1. The second law of thermodynamics involves the concept of
    a. entropy
    b. spontaneous reactions
    c. enthalpy
    d. catalyzed reactions
    e. calorimetry

2. When an acid and a base react, the products are
    a. chlorofluorocarbons
    b. water and oxygen
    c. a salt and water
    d. a precipitate and a liquid
    e. water and carbon dioxide

3. The other passenger, besides Jacques Charles, on the first manned hydrogen-fueled balloon flight was
    a. Anne-Jean Robert
    b. Robert Boyle
    c. Nicolas-Louis Robert
    d. James Watson
    e. Benjamin Franklin

4. In 1808, John Dalton published
    a. *A New System of Chemical Philosophy*
    b. *A System of Chemistry*
    c. *Philosophia Naturalis Principia Mathematica*
    d. *Journal de Physique*
    e. *Daltonian Theory*

5. Which of the following reactions is NOT one of the five basic types of reactions?
    a. single replacement
    b. synthesis
    c. acid-base
    d. combustion
    e. double replacement

6. In which manner are elements arranged in the periodic table?
    a. decreasing electron affinity
    b. increasing atomic radius
    c. increasing ionization energy
    d. increasing atomic number
    e. decreasing atomic mass

7. Which of the following concepts is NOT a state function?
    a. Gibbs Free Energy
    b. heat
    c. enthalpy
    d. pressure
    e. entropy

8. Joseph Black's term "fixed air" referred to
    a. carbon dioxide
    b. nitrogen
    c. oxygen
    d. hydrogen
    e. helium

9. The law of multiple proportions states that
    a. chemical reactions can cause atoms to combine, separate, and rearrange
    b. if two elements combine to form more than one compound, their masses will combine in whole number ratios
    c. a substance's properties depend on the ratios of its elements according to mass
    d. a substance is always composed of the same proportion of each element
    e. the proportions in which atoms combine are dependent on their weight

10. Organic solutions are those in which the solvent
    a. is a polar substance
    b. is a nonpolar substance
    c. is water
    d. occurs naturally
    e. contains carbon

11. Which intermolecular force creates electrical conductivity?
    a. hydrogen bonds
    b. dipole moments
    c. metallic bonds
    d. ionic bonds
    e. covalent bonds

12. Which element did Henry Cavendish identify?
    a. carbon
    b. helium
    c. hydrogen
    d. carbon dioxide
    e. oxygen

13. Which of the following properties do metals NOT have?
    a. sonorous
    b. lustrous
    c. malleable
    d. insulating
    e. ductile

14. When the ΔG value of a reaction is negative, the
    a. spontaneity of the reaction depends on the temperature
    b. reaction is nonspontaneous
    c. change in enthalpy is positive
    d. reaction is spontaneous
    e. change in entropy is negative

15. A positive cell voltage indicates a(n)
    a. nonspontaneous reaction
    b. spontaneous reaction
    c. change in entropy
    d. change in enthalpy
    e. release of heat

16. Which of the following ideas did Dalton NOT propose?
    a. Atoms of the same element will have the same properties.
    b. All matter is composed of indivisible particles.
    c. Chemical reactions cause atoms to combine, separate and rearrange.
    d. Atoms of different elements can combine in certain ratios to form compounds.
    e. Atoms are composed of protons, neutrons, and electrons.

17. The chemical formula of mercuric oxide is
    a. HgO_2
    b. HgO_4
    c. HgO
    d. Hg_2O
    e. Hg_2O_3

18. The field of science that deals with the wave-particle duality of matter is
    a. quantum physics
    b. electromagnetism
    c. cosmology
    d. relativity
    e. electrochemistry

19. Which of the following scientific devices are used commonly in airports?
    a. micrometers
    b. magnetographs
    c. electroscopes
    d. mass spectrometers
    e. burets

20. Charged atoms are referred to as
    a. isotopes
    b. positrons
    c. ions
    d. alpha particles
    e. beta particles

21. Which of these quantities strictly increases down a group of the periodic table?
    a. atomic radius
    b. ionization energy
    c. number of valence electrons
    d. electron affinity
    e. electronegativity

22. The type of relationship between the volume and temperature of a gas is called
    a. constant proportionality
    b. geometric proportionality
    c. inverse proportionality
    d. direct proportionality
    e. inverse-square proportionality

23. Which main question could phlogiston theory not answer?
    a. Why is oxygen emitted during combustion?
    b. Why do humans exhale carbon dioxide?
    c. Why is hydrogen tasteless and odorless?
    d. Why is carbon monoxide undetectable?
    e. Why does air require combustion?

24. Solubility refers to the
    a. amount of solute that will dissolve in a certain amount of solvent
    b. relative amounts of solute and solvent present
    c. interaction of polar and nonpolar molecules
    d. effects of the forces of hydration on polar molecules
    e. changes in physical properties as a solution is formed

25. What makes a solution acidic?
    a. an excess of H^+ ions
    b. a lack of OH^- ions
    c. its ability to react with bases
    d. a positive charge
    e. its ability to accept H^+ ions in a reaction

26. Which of the following formulae is the chemical formula for table salt?

    a. $NaCl_2$
    b. Na_2Cl
    c. $NaCl_4$
    d. NaCl
    e. Na_2Cl_3

27. The transition towards empiricism occurred in the

    a. 1400s
    b. 1800s
    c. 1700s
    d. 1600s
    e. 1300s

28. Which types of molecules can be characterized as having permanent van der Waals forces?

    a. molecules with covalent bonds
    b. nonpolar molecules
    c. polar molecules
    d. molecules with hydrogen bonds
    e. molecules with ionic bonds

29. When a silver metal is placed in a copper solution, what will happen?

    a. Combustion will occur.
    b. No reaction will occur.
    c. Carbon dioxide will be produced.
    d. A precipitate will form.
    e. Hydrogen gas will be produced.

30. When the heat of fusion is involved in the phase change of a solid, the solid

    a. dissociates
    b. breaks
    c. melts
    d. sublimates
    e. freezes

31. In the photoelectric effect, energy is transferred to an electron from a

    a. proton
    b. positron
    c. photon
    d. neutron
    e. beta particle

32. Jacques Charles was interested in hydrogen as a means of

    a. exploring alternative electricity sources
    b. fueling balloon flight
    c. refining petroleum
    d. methanol production
    e. manufacturing ammonia

33. Raising the temperature of 1 gram of water by 1° C takes

    a. 5.85 J of heat
    b. 4.18 J of heat
    c. 4.37 J of heat
    d. 4 J of heat
    e. 3.29 J of heat

34. Enthalpy is proportional to the

    a. volume of a gas
    b. amount of heat added
    c. pressure of a gas
    d. amount of a chemical present
    e. temperature of a gas

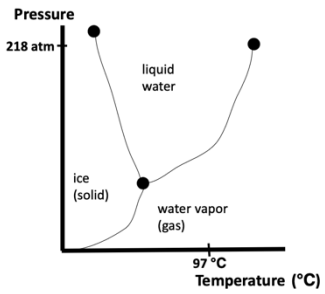
35. Nonpolar solvents normally only contain

    a. hydrogen and oxygen
    b. nitrogen and oxygen
    c. carbon and hydrogen
    d. carbon and hydrogen
    e. carbon and oxygen

36. The scientific principle that essentially restates the law of conservation of mass is

    a. Hess's law
    b. Raoult's law
    c. Lavoisier's principle
    d. Avogadro's law
    e. Boyle's law

37. At 97° C and 218 atm, according to the phase diagram below, matter is an



    a. gas
    b. supercritical fluid
    c. solid
    d. liquid
    e. plasma

38. Which experiment showed the wave properties of electrons?

    a. Gay-Lussac experiment
    b. Raoult-Lewis experiment
    c. Scheele-Davisson experiment
    d. Davisson-Germer experiment
    e. Franklin-Watson experiment

39. Forces between temporary dipoles are called

    a. hydrogen bonds
    b. intramolecular forces
    c. van der Waals forces
    d. London dispersion forces
    e. dipole-dipole forces

40. An atom's electronegativity refers to

    a. its ability to form covalent bonds
    b. its level of polarity
    c. its number of electron shells
    d. the attraction it has for neighboring electrons
    e. the energy required to remove an outer electron from it

41. Which of the following substances is a substitute for chlorofluorocarbons?

    a. ammonia
    b. nitrogen
    c. methane
    d. ozone
    e. carbon

42. Which molecule is chemically arranged in a ratio of 1:2:1?

    a. salt
    b. methane
    c. ammonia
    d. glucose
    e. caffeine

43. Which of these compounds combines in a ratio of 1:19?

    a. HF
    b. H_2O
    c. CO_2
    d. NaCl
    e. CH_4

44. Generally, increasing temperature will

    a. increase the chance of a spontaneous reaction
    b. decrease reaction rates
    c. increase the stability of a substance
    d. increase the amount of a substance
    e. increase reaction rates

45. Which of the following contributions did Antoine Lavoisier NOT make to the field of chemistry?

    a. proving that matter is conserved in chemical and physical interactions
    b. refuting the notion of element transmutation
    c. discovering that air is composed mostly of oxygen and nitrogen
    d. developing the current system of chemical nomenclature
    e. discovering that water cannot be converted into Earth

46. Which scientific concept did James Watt use when inventing the steam engine?

    a. distillation
    b. sublimation
    c. combustion
    d. oxidization
    e. latent heat

47. Reactions that have a net absorption of heat are called

    a. nonspontaneous
    b. endothermic
    c. spontaneous
    d. catalyzed
    e. exothermic

48. The metal single replacement reaction of Cu + $2AgNO_3$ will have products

    a. $2Cu(NO_3)_2 + Ag$
    b. $2CuAg + NO_3$
    c. $Cu(NO_3)_2 + 2Ag$
    d. $Cu_2NO_3 + Ag_2$
    e. $CuNO_3 + Ag$

49. The use of supernatural explanations for natural phenomena is characteristic of

    a. hermeticism
    b. transmutation
    c. phrenology
    d. alchemy
    e. astronomy

50. No temperature can ever go lower than

    a. -273° C
    b. -273° F
    c. 273 K
    d. -273 K
    e. 0° C

1. Two water molecules are produced when methane is used in the process of
   a. precipitation
   b. decomposition
   c. combustion
   d. percolation
   e. oxidation

2. The Davisson-Germer experiment proved the
   a. particle properties of electrons
   b. radioactivity of deuterium
   c. existence of hydrogen bonds
   d. double helix model of DNA
   e. wave properties of electrons

3. Absorbing a photon makes an electron
   a. move to a higher energy level
   b. leave its atom entirely
   c. move to a lower energy level
   d. become more negatively charged
   e. attract other electrons towards its atom

4. Who identified hydrogen?
   a. Joseph Black
   b. Antoine Lavoisier
   c. Nicolas-Louis Robert
   d. Robert Boyle
   e. Henry Cavendish

5. 96,500 coulombs of charge are present in a(n)
   a. becquerel
   b. Faraday
   c. volt
   d. candela
   e. ampere

6. 3:8 is the mass ratio of the atoms in a molecule of
   a. ammonia
   b. permanganate
   c. octane
   d. carbon dioxide
   e. chromate

7. Which of the following isotopes is radioactive?
   a. ${}^{2}_{1}H$
   b. ${}^{37}_{17}Cl$
   c. ${}^{35}_{17}Cl$
   d. ${}^{18}_{8}O$
   e. ${}^{60}_{27}Co$

8. The MOST ordered substance at room temperature out of the following is
   a. methane
   b. mercury
   c. carbon dioxide
   d. water
   e. lead

9. How many kilograms of gold did construction of the *Columbia* require?
   a. 42
   b. 40
   c. 44
   d. 36
   e. 38

10. The Brønsted-Lowry model expands on Arrhenius's work by explaining why
    a. water is amphoteric
    b. weak bases do not ionize
    c. bases have an excess of OH^-
    d. ammonia is basic despite not containing OH^-
    e. the molarity of every acid and base is different

11. Which of the following reactions is an example of a metal replacement reaction?
    a. $Cl_2 + 2NaBr$ <sym-Wingdings-F0E0> $2NaCl + Br_2$
    b. $K + NaCl$ <sym-Wingdings-F0E0> $KCl + Na$
    c. $Cl_2 + CaI_2$ <sym-Wingdings-F0E0> $CaCl_2 + I_2$
    d. $Cu + 2AgNO_3$ <sym-Wingdings-F0E0> $2Ag + Cu(NO_3)_2$
    e. $2K + 2H_2O$ <sym-Wingdings-F0E0> $2KOH + H_2$

12. Dalton's findings drew on the work of
    a. Nicolas-Louis Robert and Anne-Jean Robert
    b. Antoine Lavoisier and Joseph Louis Proust
    c. Clinton Davisson and Lester Germer
    d. Leucippus and Democritus
    e. James Watson and Francis Crick

13. Calorimetry is the process of measuring

    a. changes in enthalpy
    b. the activation energy required for a reaction
    c. the spontaneity of a reaction
    d. the Gibbs Free Energy
    e. changes in entropy

14. Carl Wilhelm Scheele discovered the physical properties of

    a. helium
    b. hydrogen
    c. oxygen
    d. carbon
    e. nitrogen

15. The 1600s saw a transition towards

    a. alchemy
    b. empiricism
    c. hereticism
    d. supernatural thought
    e. deism

16. NaCl combines in a ratio of

    a. 23:35
    b. 8:13
    c. 8:19
    d. 3:7
    e. 11:17

17. When 1 mole of carbon is converted to 1 mole of carbon dioxide, the heat given off is equal to

    a. 594 kJ
    b. 394.5 kJ
    c. 362 kJ
    d. 393.5 kJ
    e. 395.5 kJ

18. Different isotopes of the same atom have different

    a. atomic masses
    b. numbers of valence electrons
    c. numbers of electrons
    d. atomic numbers
    e. radioactivity levels

19. A mass spectrometer separates atoms and compounds using

    a. Faraday collectors
    b. electromagnetic fields
    c. radioactivity levels
    d. magnetic fields
    e. electric fields

20. An atom's attraction for neighboring electrons is its

    a. electronegativity
    b. electron affinity
    c. polarity
    d. ionization energy
    e. atomic radius

21. Boyle's law influenced the invention of the

    a. cotton gin
    b. telegraph
    c. jet engine
    d. hydrogen-powered balloon
    e. steam engine

22. The first manned hydrogen-fueled balloon flight took place on

    a. December 1, 1789
    b. December 1, 1783
    c. December 1, 1783
    d. December 1, 1782
    e. December 1, 1785

23. John Dalton's *A New System of Chemical Philosophy* contained his

    a. support for the Copernican model
    b. proof of the ideal gas law
    c. conclusions on atomic behavior
    d. refutation of atomism
    e. experiments with gases

24. Johann Baptista van Helmont wanted to apply his findings in chemistry to understand the

    a. inaccuracies of phlogiston theory
    b. bonding of atoms
    c. structure of DNA
    d. causes of disease
    e. relationship between a gas's temperature and pressure

25. Which of the following chemical processes is NOT associated with alchemy?

    a. distillation
    b. combustion
    c. percolation
    d. transmutation
    e. extraction

26. Which characteristic explains water's high melting point?

    a. hydrogen bonds
    b. surface tension
    c. polarity
    d. atomic structure
    e. strong covalent bonds

27. The molecular motion within a substance can be measured using its

    a. heat
    b. temperature
    c. density
    d. electrical conductivity
    e. volume

28. Water's amphoteric state describes its

    a. ability to be an acid or base
    b. low boiling point
    c. high level of polarity
    d. good surface tension
    e. high boiling point

29. The symbol used to denote enthalpy is

    a. *G*
    b. *E*
    c. *H*
    d. *L*
    e. *S*

30. Joseph Black started researching heat directly after he

    a. invented the steam engine
    b. discovered carbon dioxide
    c. invented the ice-calorimeter
    d. published his findings on latent heat
    e. observed melting snow

31. Which of the following materials are allotropes of the same element?

    a. ozone and black selenium
    b. diamond and graphite
    c. stanene and diamond
    d. samarium and graphite
    e. austenite and ferrite

32. Non-bonding electron pairs are specifically called lone pairs within the

    a. collision model
    b. quantum mechanical model
    c. planetary model
    d. Bohr model
    e. Lewis structure

33. An element's chemical behavior is determined by the atom's

    a. internal structure
    b. electronegativity
    c. valence electrons
    d. polarity
    e. adjacent atoms

34. The parameters within the equation for non-ideal gases are called

    a. Faraday constants
    b. coulombs
    c. Boyle's parameters
    d. molecular activity constants
    e. van der Waals constants

35. Brass is an alloy of

    a. gold and silver
    b. copper and silver
    c. copper and zinc
    d. silver and zinc
    e. gold and platinum

36. The 1840s saw the rise of

    a. electroplating
    b. transmutation
    c. effusion
    d. distillation
    e. controlled combustion

37. Who MOST likely benefited from the work of Joseph Louis Proust?

    a. John Dalton
    b. Claude Louis Berthollet
    c. Joseph Black
    d. Antoine Lavoisier
    e. Francis Crick

38. When lithium is added to water, Which gas is produced?

    a. oxygen
    b. nitrogen
    c. helium
    d. carbon
    e. hydrogen

39. Which idea did Dalton NOT originally propose?

    a. Atoms cannot be created or destroyed.
    b. Atoms of the same element have the same properties.
    c. Chemical reactions can cause atoms to combine, separate, and rearrange.
    d. Matter is composed of extremely small, indivisible particles.
    e. Atoms of different elements can combine in whole-number ratios to form compounds.

40. Metallic bonds explain why metals are

    a. ductile
    b. lustrous
    c. sonorous
    d. malleable
    e. electrical conductors

41. Chrome plating is used to

    a. raise the conductivity of certain metals
    b. make airplanes more aerodynamic
    c. create shiny parts on automobiles
    d. transfer electrons from one metal to another
    e. prevent tarnishing on silverware

42. Quantum physics deals with matter's

    a. particle properties
    b. electromagnetic radiation
    c. special relativity
    d. wave properties
    e. wave-particle duality

43. The idea that nature was made of four elements was an

    a. Paracelsian view
    b. Galilean view
    c. Aristotelian view
    d. Copernican view
    e. Ptolemaic view

44. Water and carbon dioxide are always products when the reactant is a(n)

    a. organic hydrocarbon
    b. ethanol
    c. mercuric substance
    d. oxide
    e. nonpolar substance

45. How many more electrons does sodium need to fill its valence shell?

    a. two
    b. five
    c. one
    d. eight
    e. seven

46. Paracelsus accidentally produced

    a. hydrogen
    b. carbon
    c. carbon dioxide
    d. oxygen
    e. nitrogen

47. The main factor for lowered soil pH in some regions is the absorption of

    a. chlorofluorocarbons
    b. silver halide
    c. chlorine
    d. metallic mercury
    e. acid rain

48. Beyond the critical point on a phase diagram, all substances exist as

    a. gases
    b. supercritical fluids
    c. solids
    d. plasma
    e. liquids

49. Many acids are substances whose formulas start with atoms or compounds of

    a. oxygen
    b. hydroxide
    c. hydrogen
    d. carbon
    e. hydrate

50. Dissolved toxic substances are often removed from contaminated water using

    a. distillation
    b. percolation
    c. oxidation
    d. dehydration
    e. precipitation

1. Which of the following forces are the only intermolecular forces that occur between nonpolar molecules?
    a. London dispersion forces
    b. dipole-dipole moments
    c. hydrogen bonds
    d. metallic bonds
    e. van der Waals forces

2. Which of the following substances is NOT an acid?
    a. HBr
    b. HCl
    c. HNO_3
    d. HNO_3
    e. $CaCO_3$

3. Which diagram or model shows the interchange of all three states of matter of a pure substance?
    a. concentration model
    b. phase diagram
    c. energy diagram
    d. molecular motion projection
    e. collision model

4. Luigi Galvani discovered what he termed "animal electricity" using
    a. dogs
    b. rats
    c. frogs
    d. hamsters
    e. cats

5. Alchemists pioneered all the following chemical processes EXCEPT
    a. electroplating
    b. transmutation
    c. percolation
    d. extraction
    e. distillation

6. The equation for a gas molecule's "root mean square" speed is
    a. $m = \sqrt{\frac{3kT}{m}}$
    b. $r = \sqrt{\frac{3kT}{m}}$
    c. $u = \sqrt{\frac{3kT}{m}}$
    d. $s = \sqrt{\frac{kT}{3m}}$
    e. $u = \sqrt{\frac{5kT}{2m}}$

7. The sign that indicates a partial charge within a molecule is
    a. ±
    b. §
    c. δ
    d. þ
    e. Ø

8. In which ratio of deuterium to hydrogen does the former compound naturally exist?
    a. 1:5000
    b. 1:5682
    c. 1:10000
    d. 1:7500
    e. 1:6500

9. When a proton is added to an atom's nucleus, its atomic number
    a. increases by three
    b. decreases by one
    c. decreases by two
    d. increases by one
    e. increases by two

10. $2Na + Cl_2$ <sym-Wingdings-F0E0> $2NaCl$ is an example of a
    a. double replacement reaction
    b. synthesis reaction
    c. salt-water reaction
    d. single replacement reaction
    e. decomposition reaction

11. Which of the following hydrogen bases bonds with thymine within a DNA molecule?

    a. ligase
    b. guanine
    c. adenine
    d. uracil
    e. cytosine

12. Which of the following statements is NOT a rule concerning oxidation numbers?

    a. Oxidation numbers of atoms in neutral compounds must add up to 0.
    b. The oxidation number of all monatomic ions is the ion's charge.
    c. Halogens have oxidation numbers of -1.
    d. H and Group 1 elements have oxidation numbers of +1.
    e. All neutral atoms have an oxidation number of 0.

13. When copper wire is added to silver nitrate, what occurs is a

    a. acid-base reaction
    b. double replacement reaction
    c. single replacement reaction
    d. precipitation reaction
    e. oxidation reaction

14. Who disproved phlogiston theory?

    a. Antoine Lavoisier
    b. Johann Baptista van Helmont
    c. Henry Cavendish
    d. Joseph Priestley
    e. Joseph Black

15. The collisions that occur between gas molecules and the walls of their container are

    a. ideal
    b. one-dimensional
    c. partially inelastic
    d. completely inelastic
    e. elastic

16. Which of the following substances is used to manufacture artificial diamonds?

    a. carbon nanotubes
    b. ethanol
    c. octane
    d. graphite
    e. graphene

17. The hydrogen bonds present in water molecules explain why

    a. water has a low boiling point
    b. ice has a higher density than liquid water
    c. ice has a lower density than liquid water
    d. a warm body of water has less surface tension
    e. water takes up less volume when it freezes

18. Which of the following metals can displace hydrogen from its source in a single replacement reaction?

    a. Au
    b. Ag
    c. Cu
    d. Fe
    e. Hg

19. The MOST common use of Carbon-14 is

    a. cosmic ray identification
    b. detecting bacteria
    c. radiolabeling
    d. carbon dating
    e. disinfect nuclear power plants

20. Joseph Priestley observed the release of oxygen in 1774 by heating a sample of

    a. magnesium oxide
    b. silica
    c. mercuric oxide
    d. ethanol
    e. sulfur dioxide

21. Which part of the chemical reaction $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$ allows us to conclude that the reactant is an organic hydrocarbon?

    a. water as a combustion product
    b. carbon dioxide as a combustion product
    c. oxygen being a reactant
    d. methane being a natural gas
    e. water & carbon dioxide as combustion products

22. What fraction of helium's mass carbon's mass?

    a. 1/5
    b. 1/4
    c. 1/7
    d. 1/2
    e. 1/3

23. How many carbon isotopes are found in nature?
    a. four
    b. one
    c. five
    d. two
    e. three

24. Which function does the pH scale use?
    a. exponential
    b. linear
    c. inverse-square
    d. logarithmic
    e. square

25. Except at absolute zero, all substances are considered
    a. a mixture of a solute and a solvent
    b. mixtures of gases
    c. an ensemble of rapidly moving particles
    d. particles bonded together
    e. mixtures of other substances

26. Which radioactive isotope is used to examine steel components?
    a. $^{13}_{6}C$
    b. $^{2}_{1}H$
    c. $^{3}_{1}H$
    d. $^{14}_{6}C$
    e. $^{60}_{27}Co$

27. Which of the following atomic structural models is NOT a type of solid?
    a. metallic
    b. covalent lattice
    c. covalent network
    d. ionic lattice
    e. molecular

28. Electrons are symmetrically distributed between two nuclei when the two atoms
    a. are ionically bonded
    b. are covalently bonded
    c. are hydrogen and oxygen
    d. are identical
    e. have an electronegativity difference greater than 1.8

29. Which element has the highest Pauling electronegativity?
    a. lithium
    b. chlorine
    c. fluorine
    d. nitrogen
    e. helium

30. The Brønsted-Lowry acid-base theory defined a base as any
    a. amphoteric substance
    b. H+ donator in a reaction
    c. H^+ acceptor in a reaction
    d. reactant with a pH below seven
    e. reactant that forms hydronium ions

31. 41 kilograms of gold were used in the construction of the space shuttle
    a. *Columbia*
    b. *Voyager*
    c. *Discovery*
    d. *Sputnik*
    e. *Challenger*

32. The relationship PV/T = CD is characteristic of combining Boyle's law with
    a. the ideal gas law
    b. Raoult's Law
    c. Avogadro's law
    d. Gay-Lussac's Law
    e. Charles's law

33. The electric charge on one mole of electrons is called a(n)
    a. Weber
    b. Faraday
    c. ampere
    d. volt-meter
    e. Gauss

34. In the modern periodic table, elements are arranged in order of increasing
    a. ionization energy
    b. valence electrons
    c. electron shells
    d. atomic number
    e. electronegativity

35. When lithium metal is added to water, what results is
    a. ice
    b. water vapor
    c. hydrogen gas
    d. oxygen gas
    e. liquid oxygen

36. Chrome plating is used to help manufacture

    a. railroad tracks
    b. automobiles
    c. nanotubes
    d. refrigerators
    e. airplanes

37. Which of the following type of chemical bonds is NOT an intramolecular force?

    a. hydrogen
    b. dipole-dipole
    c. metallic
    d. covalent
    e. ionic

38. Which of the following statements is NOT an assumption of kinetic-molecular theory?

    a. Gas molecules all move at the same speed in random directions.
    b. Gas molecules are moving rapidly in all directions.
    c. The volume of actual gas molecules is negligible.
    d. Gas pressure is a result of molecules colliding with the walls of their container.
    e. No intermolecular forces exist between adjacent gas molecules.

39. Which main question could phlogiston theory not answer?

    a. Why is carbon dioxide a product of combustion?
    b. Why is water a product of combustion?
    c. Why do acid-base reactions produce a salt and water?
    d. Why is air required for combustion?
    e. Why does the activity series of metals affect single replacement reactions?

40. Where is Carbong-14 naturally formed?

    a. underwater
    b. hydrothermal vents
    c. peat bogs
    d. the upper atmosphere
    e. plant leaves

41. The field of alchemy is defined as

    a. the relationship between heat and substances
    b. the interaction of different substances
    c. scientific conclusions based on experiments
    d. the continuum of human exploration
    e. mystical explanations for natural phenomena

42. Which two scientists performed an experiment that showed the wave properties of electrons?

    a. Clinton Davisson and Luigi Brugnatelli
    b. Clinton Davisson and Lester Germer
    c. Johannes Brønsted and Thomas Lowry
    d. Henry Cavendish and Lester Germer
    e. Francis Crick and Ernest Rutherford

43. The transfer of electrons from one molecule to another occurs in a

    a. decomposition reaction
    b. dipole moment
    c. covalent bond
    d. combustion reaction
    e. redox reaction

44. Which of these quantities decreases from left to right across a period in the periodic table?

    a. electron affinity
    b. electronegativity
    c. ionization energy
    d. bonding ability
    e. atomic radius

45. Which type of reaction occurs when a substance reacts with oxygen gas?

    a. oxidation reaction
    b. dehydration reaction
    c. decomposition reaction
    d. organic decomposition
    e. combustion reaction

46. Isotopes differ from atoms in their

    a. number of neutrons
    b. number of protons
    c. number of electrons
    d. electrical conductivity
    e. electronegativity

47. The first hydrogen-fueled balloon flight lasted

    a. 50 minutes
    b. 2 hours
    c. 30 minutes
    d. 1 hour
    e. 45 minutes

48. Robert Boyle first suggested the relationship between a gas's pressure and

    a. Boltzmann constant
    b. temperature
    c. molar mass
    d. volume
    e. number of moles

49. To which gas did Carl Wilhelm Scheele refer using the term "fire-air"?

    a. oxygen
    b. nitrogen
    c. helium
    d. carbon dioxide
    e. phlogiston

50. The oxygen side of the molecule has a partial negative charge in a molecule of

    a. methane
    b. carbon dioxide
    c. water
    d. sulfuric acid
    e. calcium carbonate

1. How many gases is Joseph Priestley credited with isolating?
    a. 11
    b. 8
    c. 0
    d. 9
    e. 10

2. Which of the following processes is NOT a type of naturally occurring chemical process?
    a. acid-base reactions
    b. transmutation
    c. redox reactions
    d. beta minus decay
    e. precipitation reactions

3. Joseph Black conducted his experiments involving the heating of limestone in
    a. 1754
    b. 1755
    c. 1730
    d. 1772
    e. 1786

4. Relative atomic masses were established for every element in relation to
    a. hydrogen
    b. rubidium
    c. carbon
    d. nitrogen
    e. oxygen

5. The quantity that results from the calculation $E°_{red} - E°_{ox}$ is the
    a. galvanic projection
    b. Faraday parameter
    c. electron gain
    d. possible voltage
    e. redox potential

6. A methane molecule's shape can be described as
    a. bent
    b. trigonal pyramidal
    c. tetrahedral
    d. linear
    e. square pyramidal

7. Which of the following is NOT a solubility rule for common compounds?
    a. All acetates and chlorates are soluble.
    b. All common compounds of Group I are soluble.
    c. Most sulfides are insoluble, except for calcium and barium.
    d. Strontium and magnesium are insoluble.
    e. All carbonates and hydroxides are insoluble.

8. Historians use the term "Scientific Revolution" to refer to scientific developments in the
    a. fourteenth and fifteenth centuries
    b. seventeenth and eighteenth centuries
    c. eighteenth and nineteenth centuries
    d. sixteenth and seventeenth centuries
    e. fifteenth and sixteenth centuries

9. Which of the following statements does NOT express an advantage of distillation over reverse osmosis?
    a. It is easier to scale up to large sizes.
    b. There is less pretreatment needed.
    c. It has lower energy needs.
    d. There is less waste to dispose of.
    e. There is less need for membrane cleaning.

10. Increasing the temperature of a substance generally increases its
    a. number of moles
    b. volume
    c. heat
    d. pressure
    e. rate of chemical change

11. Impurities are added to metal to increase the substance's
    a. malleability
    b. conductivity
    c. sonority
    d. lustrousness
    e. strength

12. In the chemical symbol ${}^{A}_{Z}X$, Z stands for the
    a. mass number
    b. atomic number
    c. element symbol
    d. molar mass
    e. number of valence electrons

13. James Watt's invention of the steam engine drew inspiration from the discovery of his teacher

    a. Fritz London
    b. Antoine Henri Becquerel
    c. Joseph Black
    d. Francis Crick
    e. Luigi Galvani

14. Which of the following properties is NOT considered a state function?

    a. heat
    b. energy
    c. pressure
    d. volume
    e. temperature

15. In a nuclear reactor, uranium fission begins when the uranium atom is hit by a free

    a. positron
    b. helium atom
    c. beta particle
    d. electron
    e. neutron

16. The pressure at the critical point of carbon dioxide is

    a. 41 atm
    b. 65 atm
    c. 94 atm
    d. 73 atm
    e. 89 atm

17. Which law explains the colligative properties of solutions?

    a. Proust's law
    b. Hess's law
    c. Charles's law
    d. Rate law
    e. Raoult's law

18. The Nernst equation connects cell potentials to the

    a. reaction's equilibrium constant
    b. ratio of product to reactant concentrations
    c. spontaneity of reactions
    d. the changes in entropy
    e. free energy changes

19. Nuclei break down via alpha decay when they have an atomic number greater than 83, or are larger than

    a. thallium
    b. bismuth
    c. radon
    d. lead
    e. polonium

20. The oxidation state of Li^+ is

    a. +2
    b. 0
    c. -1
    d. -2
    e. +1

21. The wave properties of electrons are shown in the

    a. quantum mechanical model
    b. molecular orbital projection
    c. orbital projection model
    d. Bohr model
    e. collision model

22. Which of the following rules does NOT apply to oxidation numbers?

    a. Alkali metals have oxidation numbers of +1.
    b. The oxidation number of O is +2.
    c. All neutral atoms have an oxidation number of 0.
    d. H has an oxidation number of +1.
    e. The sum of the oxidation numbers must equal the charge of the polyatomic ion.

23. Which of the following letters does NOT refer to a type of orbital shape?

    a. e
    b. p
    c. s
    d. d
    e. f

24. The process by which enthalpy changes are measured is called

    a. calibration
    b. potentiometry
    c. spectroscopy
    d. spectrophotometry
    e. calorimetry

25. Who established that elements combine in defined ratios to form compounds?

    a. Linus Pauling
    b. Joseph-Louis Proust
    c. Joseph-Louis Gay-Lussac
    d. Jean Baptiste Perrin
    e. Leucippus

26. The empirical formula for acetylene is
    a. HiC
    b. HeC
    c. C_2H_2
    d. 2CH
    e. CH

27. The molality unit used is a
    a. milliliter
    b. kilogram
    c. gram
    d. kiloliter
    e. liter

28. Which of the following metals is NOT often used chrome plating?
    a. palladium
    b. copper
    c. platinum
    d. rhodium
    e. bronze

29. The idea that all substances are comprised of small indivisible particles is called
    a. atomism
    b. kinetic-molecular theory
    c. Charles' Law
    d. empiricism
    e. Raoult's Law

30. Atoms that decay over time are
    a. radioactive atoms
    b. nuclides
    c. ions
    d. positrons
    e. isotopes

31. In 1919, the physicist Ernest Rutherford created oxygen atoms by colliding alpha particles with atoms of
    a. fluorine
    b. hydrogen
    c. chlorine
    d. helium
    e. nitrogen

32. Which of the following symbols is NOT used for an equilibrium constant?
    a. *Ka*
    b. *Ksp*
    c. *Kd*
    d. *Kc*
    e. *Kb*

33. The point past which both a liquid and a gas exhibit the same properties is called the
    a. triple point
    b. transitional point
    c. critical point
    d. point of no return
    e. supercritical point

34. Reactions that have a net absorption of heat are described as
    a. nonspontaneous
    b. endothermic
    c. spontaneous
    d. catalyzed
    e. exothermic

35. The chlorine isotope with 25% abundance is
    a. Cl-33
    b. Cl-37
    c. Cl-35
    d. Cl-32
    e. Cl-31

36. In caves, stalactites and stalagmites are formed from the compound
    a. calcium chloride
    b. calcium carbonate
    c. calcium phosphate
    d. calcium carbide
    e. calcium citrate

37. How many electrons are shared between two atoms with a triple covalent bond?
    a. 2
    b. 3
    c. 9
    d. 6
    e. 1

38. What is the MOST well-known environmental contaminant?

    a. metal hydroxides
    b. chlorine
    c. chlorofluorocarbons
    d. ammonium
    e. mercury

39. The geometric shapes of molecules are predicted using the

    a. quantum mechanical model
    b. Bohr model
    c. resonance model
    d. VSEPR model
    e. collision model

40. Dalton presented his research on gases to the Literary and Philosophical Society in

    a. London
    b. Newcastle-upon-Tyne
    c. Birmingham
    d. Manchester
    e. Paris

41. Who is MOST associated with the view that natural processes revolved around four elements (earth, fire, air and water)?

    a. Democritus
    b. Socrates
    c. Plato
    d. Leucippus
    e. Aristotle

42. When ΔH is positive and ΔS is negative, the

    a. reaction will be spontaneous
    b. reaction's spontaneity will depend on the current atmospheric pressure
    c. reaction's spontaneity will depend on the temperature
    d. reaction's spontaneity will depend on the heat added or removed
    e. reaction will be nonspontaneous

43. The chemical formula for a molecule of bleach is

    a. Na_2HCl
    b. Na_2OCl
    c. Na_2Cl
    d. $NaOCl$
    e. O_2NaCl

44. The lowest melting and boiling points are present in molecules that

    a. are covalently bonded
    b. have a bent shape
    c. are nonpolar
    d. are ionically bonded
    e. are polar

45. The "father of modern chemistry" was another name for

    a. Aristotle
    b. Robert Boyle
    c. Paracelsus
    d. Antoine Lavoisier
    e. Johann Baptista van Helmont

46. Alpha decay results in the loss of

    a. two protons and two neutrons
    b. one proton and two neutrons
    c. three protons
    d. one proton and one electron
    e. three neutrons

47. The salt produced from the reaction of HBr and KOH is

    a. KBr
    b. BrOH
    c. 2OH
    d. HK
    e. HBr

48. Electrons are excited to the next energy level when they absorb a(n)

    a. photon
    b. quantum
    c. coulomb
    d. ampere
    e. Faraday

49. The molar mass of water is

    a. 14 g/mol
    b. 12 g/mol
    c. 2 g/mol
    d. 18 g/mol
    e. 16 g/mol

50. When a metal is sonorous, it

    a. can be beaten into different shapes
    b. can be pulled into a wire
    c. is shiny
    d. conducts electricity well
    e. rings when struck

1. The energies before and after a chemical reaction appear on a
    a. collision model
    b. potential energy diagram
    c. VSEPR model
    d. rate projection
    e. Lewis structure

2. Which of the following substances is a weak base?
    a. silver nitrate
    b. sodium acetate
    c. strontium
    d. chlorine
    e. ammonia

3. The 1600s saw a transition towards
    a. transmutation
    b. empiricism
    c. alchemy
    d. astrology
    e. hermeticism

4. Calorimetry measures changes in
    a. entropy
    b. cell potential
    c. temperature
    d. pressure
    e. enthalpy

5. Which of the following equations best describes the ideal gas law?
    a. PV = T/nR
    b. PV/T = CD
    c. PV = C
    d. V/T = D
    e. PV = nRT

6. Paracelsus accidentally produced hydrogen when
    a. dissolving copper in silver nitrate
    b. heating mercury calx
    c. burning liquid oxygen
    d. mixing ammonia with water
    e. dissolving metals in acid

7. When a rotational field exists if a molecule is placed in an electric field, the molecule is said to have a
    a. hydrogen bond
    b. dipole moment
    c. polarizable electron cloud
    d. dipole-dipole force
    e. induced dipole

8. The backbone of a DNA double helix is made up of bonds between sugars and
    a. phosphites
    b. oxalates
    c. sulfates
    d. sulfites
    e. phosphates

9. Which processes refers to the interactions of ions with water molecules when a salt dissolves in water?
    a. hydrolysis
    b. precipitation
    c. cataclysm
    d. conjugation
    e. dehydration synthesis

10. Which of the following features is NOT part of a typical phase diagram?
    a. pressure axis
    b. volume axis
    c. triple point
    d. temperature axis
    e. critical point

11. Ammonia is a substitute for
    a. butane
    b. ethanol
    c. chlorofluorocarbons
    d. methane
    e. ozone

12. Kinetic-molecular theory concerns the
    a. behavior of gases
    b. bonding of atoms
    c. behavior of solids
    d. behavior of liquids
    e. interaction between metals and nonmetals

13. Which of the following is NOT a main element of nature, according to the Aristotelian view?
    a. water
    b. fire
    c. space
    d. earth
    e. air

14. Hydrogen combines in a 1:19 ratio with

    a. fluorine
    b. carbon
    c. sodium
    d. oxygen
    e. chlorine

15. The type of relationship between the pressure and volume of a gas is called

    a. inverse proportionality
    b. inverse-square proportionality
    c. constant proportionality
    d. geometric proportionality
    e. direct proportionality

16. Energy is transferred from an electron to a photon in

    a. hybridization
    b. the photoelectric effect
    c. redox reactions
    d. distillation
    e. Induced dipoles

17. Which scale do scientists use to measure temperature?

    a. Celsius
    b. Fahrenheit
    c. Rankine
    d. Delisle
    e. Kelvin

18. Which of the following reactions has the lowest electrode potential?

    a. $Li^+ + e^- \rightarrow Li$
    b. $2H^+ + 2e^- \rightarrow H_2$
    c. $F_2 + 2e^- \rightarrow 2F^-$
    d. $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$
    e. $Cl_2 + 2e^- \rightarrow 2Cl^-$

19. Nonpolar solvents are characteristic of

    a. isotonic solutions
    b. supersaturated solutions
    c. heterogenous solutions
    d. organic solutions
    e. hypertonic solutions

20. In general, substances that speed up reactions are called

    a. enzymes
    b. sparks
    c. stimuli
    d. activators
    e. catalysts

21. Which of the following inventions does NOT date from the eighteenth century?

    a. sewing machine
    b. steamship
    c. steam engine
    d. power looms
    e. gas lighting

22. Neutral substances have a pH of exactly

    a. 5
    b. 14
    c. 1
    d. 0
    e. 7

23. Along with Antoine Lavoisier, the scientist that inspired Dalton's research was

    a. Lester Germer
    b. Joseph Louis Proust
    c. Democritus
    d. Francis Crick
    e. James Watson

24. Which scientist referred to carbon dioxide as "fixed air"?

    a. Robert Boyle
    b. John Dalton
    c. Fritz London
    d. Joseph Black
    e. Albert Einstein

25. The chemist that determined the relationship between enthalpy and entropy was

    a. British
    b. Russian
    c. Scottish
    d. American
    e. French

26. Along with Joseph Louis Proust, the scientist who inspired Dalton's research was

    a. Leucippus
    b. Aristotle
    c. Anne-Jean Robert
    d. Nicolas-Louis Robert
    e. Clinton Davisson

27. HgO is the chemical formula for

    a. mercuric oxide
    b. dimethylmercury
    c. thiomersal
    d. methylmercury
    e. calomel

28. London dispersion forces are the only type of intermolecular forces between molecules that are

    a. nonpolar
    b. covalently bonded
    c. radioactive
    d. polar
    e. ionically bonded

29. Which of the following reactions is MOST likely a synthesis reaction?

    a. Cu + 2AgNO3 → 2Ag + Cu(NO3)2
    b. H2O2 → H2O + O2
    c. $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$
    d. $2Na + Cl_2 \rightarrow 2NaCl$
    e. $CH_4 + 2O_2 \rightarrow H_2O + CO_2$

30. Ernest Rutherford created oxygen by colliding nitrogen with

    a. hydrogen
    b. beta particles
    c. alpha particles
    d. positrons
    e. neutrinos

31. When did Ernest Rutherford create oxygen?

    a. 1920
    b. 1914
    c. 1925
    d. 1928
    e. 1919

32. Brass is made from copper and

    a. germanium
    b. arsenic
    c. mercury
    d. yttrium
    e. zinc

33. A mixture is called a solution when

    a. it looks like a single substance
    b. the substances are heated
    c. the substances are covalently bonded together
    d. the substances have undergone radioactive decay
    e. it is made up of a single substance

34. One of the half-reactions for the reaction of copper with a silver ion is

    a. $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$
    b. $Ag^+ + 1e^- \rightarrow Ag$
    c. $2Ag^+ + 2e^- \rightarrow 2Ag$
    d. $Ag^+ + 2e^- \rightarrow Ag^+$
    e. $Cu \rightarrow Cu^{2+} + 3e^-$

35. If silver metal were to be put in a copper solution, then

    a. no reaction would occur
    b. a precipitate would form
    c. combustion would occur
    d. water vapor would be produced
    e. oxidation would occur

36. Which scientist made significant contributions to the field of thermochemistry?

    a. Ludwig Boltzmann
    b. Johannes Brønsted
    c. Jean Baptiste Perrin
    d. Luigi Brugnatelli
    e. Joseph Black

37. Which of the following relationships represents Charles's law?

    a. VT = D
    b. P/T = D
    c. PV = nRT
    d. PT = D
    e. V/T = D

38. The enthalpy of formation of CO is

    a. -110 kJ/mol
    b. 200 kJ/mol
    c. -150 kJ/mol
    d. -100 kJ/mol
    e. -164 kJ/mol

39. If the products are placed lower on a potential energy diagram than the reactants, then the reaction is

    a. endothermic
    b. spontaneous
    c. transitional
    d. nonspontaneous
    e. exothermic

40. Catalysts are used to
    a. increase reaction rates
    b. increase pH
    c. increase temperatures
    d. decrease reaction rates
    e. decrease pressure

41. London dispersion forces occur between
    a. temporary dipoles
    b. polar molecules
    c. unstable atoms
    d. ionically bonded atoms
    e. adjacent molecules

42. Carbon was used to establish
    a. molar masses
    b. atomic radii
    c. electronegativity
    d. relative atomic masses
    e. atomic numbers

43. Water combines in a ratio of
    a. 2:16
    b. 1:10
    c. 1:8
    d. 5:8
    e. 1:2

44. To which branch of science did Joseph Black make significant contributions?
    a. thermochemistry
    b. kinetic-molecular theory
    c. quantum physics
    d. thermodynamics
    e. calorimetry

45. How many neutrons does a hydrogen atom have?
    a. zero
    b. one
    c. four
    d. three
    e. two

46. The equation to change from free energy to equilibrium constants is
    a. $\Delta G = -nFE°_{cell}$
    b. $u = \sqrt{\frac{3RT}{m}}$
    c. $\Delta G = \Delta H - T\Delta S$
    d. $\Delta G = -RT \ln K$
    e. $E = E° - \frac{.0592 \ln Q}{n}$

47. Carbon and hydrogen are elements characteristic of
    a. amphoteric solvents
    b. protophilic solvents
    c. protogenic solvents
    d. polar solvents
    e. nonpolar solvents

48. Who published *A New System of Chemical Philosophy*?
    a. Henry Cavendish
    b. Paracelsus
    c. John Dalton
    d. Joseph Priestley
    e. Robert Boyle

49. Which of the following groups of substances is soluble according to solubility rules?
    a. silicates
    b. hydroxides
    c. chlorates
    d. carbonates
    e. phosphates

50. Quantum mechanical models are used to show the
    a. bonding between valence electrons
    b. wave properties of electrons
    c. attractive force between protons and neutrons
    d. particle properties of electrons
    e. shapes of orbitals

1. When a certain atom has a different atomic mass than the standard form of the atom, it is called a/an
    a. nuclide
    b. ion
    c. isotope
    d. element
    e. inotrope

2. When a metal is described as lustrous, it
    a. can be hammered into wires
    b. can conduct electricity
    c. can be bent into shapes
    d. has a shiny experience
    e. rings when struck

3. All standard half-cell potentials are measured relative to the reduction of
    a. helium
    b. hydrogen
    c. carbon
    d. rubidium
    e. oxygen

4. The idea that elements combine in whole-number ratios to form compounds is characteristic of
    a. the law of multiple proportions
    b. the law of definite proportions
    c. Hess's law
    d. Raoult's law
    e. Proust's law

5. A positive ion is also referred to as a(n)
    a. alpha particle
    b. nuclide
    c. beta particle
    d. cation
    e. anion

6. Which of the following values is NOT a possible oxidation number for bromine?
    a. +3
    b. +2
    c. +1
    d. -1
    e. +5

7. Elements are arranged by increasing electrons in the
    a. Newland elemental grid
    b. activity series
    c. familial model
    d. reactivity series
    e. periodic table

8. Which idea of Dalton's was later proven wrong?
    a. Chemical reactions can cause atoms to combine, separate, and rearrange.
    b. Matter is composed of indivisible particles called atoms.
    c. Atoms of different elements can combine in whole-number ratios to form compounds.
    d. Atoms of the same element have the same properties.
    e. Atoms cannot be created or destroyed.

9. At their triple point, all substances can be
    a. plasma
    b. transitional fluids
    c. universal solvents
    d. supercritical fluids
    e. every state of matter simultaneously

10. The state function that tracks the relationship between enthalpy and entropy is symbolized by
    a. ΔH
    b. ΔG
    c. ΔE
    d. ΔS
    e. $\Delta Þ$

11. When a metal ion replaces a hydrogen ion in an acid, the substance that is formed is (a)
    a. nuclide
    b. ciprotic acid
    c. base
    d. salt
    e. water

12. When the reactant in a combustion reaction is an organic hydrocarbon, the products will be carbon dioxide and
    a. ammonia
    b. ozone
    c. carbon monoxide
    d. oxygen
    e. water

13. With which property of matter does quantum physics deal?

    a. Doppler effect
    b. relativity
    c. wave-particle duality
    d. electromagnetism
    e. mass-energy equivalence

14. The Aristotelian view of nature was that

    a. the Earth is at the center of the universe
    b. different types of organisms possess different types of souls
    c. a separate being is the source of all other beings
    d. nature is made up of four elements
    e. the soul dies with the animal

15. The MOST similar subatomic particle to an electron is a(n)

    a. alpha particle
    b. beta particle
    c. proton
    d. neutrino
    e. neutron

16. Van der Waals constants are parameters used for

    a. supercritical fluids
    b. substances at their triple point
    c. plasma
    d. ideal gases
    e. non-ideal gases

17. The substance that Antoine Lavoisier heated to create oxygen was

    a. gypsum
    b. gold hydrazide
    c. cinnabar
    d. bluestone
    e. mercury calx

18. How many electrons do two atoms with a double covalent bond share?

    a. 4
    b. 2
    c. 12
    d. 8
    e. 6

19. Isotopes differ from atoms in their standard form in their number of

    a. orbitals
    b. electrons
    c. protons
    d. neutrons
    e. valence electrons

20. To convert a temperature from Kelvin to Celsius,

    a. subtract 273
    b. multiply by 9/5
    c. add 274
    d. add 273
    e. divide by 9/5

21. Which substance protected the *Columbia* from solar radiation?

    a. bronze
    b. silver
    c. tungsten
    d. gold
    e. platinum

22. The type of relationship between the temperature and pressure of a gas is called

    a. constant proportionality
    b. geometric proportionality
    c. inverse proportionality
    d. inverse-square proportionality
    e. direct proportionality

23. How many electrons does hydrogen need to fill its valence shell?

    a. 6
    b. 4
    c. 10
    d. 2
    e. 8

24. Joseph Black made significant contributions to thermochemistry through his

    a. invention of the steam engine
    b. creation of phase diagrams
    c. discovery of carbon dioxide
    d. research into melting snow
    e. proposal of kinetic-molecular theory

25. Besides Jacques Charles and Nicolas-Louis Robert, the third person involved with hydrogen balloon flight was

    a. Ernest Rutherford
    b. Albert Einstein
    c. Benjamin Franklin
    d. J.J. Thompson
    e. Anne-Jean Robert

26. If the cell voltages of the reactions $Li^{+} + e^{-}$ <sym-Symbol-F0AE> Li and Fe^{2+} <sym-Symbol-F0AE> $Fe^{3+} + e^{-}$ are -3.05 V and -0.77 V respectively, the total cell voltage is

    a. 3.82 V
    b. 2.28 V
    c. -3.82 V
    d. -2.28 V
    e. 2.34 V

27. At which temperature does "zero volume" temperature occur?

    a. -273° C
    b. 273° K
    c. 273° C
    d. -273° F
    e. -273 K

28. The temperature of a substance has a direct relationship to its

    a. volume
    b. density
    c. molecular motion
    d. pressure
    e. mass

29. Henry Cavendish confirmed that water was produced through the

    a. combustion of methane
    b. burning of oxygen
    c. decomposition of carbonic acid
    d. addition of oxygen to a methane molecule
    e. burning of hydrogen

30. *A New System of Chemical Philosophy* was published in

    a. 1808
    b. 1809
    c. 1810
    d. 1812
    e. 1811

31. The lowest pH that an acid can have is

    a. 5
    b. 1
    c. 7
    d. 14
    e. 0

32. Which scientist accidentally produced hydrogen?

    a. Thales of Miletus
    b. Leucippus
    c. Paracelsus
    d. Democritus
    e. Hipparchus

33. The process of electroplating was discovered in the

    a. early 1810s
    b. mid 1880s
    c. late 1890s
    d. early 1800s
    e. late 1850s

34. Which of the following properties is NOT an elemental property that the periodic table can explain?

    a. radioactivity
    b. electron affinity
    c. electronegativity
    d. atomic radius
    e. ionization energy

35. Which of the following ideas does Hess's law state?

    a. The heat evolved or absorbs in a chemical reaction no matter how many steps the process takes steps in.
    b. No mass is lost or gained as substances change during a reaction.
    c. The volume of a gas is directly proportional to the number of moles of the gas.
    d. A compound is always composed of the same elements in the same ratios according to mass.
    e. The total pressure of a mixture of gases equals the sum of the pressures of each individual gas.

36. The earliest created reliable battery was the

    a. lithium battery
    b. lead-acid battery
    c. chromic acid cell
    d. flow battery
    e. galvanic electrochemical cell

37. What is the subatomic breakdown of an alpha particle?

a. 2 neutrons, 2 electrons
b. 1 proton, 2 electrons
c. 2 protons, 2 neutrons
d. 4 electrons
e. 2 beta particles

38. A mass spectrometer uses magnetic fields to

a. identify isotopes of elements
b. quantify the number of protons present
c. separate atoms and compounds
d. identify types of radiation
e. perform titrations

39. Which compound was used to process photographs?

a. silver fluoride
b. silver iodide
c. silver chloride
d. silver halide
e. silver bromide

40. When ΔG is negative,

a. the reaction favors the formation of reactants
b. $K < 1$
c. E°_{cell} is positive
d. E°_{cell} is negative
e. $K > 1$

41. The measure of the acidity or basicity of an aqueous solution is called

a. saturation
b. polarity
c. pH
d. solubility
e. concentration

42. Which of the following substances is NOT a solution?

a. tea
b. smog
c. lemonade
d. air
e. steel

43. Polar molecules have permanent

a. dipole moments
b. hydrogen bonds
c. London dispersion forces
d. van der Waals forces
e. dipole-dipole forces

44. Antoine Lavoisier is often called the father of modern

a. chemistry
b. biology
c. calorimetry
d. physics
e. thermochemistry

45. It takes 4.18 joules of heat to raise the temperature by 1° C for 1 gram of

a. alcohol
b. oil
c. water
d. octane
e. distilled water

46. Joseph Black began researching heat in the

a. 1780s
b. 1770s
c. 1790s
d. 1760s
e. 1750s

47. Ions differ from atoms in their standard form in their number of

a. neutrons
b. electrons
c. positrons
d. valence electrons
e. protons

48. The Greek letter used to denote a change in a quantity is

a. β
b. γ
c. α
d. δ
e. Δ

49. An atom's ionization energy is its

a. attractive force within the nucleus
b. amount of energy needed to add an electron
c. amount of energy needed to remove an electron
d. attraction for neighboring electrons
e. ability to merge electron orbitals

50. The endpoint of a titration is also called its

a. equivalence point
b. equilibrium
c. conclusion
d. stable state
e. transitional equilibrium

1. Which of the following quantities increases down a group of the periodic table?
    a. electronegativity
    b. radioactivity
    c. ionization energy
    d. atomic radius
    e. electron affinity

2. Enthalpy for the formation of CO_2 is equal to the
    a. enthalpy for oxidation of CO to CO_2
    b. heat of reaction for the combustion of CO_2
    c. heat of formation for CO_2
    d. enthalpy of formation for CO
    e. heat of vaporization for CO

3. When water accepts a hydrogen ion, it forms a(n)
    a. molten salt
    b. nitrate
    c. acetate
    d. electrolyte
    e. nitrite

4. The lowest temperature physically possible is
    a. -273° F
    b. -273° C
    c. -273 K
    d. -274° C
    e. 273 K

5. Van der Waals constants *a* and *b* are correction values for the volume of molecules and the
    a. levels of electronegativity
    b. levels of ionization energy
    c. intramolecular forces
    d. intermolecular forces
    e. repelling force between electrons

6. Which type of relationship does free energy have with equilibrium constants?
    a. exponential
    b. direct
    c. logarithmic
    d. inverse
    e. Inverse-square

7. When a reaction is endothermic, it
    a. absorbs heat
    b. releases heat
    c. occurs naturally
    d. favors reactants over products
    e. occurs naturally in reverse

8. The term MOST likely to be used as a synonym for entropy is
    a. chaos
    b. spontaneity
    c. transformation
    d. uncertainty
    e. thermal energy

9. How many electrons do most atoms have in their valence shell?
    a. 10
    b. 7
    c. 12
    d. 16
    e. 8

10. Which of the following substances forms when acetic acid is added to water?
    a. bleach
    b. ammonia
    c. vinegar
    d. yeast
    e. ethanol

11. Which of the following contributions to chemistry did Johann Baptista van Helmont NOT make?
    a. developing a scientific explanation for combustion
    b. developing the balance
    c. refuting element transmutation
    d. introducing the term “gas”
    e. anticipating the law of conservation of mass

12. Which gas did Jacques Charles wish to use to fuel balloon flight?
    a. oxygen
    b. neon
    c. nitrogen
    d. helium
    e. hydrogen

13. The sign of ΔG determines the
    a. ideal temperature of the reaction
    b. cell potential of the reaction
    c. spontaneity of a reaction
    d. existence of a change in enthalpy
    e. existence of a change in entropy

14. Which of the following relationships represents Boyle's law?

    a. P/V = C
    b. PV/T = C
    c. VT = C
    d. V/T = C
    e. PV = C

15. With which of the following quantities does entropy have an inverse relationship?

    a. Gibbs Free Energy
    b. enthalpy
    c. temperature
    d. heat
    e. order

16. How many electrons are shared between two atoms with a single covalent bond?

    a. 2
    b. 0
    c. 6
    d. 4
    e. 1

17. $C_8H_{10}N_4O_2$ is the chemical formula for

    a. caffeine
    b. methane
    c. ammonia
    d. ethanol
    e. polyester

18. Plant growth relies MOST on controlling the soil's

    a. deposition
    b. acidity
    c. volatilization
    d. sedimentation
    e. friability

19. How many more electrons does oxygen need to fill its valence shell?

    a. 5
    b. 3
    c. 8
    d. 2
    e. 1

20. In which direction does the ionization energy of an element decrease?

    a. diagonally up
    b. left across a period
    c. down a group
    d. up a group
    e. right across a period

21. Shiny parts on automobiles are created with

    a. percolation
    b. chrome plating
    c. distillation
    d. extraction
    e. effusion

22. Mass spectrometers are MOST likely to be used at

    a. grocery stores
    b. airports
    c. police stations
    d. hospitals
    e. post offices

23. Which of the following statements is NOT correct?

    a. The oxidation number of O is +2.
    b. The oxidation number of Rb is +1.
    c. The oxidation number of H is +1.
    d. The oxidation number of Li is +1.
    e. The oxidation number of Cs is +1.

24. Which of the following molecules is bonded by triple covalent bonds?

    a. O_3
    b. CH_4
    c. H_2
    d. O_2
    e. N_2

25. Which decomposition reaction was used to make oxygen gas when it was first discovered?

    a. water into hydrogen and oxygen
    b. iron oxide into iron and oxygen
    c. mercury oxide into mercury and oxygen
    d. carbonic acid into water and carbon dioxide
    e. hydrogen peroxide into water and oxygen

26. When experimenting with dissolving metals in acids, Paracelsus accidentally produced

    a. helium
    b. oxygen
    c. carbon
    d. nitrogen
    e. hydrogen

27. The branch of science that focuses on the quantities of heat released or absorbed is

    a. entropy
    b. thermodynamics
    c. calorimetry
    d. thermochemistry
    e. enthalpy

28. Which of the following compounds is NOT a triprotic acid?

    a. H_3SO_4
    b. H_3PO_4
    c. H_3SO_4
    d. CH_3COOH
    e. $C_6H_8O_7$

29. The "root mean square" speed is symbolized by the letter

    a. *u*
    b. *U*
    c. *s*
    d. *R*
    e. *r*

30. The person who expanded on Leucippus's concept of atomism was

    a. Paracelsus
    b. Hipparchus
    c. Leucippus
    d. John Dalton
    e. Democritus

31. ΔG is equal to zero when the reaction is

    a. exothermic
    b. spontaneous
    c. endothermic
    d. at equilibrium
    e. nonspontaneous

32. All substances exist as supercritical fluids beyond their

    a. gaseous boundary
    b. final boundary
    c. transitional point
    d. critical point
    e. triple point

33. The highest pH that an base can have is

    a. 1
    b. 0
    c. 7
    d. 14
    e. -14

34. On what grounds do scientists question the idea of the Scientific Revolution?

    a. Great Awakening
    b. Second Great Awakening
    c. Scientific Revolution
    d. Enlightenment
    e. Renaissance

35. If the products are placed higher on a potential energy diagram than the reactants, the reaction is

    a. spontaneous
    b. exothermic
    c. transitional
    d. endothermic
    e. nonspontaneous

36. For an ionic bond to form, the difference in electronegativity between two atoms has to be greater than

    a. 1.5
    b. 2.0
    c. 1.8
    d. 4.0
    e. .5

37. Which atom has 6 protons, 6 neutrons and 6 electrons?

    a. Carbon-15
    b. Carbon-13
    c. Carbon-12
    d. Carbon-16
    e. Carbon-14

38. The Pauling electronegativity value of beryllium is

    a. 2.1
    b. 1.5
    c. 1.0
    d. 4.0
    e. 3.0

39. Mass spectrometers scan different masses by varying their

    a. ion source strength
    b. detector strength
    c. resonance levels
    d. magnetic fields
    e. electric fields

40. What type of relationship does free energy have with electrode potentials?

    a. inverse
    b. inverse-square
    c. logarithmic
    d. direct
    e. exponential

41. The number of elements within the periodic table is over

    a. 10
    b. 75
    c. 25
    d. 100
    e. 50

42. Which of the following statements is LEAST likely to have been published in *A New System of Chemical Philosophy?*

    a. All matter is composed of atoms.
    b. Atoms combine in certain ratios to form compounds.
    c. Atoms can be divided into protons, neutrons, and electrons.
    d. Atoms cannot be created or destroyed.
    e. Chemical reactions cause atoms to combine and separate.

43. The first hydrogen-fueled balloon flight took place in

    a. 1754
    b. 1783
    c. 1729
    d. 1782
    e. 1795

44. The law of definite proportions is also called

    a. Dalton's law
    b. Hess's law
    c. Proust's law
    d. Lavoisier's principle
    e. Raoult's law

45. John Dalton was born in

    a. 1766
    b. 1720
    c. 1795
    d. 1738
    e. 1750

46. Van der Waals constants *a* and *b* are correction values for the intermolecular forces and the

    a. repelling force between electrons
    b. molecular motion
    c. intramolecular forces
    d. volume of molecules
    e. temperature of the substances

47. Which isotope of carbon does carbon dating use?

    a. Carbon-14
    b. Carbon-16
    c. Carbon-12
    d. Carbon-13
    e. Carbon-15

48. All substances can be considered ensembles of rapidly moving particles, except when they

    a. are radioactive
    b. have reached their triple point
    c. are in a plasmatic state of matter
    d. have reached their critical point
    e. are at absolute zero temperature

49. "Electron seas" are associated with

    a. covalent bonds
    b. hydrogen bonds
    c. metallic bonds
    d. dipole moments
    e. ionic bonds

50. When uranium-238 undergoes alpha decay, the resulting product is

    a. europium-151
    b. neon-22
    c. ytterbium-173
    d. uranium-236
    e. thorium-234

1. The difference in electronegativity between an Na atom and an F atom is
    a. .2
    b. 2.3
    c. 1.7
    d. 3.8
    e. .3

2. A sample of contained gas with a volume of 1 liter has a pressure of 5.0 atm at a temperature of 200 K. What is the pressure at 400 K?
    a. 10.0 atm
    b. 5.0 atm
    c. 20.0 atm
    d. 40.0 atm
    e. 7.5 atm

3. Which of the following substances is amphoteric?
    a. water
    b. octane
    c. ethanol
    d. vinegar
    e. liquid nitrogen

4. How many elements did the Aristotelian view of science describe?
    a. three
    b. five
    c. two
    d. one
    e. four

5. The collisions between gas molecules and the walls of their container are elastic, which means that
    a. no kinetic energy is lost
    b. no momentum or kinetic energy is lost
    c. momentum is conserved, but kinetic energy is lost
    d. kinetic energy is conserved, but momentum is lost
    e. no momentum is lost

6. Which type of reaction was used to discover oxygen gas?
    a. synthesis
    b. combustion
    c. decomposition
    d. oxidation
    e. precipitation

7. When the *K* value of a reaction is positive, the reaction
    a. favors the formation of products
    b. is nonspontaneous
    c. favors the formation of reactants
    d. is endothermic
    e. is spontaneous

8. The inverse relationship between pressure and volume is highlighted in
    a. Charles's law
    b. Proust's law
    c. Gay-Lussac's law
    d. Avogadro's law
    e. Boyle's law

9. How many electrons does helium need to fill its valence shell?
    a. 4
    b. 2
    c. 10
    d. 6
    e. 8

10. Which of the following is a similarity between the Bohr model and quantum mechanical model?
    a. Electron energies are limited to certain values.
    b. The electron is put in a stationary, fixed location.
    c. The electron rotates in a certain orbit.
    d. The electron's path around the nucleus is described.
    e. The electron is placed at an exact distance from the nucleus.

11. Hess's law is MOST useful to calculate changes in
    a. Gibbs Free Energy
    b. Ionization energy
    c. enthalpy
    d. entropy
    e. radioactivity

12. Which Founding Father watched the first hydrogen-powered balloon flight?
    a. George Washington
    b. Thomas Jefferson
    c. Benjamin Franklin
    d. John Hancock
    e. John Adams

13. How many grams of Carbon-12 does it take for the number of carbon atoms to equal 1 mole?

    a. 6
    b. 15
    c. 8
    d. 12
    e. 10

14. Hydroxide ions are formed when

    a. acids break apart in water
    b. hydrogen ions are donated by an acid
    c. the pH of a solution is too high
    d. there is an excess of hydrogen ions
    e. bases break apart in water

15. Luigi Galvani's research into electricity revolved around experiments involving

    a. hamsters
    b. rats
    c. newts
    d. mice
    e. frogs

16. Which famous figure was in the audience during the launch of the first hydrogen-powered balloon?

    a. Nikola Tesla
    b. Thomas Edison
    c. Benjamin Franklin
    d. Samuel Morse
    e. James Watt

17. The law of definite proportions was proposed in

    a. 1956
    b. 1799
    c. 1689
    d. 2001
    e. 1497

18. Ernest Rutherford created oxygen atoms by combining nitrogen atoms with

    a. beta particles
    b. alpha particles
    c. Hydrogen nuclei
    d. photons
    e. neutrinos

19. Empiricism was rooted in

    a. experimentation
    b. mysticism
    c. debate
    d. philosophy
    e. theory

20. Dalton proposed the first modern atomic theory in the early

    a. fifteenth century
    b. nineteenth century
    c. seventeenth century
    d. twentieth century
    e. sixteenth century

21. A neutral substance has a H^+ concentration of

    a. $1.0 * 10^{-7}$ M
    b. $1.0 * 10^{7}$ M
    c. $1.0 * 10^{-5}$ M
    d. $1.0 * 10^{9}$ M
    e. $1.0 * 10^{-6}$ M

22. Gold plating is most notably used in the industry of

    a. electronics
    b. aerospace
    c. photonics
    d. biomechanics
    e. nuclear research

23. Which scientist showed that two volumes of hydrogen and one volume of oxygen were needed to produce water?

    a. Amedeo Avogadro
    b. Alessandro Volta
    c. Maurice Wilkins
    d. Joseph-Louis Gay Lussac
    e. Joseph-Louis Proust

24. Which of the following physicists was inspired by love for the weather?

    a. Francis Crick
    b. Amedeo Avogadro
    c. Robert Boyle
    d. John Dalton
    e. Antoine Lavoisier

25. John Dalton first observed the direct relationship between a gas's pressure and

    a. temperature
    b. heat added
    c. mass
    d. volume
    e. number of moles

26. Which of the following factors would LEAST influence a person's choice of water purification method?

    a. energy used
    b. pretreatment needed
    c. proximity to water source
    d. maintenance frequency
    e. waste to be discharged

27. The rarest carbon isotope is

    a. Carbon-16
    b. Carbon-14
    c. Carbon-12
    d. Carbon-13
    e. Carbon-18

28. The steam engine was an invention of the

    a. nineteenth century
    b. eighteenth century
    c. seventeenth century
    d. twentieth century
    e. sixteenth century

29. C_2H_2 is the chemical formula for

    a. acetylene
    b. ethanol
    c. propylene
    d. acetone
    e. propane

30. Sigma and pi bonds form through the combination of

    a. atomic orbitals
    b. nuclides
    c. nuclei
    d. valence shells
    e. electron shells

31. How many coulombs of charge does 1 Faraday have?

    a. 96,500
    b. 99,500
    c. 97,500
    d. 95,500
    e. 98,500

32. Neutrons are converted to protons during

    a. beta plus decay
    b. nuclear fusion
    c. beta minus decay
    d. nuclear fission
    e. alpha decay

33. What did Antoine Lavoisier call the gas he discovered?

    a. hydrogène
    b. hélium
    c. néodyme
    d. oxygène
    e. manganèse

34. When a reaction is exothermic, it

    a. absorbs heat
    b. occurs naturally in reverse
    c. occurs naturally
    d. releases heat
    e. favors products over reactants

35. The hydrogen-powered balloon was based on

    a. Charles's law
    b. Avogadro's law
    c. Gay-Lussac's law
    d. Raoult's law
    e. Boyle's law

36. How many assumptions does kinetic-molecular theory make?

    a. 3
    b. 1
    c. 4
    d. 5
    e. 2

37. A positive sign for the enthalpy of formation for a certain compound indicates that the reaction is

    a. non-spontaneous
    b. exothermic
    c. endothermic
    d. spontaneous
    e. unstable

38. Which compound is added to silver to make it precipitate as metallic silver?

    a. mercury
    b. iron
    c. zirconium
    d. nickel
    e. zinc

39. The photoelectric effect is very common in

    a. laptops
    b. flash drives
    c. digital cameras
    d. smartphones
    e. televisions

40. Which is the CLOSEST figure to the ratio of naturally found deuterium atoms to hydrogen atoms?

    a. 1:15000
    b. 1:10000
    c. 1:5000
    d. 1:500
    e. 1:100

41. ΔH - TΔS is the equation to find a certain quantity of

    a. temperature
    b. entropy
    c. Faradays
    d. Gibbs Free Energy
    e. enthalpy

42. The sum of the oxidation numbers of atoms that are bonded together must be equal to the total

    a. cell potential of each atom
    b. number of valence electrons
    c. charge of the compound
    d. number of bonds between atoms
    e. Pauling electronegativity

43. Nonpolar solvents are compounds that contain only carbon and

    a. oxygen
    b. hydrogen
    c. nitrogen
    d. helium
    e. phosphorus

44. A vertical column on the periodic table is called a

    a. period
    b. set
    c. level
    d. group
    e. class

45. If an atom of a certain element has an oxidation number of + 1, it is likely

    a. a lanthanide
    b. an alkali metal
    c. an actinide
    d. a metalloid
    e. an alkaline earth metal

46. The publication of scientific papers is MOST associated with

    a. formation of scientific societies
    b. creation of an international postage system
    c. increase in funding for scientific research
    d. rise in literacy
    e. invention of the printing press

47. Within equilibrium problems, the concentration of substance A in moles per liter would be denoted by the symbol

    a. {A}
    b. <A>
    c. [A]
    d. |A|
    e. (A)

48. Who proposed that a substance's properties are determined by the properties of its particles?

    a. John Dalton
    b. Antoine Lavoisier
    c. Leucippus
    d. Democritus
    e. Joseph-Louis Proust

49. Which of the following structures is NOT a VSEPR shape?

    a. octahedral
    b. trigonal bipyramidal
    c. hexagonal bipyramidal
    d. trigonal planar
    e. tetrahedral

50. Which idea was first proposed in the fifth century CE?

    a. atomism
    b. kineticism
    c. VSEPR theory
    d. thermodynamics
    e. entropy

1. If the gas molecules within a container are moving very rapidly, that is a clear indication that MOST likely the gas has a
    a. high pressure
    b. high temperature
    c. high volume
    d. low pressure
    e. low temperature

2. A negative sign for the enthalpy of formation for a certain compound indicates that the reaction is
    a. exothermic
    b. non-spontaneous
    c. unstable
    d. endothermic
    e. spontaneous

3. Properties that depend on the relative numbers of moles of solute and solvent are called
    a. paragonal properties
    b. concentrated properties
    c. isotopes
    d. allotropes
    e. colligative properties

4. The latent heat associated with vaporizing a solid is called the
    a. heat of sublimation
    b. heat of fusion
    c. heat of condensation
    d. heat of vaporization
    e. heat of solidification

5. The measurement of a mole is based on 12 grams of
    a. helium
    b. oxygen
    c. iron
    d. hydrogen
    e. carbon

6. What type of conditions are measured at 298 K with regards to cell potential?
    a. “stable”
    b. “standard state”
    c. “increased activity”
    d. “equilibrium”
    e. “reduced activity”

7. During uranium fission, the uranium atom is hit by a free
    a. neutron
    b. proton
    c. neutrino
    d. electron
    e. positron

8. How many electrons can exist in the same orbit?
    a. 2
    b. 4
    c. 6
    d. 8
    e. 1

9. The “energy associated with disorder” is also known as
    a. enthalpy
    b. Internal energy
    c. entropy
    d. exergy
    e. Gibbs Free Energy

10. An atom’s mass number is equal to the sum of its
    a. neutrons and valence electrons
    b. protons and valence electrons
    c. protons and neutrons
    d. neutrons and electrons
    e. protons and electrons

11. Which of the following elements could replace H_2 from any source?
    a. Ag
    b. Cu
    c. Au
    d. Li
    e. Hg

12. Which of the following materials can be carbon dated?
    a. glass
    b. metal
    c. rock
    d. wood
    e. clay

13. What fraction of the mass of a carbon atom is a hydrogen atom?
    a. 1/10
    b. 1/2
    c. 1/4
    d. 1/3
    e. 1/12

14. Which of the following isotopes is made in nuclear reactors?

    a. Actinium-227
    b. Carbon-14
    c. Cobalt-60
    d. Uranium-235
    e. Hydrogen-2

15. John Dalton maintained daily records of the weather for

    a. 37 years
    b. 17 years
    c. 57 years
    d. 64 years
    e. 84 years

16. In what unit is heat measured?

    a. amperes
    b. watt-seconds
    c. coulombs
    d. joules
    e. hertz

17. Which substance forms when cosmic rays interact with nitrogen atoms?

    a. Nitrogen-12
    b. ozone
    c. Carbon-12
    d. Carbon-14
    e. carbon monoxide

18. The first manned hydrogen-fueled balloon flight took place in the

    a. late 1750s
    b. late 1760s
    c. early 1740s
    d. early 1730s
    e. early 1770s

19. V/T = D is the relationship highlighted in

    a. Avogadro's law
    b. Charles's law
    c. Proust's law
    d. Raoult's law
    e. Gay-Lussac's law

20. Which of the following contributions did Antoine Lavoisier NOT make to the field of chemistry?

    a. the law of partial pressure
    b. the principle of conservation of mass
    c. the current system of chemical nomenclature
    d. the composition of air
    e. a better understanding of combustion

21. The first modern atomic theory was put forth in the early

    a. 16th century
    b. 18th century
    c. 19th century
    d. 20th century
    e. 17th century

22. When the *K* value of a reaction is negative, the reaction

    a. is exothermic
    b. favors the formation of reactants
    c. favors the formation of products
    d. requires a catalyst to occur naturally
    e. is endothermic

23. Which scientist first estimated Avogadro's number?

    a. J.J. Thompson
    b. Jean Baptiste Perrin
    c. Amedeo Avogadro
    d. Joseph-Louis Gay-Lussac
    e. Fritz London

24. How long did Charles's second hydrogen-powered balloon flight last?

    a. 2 hours
    b. 1 hour
    c. 30 minutes
    d. 2.5 hours
    e. 3 hours

25. Which of the following scientists worked at the University of California?

    a. Niels Bohr
    b. Maurice Wilkins
    c. Gilbert N. Lewis
    d. Joseph Black
    e. Lester Germer

26. A horizontal row on the periodic table is called a

    a. set
    b. level
    c. period
    d. class
    e. group

27. Thermodynamics is the study of

    a. how molecules react with each other
    b. energy and temperature in relation to particle motion
    c. wave-particle duality
    d. the movement of matter and energy within systems
    e. energy changes in chemical reactions

28. A basic substance has a H^+ concentration below
    a. $1.0 * 10^{-7}$ M
    b. $1.0 * 10^{-8}$ M
    c. $1.0 * 10^{-4}$ M
    d. $1.0 * 10^{3}$ M
    e. $1.0 * 10^{5}$ M

29. In some regions, the lowering of soil pH is due to
    a. sulfur fertilizers
    b. loss of organic matter
    c. acid rain
    d. nitrogen fertilizers
    e. erosion

30. Which of the following options is the NEXT most ordered state of matter after liquids?
    a. solids
    b. liquids
    c. gases
    d. solutions
    e. precipitates

31. Who proposed the first modern atomic theory?
    a. Walther Nernst
    b. Joseph Priestley
    c. Robert Boyle
    d. Sir James Chadwick
    e. John Dalton

32. If the pressure of a gas is increased, its volume will
    a. decrease linearly
    b. increase exponentially
    c. increase linearly
    d. decrease exponentially
    e. stay the same

33. Which of the following groups contains all the elements identified by Aristotle?
    a. earth, air, fire, water
    b. air, fire, water
    c. air, earth, space, fire
    d. earth, air, fire, water, space
    e. fire, water

34. Joseph Black derived his inspiration for his experiments from his observations of
    a. the phase diagram of water
    b. ice's expansion in volume
    c. melting snow
    d. the decomposition of silver halide salts
    e. the combustion process

35. Which Western scientist built off the ideas of Leucippus and Democritus?
    a. Joseph-Louis Proust
    b. Carl Wilhelm Scheele
    c. John Dalton
    d. Antoine Lavoisier
    e. Antoine Henri Becquerel

36. Which of the following carbon isotopes is NOT radioactive?
    a. Carbon-8
    b. Carbon-21
    c. Carbon-22
    d. Carbon-14
    e. Carbon-13

37. When was gas lighting adopted?
    a. 1700s
    b. 1400s
    c. 1500s
    d. 1600s
    e. 1800s

38. Scientists didn't agree that elements mixed in fixed ratios until the
    a. late 1700s
    b. late 1800s
    c. early 1800s
    d. early 1700s
    e. early 1900s

39. Which of the following scientists did the research of Robert Boyle inspire?
    a. Joseph Black
    b. Maurice Wilkins
    c. Jacques Charles
    d. Luigi Galvani
    e. Lester Germer

40. When a region of high electron density holds two nuclei together, the bond that forms is a(n)
    a. sigma bond
    b. beta bond
    c. pi bond
    d. gamma bond
    e. alpha bond

41. How many coulombs of charge do three Faradays contain?

    a. 395,000
    b. 289,500
    c. 267,500
    d. 270,000
    e. 280,000

42. The process of removing excess silver while developing photographs is called

    a. plating
    b. fixing
    c. dissolving
    d. eroding
    e. exposing

43. Which of the following compounds is MOST likely to dissolve in octane?

    a. water
    b. ammonia
    c. vegetable oil
    d. hydrogen fluoride
    e. ethanol

44. Isotopes are formed by changing an atom's

    a. positrons
    b. electrons
    c. neutrinos
    d. neutrons
    e. protons

45. Which of the following scientific principles basically restates the law of conservation of energy?

    a. Dalton's law
    b. Hess's law
    c. Gay-Lussac's law
    d. Proust's law
    e. Raoult's law

46. How many neutrons does a +2 cation of silver (108-47 Ag) have?

    a. 62
    b. 61
    c. 67
    d. 58
    e. 59

47. Who originally proposed the theory of atomism?

    a. Aristarchus
    b. Leucippus
    c. Aristotle
    d. Democritus
    e. Paracelsus

48. Which of the following transformations was MOST often the goal of transmutation?

    a. solid to gas
    b. lead to gold
    c. deuterium to hydrogen
    d. ozone to oxygen
    e. fire to water

49. What is 100° C in Kelvin?

    a. 73 K
    b. 373 K
    c. 173 K
    d. -273 K
    e. -173 K

50. The idea that all substances are comprised of very small indivisible particles is characteristic of

    a. Hess's law
    b. the law of definite proportions
    c. atomism
    d. Proust's law
    e. Dalton's atomic theory

1. Nonpolar solvents are compounds that contain only hydrogen and
   a. oxygen
   b. phosphorus
   c. silicon
   d. boron
   e. carbon

2. Hydrogen ions are formed when
   a. bases break apart in water
   b. acids break apart in water
   c. hydrogen ions are donated by an acid
   d. there is an excess of hydrogen ions
   e. the pH of a solution is too high

3. The moles of gas A divided by the sum of the moles of all the gases present is referred to as a
   a. partial pressure fraction
   b. partial gas fraction
   c. mole fraction
   d. amount fraction
   e. gas fraction

4. Which of the following people was a student of Leucippus?
   a. Aristotle
   b. Democritus
   c. Euclid
   d. Paracelsus
   e. Plato

5. Who invented the steam engine?
   a. Charles Babbage
   b. Eli Whitney
   c. James Watt
   d. James Naismith
   e. Cyrus McCormick

6. A cell that contains a voltage even when $E^\circ = 0$ is called a(n)
   a. electrochemical cell
   b. concentration cell
   c. electrolytic cell
   d. galvanic electrochemical cell
   e. fuel cell

7. An acidic substance has a H^+ concentration above
   a. $1.0 * 10^{8}$ M
   b. $1.0 * 10^{-4}$ M
   c. $1.0 * 10^{5}$ M
   d. $1.0 * 10^{9}$ M
   e. $1.0 * 10^{-7}$ M

8. Who proposed that the physical properties of a solution are determined by the relative number of moles of solute?
   a. Raoult's law
   b. Proust's law
   c. Charles's law
   d. Hess's law
   e. Boyle's law

9. The goal of kinetic-molecular theory is to explain
   a. how acids and bases interact with each other
   b. orbital behavior when molecules form
   c. the behavior of gases
   d. the behavior of atomic structures
   e. the motion of particles

10. With which of the following elements is the process of "fixing" associated?
    a. molybdenum
    b. silver
    c. manganese
    d. gold
    e. platinum

11. What was Alessandro Volta's accomplishment?
    a. causing dissected frogs to twitch by applying electrical currents
    b. proving that electricity caused blood to circulate
    c. discovering that current flow through a conductor is directly proportional to the potential difference
    d. creating the first battery to provide a continuous electrical current
    e. discovering the process of gold plating

12. The collision rate of gas molecules increases in proportion to the increase in
    a. moles of gas
    b. the gas container's volume
    c. gas pressure
    d. the temperature of the gas
    e. the number of gas molecules

13. Positron emission occurs during
    a. beta plus decay
    b. nuclear fusion
    c. nuclear fission
    d. beta minus decay
    e. alpha decay

14. Which equilibrium constant would a chemical reaction involving precipitate formation MOST likely use?

    a. Kpr
    b. Kp
    c. Ksp
    d. Kpre
    e. Kpc

15. An alpha particle has the same composition as a

    a. tritium atom
    b. hydrogen isotope
    c. helium nucleus
    d. deuterium atom
    e. helium cation

16. The most abundant carbon isotope is

    a. Carbon-12
    b. Carbon-18
    c. Carbon-14
    d. Carbon-13
    e. Carbon-16

17. The hydrogen-powered balloon was based on the research of

    a. Amedeo Avogadro
    b. Jacques Charles
    c. Joseph-Louis Gay-Lussac
    d. Robert Boyle
    e. Johann Baptista van Helmont

18. An atom's number of protons is equal to its

    a. electronegativity
    b. atomic number
    c. number of valence electrons
    d. ionization energy
    e. number of neutrons

19. Photons are emitted from metal surfaces in the

    a. callendar effect
    b. Compton effect
    c. Eberhard effect
    d. photovoltaic effect
    e. photoelectric effect

20. Ions are formed by changing an atom's

    a. electrons
    b. neutrinos
    c. protons
    d. neutrons
    e. positrons

21. Of which reaction type are precipitation reactions an example?

    a. synthesis
    b. single-replacement
    c. acid-base
    d. decomposition
    e. double replacement

22. Jacques Charles was inspired by the research of

    a. Robert Boyle
    b. John Jacoband Berzelius
    c. Germain Hess
    d. J.W. Gibbs
    e. Johannes van der Waals

23. What fraction of the mass of a carbon atom is a helium atom?

    a. 1/6
    b. 1/3
    c. 1/4
    d. 1/5
    e. 1/2

24. Which California city uses reverse osmosis at their desalination operation?

    a. San Bruno
    b. Bakersfield
    c. Carlsbad
    d. Sacramento
    e. Fresco

25. Which scientist built off of the research of Luigi Galvani?

    a. James Clark Maxwell
    b. Sir James Chadwick
    c. Linus Pauling
    d. Alessandro Volta
    e. John Jacoband Berzelius

26. The equation PV/T = CD is derived by combining

    a. Gay-Lussac's law and Avogadro's law
    b. Boyle's law and Avogadro's law
    c. Charles's law and Gay-Lussac's law
    d. Boyle's law and Gay-Lussac's law
    e. Boyle's law and Charles' law

27. Dalton's law is also known as the law of

    a. kinetic-molecular motion
    b. conservation of mass
    c. definite proportions
    d. partial pressures
    e. multiple proportions

28. Chemistry's origins are in the field of

    a. hermeticism
    b. esotericism
    c. herbalism
    d. transmutation
    e. alchemy

29. Which scientist's ideas were notably challenged by leading physicians at first?

    a. Joseph Black
    b. Henry Cavendish
    c. Robert Boyle
    d. Johann Baptista van Helmont
    e. Joseph Priestley

30. Oxygen atoms can be created by combining alpha particles with atoms of

    a. chlorine
    b. carbon
    c. fluorine
    d. nitrogen
    e. boron

31. One would measure the heat given off in a chemical reaction to find its

    a. enthalpy
    b. free energy
    c. entropy
    d. potential energy
    e. spontaneity

32. Where does Carbon-14 naturally form?

    a. within inactive volcanoes
    b. along fault lines
    c. the upper atmosphere
    d. the lower atmosphere
    e. within hot springs

33. The leftmost elements on the periodic table have oxidation numbers of

    a. -2
    b. +2
    c. -1
    d. +1
    e. 0

34. Which of the following scientists refuted phlogiston theory?

    a. Antoine Lavoisier
    b. Joseph Black
    c. Henry Cavendish
    d. Johann Baptista van Helmont
    e. Robert Boyle

35. How many groups does the periodic table contain?

    a. 16
    b. 10
    c. 20
    d. 18
    e. 24

36. Which element's atomic mass was established FIRST?

    a. sulfur
    b. helium
    c. carbon
    d. hydrogen
    e. oxygen

37. When atomic orbitals combine, the new orbitals that form are referred to as

    a. merged
    b. hybridized
    c. crossed
    d. combined
    e. integrated

38. Which atomic model predicts the geometry of simple molecules?

    a. collision model
    b. VSEPR model
    c. Molecular orbital theory
    d. Lewis structures
    e. quantum mechanical model

39. The point within an orbital where an electron CANNOT be located is called a(n)

    a. intersection
    b. singularity
    c. node
    d. junction
    e. knot

40. Lower energy pathways for reactions are provided by the

    a. catalyst
    b. enzymes
    c. reactants
    d. transition states
    e. activation energy

41. Which of the following groups of compounds is soluble?

    a. carbonates
    b. hydroxides
    c. sulfates
    d. oxides
    e. silicates

42. Decomposition reactions were used to create

    a. carbon monoxide
    b. ozone
    c. water vapor
    d. oxygen
    e. carbon dioxide

43. The rise in publications of scientific papers was encouraged by the

    a. invention of the printing press
    b. founding of scientific societies
    c. rise in literacy rates among the public
    d. the rise of empiricism
    e. increase in philosophical debates

44. Which scientific principle did Antoine Lavoisier propose?

    a. law of definite proportions
    b. law of partial pressures
    c. ideal gas law
    d. law of multiple proportions
    e. law of conservation of mass

45. How many neutrons does deuterium contain?

    a. 0
    b. 4
    c. 3
    d. 2
    e. 1

46. Electrons are not placed in fixed locations in

    a. covalent networks
    b. VSEPR models
    c. quantum mechanical models
    d. Bohr models
    e. Lewis structures

47. Which scientist created oxygen atoms manually in 1919?

    a. Ernest Rutherford
    b. Jean Baptiste Perrin
    c. James Clerk Maxwell
    d. Luigi Galvani
    e. Albert Einstein

48. Avogadro's law is MOST related to

    a. temperature
    b. pressure
    c. volume
    d. root mean square speed
    e. moles of gas

49. What was NOT a feature of the balloon flight of December 1, 1783?

    a. Peasants attacked the balloon at the end of the flight.
    b. The flight lasted over two hours.
    c. Charles experienced ear pain during the second ascent.
    d. Nicolas-Louis Robert was a passenger.
    e. Hydrogen was the gas used.

50. Even after temperatures are above freezing temperatures, ice will still melt at a slow pace. This phenomenon is associated with the idea of

    a. insulating temperatures
    b. heat of fusion
    c. latent heat
    d. heat conductivity
    e. heat of vaporization