ATOMIC STRUCTURE

Speed of light = (frequency)(wavelength)
\[ c = f\lambda \]

Energy = (Planck’s constant)(frequency)
\[ E_{\text{photon}} = hf \]

Energy = \frac{(Planck’s constant)(speed of light)}{(wavelength)}
\[ E_{\text{photon}} = \frac{hc}{\lambda} \]

BEHAVIOR OF GASES

Total pressure of a gas = \left(\text{sum of the partial pressures of the component gases}\right)
\[ P_T = P_1 + P_2 + P_3 + \ldots \]

(Pressure)(volume) = (moles)(ideal gas constant)(temperature)
\[ PV = nRT \]

\frac{(Initial pressure)(initial volume)}{(Initial moles)(initial temperature)} = \frac{(final pressure)(final volume)}{(final moles)(final temperature)}
\[ \frac{PV_{11}}{n_1T_1} = \frac{PV_{22}}{n_2T_2} \]

(Initial pressure)(initial volume) = (final pressure)(final volume)
\[ PV_{11} = PV_{22} \]

\frac{(Initial volume)}{(Initial temperature)} = \frac{(final volume)}{(final temperature)}
\[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

\frac{(Initial volume)}{(Initial moles)} = \frac{(final volume)}{(final moles)}
\[ \frac{V_1}{n_1} = \frac{V_2}{n_2} \]

SOLUTIONS

Molarity = \frac{\text{moles of solute}}{\text{liter of solution}}
\[ M = \frac{\text{mol}}{L} \]

Ionization constant of water = \left(\text{hydrogen ion concentration}\right)\left(\text{hydroxide ion concentration}\right)
\[ K_w = [H^+][OH^-] \]

\frac{\text{(Volume of solution 1)}(\text{molarity of solution 1})}{\text{Volume of solution 2}(\text{molarity of solution 2})} = \frac{V_1M_1}{V_2M_2} \]

pH = −\text{logarithm (hydrogen ion concentration)}
\[ \text{pH} = -\log[H^+] \]

THERMOCHEMISTRY

Heat gained or lost = (mass)(specific heat)(change in temperature)
\[ Q = mc_p\Delta T \]

Enthalpy of reaction = \left(\text{enthalpy of products}\right) - \left(\text{enthalpy of reactants}\right)
\[ \Delta H = \Delta H_f^{\circ}(\text{products}) - \Delta H_f^{\circ}(\text{reactants}) \]
### OTHER FORMULAS

\[
\text{Density} = \frac{\text{mass}}{\text{volume}} \quad D = \frac{m}{V}
\]

\[
\text{Percent error} = \left( \frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}} \right) \times 100
\]

\[
\text{Percent yield} = \left( \frac{\text{actual yield}}{\text{theoretical yield}} \right) \times 100
\]

### CONSTANTS AND CONVERSIONS

- **Avogadro’s number** = \(6.02 \times 10^{23}\) particles per mole

- **Planck’s constant** = \(6.63 \times 10^{-34}\) J \(\cdot\) s

- **Speed of light** = \(3.00 \times 10^8\) m/s

- **Ionization constant of water** = \(1.00 \times 10^{-14}\) (mol/L)^2

- **Alpha particle** (α) = \(^4_2\)He

- **Beta particle** (β) = \(^0_e\)

- **Neutron** = \(^1_0\)n

- **Standard temperature and pressure (STP)** = 0°C and 1 atm

\[0°C = 273\ K\]

\[\text{Volume of ideal gas at STP} = 22.4 \frac{\text{L}}{\text{mol}}\]

\[1\ \text{cm}^3 = 1\ \text{mL} = 1\ \text{cc}\]

\[1\ \text{atm} = 760\ \text{mm Hg} = 101.3\ \text{kPa}\]

\[R = \text{ideal gas constant} = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 8.31 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} = 62.4 \frac{\text{L} \cdot \text{mm Hg}}{\text{mol} \cdot \text{K}}\]

\[1\ \text{calorie (cal)} = 4.18\ \text{joules (J)}\]

\[1000\ \text{calories (cal)} = 1\ \text{Calorie (Cal)} = 1\ \text{kilocalorie (kcal)}\]

### RULES FOR SIGNIFICANT FIGURES

1. Non-zero digits and zeros between non-zero digits are always significant.
2. Leading zeros are not significant.
3. Zeros to the right of all non-zero digits are only significant if a decimal point is shown.
4. For values written in scientific notation, the digits in the coefficient are significant.
5. In a common logarithm, there are as many digits after the decimal point as there are significant figures in the original number.
## Polyatomic Ions

<table>
<thead>
<tr>
<th>Polyatomic Ions</th>
<th>Soluble compounds contain</th>
<th>Common exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetate</td>
<td>C₂H₃O₂⁻, CH₃COO⁻</td>
<td>None</td>
</tr>
<tr>
<td>Ammonium</td>
<td>NH₄⁺</td>
<td>None</td>
</tr>
<tr>
<td>Carbonate</td>
<td>CO₃²⁻</td>
<td>None</td>
</tr>
<tr>
<td>Chlorate</td>
<td>ClO₃⁻</td>
<td>None</td>
</tr>
<tr>
<td>Chlorite</td>
<td>ClO₂⁻</td>
<td>None</td>
</tr>
<tr>
<td>Chromate</td>
<td>CrO₄²⁻</td>
<td>None</td>
</tr>
<tr>
<td>Cyanide</td>
<td>CN⁻</td>
<td>None</td>
</tr>
<tr>
<td>Dichromate</td>
<td>Cr₂O₇²⁻</td>
<td>None</td>
</tr>
<tr>
<td>Hydrogen carbonate</td>
<td>HCO₃⁻</td>
<td>None</td>
</tr>
<tr>
<td>Hydroxide</td>
<td>OH⁻</td>
<td>None</td>
</tr>
<tr>
<td>Hypochlorite</td>
<td>ClO⁻</td>
<td>None</td>
</tr>
<tr>
<td>Nitrate</td>
<td>NO₃⁻</td>
<td>None</td>
</tr>
<tr>
<td>Nitrite</td>
<td>NO₂⁻</td>
<td>None</td>
</tr>
<tr>
<td>Perchlorate</td>
<td>ClO₄⁻</td>
<td>None</td>
</tr>
<tr>
<td>Permanganate</td>
<td>MnO₄⁻</td>
<td>None</td>
</tr>
<tr>
<td>Phosphate</td>
<td>PO₄³⁻</td>
<td>None</td>
</tr>
<tr>
<td>Sulfate</td>
<td>SO₄²⁻</td>
<td>None</td>
</tr>
<tr>
<td>Sulfite</td>
<td>SO₃²⁻</td>
<td>Compound of NH₄⁺, the alkali metal cations, Ca²⁺, Sr²⁺, and Ba²⁺</td>
</tr>
</tbody>
</table>
### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>Symbol</th>
<th>Name</th>
<th>Atomic Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td>Hydrogen</td>
<td>1.008</td>
</tr>
<tr>
<td>2</td>
<td>He</td>
<td>Helium</td>
<td>4.003</td>
</tr>
<tr>
<td>3</td>
<td>Li</td>
<td>Lithium</td>
<td>6.941</td>
</tr>
<tr>
<td>4</td>
<td>Be</td>
<td>Beryllium</td>
<td>9.012</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
<td>Boron</td>
<td>10.812</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>Carbon</td>
<td>12.011</td>
</tr>
<tr>
<td>7</td>
<td>N</td>
<td>Nitrogen</td>
<td>14.007</td>
</tr>
<tr>
<td>8</td>
<td>O</td>
<td>Oxygen</td>
<td>15.999</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>Fluorine</td>
<td>18.998</td>
</tr>
<tr>
<td>10</td>
<td>Ne</td>
<td>Neon</td>
<td>20.180</td>
</tr>
<tr>
<td>11</td>
<td>Na</td>
<td>Sodium</td>
<td>22.990</td>
</tr>
<tr>
<td>12</td>
<td>Mg</td>
<td>Magnesium</td>
<td>24.305</td>
</tr>
<tr>
<td>13</td>
<td>Al</td>
<td>Aluminum</td>
<td>26.982</td>
</tr>
<tr>
<td>14</td>
<td>Si</td>
<td>Silicon</td>
<td>28.086</td>
</tr>
<tr>
<td>15</td>
<td>P</td>
<td>Phosphorus</td>
<td>30.974</td>
</tr>
<tr>
<td>16</td>
<td>S</td>
<td>Sulfur</td>
<td>32.066</td>
</tr>
<tr>
<td>17</td>
<td>Cl</td>
<td>Chlorine</td>
<td>35.453</td>
</tr>
<tr>
<td>18</td>
<td>Ar</td>
<td>Argon</td>
<td>39.948</td>
</tr>
</tbody>
</table>

**Lanthanide Series**

<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>Symbol</th>
<th>Name</th>
<th>Atomic Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>La</td>
<td>Lanthanum</td>
<td>138.905</td>
</tr>
<tr>
<td>58</td>
<td>Ce</td>
<td>Cerium</td>
<td>140.116</td>
</tr>
<tr>
<td>59</td>
<td>Pr</td>
<td>Praseodymium</td>
<td>140.908</td>
</tr>
<tr>
<td>60</td>
<td>Nd</td>
<td>Neodymium</td>
<td>144.242</td>
</tr>
<tr>
<td>61</td>
<td>Pm</td>
<td>Promethium</td>
<td>145.011</td>
</tr>
<tr>
<td>62</td>
<td>Sm</td>
<td>Samarium</td>
<td>150.36</td>
</tr>
<tr>
<td>63</td>
<td>Eu</td>
<td>Europium</td>
<td>151.964</td>
</tr>
<tr>
<td>64</td>
<td>Gd</td>
<td>Gadolinium</td>
<td>157.25</td>
</tr>
<tr>
<td>65</td>
<td>Tb</td>
<td>Terbium</td>
<td>158.925</td>
</tr>
<tr>
<td>66</td>
<td>Dy</td>
<td>Dysprosium</td>
<td>162.500</td>
</tr>
<tr>
<td>67</td>
<td>Ho</td>
<td>Holmium</td>
<td>164.930</td>
</tr>
<tr>
<td>68</td>
<td>Er</td>
<td>Erbium</td>
<td>167.259</td>
</tr>
<tr>
<td>69</td>
<td>Tm</td>
<td>Thulium</td>
<td>168.934</td>
</tr>
<tr>
<td>70</td>
<td>Yb</td>
<td>Ytterbium</td>
<td>173.055</td>
</tr>
</tbody>
</table>

**Actinide Series**

<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>Symbol</th>
<th>Name</th>
<th>Atomic Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>Ac</td>
<td>Actinium</td>
<td>227.038</td>
</tr>
<tr>
<td>90</td>
<td>Th</td>
<td>Thorium</td>
<td>232.038</td>
</tr>
<tr>
<td>91</td>
<td>Pa</td>
<td>Protactinium</td>
<td>231.036</td>
</tr>
<tr>
<td>92</td>
<td>U</td>
<td>Uranium</td>
<td>238.029</td>
</tr>
<tr>
<td>93</td>
<td>Np</td>
<td>Neptunium</td>
<td>237.048</td>
</tr>
<tr>
<td>94</td>
<td>Pu</td>
<td>Plutonium</td>
<td>244.092</td>
</tr>
<tr>
<td>95</td>
<td>Am</td>
<td>Americium</td>
<td>243.067</td>
</tr>
<tr>
<td>96</td>
<td>Cm</td>
<td>Curium</td>
<td>247.062</td>
</tr>
<tr>
<td>97</td>
<td>Bk</td>
<td>Berkelium</td>
<td>247.062</td>
</tr>
<tr>
<td>98</td>
<td>Cf</td>
<td>Californium</td>
<td>251.044</td>
</tr>
<tr>
<td>99</td>
<td>Es</td>
<td>Einsteinium</td>
<td>252.075</td>
</tr>
<tr>
<td>100</td>
<td>Fm</td>
<td>Fermium</td>
<td>257.040</td>
</tr>
<tr>
<td>101</td>
<td>Md</td>
<td>Mendelevium</td>
<td>259.076</td>
</tr>
<tr>
<td>102</td>
<td>No</td>
<td>Nobelium</td>
<td>259.076</td>
</tr>
</tbody>
</table>

Mass numbers in parentheses are those of the most stable or most common isotope.

Updated Spring 2011
Chemistry
DIRECTIONS
Read each question carefully. For a multiple-choice question, determine the best answer to the question from the four answer choices provided. For a griddable question, determine the best answer to the question. Then fill in the answer on your answer document.

1. What is the formula of the ion hydrogen sulfite, which has a charge of $-1$?

   A. $\text{SO}_3^{-1}$
   B. $\text{SO}_4^{-1}$
   C. $\text{HSO}_3^{-1}$
   D. $\text{HSO}_4^{-1}$

2. What is the pH of a substance that has a hydrogen ion concentration of $1.2 \times 10^{-2}$ M?

   F. 2.08
   G. 1.92
   H. 1.00
   J. 0.080
3 Which of the following includes an example of a chemical property of an element?

A Aluminum is a solid at room temperature and is a poor thermal insulator.
B Sulfur is not shiny and is not malleable.
C Sodium is a solid at room temperature and reacts with other elements.
D Silicon is shiny and is a poor conductor of electricity.

4 Elements in a group of the periodic table are described below.

Some Properties of a Certain Group of Elements

- Soft silvery-white color
- Good conductor of thermal energy
- Good conductor of electricity
- Atoms contain a single valence electron

These elements most likely belong to which group?

F Alkali metals
G Alkaline earth metals
H Halogens
J Noble gases
The diagram below shows what happens when zinc reacts with hydrochloric acid.

Which of these best describes the energy transformation that occurs during this reaction?

A  Thermal energy → kinetic energy
B  Kinetic energy → potential energy
C  Chemical energy → thermal energy
D  Potential energy → chemical energy
The diagram below represents a nuclear reaction.

Which of the following best describes this reaction?

F  Nuclear fusion is occurring because many smaller nuclei are being fused.
G  Nuclear fission is occurring because large amounts of energy are being absorbed.
H  Nuclear fusion is occurring because many energetic neutrons are being emitted.
J  Nuclear fission is occurring because a nucleus is being split into smaller nuclei.
7 A detail from a label on a bottle of a water-softening agent is shown below.

A detail from a label on a bottle of a water-softening agent is shown below.

Which inference about the contents of the bottle can best be drawn?

A They consist of barium chloride anhydrous.
B They consist of barium chloride dihydrate.
C They consist of barium chloride hexahydrate.
D They consist of barium chloride heptahydrate.

8 Heart cells require a certain balance of sodium and potassium ions to function. The blood, which is approximately 83% water, carries these two types of ions to the heart. The property of water that allows it to carry ions to the heart is its —

F molecular mass
G specific heat
H polarity
J density
9 The equation below represents a chemical reaction that produces a gas.

\[ 2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) \]

What is the theoretical yield in liters of \( H_2 \) gas if 5.00 g of Na are completely reacted and the \( H_2 \) gas is collected at STP?

A 0.109 L  
B 2.44 L  
C 4.88 L  
D 5.09 L

10 Which of these is the electron-dot diagram for \( Br_2(l) \)?

F \[ \ddots \ddots : Br : : Br : \]  
H \[ Br : \ddots : Br : \]  
G \[ \ddots : Br : : Br : \]  
J \[ Br : : Br : \]
11 The table below lists some properties of a sample of lauric acid.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>79.6 mL</td>
</tr>
<tr>
<td>Mass</td>
<td>70.022 g</td>
</tr>
<tr>
<td>Boiling point</td>
<td>222°C</td>
</tr>
<tr>
<td>Number of moles</td>
<td>0.350</td>
</tr>
</tbody>
</table>

Which of these is an intensive property of this sample?

A Volume  
B Mass  
C Boiling point  
D Number of moles

12 When the equation below is balanced, what is the coefficient for oxygen?

$$\text{C}_3\text{H}_8(g) + \_\_\_\_\text{O}_2(g) \xrightarrow{\Delta} \_\_\_\_\text{CO}_2(g) + \_\_\_\_\text{H}_2\text{O}(g)$$

Record your answer and fill in the bubbles on your answer document.
13 Which mixture can be separated through filtration because one of the substances is insoluble in water?

A NaClO₃ and Pb(ClO₃)₂
B Na₂SO₄ and SrSO₄
C NaNO₃ and Pb(NO₃)₂
D NaC₂H₃O₂ and Pb(C₂H₃O₂)₂

14 Some students used a variety of procedures to investigate four liquid samples. The students recorded the following information.

- When Sample W was cooled, solid particles settled out of the liquid.
- The mass and volume of Sample X were measured, and the density of Sample X was calculated to be 1.6 g/mL.
- Sample Y was heated, and the temperature was recorded. All the liquid boiled away at the same temperature and left no residue in the container.
- When a dilute acid was added to Sample Z, gas bubbles formed and rapidly rose to the surface of the liquid.

Based on these observations, which sample was clearly identifiable as a pure substance?

F Sample W
G Sample X
H Sample Y
J Sample Z
15 What is the electron configuration for an atom of germanium at ground state?

A  [Ar]4s^23d^104p^2
B  [Ar]4s^24d^104p^2
C  [Kr]4s^23d^104p^2
D  [Kr]4s^24d^104p^2

16 Which of the following correctly matches a compound with its molecular geometry?

F  Water (H₂O): linear
G  Carbon dioxide (CO₂): tetrahedral
H  Ammonia (NH₃): trigonal planar
J  Methane (CH₄): tetrahedral

17 A sample of a compound is added to distilled water in a clean beaker. A reaction occurs, and the water temperature drops rapidly. Which of the following statements is best supported by this observation?

A  An endothermic reaction occurred.
B  A dehydration reaction occurred.
C  The water was originally warmer than the compound.
D  The beaker was contaminated by another compound.
18 Use the equation below to answer the following question.

\[ \text{BaCl}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{BaSO}_4(\text{s}) \]

The theoretical yield of \( \text{BaSO}_4 \) is 58.35 g. If 44.34 g of \( \text{BaSO}_4 \) are produced from the reaction shown above, what is the percent yield of \( \text{BaSO}_4 \)?

- F 31.67%
- G 52.03%
- H 75.99%
- J 85.17%

19 When zinc is exposed to air, zinc oxide is produced. What happens in this reaction?

- A Zinc is oxidized, and oxygen is reduced.
- B Zinc is reduced, and oxygen is oxidized.
- C Both zinc and oxygen are oxidized.
- D Both zinc and oxygen are reduced.

20 The equation below represents a nuclear reaction.

\[
\frac{27}{13}\text{Al} + \frac{1}{0}\text{n} \rightarrow ? + \frac{4}{2}\text{He}
\]

What is the mass number of the missing particle in this reaction?

Record your answer and fill in the bubbles on your answer document.
21 The graph below shows a solubility curve for ammonia gas and solubility measurements taken at different temperatures.

![Solubility graph](image)

Between which two points did the ammonia solution change from being unsaturated to saturated?

A $V \rightarrow W$
B $W \rightarrow X$
C $X \rightarrow Y$
D $Y \rightarrow Z$

22 How many molecules are in 0.500 mole of $\text{N}_2\text{O}_5$?

F $1.20 \times 10^{23}$ molecules
G $3.01 \times 10^{23}$ molecules
H $6.02 \times 10^{23}$ molecules
J $3.01 \times 10^{24}$ molecules
The following table lists some properties of copper and sulfur.

<table>
<thead>
<tr>
<th>Property</th>
<th>Copper</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Reddish</td>
<td>Pale yellow</td>
</tr>
<tr>
<td>Conductor of electricity</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>State of matter at room temperature</td>
<td>Malleable solid</td>
<td>Brittle solid</td>
</tr>
<tr>
<td>Metal or nonmetal</td>
<td>Metal</td>
<td>Nonmetal</td>
</tr>
<tr>
<td>Luster</td>
<td>Metallic</td>
<td>Dull</td>
</tr>
<tr>
<td>Ductile</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Density (g/cm(^3))</td>
<td>8.96</td>
<td>2.07</td>
</tr>
</tbody>
</table>

Samples of copper metal and sulfur powder are placed in the same test tube and heated over a Bunsen burner. The resulting substance has the following properties.

- Does not conduct electricity
- Has a density of 5.6 g/cm\(^3\)
- Has a metallic luster
- Is a black brittle crystalline solid

This black substance is classified as —

A  a heterogeneous mixture
B  an element
C  a compound
D  a homogeneous mixture
24 The diagram below shows a gas with an initial pressure of 3060 mm Hg in a cylinder at a constant temperature. The gas expands inside the cylinder and pushes the piston up.

\[ V = 0.520 \text{ L} \]

Initial

\[ V = 2.03 \text{ L} \]

Final

What is the final pressure of the gas after the expansion?

F 544 mm Hg
G 784 mm Hg
H 1830 mm Hg
J 6212 mm Hg

25 Which of these statements is an accurate description of the ionization energies of elements in the periodic table?

A The ionization energy of lithium is greater than that of potassium.
B The ionization energy of iodine is greater than that of fluorine.
C The ionization energy of magnesium is greater than that of sulfur.
D The ionization energy of krypton is greater than that of neon.
26 Which of the following shows a correct Lewis dot structure?

F \cdot \text{Si} \cdot 

H \cdot \text{Al} \cdot 

G \cdot \text{Y} 

J \cdot \text{N} : 

27 What is the volume of 2.00 moles of chlorine (\text{Cl}_2) at STP, to the nearest tenth of a liter?

Record your answer and fill in the bubbles on your answer document.

28 In a famous experiment conducted by Ernest Rutherford, positively charged alpha particles were scattered by a thin gold foil. Which of the following is a conclusion that resulted from this experiment?

F The nucleus is negatively charged.

G The atom is a dense solid and is indivisible.

H The mass is conserved when atoms react chemically.

J The nucleus is very small and the atom is mostly empty space.
29 The diagram below shows a battery giving off a current producing bubbles in two test tubes.

Which of the following best shows that the investigation results in a chemical change?

A Liquid condenses on a cold glass rod when gas from the test tube on the left is released.

B A gas probe indicates that the water in the beaker contains dissolved nitrogen and oxygen.

C A burning wood splint placed above the mouth of the test tube on the right glows brighter when some gas is released from the test tube.

D The temperature of the wire connected to the battery increases.
A material safety data sheet (MSDS) for a chemical is shown below.

**MSDS**

H₃PO₄(ₐq)

Section 9: Physical and Chemical Properties

**Physical state and appearance:** Viscous liquid

**Odor:** Odorless

**Color:** Clear, colorless

**Boiling point:** 158°C

**Melting point:** 21°C

**Specific gravity:** 1.685 at 25°C

Which of these is the IUPAC name for H₃PO₄(ₐq)?

- F  Trihydrogen phosphite
- G  Phosphoric acid
- H  Phosphorous hydroxide
- J  Phosphorous acid
31. The diagram below shows part of Dmitri Mendeleev’s original periodic table, with symbols of known elements and their atomic masses.

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be</td>
<td>9.4</td>
</tr>
<tr>
<td>B</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
</tr>
<tr>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>O</td>
<td>16</td>
</tr>
<tr>
<td>F</td>
<td>19</td>
</tr>
<tr>
<td>Mg</td>
<td>24</td>
</tr>
<tr>
<td>Al</td>
<td>27.1</td>
</tr>
<tr>
<td>Si</td>
<td>28</td>
</tr>
<tr>
<td>P</td>
<td>31</td>
</tr>
<tr>
<td>S</td>
<td>32</td>
</tr>
<tr>
<td>Cl</td>
<td>35.5</td>
</tr>
<tr>
<td>Cu</td>
<td>63.4</td>
</tr>
<tr>
<td>Zn</td>
<td>65.2</td>
</tr>
<tr>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>75</td>
</tr>
<tr>
<td>Se</td>
<td>79.4</td>
</tr>
<tr>
<td>Br</td>
<td>80</td>
</tr>
</tbody>
</table>

Mendeleev’s arrangement of elements is different than that of the modern periodic table. Based on Mendeleev’s arrangement, which elements should be placed in the shaded boxes labeled X and Z respectively?

A. Indium (In), because it has a slightly higher atomic mass than aluminum (Al), and tin (Sn), because it has a slightly higher atomic mass than silicon (Si)

B. Cadmium (Cd), because it has chemical properties similar to those of zinc (Zn), and mercury (Hg), because it has chemical properties similar to those of arsenic (As)

C. Antimony (Sb), because it has a slightly higher atomic mass than zinc (Zn), and bismuth (Bi), because it also has a higher atomic mass than zinc (Zn)

D. Gallium (Ga), because it has chemical properties similar to those of aluminum (Al), and germanium (Ge), because it has chemical properties similar to those of silicon (Si)

32. Which particle has the lightest mass?

F. $^4_2$He

G. $^0_{-1}$e

H. $^1_1$H

J. $^1_0$n
33 A 5.0 g sample of aluminum with a specific heat of 0.90 J/(g °C) was heated from 22.1°C to 32.1°C. How much heat, to the nearest joule, did the aluminum gain?

Record your answer and fill in the bubbles on your answer document.

34 Chemists can identify the composition of some unknown salts by conducting a flame test. When potassium salts are heated in a flame, a purple color is observed. This is due to the movement of electrons between energy levels. What is the electron configuration of a potassium atom at ground state?

F 1s²2s²2p⁶3s²3p⁶4d¹

G 1s²2s²2p⁶3s²3p⁶d¹

H 1s²2s²2p⁶3s²3d⁶4s¹

J 1s²2s²2p⁶3s²3p⁶4s¹

35 Which product balances the chemical equation below?

3AgNO₃(aq) + FeCl₃(aq) → 3AgCl(s) + ____

A FeCl(aq)

B FeCl₂(aq)

C FeNO₃(aq)

D Fe(NO₃)₃(aq)
36 Sodium, mercury, argon, and neon are used in the production of lamps. There are fewer safety guidelines regarding the handling of neon and argon than for mercury and sodium. Which of the following best describes the elements within the group of the periodic table that contains neon and argon gas?

F Gaseous at room temperature and highly reactive with metals
G Solid at room temperature and mildly reactive with strong acids
H Gaseous at room temperature and mostly unreactive with metals
J Solid at room temperature and mostly unreactive with strong acids

37 The table below shows the standard enthalpy of formation for each of three substances.

<table>
<thead>
<tr>
<th>Compound</th>
<th>ΔH° (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCO₃(s)</td>
<td>−1206.9</td>
</tr>
<tr>
<td>CaO(s)</td>
<td>−635.1</td>
</tr>
<tr>
<td>CO₂(g)</td>
<td>−393.5</td>
</tr>
</tbody>
</table>

CaCO₃ decomposes according to the equation \( \text{CaCO}_3(s) \xrightarrow{\Delta} \text{CaO}(s) + \text{CO}_2(g) \). What is the enthalpy of reaction?

A 178.3 kJ
B 571.8 kJ
C −1029 kJ
D −2236 kJ
38 What is the percentage by mass of sodium (Na) in a formula unit of sodium hydrogen carbonate (NaHCO₃)?

F 44.2%
G 37.7%
H 27.4%
J 16.7%

39 A form of technetium-99 has a half-life of approximately 6 hours.

\[ ^{99}_{43} \text{Tc} \rightarrow \_\_ \, + \, ^{0}_{-1} \text{e} + \gamma \]

Which substance correctly completes the equation above?

A \( ^{99}_{42} \text{Mo} \)
B \( ^{94}_{43} \text{Te} \)
C \( ^{99}_{43} \text{Es} \)
D \( ^{99}_{44} \text{Ru} \)

40 How many atoms are present in 179.0 g of iridium?

F \( 5.606 \times 10^{23} \) atoms
G \( 6.464 \times 10^{23} \) atoms
H \( 1.078 \times 10^{26} \) atoms
J \( 1.157 \times 10^{26} \) atoms
41. What volume of 1.0 M sodium phosphate, to the nearest tenth of a liter, must be used to make 4.0 L of 0.80 M sodium phosphate?

Record your answer and fill in the bubbles on your answer document.

42. X-ray crystallography is a technique that allows scientists to determine the ionic and atomic radii of elements. Which of these statements correctly describes a trend in ionic or atomic radii in the periodic table?

- F The ionic radius decreases from top to bottom in a group.
- G The atomic radius increases from left to right across a period.
- H The ionic radius remains constant from right to left across a period.
- J The atomic radius increases from top to bottom in a group.

43. Which of the following substances is a strong electrolyte when dissolved in water?

- A NaNO₃
- B C₂H₅OH
- C S₂Cl₂
- D C₁₂H₂₂O₁₁
44 Which of the following best explains why doubling the temperature of an ideal gas in a closed vessel doubles the pressure?

F  Increasing the temperature increases the size of the gas molecules, which then can put more pressure on the vessel walls.

G  Increasing the temperature decreases the volume, causing molecules to strike the vessel walls more frequently.

H  Increasing the temperature causes gas molecules to collide more often and with enough force to displace electrons.

J  Increasing the temperature causes gas molecules to move more rapidly, striking the vessel walls more frequently and with greater force.

45 Which of the following diagrams correctly represents the formation of a compound consisting of magnesium and fluorine?

A

B

C

D
46 Which equation represents a neutralization reaction?

F \( \text{H}_2\text{CO}_3(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) \)

G \( \text{H}_2\text{SO}_4(aq) + 2\text{NaOH}(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + 2\text{H}_2\text{O}(l) \)

H \( 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(l) \)

J \( 2\text{Al(OH)}_3(s) \rightarrow \text{Al}_2\text{O}_3(s) + 3\text{H}_2\text{O}(l) \)

47 A scientist filters a sample of river water. The data from this process are listed below.

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial mass of dry filter paper (g)</td>
<td>2.05</td>
<td>2.06</td>
<td>2.04</td>
</tr>
<tr>
<td>Mass of filter paper after filtering river water and drying sample (g)</td>
<td>2.64</td>
<td>2.53</td>
<td>2.61</td>
</tr>
</tbody>
</table>

These data support which of the following descriptions of the sample?

A It is a pure substance because solid particles cannot pass through the filter paper.

B It is a pure substance because the river water is composed only of free elements.

C It is a mixture because dissolved ions in the water pass through the filter paper.

D It is a mixture because solid particles are separated from the river water.
48  As a distant star moves away from Earth, the light given off by the star has a measurably lower frequency. What happens to the wavelength and energy of the photons of light when the frequency becomes lower?

F  The wavelength becomes longer, and the energy decreases.
G  The wavelength becomes shorter, and the energy decreases.
H  The wavelength becomes longer, and the energy increases.
J  The wavelength becomes shorter, and the energy increases.

49  Which of these is a postulate of kinetic molecular theory?

A  Molecules of gases have a finite volume.
B  Molecules of gases attract and repel one another.
C  Collisions between gas molecules are inelastic.
D  The kinetic energy of gas molecules depends on temperature.
The solubility of an unknown substance was tested during an experiment.

Based on the solubility curve information and the results of the experiment, what is most likely the identity of this unknown solute?

F  NaCl

G  KCl

H  KNO₃

J  NaNO₃
51 Which of the following best explains why CO₂ gas is easily compressible but solid CO₂ (dry ice) is incompressible?

A The molecules of CO₂ gas are much closer together than the molecules in dry ice.

B The molecules of solid CO₂ are much closer together than the molecules of CO₂ gas.

C The molecules of CO₂ gas are much smaller than the molecules of solid CO₂.

D The molecules of CO₂ gas attract one another, while the molecules of the solid CO₂ repel one another.

52 What is the chemical formula for disulfur decafluoride?

F S₁₀F₂

G S₃F₉

H S₂F₁₀

J S₂F₈