1. In the wave-mechanical model, an orbital is a region of space in an atom where there is
    A.   a high probability of finding an electron   B. a high probability of finding a neutron
    C.   a circular path in which electrons are found   D. a circular path in which neutrons are found

2. What is the charge of the nucleus in an atom of oxygen-17?
    A. 0   B. +8   C. –2   D. +17

3. Helium is most likely to behave as an ideal gas when it is under
    A. high pressure and high temperature   B. high pressure and low temperature
    C. low pressure and high temperature   D. low pressure and low temperature

4. At STP, the element oxygen can exist as either O_2 or O_3 molecules. These two forms of the element have
    A. the same chemical and physical properties
    B. the same chemical properties and different physical properties
    C. different chemical properties and the same physical properties
    D. different chemical and physical properties

5. In a nuclear fusion reaction, the mass of the products is
    A. less than the mass of the reactants because some of the mass has been converted to energy.
    B. less than the mass of the reactants because some of the energy has been converted to mass.
    C. more than the mass of the reactants because some of the mass has been converted to energy.
    D. more than the mass of the reactants because some of the energy has been converted to mass.

6. Which pair of formulas represents two compounds that are electrolytes?
    A. HCl and CH_3OH B. HCl and NaOH   C. C_5H_{12} and CH_3OH D. C_5H_{12} and NaOH

7. Which compound could serve as a reactant in neutralization reaction?
    A. NaCl   B. KOH   C. CH_3OH D. CH_3CHO

8. How many electrons are contained in an Au^{3+} ion?   A. 76   B. 79   C. 82   D. 197

9.   Using your knowledge of chemistry and the information in Reference Table H, which statement concerning propanone and water at 50°C is true?
    A. Propanone has a higher vapor pressure and stronger intermolecular forces than water.
    B. Propanone has a higher vapor pressure and weaker intermolecular forces than water.
    C. Propanone has a lower vapor pressure and stronger intermolecular forces than water.
    D. Propanone has a lower vapor pressure and weaker intermolecular forces than water.

10. In a nuclear fusion reaction, the mass of the products is
    A. less than the mass of the reactants because some of the mass has been converted to energy
    B. less than the mass of the reactants because some of the energy has been converted to mass
    C. more than the mass of the reactants because some of the mass has been converted to energy
    D. more than the mass of the reactants because some of the energy has been converted to mass

11. Which type of molecule is CF_4?
    A. polar, with a symmetrical distribution of charge
    B. polar, with an asymmetrical distribution of charge
    C. nonpolar, with a symmetrical distribution of charge
    D. nonpolar, with an asymmetrical distribution of charge

12. Conductivity in a metal results from the metal atoms having
    A. high electronegativity   B. high ionization energy
    C. highly mobile protons in the nucleus   D. highly mobile electrons in the valence shell

13. Which of these elements has the *least* attraction for electrons in a chemical bond?
    A. oxygen   B. fluorine   C. nitrogen   D. chlorine

14. Given the reaction for the corrosion of aluminum: $4\ Al\ +\ 3\ O_2\ \rightarrow\ 2\ Al_2O_3$
    Which half-reaction correctly represents the oxidation that occurs?
    A. $Al\ +\ 3e^-\ \rightarrow\ Al^{3+}$ B. $Al\ \rightarrow\ Al^{3+}\ +\ 3e^-$
    C. $O_2\ +\ 4e^-\ \rightarrow\ 2\ O^{2-}$ D. $O_2\ \rightarrow\ 2\ O^{2-}\ +\ 4e^-$

15. Given the reaction:

$$\overset{\displaystyle O}{\overset{\displaystyle \|}{CH_3C}}-OH\ +\ HOC_2H_5\ \rightarrow\ \overset{\displaystyle O}{\overset{\displaystyle \|}{CH_3C}}-O-C_2H_5\ +\ H_2O$$

    This reaction is an example of
    A. fermentation   B. saponification   C. hydrogenation   D. esterification

16. Systems in nature tend to undergo changes toward
    A. lower energy and lower entropy   B. lower energy and higher entropy
    C. higher energy and lower entropy   D. higher energy and higher entropy

17. Which molecule contains a nonpolar covalent bond?
    A. $O=C=O$ B. $Br-Br$ C. $C\equiv O$ D. CCl_4

18. Which equation represents a fusion reaction?
    A. $H_2O_{(G)}\ \rightarrow\ H_2O_{(L)}$ B. $C_{(S)}\ +\ O_{2(G)}\ \rightarrow\ CO_{2(G)}$
    C. $^2_1H\ +\ ^3_1H\ \rightarrow ^4_2He\ +\ ^1_0n$ D. $^{235}_{92}U\ +\ ^1_0n\ \rightarrow\ ^{142}_{56}Ba\ +\ ^{91}_{36}Kr\ +\ 3^1_0n$

19. Compared to a 0.1 M aqueous solution of NaCl, a 0.8 M aqueous solution of NaCl has a
    A. higher boiling point & a higher freezing point   B. higher boiling point & a lower freezing point
    C. lower boiling point & a higher freezing point   D. lower boiling point & a lower freezing point

20. The kinetic molecular theory assumes that the particles of an ideal gas
    A. are in random, constant, straight-line motion
    B. are arranged in a regular geometric pattern
    C. have strong attractive forces between them
    D. have collisions that result in the system lowing energy

21. At STP, solid carbon can exist as graphite or as diamond. These two forms of carbon have
    A. the same properties & the same crystal structures
    B. the same properties & different crystal structures
    C. different properties & the same crystal structures
    D. different properties & different crystal structures

22. According to Reference Table G, which substance forms an unsaturated solution when 80 grams of the substance is dissolved in 100 grams of H_2O at 10°C?
    A. KI   B. KNO_3 C. $NaNO_3$ D. NaCl

23. Where does oxidation occur in an electrochemical cell?
    A. at the cathode in both an electrolytic and a voltaic cell
    B. at the cathode in an electrolytic cell and at the anode in a voltaic cell
    C. at the anode in both an electrolytic cell and a voltaic cell
    D. at the anode in an electrolytic cell and at the cathode in a voltaic cell

24. What is the formula of titanium(II) oxide?
    A. TiO   B. TiO_2 C. Ti_2O D. Ti_2O_3

25. A 1.0-gram piece of zinc reacts with 5 milliliters of $HCl_{(AQ)}$. Which of these conditions of concentration and temperature would produce the greatest rate of reaction?
    A. 1.0 M $HCl_{(AQ)}$ at 20.°C   B. 1.0 M $HCl_{(AQ)}$ at 40.°C
    C. 2.0 M $HCl_{(AQ)}$ at 20.°C   D. 2.0 M $HCl_{(AQ)}$ at 40.°C

26. Which equation represents a transmutation reaction?
    A. $^{239}_{92}U \rightarrow ^{239}_{92}U + ^0_0\gamma$ B. $^{14}_6C \rightarrow ^{14}_7N + ^0_{-1}e$
    C. $C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O$ D. $nC_2H_4 \rightarrow (-C_2H_4-)_n$

27. Given the balanced ionic equation: $Zn_{(S)} + Cu^{2+}_{(AQ)} \rightarrow Zn^{2+}_{(AQ)} + Cu_{(S)}$
    Which equation represents the oxidation half-reaction?
    A. $Zn_{(S)} + 2e^- \rightarrow Zn^{2+}_{(AQ)}$ B. $Zn_{(S)} \rightarrow Zn^{2+}_{(AQ)} + 2e^-$
    C. $Cu^{2+}_{(AQ)} \rightarrow Cu_{(S)} + 2e^-$ D. $Cu^{2+}_{(AQ)} + 2e^- \rightarrow Cu_{(S)}$

28. As a chlorine atom becomes a negative ion, the atom
    A. gains an electron & its radius increases   B. gains an electron & its radius decreases
    C. loses an electron & its radius increases   D. loses an electron & its radius decreases

29. Which symbol represents a particle that has the same total number of electrons as S^{2-}?
    A. O^{2-} B. Si   C. Se^{2-} D. Ar

30. Given the balanced equation: $KNO_{3(S)} + 34.89kJ \rightarrow K^{+1}_{(AQ)} + NO_3^{-1}_{(AQ)}$
    Which statement best describes this process?
    A. It is endothermic and entropy increases   B. It is endothermic and entropy decreases
    C. It is exothermic and entropy increases   D. It is exothermic and entropy decreases

31. Atoms of different isotopes of the same element differ in their total number of
   A. electrons   B. neutrons   C. protons   D. valence electrons

32. Which balanced equation represents a redox reaction?
   A. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
   B. $BaCl_2 + K_2CO_3 \rightarrow BaCO_3 + 2KCl$
   C. $CuO + CO \rightarrow Cu + CO_2$
   D. $HCl + KOH \rightarrow KCl + H_2O$

33. A saturated solution of $NaNO_3$ is prepared at 60.°C using 100. grams of water. As this solution is cooled to 10.°C, $NaNO_3$ precipitates (settles) out of the solution. The resulting solution is saturated. Approximately how many grams of $NaNO_3$ settled out of the original solution?
   A. 46 g   B. 61 g   C. 85 g   D. 126 g

34. What is the IUPAC name for the compound that has the condensed structural formula $CH_3CH_2CH_2CHO$?
   A. butanal   B. butanol   C. propanal   D. propanol

35. A student tested a 0.1 M aqueous solution and made the following three observations:
       Conducts electricity   Turns blue litmus red   Reacts with $Zn_{(S)}$ to produce gas bubbles
   Which compound could be the solute in this solution?
   A. CH_3OH B. LiBr   C. HBr   D. LiOH

36. What is the half-life of sodium-25 if 1.00 grams of a 16.00-gram sample of sodium-25 remains unchanged after 237 seconds?
   A. 47.4 s   B. 59.3 s   C. 79.0 s   D. 118 s

37. Given the table below that shows students' examples of proposed models of the atom:

Proposed Models of the Atom

| Model	Location of Protons	Location of Electrons
A	in the nucleus	specific shells
B	in the nucleus	regions of most probable location
C	dispersed throughout the atom	specific shells
D	dispersed throughout the atom	regions of most probable location

Which model correctly describes the locations of protons and electrons in the wave-mechanical model of the atom?   A. A   B. B   C. C   D. D

38. Which reactants form the salt $CaSO_{4(S)}$ in a neutralization reaction?
   A. $H_2S_{(G)} + Ca(ClO_4)_{2(S)}$
   B. $H_2SO_{3(AQ)} + Ca(NO_3)_{2(AQ)}$
   C. $H_2SO_{4(AQ)} + Ca(OH)_{2(AQ)}$
   D. $SO_{2(G)} + CaO_{(S)}$

39. A metal, M forms an oxide compound with the general formula M_2O. In which group on the Periodic Table could metal M be found?
   A. Group 1   B. Group 2   C. Group 15   D. Group 17

40. What volume of 0.500 M $HNO_{3(AQ)}$ must completely react to neutralize 100.0 mL of 0.100 M $KOH_{(AQ)}$
    A. 10.0 mL   B. 20.0 mL   C. 50.0 mL   D. 500. mL

41. Given the balanced equation with an unknown compound "X": $C_6H_{12}O_{6(AQ)} \rightarrow 2X + 2CO_{2(G)}$
    Which compound is represented by X?
    A. $CH_3OH_{(AQ)}$ B. $CH_2(OH)_{4(AQ)}$ C. $CH_3CH_2OH_{(AQ)}$ D. $CH_2OHCH_2OH_{(AQ)}$

42. Which statement correctly describes the two forms of oxygen, O_2 and O_3?
    A. They have identical molecular structures and identical properties.
    B. They have identical molecular structures and different properties.
    C. They have different molecular structures and identical properties.
    D. They have different molecular structures and different properties.

43. What is the total number of electrons shared in the bonds between the carbon atoms in a molecule of
    $H—C≡C—H$?   A. 6   B. 2   C. 3   D. 8

44. Which changes occur as a cadmium atom, Cd, becomes a cadmium ion, Cd^{2+}?   The Cd atom
    A. gains two electrons and its radius decreases.   B. gains two electrons and its radius increases.
    C. loses two electrons and its radius decreases.   D. loses two electrons and its radius increases.

45. The compounds CH_3OCH_3 & CH_3CH_2OH are isomers of each other. These compounds must have the same
    A. density   B. reactivity   C. melting point   D. molecular formula

46. Which process occurs at the anode in an electrochemical cell? The
    A. loss of protons B. loss of electrons   C. gain of protons   D. gain of electrons

47. Which substance is an electrolyte?
    A. CH_3OH B. $C_6H_{12}O_6$ C. H_2O D. KOH

48. Which ion is the only negative ion present in an aqueous solution of an Arrhenius base?
    A. hydride ion   B. hydrogen ion   C. hydronium ion   D. hydroxide ion

49. A dilute, aqueous potassium nitrate solution is best qualified as a
    A. homogeneous compound   B. homogeneous mixture
    C. heterogeneous compound   D. heterogeneous mixture

50. Which energy conversion occurs during the operation of a voltaic cell?
    A. Chemical energy is spontaneously converted to electrical energy.
    B. Chemical energy is converted to electrical energy only when an external power source is provided.
    C. Electrical energy is spontaneously converted to chemical energy
    D. Electrical energy is converted to chemical energy only when an external power source is provided.

51. Which balanced equation represents nuclear fusion?
    A. $n^0 + {}^{235}_{92}U \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3n^0$ B. ${}^{236}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^4_2He$
    C. ${}^6_3Li + n^0 \rightarrow {}^3_1H + {}^4_2He$ D. ${}^2_1H + {}^3_1H \rightarrow {}^4_2He + n^0$

52. Which electron configuration could represent a strontium atom in an excited state?

    A. 2−8−18−7−1   B. 2−8−18−7−3   C. 2−8−18−8−1   D. 2−8−18−8−2

53. At STP, which element is brittle and *not* a conductor of electricity?

    A. S   B. K   C. Na   D. Ar

54. Compared to an electron in the 1st electron shell of an atom, an electron in the 3rd shell of the same atom as

    A. less mass   B. less energy   C. more mass   D. more energy

55. At which Celcius temperature does lead change from a solid to a liquid?

    A. 874 ºC   B. 601 ºC   C. 328 ºC   D. 0 ºC

56. Information related to a titration experiment is given in the balanced equation and table below.

$$H_2SO_{4(AQ)} + 2\ KOH_{(AQ)} \rightarrow K_2SO_{4(AQ)} + 2\ H_2O_{(L)}$$
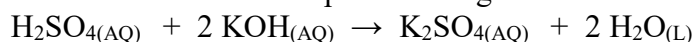
Titration Experiment Results

volume of $H_2SO_4(AQ)$ used	12.9 mL
concentration of $H_2SO_4(AQ)$	?
volume of KOH(AQ) used	36.0 mL
concentration of KOH(AQ)	0.16 M

Based on the equation and the titration results, what is the concentration of the $H_2SO_{4(AQ)}$?
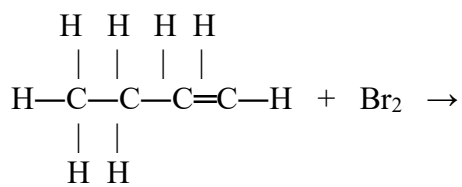
    A. 0.12 M   B. 0.16 M   C. 0.24 M   D. 0.96 M

57. Which radioisotope is used in medicine to diagnose thyroid disorders?

    A. cobalt-60   B. iodine-131   C. phosphorus-32   D. uranium-238

58. What is the total charge on the nucleus of a carbon atom?

    A. −6   B. 0   C. +6   D. +12

59. What is the name of the polyatomic ion in the compound Na_2O_2?

    A. hydroxide   B. oxalate   C. oxide   D. peroxide

60. For a given reaction, adding a catalyst increases the rate of the reaction by

    A. providing an alternate reaction pathway that has a higher activation energy

    B. providing an alternate reaction pathway that has a lower activation energy

    C. using the same reaction pathway and increasing the activation energy

    D. using the same reaction pathway and decreasing the activation energy

Students Constructed Responses.   (Part 2 - requires writing)

61. Write the reduction half-reaction for the following equation: $Cu_{(S)} + AgNO_{3(AQ)} \rightarrow Cu(NO_3)_{2(AQ)} + Ag_{(S)}$

62. A student titrates 60.0 mL of $HNO_{3(AQ)}$ with 0.30 M $NaOH_{(AQ)}$. Phenolphthalein is used as the indicator. After adding 42.2 mL of $NaOH_{(AQ)}$, a color change remains for 25 seconds, and the student stops the titration. Write a balanced equation and calculate the molarity of the of $HNO_{3(AQ)}$, with sig figs and units.

63. Draw the structural formula for the product of the reaction shown.

$$
\begin{array}{c}
\quad\;\; H\;\; H\;\; H\;\; H \\
\quad\;\; |\;\;\; |\;\;\; |\;\;\; | \\
H-C-C-C{=}C-H \;\; + \;\; Br_2 \;\; \rightarrow \\
\quad\;\; |\;\;\; | \\
\quad\;\; H\;\; H
\end{array}
$$

64. Antacids can be used to neutralize excess stomach acid. Brand A antacid contains the acid neutralizing agent magnesium hydroxide, $Mg(OH)_2$. It reacts with $HCl_{(AQ)}$ in the stomach, according to the following balanced equation:

$$2\,HCl_{(AQ)} + Mg(OH)_{2(S)} \rightarrow MgCl_{2(AQ)} + 2\,H_2O_{(L)}$$
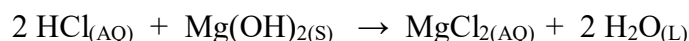
If a person produces 0.050 mole of excess HCl in the stomach, how many moles of $Mg(OH)_2$ are needed to neutralize this excess hydrochloric acid? Include equation, set-up, and answer with sig figs and units.

65. Napthalene, a nonpolar substance that sublimes at room temperature, can be used to protect wool clothes from being eaten by moths.
   a) Explain, in terms of *intermolecular forces*, why napthalene sublimes.

   b) Explain why naphthalene is not expected to dissolve in water.

66. A weather balloon has a volume of 52.5 liters at a temperature of 295 K. the balloon is released and rises to an altitude where the temperature is 252 K. The original pressure was 100.8 kPa and the pressure at the higher altitude is 45.6 kPa. Assume the balloon does not burst calculate the volume of the balloon at the higher altitude using sig figs and units.

67. Draw the Lewis electron-dot diagram for fluoride ion.

68. The following table shows three isotopes of neon.

Isotope	Atomic Mass (atomic mass units)	Percent Natural Abundance
^{20}Ne	19.99	90.9%
^{21}Ne	20.99	0.3%
^{22}Ne	21.99	8.8%

Show a correct set-up and calculate the average atomic mass of neon.

69. Given the reaction at dynamic equilibrium:
$$2\ NO_{2(G)}\ +\ 7\ H_{2(G)}\ \leftrightarrow\ 2\ NH_3(g)\ +\ 2\ H_2O_{(G)}\ +\ 1127\ kJ$$
Draw a potential energy diagram for the forward reaction. Be sure your drawing shows the activation energy and the potential energy of the products.

Then, explain in terms of Le Chatelier's principle, why the concentration of $NH_{3(G)}$ *decreases* when the temperature of the equilibrium system increases.

70. Given the reaction between 1-butene and chlorine gas: $C_4H_8\ +\ Cl_2\ \rightarrow\ C_4H_8Cl_2$
Which type of chemical reaction is represented by this equation?

71. In the early 1900's, experiments were conducted to determine the structure of the atom. One of these experiments involved bombarding gold foil with alpha particles. Most alpha particles passed directly through the foil. Some, however, were deflected at various angles. Based on this alpha particle experiment, state *two* conclusions that were made concerning the structure of an atom.

72. Given the balanced equation for dissolving $NH_4Cl_{(S)}$ in water: $NH_4Cl_{(S)} \rightarrow NH_4^+{}_{(AQ)} + Cl^-{}_{(AQ)}$

A student is holding a test tube containing 5.0 milliliters of water. When a sample of NH_4Cl is placed in the test tube, the test tube feels colder to the student's hand. Describe the direction of heat flow between the test tube and the hand.

Also, using the representation of a chloride ion, $Cl^-{}_{(AQ)}$ in the aqueous solution, draw at least two water molecules around it, showing the correct orientation of each water molecule next to the ion.

$\left(\text{Cl}^-\right)$
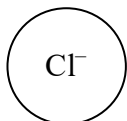
73. Ethanol, C_2H_5OH, is a volatile and flammable liquid with a distinct odor at room temperature. Ethanol is soluble in water. The boiling point of ethanol is 78.2°C at 1 atmosphere. Ethanol can be used as a fuel to produce heat energy, as shown below;

$$C_2H_5OH_{(L)} + 3 O_{2(G)} \rightarrow 2 CO_{2(G)} + 3 H_2O_{(L)} + 1367 \text{ kJ}$$

   a) At 1 atmosphere, compare the boiling point of pure ethanol to the boiling point of a solution in which a nonvolatile substance is dissolved in ethanol.

   b) Determine the total amount of heat produced by the complete combustion of 2.00 moles of ethanol.

   c) Identify *one* physical property of ethanol, stated in the passage that can be explained in terms of chemical bonds and intermolecular forces.

74. An atom in the ground state contains a total of 5 electrons, 5 protons, and 5 neutrons. Draw the Lewis electron-dot diagram that represents this atom, using X as the symbol of the element.

$$\boxed{X}$$
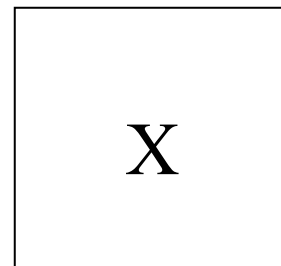
75. A 1.00-mole sample of neon gas occupied a volume of 24.4 liters at 298 K and 101.3 kilopascals. Calculate the density of this sample. Your response must include both a correct numerical setup and the calculated result.

76. A 5.00 gram sample of liquid ammonia is originally at 210. K. The diagram of the partial heating curve below represents the vaporization of the sample of ammonia at standard pressure due to the addition of heat. The heat is *not* added at a constant rate.

Partial Heating Curve for Ammonia
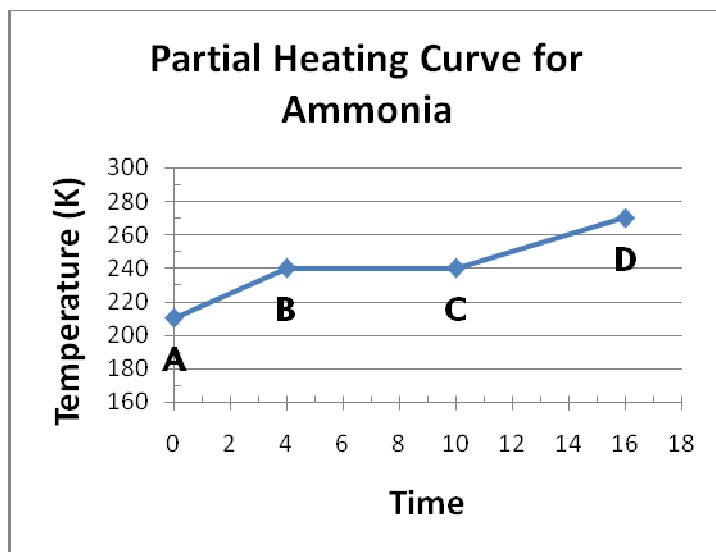
Some physical constants for ammonia are shown in the data table below.

Some Physical Constants for Ammonia	
Specific heat capacity of $NH_{3(L)}$	4.71 J/g·K
Heat of fusion	332 J/g
Heat of vaporization	1370 J/g

a) Calculate the total heat absorbed by the 5.00-gram sample of ammonia during time interval AB. Your response must include both a correct numerical setup and calculated response.

b) Describe what is happening to both the potential energy and the average kinetic energy of the molecules in the ammonia sample during time interval BC. Your response must include both potential energy and average kinetic energy.

c) Determine the total amount of energy required to vaporize this 5.00-gram sample of ammonia at its boiling point.