1. According to the modern model of the atom, the nucleus of an atom is surrounded by one or more
   A) electrons  C) positrons
   B) neutrons  D) protons

2. Which particle has a mass of approximately 1 atomic mass unit?
   A) an alpha particle  C) an electron
   B) a beta particle  D) a neutron

3. A specific amount of energy is emitted when excited electrons in an atom in a sample of an element return to the ground state. This emitted energy can be used to determine the
   A) mass of the sample
   B) volume of the sample
   C) identity of the element
   D) number of moles of the element

4. According to the wave-mechanical model, an orbital is defined as the
   A) circular path for electrons
   B) circular path for neutrons
   C) most probable location of electrons
   D) most probable location of neutrons

5. All phosphorus atoms have the same
   A) atomic number
   B) mass number
   C) number of neutrons plus the number of electrons
   D) number of neutrons plus the number of protons

6. At STP, which element is a good conductor of electricity?
   A) chlorine  C) silver
   B) iodine  D) sulfur

7. Which phrase describes the molecular structure and properties of two solid forms of carbon, diamond and graphite?
   A) the same molecular structures and the same properties
   B) the same molecular structures and different properties
   C) different molecular structures and the same properties
   D) different molecular structures and different properties

8. Which quantity is equal to one mole of Au?
   A) the atomic mass in grams
   B) the atomic number in grams
   C) the mass of neutrons in grams
   D) the number of neutrons in grams

9. Given the balanced equation representing the reaction between methane and oxygen:
   \( \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \)
   According to this equation, what is the mole ratio of oxygen to methane?
   A) \( \frac{1\text{ gram O}_2}{2 \text{ grams CH}_4} \)
   B) \( \frac{1 \text{ mole O}_2}{2 \text{ moles CH}_4} \)
   C) \( \frac{2\text{ grams O}_2}{1\text{ gram CH}_4} \)
   D) \( \frac{2 \text{ moles O}_2}{1 \text{ mole CH}_4} \)

10. Which list includes three types of chemical reactions?
    A) decomposition, single replacement, and solidification
    B) decomposition, single replacement, and double replacement
    C) solidification, double replacement, and decomposition
    D) solidification, double replacement, and single replacement

11. Which compound has the greatest percent composition by mass of sulfur?
    A) BaS  B) CaS  C) MgS  D) SrS
12. Two molecules of HBr collide and then form H₂ and Br₂. During the collision, the bonds in the HBr molecules are
   A) broken as energy is absorbed
   B) broken as energy is released
   C) formed as energy is absorbed
   D) formed as energy is released

13. Which atom in the ground state has a stable electron configuration?
   A) carbon
   B) magnesium
   C) neon
   D) oxygen

14. Which statement describes a multiple covalent bond?
   A) Two electrons are shared.
   B) Four electrons are shared.
   C) Two electrons are transferred.
   D) Four electrons are transferred.

15. The electronegativity difference between the atoms in a molecule of HCl can be used to determine
   A) the entropy of the atoms
   B) the atomic number of the atoms
   C) the first ionization energy of the atoms
   D) the polarity of the bond between the two atoms

16. Which two gases can not be broken down by chemical means?
   A) CO and He
   B) CO and NH₃
   C) Xe and He
   D) Xe and NH₃

17. Two substances in a mixture differ in density and particle size. These properties can be used to
   A) separate the substances
   B) chemically combine the substances
   C) determine the freezing point of the mixture
   D) predict the electrical conductivity of the mixture

18. Which unit is used to express an amount of thermal energy?
   A) gram
   B) mole
   C) joule
   D) pascal

19. Under which conditions of temperature and pressure does a real gas behave most like an ideal gas?
   A) low temperature and low pressure
   B) low temperature and high pressure
   C) high temperature and low pressure
   D) high temperature and high pressure

20. According to the kinetic molecular theory for an ideal gas, all gas particles
   A) are in random, constant, straight-line motion
   B) are separated by very small distances relative to their sizes
   C) have strong intermolecular forces
   D) have collisions that decrease the total energy of the system

21. Which mathematical expression represents the heat of reaction for a chemical reaction?
   A) (the heat of fusion) – (the heat of vaporization)
   B) (the heat of vaporization) – (the heat of fusion)
   C) (the potential energy of the products) – (the potential energy of the reactants)
   D) (the potential energy of the reactants) – (the potential energy of the products)

22. At 101.3 kPa and 298 K, a 1.0-mole sample of which compound absorbs the greatest amount of heat as the entire sample dissolves in water?
   A) LiBr
   B) NaCl
   C) NaOH
   D) NH₄Cl

23. For a reaction at equilibrium, which change can increase the rates of the forward and reverse reactions?
   A) a decrease in the concentration of the reactants
   B) a decrease in the surface area of the products
   C) an increase in the temperature of the system
   D) an increase in the activation energy of the forward reaction

24. Positrons and beta particles have
   A) the same charge and the same mass
   B) the same charge and different masses
   C) different charges and the same mass
   D) different charges and different masses
25. Which term identifies a type of nuclear reaction?
   A) transmutation    C) deposition
   B) neutralization   D) reduction

26. What is the number of electrons in an Al\(^{3+}\) ion?
   A) 10   B) 13   C) 3   D) 16

27. The valence electron of which atom in the ground state has the greatest amount of energy?
   A) cesium         C) rubidium
   B) lithium        D) sodium

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

<table>
<thead>
<tr>
<th>Atom</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>D</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

   Which two atoms represent isotopes of the same element?
   A) A and D   C) E and D
   B) A and G   D) E and G

29. Which elements have the most similar chemical properties?
   A) boron and carbon
   B) oxygen and sulfur
   C) aluminum and bromine
   D) argon and silicon

30. Which element reacts with oxygen to form ionic bonds?
   A) calcium     C) chlorine
   B) hydrogen     D) nitrogen
31. The table below gives the atomic mass and the abundance of the two naturally occurring isotopes of chlorine.

**Naturally Occuring Isotopes of Chlorine**

<table>
<thead>
<tr>
<th>Isotopes</th>
<th>Atomic Mass of the Isotopes (u)</th>
<th>Natural Abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{35}\text{Cl}$</td>
<td>34.97</td>
<td>75.76</td>
</tr>
<tr>
<td>$^{37}\text{Cl}$</td>
<td>36.97</td>
<td>24.24</td>
</tr>
</tbody>
</table>

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

A) $(34.97 \text{ u})(75.76) + (36.97 \text{ u})(24.24)$

B) $(34.97 \text{ u})(0.2424) + (36.97 \text{ u})(0.7576)$

C) $(34.97 \text{ u})(0.7576) + (36.97 \text{ u})(0.2424)$

D) $(34.97 \text{ u})(24.24) + (36.97 \text{ u})(75.76)$

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

A) **The first ionization energy decreases and the electronegativity decreases.**

B) The first ionization energy increases and the electronegativity increases.

C) The first ionization energy decreases and the electronegativity increases.

D) The first ionization energy increases and the electronegativity decreases.

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

A) 1  B) 2  C) 3  D) 4

34. Given four particle models:

<table>
<thead>
<tr>
<th>Key</th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
<th>Model IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$@$</td>
<td>$@$</td>
<td>$@$</td>
<td>$@$</td>
<td>$@$</td>
</tr>
</tbody>
</table>

Which two models can be classified as elements?

A) I and II  B) I and IV  C) II and III  D) II and IV

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

A) 25.0 g of KCl and 100. g of H$_2$O

B) 25.0 g of KNO$_3$ and 100. g of H$_2$O

C) 25.0 g of NaCl and 100. g of H$_2$O

D) 25.0 g of NaNO$_3$ and 100. g of H$_2$O
36. Which statement explains why a CO₂ molecule is nonpolar?
   A) Carbon and oxygen are both nonmetals.
   B) Carbon and oxygen have different electronegativities.
   C) The molecule has a symmetrical distribution of charge.
   D) The molecule has an asymmetrical distribution of charge.

37. Which temperature change indicates an increase in the average kinetic energy of the molecules in a sample?
   A) 15°C to 298 K
   B) 37°C to 273 K
   C) 305 K to 0°C
   D) 355 K to 25°C

38. Given the particle diagram:

Which substance at STP can be represented by this particle diagram?
   A) N₂  B) H₂  C) Mg  D) Kr

39. Which type of equilibrium exists in a sealed flask containing Br₂(l) and Br₂(g) at 298 K and 1.0 atm?
   A) static phase equilibrium
   B) static solution equilibrium
   C) dynamic phase equilibrium
   D) dynamic solution equilibrium

40. What fraction of a Sr-90 sample remains unchanged after 87.3 years?
   A) 1/2
   B) 1/3
   C) 1/4
   D) 1/8
41. Which potential energy diagram represents the change in potential energy that occurs when a catalyst is added to a chemical reaction?

<table>
<thead>
<tr>
<th>Key</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>reaction without catalyst</td>
<td>reaction with catalyst</td>
</tr>
</tbody>
</table>

A)  
B)  
C)  
D)  

42. Which balanced equation represents a spontaneous radioactive decay?

A) $^{14}\text{C} + \text{Ca}_{3}(\text{PO}_{4})_{2} \rightarrow 3\text{CaC}_2 + 2\text{P} + 8\text{CO}$  
B) $^{14}_7\text{N} + ^{1}\text{n} \rightarrow ^{14}_6\text{C} + ^{1}_1\text{P}$  
C) $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$  
D) $^{14}_6\text{C} \rightarrow ^{14}_7\text{N} + ^{0}_1\text{e}$

Base your answers to questions 43 through 45 on the information below and on your knowledge of chemistry.

The balanced equation below represents the reaction of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, with oxygen at 298 K and 101.3 kPa.

$$\text{C}_6\text{H}_{12}\text{O}_6(s) + 6\text{O}_2(g) \rightarrow 6\text{CO}_2(g) + 6\text{H}_2\text{O}(l)$$

43. Determine the mass of CO$_2$ produced when 9.0 grams of glucose completely reacts with 9.6 grams of oxygen to produce 5.4 grams of water.

44. Compare the entropy of the reactants to the entropy of the products.
45. Write the empirical formula for glucose.

Base your answers to questions 46 and 47 on the information below and on your knowledge of chemistry.

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

46. Determine the new pressure of O_2(g) in the cylinder, in atmospheres.

47. State the effect on the frequency of gas molecule collisions when the movable piston is pushed farther downward into the cylinder.
Base your answers to questions 48 through 50 on the information below and on your knowledge of chemistry.

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

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethane</td>
<td>H_2C_2H_6</td>
<td>-88.6</td>
</tr>
<tr>
<td>methane</td>
<td>H_2C_2H</td>
<td>-161.5</td>
</tr>
<tr>
<td>methanol</td>
<td>H_2C_2OH</td>
<td>64.6</td>
</tr>
<tr>
<td>water</td>
<td>H_2O</td>
<td>100.0</td>
</tr>
</tbody>
</table>

48. Identify the compound that has the strongest intermolecular forces.

49. State the change in potential energy that takes place in a sample of methane as it boils at -161.5°C.

50. Explain, in terms of molecular polarity, why the solubility of methanol in water is greater than the solubility of methane in water.
51. Base your answer to the following question on the information below and on your knowledge of chemistry.

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

\[ \text{Fe}(s) + \text{O}_2(g) \rightarrow \text{Fe}_2\text{O}_3(s) \]

Balance the equation for the reaction, using the smallest whole-number coefficients.

___ \text{Fe}(s) + ___ \text{O}_2(g) \rightarrow ___ \text{Fe}_2\text{O}_3(s)

Base your answers to questions 52 through 54 on the information below and on your knowledge of chemistry.

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

52. Identify an element in Group 14 that is classified as a metalloid.

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

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

55. Explain, in terms of heat flow, the change in the temperature of the bracelet when the student wore the bracelet.

56. Determine the number of moles of copper in the bracelet.

57. Show a numerical setup for calculating the amount of heat released by the bracelet as it cooled on the desk.

58. Explain, in terms of chemical activity, why copper is a better choice than sodium to make the bracelet.

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

59. Determine the concentration, expressed as percent by mass, of the dissolved salts in the original sample of seawater.

60. At standard pressure, compare the freezing point of seawater to the freezing point of distilled water.
61. Explain why the evaporation that occurred during the investigation is an endothermic process.

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

A student makes an aqueous solution of lactic acid. A formula for one form of lactic acid is shown below.

\[
\text{H} \quad \text{OH} \\
\text{H} - \text{C} - \text{C} - \text{C} - \text{OH} \\
\text{H} \quad \text{H} \quad \text{O}
\]

The solution is placed in a sealed flask to be used in a laboratory investigation. The equation below represents the lactic acid equilibrium system in the flask:

\[
\text{CH}_3\text{CHOHCOOH}(aq) \rightleftharpoons \text{H}^+(aq) + \text{CH}_3\text{CHOHCOO}^-(aq)
\]

62. Explain, in terms of the reaction rates, why the concentrations of the reactants and products remain constant in this system.
63. Explain, in terms of LeChatelier's principle, why increasing the concentration of \( H^+ \) (aq) increases the concentration of lactic acid.

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

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

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

<table>
<thead>
<tr>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>• = Hydrogen atom</td>
</tr>
<tr>
<td>○ = Oxygen atom</td>
</tr>
<tr>
<td>•○ = Water molecule</td>
</tr>
</tbody>
</table>

64. Using the key, draw two water molecules in the box, showing the orientation of each water molecule toward the \( Cu^{2+} \) ion.

65. Show a numerical setup for calculating the concentration, in parts per million, of dissolved \( Cu^{2+} \) ions in the sample of water tested.
Base your answers to questions 66 through 69 on the information below and on your knowledge of chemistry.

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

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

\[
\frac{1}{0}n + \frac{239}{94} Pu \rightarrow X + \frac{94}{36} Kr + 2\frac{1}{0}n
\]

66. Determine the number of neutrons in an atom of the uranium isotope used in the breeder reactor.

67. Based on Table \( N \), identify the decay mode of the plutonium radioisotope produced in the breeder reactor.

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

69. Write a notation for the nuclide represented by missing product \( X \) in this equation.
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A</td>
</tr>
<tr>
<td>2.</td>
<td>D</td>
</tr>
<tr>
<td>3.</td>
<td>C</td>
</tr>
<tr>
<td>4.</td>
<td>C</td>
</tr>
<tr>
<td>5.</td>
<td>A</td>
</tr>
<tr>
<td>6.</td>
<td>C</td>
</tr>
<tr>
<td>7.</td>
<td>D</td>
</tr>
<tr>
<td>8.</td>
<td>A</td>
</tr>
<tr>
<td>9.</td>
<td>D</td>
</tr>
<tr>
<td>10.</td>
<td>B</td>
</tr>
<tr>
<td>11.</td>
<td>C</td>
</tr>
<tr>
<td>12.</td>
<td>A</td>
</tr>
<tr>
<td>13.</td>
<td>C</td>
</tr>
<tr>
<td>14.</td>
<td>B</td>
</tr>
<tr>
<td>15.</td>
<td>D</td>
</tr>
<tr>
<td>16.</td>
<td>C</td>
</tr>
<tr>
<td>17.</td>
<td>A</td>
</tr>
<tr>
<td>18.</td>
<td>C</td>
</tr>
<tr>
<td>19.</td>
<td>C</td>
</tr>
<tr>
<td>20.</td>
<td>A</td>
</tr>
<tr>
<td>21.</td>
<td>C</td>
</tr>
<tr>
<td>22.</td>
<td>D</td>
</tr>
<tr>
<td>23.</td>
<td>C</td>
</tr>
<tr>
<td>24.</td>
<td>C</td>
</tr>
<tr>
<td>25.</td>
<td>A</td>
</tr>
<tr>
<td>26.</td>
<td>A</td>
</tr>
<tr>
<td>27.</td>
<td>A</td>
</tr>
<tr>
<td>28.</td>
<td>C</td>
</tr>
<tr>
<td>29.</td>
<td>B</td>
</tr>
<tr>
<td>30.</td>
<td>A</td>
</tr>
<tr>
<td>31.</td>
<td>C</td>
</tr>
<tr>
<td>32.</td>
<td>A</td>
</tr>
<tr>
<td>33.</td>
<td>C</td>
</tr>
<tr>
<td>34.</td>
<td>C</td>
</tr>
<tr>
<td>35.</td>
<td>B</td>
</tr>
<tr>
<td>36.</td>
<td>C</td>
</tr>
<tr>
<td>37.</td>
<td>A</td>
</tr>
<tr>
<td>38.</td>
<td>C</td>
</tr>
<tr>
<td>39.</td>
<td>C</td>
</tr>
<tr>
<td>40.</td>
<td>D</td>
</tr>
<tr>
<td>41.</td>
<td>B</td>
</tr>
<tr>
<td>42.</td>
<td>D</td>
</tr>
<tr>
<td>43.</td>
<td>13.2 g or any value from 13.155 g to 13.2042 g</td>
</tr>
<tr>
<td>44.</td>
<td>–The entropy of the reactants is less than the entropy of the products. –The reactants are more ordered. –The products have greater entropy.</td>
</tr>
<tr>
<td>45.</td>
<td>CH₂O</td>
</tr>
<tr>
<td>46.</td>
<td>2 atm/2.0 atm</td>
</tr>
<tr>
<td>47.</td>
<td>–When the piston is moved farther into the cylinder, the frequency of collision between the molecules increases. –There will be more collisions per second. –Increased frequency</td>
</tr>
<tr>
<td>48.</td>
<td>H₂O/water</td>
</tr>
<tr>
<td>49.</td>
<td>–As liquid methane boils, the potential energy of the sample increases. –Potential energy increases. –Higher PE</td>
</tr>
<tr>
<td>50.</td>
<td>–Methanol and water molecules are polar, but methane molecule are nonpolar. –The compounds methanol and water have similar polarities.</td>
</tr>
<tr>
<td>51.</td>
<td>4 Fe(s) + 3 O₂(g) → 2 Fe₂O₃(s)</td>
</tr>
<tr>
<td>52.</td>
<td>–Si –germanium –element 32</td>
</tr>
<tr>
<td>53.</td>
<td>–The atomic radius of these elements increases down the group because each successive element has one more electron shell. –The number of shells per atom increases.</td>
</tr>
<tr>
<td>54.</td>
<td>–4 –four –4e⁻ –four valence electrons</td>
</tr>
<tr>
<td>55.</td>
<td>–The bracelet temperature increased because heat flowed from the body to the copper. –Energy is transferred from the student to the bracelet. –Heat is absorbed by the bracelet.</td>
</tr>
<tr>
<td>56.</td>
<td>0.474 mol or for any value from 0.47 mol to 0.47402 mol, inclusive, or for 0.5 mol</td>
</tr>
<tr>
<td>57.</td>
<td>–q = (30.1 g)(0.385 J/g•K)(19°C – 33°C) –(30.1 g)(306 K – 292 K)(0.385 J/g•K) –(0.385)(30.1)(14)</td>
</tr>
<tr>
<td>58.</td>
<td>–Copper is less chemically active than iron, so copper is less likely to react with substances in the air or on the skin. –Iron is more active. –Fe oxidizes more easily.</td>
</tr>
<tr>
<td>59.</td>
<td>3.3%/3%/3.3333%</td>
</tr>
<tr>
<td>60.</td>
<td>–Water has a higher freezing point than seawater. –Seawater's is lower.</td>
</tr>
<tr>
<td>61.</td>
<td>–Energy is needed to overcome the intermolecular forces. –Energy is required to change liquid to water vapor. –The heat of vaporization is positive.</td>
</tr>
<tr>
<td>62.</td>
<td>–The rate of the forward reaction equals the rate of the reverse reaction. –The reaction rates are the same at equilibrium.</td>
</tr>
<tr>
<td>63.</td>
<td>–The stress of adding H⁺ ions shifts the equilibrium to the left, producing more lactic acid. –Increasing the concentration of H⁺ (aq) favors the reverse reaction. –More H⁺ ions collide with lactate ions, shifting the equilibrium left.</td>
</tr>
</tbody>
</table>
64.

65.

\[
\frac{6.75 \times 10^{-4} \text{g}}{5.50 \times 10^{2} \text{g}} \times 10^{6}
\]

\[
\frac{0.000675}{550} \times 1000000
\]

66. 146

67. \(\alpha - ^{4}_{2}a - ^{4}_{2}\) He

68. –The fission of one mole of Pu-239 releases much more energy than the combustion of one mole of CH\(_{4}\). –The energy released during the chemical reaction is less than the energy released during the nuclear reaction. –greater for \(\frac{239}{94}\) Pu

69. \(-^{144}_{58}\) Ce \(-^{144}\) Ce
   –cerium-144
   –Ce-144