and all coefficients are reduced to the lowest whole-number terms, the coefficient for $H_2O(g)$ is

(A) 1
(B) 2
(C) 3
(D) 4
(E) 8

41. Which of the following solutions has the highest pH ?

(A) 0.1 *M* NH_3
(B) 0.1 *M* NaOH
(C) 0.1 *M* HOCl
(D) 0.1 *M* H_3PO_4
(E) 0.1 *M* $HC_2H_3O_2$ (acetic acid)

42. At 4°C, a 10. mL container filled with water has a mass of 35.6 g. The same container filled with methanol has a mass of 33.5 g. What is the approximate density of methanol? (The density of water at 4°C is 1.00 g/mL.)

(A) 0.79 g/mL
(B) 1.0 g/mL
(C) 1.3 g/mL
(D) 2.1 g/mL
(E) 3.3 g/mL

43. A 45 g sample of a pure compound contains 36 g of carbon and 9.0 g of hydrogen. What is its empirical (simplest) formula?

(A) CH_3
(B) CH_4
(C) C_2H_3
(D) C_3H_5
(E) C_4H

44. The Fe^{3+} ion contains how many electrons?

(A) 23
(B) 26
(C) 29
(D) 31
(E) 53

$\ldots H^+(aq) + \ldots CaCO_3(s) \rightarrow$

45. When 1 mol of solid $CaCO_3$ is added to an excess of HCl according to the reaction represented above, which of the following will be produced?

I. 1 mol of $Ca^{2+}(aq)$
II. 2 mol of $CO_2(g)$
III. 6×10^{23} molecules of H_2O

(A) I only
(B) II only
(C) I and III only
(D) II and III only
(E) I, II, and III

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46. For an atom of cobalt in its ground state, the $3d$ energy sublevel contains

(A) 10 electrons
(B) 9 electrons
(C) 8 electrons
(D) 7 electrons
(E) 5 electrons

$$Ag_2CO_3(s) \rightleftarrows 2\,Ag^+(aq) + CO_3^{2-}(aq)$$

47. Some solid Ag_2CO_3 is shaken with 50 mL of water and the equilibrium system represented above is established. The equilibrium would be shifted to the left by the addition of which of the following substances?

(A) Solid Ag_2CO_3
(B) 50 mL H_2O
(C) 0.5 *M* HCl
(D) 0.5 *M* Na_2CO_3
(E) 0.5 *M* $NaNO_3$

48. In general, when are deviations from ideal gas behavior greatest?

(A) At standard temperature and pressure
(B) When both pressure and temperature are high
(C) When both pressure and temperature are low
(D) When pressure is high and temperature is low
(E) When pressure is low and temperature is high

$$C_6H_5OH + CO_2 + HC_2H_3O_2 \rightarrow H_2O + \text{aspirin}$$

49. Phenol (C_6H_5OH), carbon dioxide (CO_2), and acetic acid ($HC_2H_3O_2$) react to form aspirin and H_2O as shown in the balanced equation above. What is the chemical formula for aspirin?

(A) $C_9H_{10}O_5$
(B) $C_9H_8O_4$
(C) $C_8H_{10}O_5$
(D) $C_8H_9O_4$
(E) $C_8H_8O_4$

50. Which of the following best describes the type of bonding between iodine atoms in a molecule of I_2 ?

(A) Ionic bonding
(B) Metallic bonding
(C) Hydrogen bonding
(D) Covalent bonding
(E) Dispersion (London) force interactions

51. A glass vessel contains 2.0 mol of $N_2(g)$ and 3.0 mol of $Ar(g)$. The total pressure is 1.5 atm. What is the partial pressure of the $Ar(g)$?

(A) 0.2 atm
(B) 0.6 atm
(C) 0.9 atm
(D) 1.0 atm
(E) 1.5 atm

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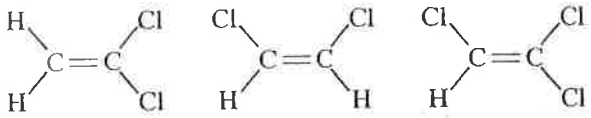
52. Which of the following statements is true of a solution of 0.10 *M* HCl(*aq*) ?

(A) The pH is 1.
(B) The concentration of $Cl^-(aq)$ is greater than the concentration of $H^+(aq)$.
(C) The concentration of $Cl^-(aq)$ is equal to the concentration of $OH^-(aq)$.
(D) The concentration of $H^+(aq)$ is equal to the concentration of $OH^-(aq)$.
(E) The indicator phenolphthalein turns pink when added to the acid solution.

53. The half-life for the radioactive decay of $^{239}_{94}Pu$ is 25,000 years. If 100. g of $^{239}_{94}Pu$ are present initially, how many grams of $^{239}_{94}Pu$ will remain after 50,000 years?

(A) 100. g
(B) 50.0 g
(C) 25.0 g
(D) 12.5 g
(E) 0.000 g



I II III

54. Which of the formulas above represent isomers of one another?

(A) None
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III

55. Which of the following is always characteristic of an oxidizing agent?

(A) It contains oxygen.
(B) It is soluble in water.
(C) It contains a transition element.
(D) It can be reduced.
(E) It forms an ionic lattice.

56. Which of the following statements about a liquid that evaporates readily at room temperature is correct?

(A) It has strong intermolecular forces.
(B) It has a high vapor pressure.
(C) It is considered to be nonvolatile.
(D) It would make its container feel warm to the touch.
(E) It should be stored in an open container.

57. Correct statements about a solution of sodium chloride include which of the following?

I. It has a normal boiling point identical with that of pure water.
II. It has a greater density than pure water at the same temperature.
III. It has a lower freezing point than pure water.

(A) I only
(B) II only
(C) III only
(D) II and III only
(E) I, II, and III

58. A 4 L sample of hydrogen and a 3 L sample of oxygen, each at 20°C and 1 atm, are mixed, exploded to form as much water as possible, and then cooled back to the initial temperature and pressure. At the end of the experiment, there remains in the system

(A) 3 L of hydrogen
(B) 2 L of hydrogen
(C) 2 L of oxygen
(D) 1 L of oxygen
(E) no gas at all

59. Each of the following ions has ten electrons. Which one has the smallest radius?

(A) N^{3-}
(B) O^{2-}
(C) F^-
(D) Na^+
(E) Mg^{2+}

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$$C_2H_5OH(l) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 3\,H_2O(g)$$

60. When the combustion reaction represented by the equation above is balanced using the lowest whole-number coefficients, what is the coefficient of $O_2(g)$?

(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

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61. If 100. mL of 0.50 *M* NaOH(*aq*) exactly neutralizes 50. mL of a solution of HCl(*aq*), the molarity of the HCl(*aq*) is

(A) 0.10 *M*
(B) 0.25 *M*
(C) 0.50 *M*
(D) 1.0 *M*
(E) 2.0 *M*

62. A 9.00 g sample of liquid water has which of the following?

I. 1.00 mol of hydrogen atoms
II. 8.50 g of oxygen
III. A volume of 11.2 L at standard temperature and pressure

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I, II, and III

63. How much energy is required to heat 100. g of H_2O from 20.0°C to 40.0°C ? (The specific heat of $H_2O(l)$ is 4.18 J/(g·°C).)

(A) 93.6 J
(B) 482 J
(C) 2,000 J
(D) 4,180 J
(E) 8,360 J

64. If a student were to accurately analyze a mixture of solid NaCl and solid NaOH by titration of the hydroxide ion with a standardized solution of HCl, which of the following would be LEAST useful?

(A) Bunsen burner
(B) Analytical balance
(C) Buret
(D) Erlenmeyer flask
(E) Indicator

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$$H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g) \quad \Delta H = -185\ kJ$$

65. According to the equation for the reaction represented above, what is ΔH for the production of 0.100 mol of $HCl(g)$?

(A) –37.0 kJ
(B) –18.5 kJ
(C) –9.25 kJ
(D) +9.25 kJ
(E) +18.5 kJ

$$2\,SO_2(g) + O_2(g) \rightleftarrows 2\,SO_3(g) + \text{heat}$$

66. For the system represented above, which of the following actions will shift the position of equilibrium to the left?

(A) Increasing the pressure
(B) Increasing the temperature
(C) Putting the mixture in a smaller container
(D) Adding some $O_2(g)$
(E) Removing some $SO_3(g)$

$$\ldots Na(s) + \ldots H_2O(l) \rightarrow$$

67. Products of the reaction represented above include which of the following?

I. $Na^+(aq)$
II. $OH^-(aq)$
III. $H_2(g)$

(A) I only
(B) III only
(C) I and II only
(D) I and III only
(E) I, II, and III

68. When the following air pollutants are present in small amounts, which is LEAST hazardous to humans?

(A) Ammonia, NH_3
(B) Carbon dioxide, CO_2
(C) Sulfur dioxide, SO_2
(D) Nitrogen dioxide, NO_2
(E) Hydrogen sulfide, H_2S

69. A compound containing only carbon and hydrogen is found to have a molar mass of 100 g/mol and to consist of 16 percent hydrogen by mass. The number of carbon atoms in one molecule of the compound is

(A) 1
(B) 3
(C) 4
(D) 6
(E) 7

70. A 21 g sample of $NaF(s)$ (molar mass 42 g/mol) is dissolved in enough water to yield 2.0 L of solution. What is the molar concentration of $Na^+(aq)$?

(A) 0.010 *M*
(B) 0.050 *M*
(C) 0.10 *M*
(D) 0.25 *M*
(E) 0.50 *M*

STOP

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS TEST ONLY. DO NOT TURN TO ANY OTHER TEST IN THIS BOOK.