Chapters 2 & 3: Atoms, Elements, Compounds, Mole

1. How many moles of oxygen atoms are present in one mole of aluminum sulfate, \( \text{Al}_2(\text{SO}_4)_3 \)?

   A) 4  
   B) 8  
   C) 12  
   D) \( 7.23 \times 10^{24} \)  
   E) \( 4.82 \times 10^{24} \)

2. How many protons, neutrons, and electrons are in one ion of \( ^{36}\text{S}^2^- \)?

   A) 16 protons, 20 neutrons, and 18 electrons. 
   B) 20 protons, 16 neutrons, and 16 electrons. 
   C) 16 protons, 20 neutrons, and 14 electrons. 
   D) 16 protons, 20 neutrons, and 16 electrons. 
   E) 0 protons, 36 neutrons, and 18 electrons.

3. Which two elements are likely to form an ionic compound with the formula \( \text{M}_3\text{X} \)?

   A) Li and I  
   B) Na and N  
   C) Al and Br  
   D) Ca and P  
   E) K and O

4. Which compound is named correctly?

   A) \( \text{CaO} \) – Calcium (II) monoxide  
   B) \( \text{P}_2\text{O}_5 \) – Diphosphorus pentoxide  
   C) \( \text{Al}_2\text{S}_3 \) – Dialuminum trusulfide  
   D) \( \text{PbI}_4 \) – Lead iodide  
   E) \( \text{H}_2\text{S} \) – Sulfuric Acid

5. Determine the molecular formula of a compound that has a molecular weight of 183 g/mol and an empirical formula of \( \text{C}_2\text{H}_5\text{O}_2 \).

   A) \( \text{C}_3\text{H}_2\text{O}_3 \)  
   B) \( \text{C}_6\text{H}_{15}\text{O}_6 \)  
   C) \( \text{C}_4\text{H}_{10}\text{O}_4 \)  
   D) \( \text{C}_2\text{H}_5\text{O}_2 \)  
   E) \( \text{C}_8\text{H}_{20}\text{O}_8 \)
CHEM 1310 Review: **Reactions, Solutions, & Stoichiometry**

**Steps and Answer Key**

1. Predict the products of the following reactions. Include the phase of each product. If there is no driving force for the reaction, write NR.

   a. \[ 3 \text{Pb(II)(CH}_3\text{COO)}_2^{2-} (aq) + 2 \text{Na}_3\text{PO}_4 (aq) \rightarrow \text{Pb(II)}_3\text{(PO}_4)_2^{2-} (s) + 6 \text{NaCH}_3\text{COO (aq)} \]

   b. \[ \text{AgNO}_2 (aq) + \text{NaCl (aq)} \rightarrow \text{AgCl (s)} + \text{NaNO}_2 (aq) \]

   c. \[ \text{NH}_4\text{OH (aq)} + \text{NaCl (aq)} \rightarrow \text{No reaction; both products are soluble} \]

   d. \[ \text{BaI}_2 (aq) + \text{MgSO}_4 (aq) \rightarrow \text{BaSO}_4 (s) + \text{MgI}_2 (aq) \]

   e. \[ \text{CaCl}_2 (aq) + \text{NaOH (aq)} \rightarrow \text{No reaction; both products are soluble} \]

2. Calcium hydroxide is formed from the reaction of calcium oxide with water. What mass of calcium hydroxide can be produced from a mixture of 25.0 g of calcium oxide and 12.0 g of water? Identify limiting and excess reagents, calculate the mass (in grams) of excess reagent remaining.

   i. Write out the reaction:
      \[ \text{CaO (s)} + \text{H}_2\text{O (l)} \rightarrow \text{Ca(OH)}_2 (s) \]

   ii. Determine moles of reactants
      \[
      \frac{25.0 \text{ g CaO}}{56.0774 \text{ g mol CaO}} = 0.446 \text{ mol CaO}
      \]
      \[
      \frac{10.0 \text{ g H}_2\text{O}}{18.015 \text{ g mol H}_2\text{O}} = 0.666 \text{ mol H}_2\text{O}
      \]

   iii. Use stoichiometric ratios to determine limiting reagent
      Since there is a 1:1 ratio between both reactants and the single product, the reactant with the smaller number of moles (CaO) is the limiting reagent.

   iv. Determine moles, mass of product from moles of limiting reagent
      Calcium oxide is the limiting reagent; the number of moles of calcium hydroxide formed is the same as the number of moles of calcium oxide used in the reaction.
      \[ \text{mol Ca(OH)}_2 = \text{mol CaO} = 0.446 \text{ mol} \]
      The mass of calcium hydroxide formed can then be determined using the molar mass of the molecule:
      \[ 0.446 \text{ mol Ca(OH)}_2 \times 74.093 \frac{\text{g}}{\text{mol}} \text{Ca(OH)}_2 = 33.1 \text{ g Ca(OH)}_2 \]

   v. Determine moles, mass of excess reagent remaining from moles of limiting reagent
      If 0.466 moles of Ca(OH)_2 are formed, than 0.466 moles of H_2O, the limiting reagent, were consumed. The remaining mass of the limiting reagent is then:
      \[ 0.666 \text{ mol H}_2\text{O} - 0.466 \text{ mol H}_2\text{O} = 0.200 \text{ mol H}_2\text{O remaining} \]
      \[ 0.200 \text{ mol H}_2\text{O} \times 18.015 \frac{\text{g}}{\text{mol}} \text{H}_2\text{O} = 3.6 \text{ g H}_2\text{O remaining} \]
3. 92 g of sulfur hexafluoride is produced from the reaction of sulfur in excess fluorine. If this corresponds to an 18% yield, what mass of sulfur was used for the reaction? Hint: Determine the theoretical yield of sulfur hexafluoride.

\[ S (s) + 3 \text{F}_2 (g) \rightarrow \text{SF}_6 (g) \]

i. The mass of the product is given, as well as a corresponding percent yield. First, find the theoretical yield of sulfur hexafluoride.

\[ \text{theoretical yield} = \frac{92 \text{ g}}{0.18} = 511.11 \text{ g SF}_6 \]

ii. With the theoretical yield, the moles of product for a 100% yield can be determined. This value can be used with the molar ratios of the reaction, given in the problem, to determine the moles of reactant.

\[ \frac{511.11 \text{ g SF}_6}{146.055 \text{ g mol} \text{ SF}_6} = 3.50 \text{ mol} \text{ SF}_6 \]

\[ 1 \text{ mol} \text{ SF}_6 = 1 \text{ mol} S \]

iii. Finally, the mass of sulfur used for the reaction can be determined.

\[ 3.50 \text{ mol S} \times 23.065 \frac{\text{g}}{\text{mol} S} = 112.2 \text{ g S} \]

4. What is the minimum volume of 1.1 M NaOH that must be reacted with excess chlorine gas to yield 2.2 grams of sodium hypochlorite?

\[ \text{2 NaOH (aq) + Cl}_2 (g) \rightarrow \text{NaClO (aq) + NaCl (aq) + H}_2\text{O (l)} \]

i. Balance the given reaction!

ii. This problem gives the desired yield: 2.2 g of NaClO. First, find the number of moles of NaClO desired.

\[ \frac{2.2 \text{ g NaClO}}{74.4422 \frac{\text{g}}{\text{mol} \text{ NaClO}}} = 0.0296 \text{ mol NaClO} \]

iii. With a 2:1 stoichiometric ratio, the number of moles of NaOH required for the reaction is twice the number of moles of NaClO desired.

\[ \text{mol NaOH} = 2 \times \text{mol NaClO} = 0.0592 \text{ mol NaOH} \]

iv. Finally, use the number of moles of NaOH to find the volume of 1.1 M solution that must be reacted.

\[ \frac{0.0592 \text{ mol NaOH}}{x L} = 1.1 \text{ M NaOH} \]

\[ 0.0296 \frac{\text{mol}}{1.1 \text{ M}} = 0.0537 L = 53.7 \text{ mL solution} \]

5. Calcium chloride is reacted with silver nitrate.
a. Write the balanced reaction, and net ionic equations. Include the phase of each product.

Full reaction:
\[
\text{Ca(Cl)}_2 (aq) + 2 \text{AgNO}_3 (aq) -> \text{Ca(NO}_3)_2 (aq) + 2 \text{AgCl (s)}
\]
Net ionic equation:
\[
2 \text{Cl}^- (aq) + 2 \text{Ag}^+ (aq) -> 2 \text{AgCl (s)}
\]

b. If exactly 1.4 g of solid is formed, what mass of each reactant was used?

i. Determine moles of AgCl formed:
\[
\frac{1.4 \text{ g AgCl}}{143.321 \text{ g mol AgCl}} = 0.0098 \text{ mol AgCl}
\]

ii. Using stoichiometric ratios, determine moles of reactants:
\[
2 \text{ mol AgCl} = 1 \text{ mol Ca(Cl)}_2
\]
\[
0.0098 \text{ mol AgCl} = 0.0049 \text{ mol Ca(Cl)}_2
\]
\[
2 \text{ mol AgCl} = 2 \text{ mol AgNO}_3
\]
\[
0.0098 \text{ mol AgCl} = 0.0098 \text{ mol AgNO}_3
\]

iii. Determine mass of reactants used:
\[
0.0049 \text{ mol Ca(Cl)}_2 \times 110.984 \text{ g mol}^{-1} \text{Ca(Cl)}_2 = 0.542 \text{ g Ca(Cl)}_2
\]
\[
0.0098 \text{ mol AgNO}_3 \times 169.873 \text{ g mol}^{-1} \text{AgNO}_3 = 1.66 \text{ g AgNO}_3
\]

c. Which reactant is limiting?

The limiting reactant has the smaller number of moles. For this reaction, calcium chloride is the limiting reactant.

d. If 2.0 mL of each reactant was used, what are the molarities of the calcium chloride and silver nitrate solutions?

The molarity of each solution can be determined as the number of moles of reactant over the liters of product used:
\[
\frac{0.0049 \text{ mol Ca(Cl)}_2}{2.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 2.44 \text{ M Ca(Cl)}_2
\]
\[
\frac{0.0098 \text{ mol AgNO}_3}{2.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 4.88 \text{ M AgNO}_3
\]

e. If 2.0 mL of 1.2 M calcium chloride is reacted with excess silver nitrate, what is the theoretical yield of the solid product?

i. Determine moles of calcium chloride used:
\[
\frac{x \text{ mol Ca(Cl)}_2}{2.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 1.2 \text{ M Ca(Cl)}_2
\]
1.2 M * 0.002 L = 0.0024 \text{mol Ca(Cl)}_2

ii. Using stoichiometric ratios, determine moles of the product:

1 \text{mol Ca(Cl)}_2 = 2 \text{mol AgCl}

0.0024 \text{mol Ca(Cl)}_2 = 0.0048 \text{mol AgCl}

iii. Finally, convert from moles to mass:

\[0.0048 \text{mol AgCl} \times \frac{143.321 \text{g mol}^{-1} \text{AgCl}}{1 \text{mol AgCl}} = 0.69 \text{g AgCl}\]

6. What is the difference between a strong, a weak, and a nonelectrolyte? Give an example of each.

A strong electrolyte dissociates completely in water. These are strong acids, strong bases, and soluble salts (ex sodium choride).

A weak electrolyte dissociates only a small amount in water (usually less than 10%). These are weak acids and weak bases (ex acetic acid).

A nonelectrolyte does not dissociate in water. These are covalent molecules (ex sugar).

7. If 100.0 mL of acetic acid is titrated to equilibrium with 10.0 mL of 1 M KOH, what is the concentration (in units of molarity) of the acetic acid solution?

i. Write out the reaction:

\[\text{CH}_3\text{COOH (aq) + KOH (aq) } \rightarrow \text{ KCH}_3\text{COO (aq) + H}_2\text{O}\]

ii. At equilibrium, with a 1:1 stoichiometric ratio, the number of moles of KOH titrated is the same as the number of moles of acetic acid in the original solution.

\[\frac{x \text{ mol KOH}}{10.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 1 \text{ M KOH}\]

\[\text{mol acetic acid} = \text{mol KOH} = 1 \text{ M} \times 0.01 \text{ L} = 0.01 \text{ mol}\]

iii. The concentration of the acetic acid solution can then be determined as moles / volume:

\[\frac{0.01 \text{ mol acetic acid}}{100.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 0.1 \text{ M acetic acid}\]
CHEM 1310 Reading Day
Chapters 7 and 8: *Gases* and *The Quantum Model of the Atom*

Answers

1. 9.65 atm
2. 5.0 x 10^{22} photons. Infrared radiation.
3. (a) 3d  (b) 1s  (c) 4f
4. (a) [He] 2s^{2}2p^{5}  (b) [Ar] 4s^{2}3d^{2}  (c) [Ne] 3s^{2}3p^{2}
5. a
CHEM 1310 Reading Day
Chapters 9, 10, and 11: *Periodicity and Ionic Bonding, Covalent Bonding, and Molecular Shape and Bonding Theories*

Answers

1. Na$^+$

2. 

3. 

4. 

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Electron Geometry</th>
<th>Molecular Geometry</th>
<th>Bond Angle</th>
<th>Polar?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClO$^-$</td>
<td>Linear</td>
<td>Linear</td>
<td>180</td>
<td>Yes</td>
</tr>
<tr>
<td>KrF$_2$</td>
<td>Trigonal bipyramidal</td>
<td>linear</td>
<td>180</td>
<td>No</td>
</tr>
<tr>
<td>XeF$_3^+$</td>
<td>Trigonal bipyramidal</td>
<td>T-shaped</td>
<td>&lt; 90, &lt; 180</td>
<td>Yes</td>
</tr>
<tr>
<td>NH$_3$Cl$^+$</td>
<td>Tetrahedral</td>
<td>Tetrahedral</td>
<td>109.5</td>
<td>Yes</td>
</tr>
</tbody>
</table>
35 sigma bonds, 4 pi bonds
1. According to the graph located below, what is the approximate energy required to evaporate 25g of water?

![Heating Curve of 25g of Water](image)

A) 10 kJ  
B) 75,000 J  
C) 55 kJ  
D) 2,500 J  
E) 9 kJ

2. How much energy (in J) is needed to convert 1.70 g of H$_2$O(l) at 100°C to H$_2$O(g) at 125°C? Use the following information as needed:

\[
\Delta H_{\text{vap}} = 4.07 \times 10^4 \text{ J/mol} \\
\Delta H_{\text{fus}} = 6.01 \times 10^3 \text{ J/mol} \\
\text{Specific heat of H}_2\text{O(s) = 2.09 J/g°C} \\
\text{Specific heat of H}_2\text{O(l) = 4.18 J/g°C} \\
\text{Specific heat of H}_2\text{O(g) = 2.03 J/g°C}
\]

A) 3930 J  
B) 4310 J  
C) 3870 J  
D) 3840 J  
E) 3310 J

3. Which of the following statements is true for a system that releases 38 J of heat and has 102 J of work done on it?

A) The $\Delta E = -64$ J and the net flow of energy is out of the system.  
B) The $\Delta E = +64$ J and the net flow of energy is out of the system.  
C) The $\Delta E = -64$ J and the net flow of energy is into of the system.  
D) The $\Delta E = +64$ J and the net flow of energy is into of the system.  
E) None of the above statements are true.
4. Which of the following signs of q and w represent a system that is doing work on the surroundings and gaining heat from the surroundings?

A) q = +, w = +
B) q = -, w = +
C) q = -, w = -
D) q = +, w = -
E) None of the above represent the system.

5. Given the data below, what is the $\Delta H^\circ_{rxn}$ in kJ for the reaction below?

$$3\text{NO}_2\text{(g)} + \text{H}_2\text{O(l)} \rightarrow 2\text{HNO}_3\text{(aq)} + \text{NO(g)}$$

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta H^\circ_f$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{H}_2\text{O(l)}$</td>
<td>-285.8</td>
</tr>
<tr>
<td>$\text{H}_2\text{O(g)}$</td>
<td>-241.8</td>
</tr>
<tr>
<td>$\text{NO(g)}$</td>
<td>90.25</td>
</tr>
<tr>
<td>$\text{NO}_2\text{(g)}$</td>
<td>33.2</td>
</tr>
<tr>
<td>$\text{HNO}_3\text{(l)}$</td>
<td>-174.1</td>
</tr>
<tr>
<td>$\text{HNO}_3\text{(g)}$</td>
<td>-135.1</td>
</tr>
<tr>
<td>$\text{HNO}_3\text{(aq)}$</td>
<td>-206.6</td>
</tr>
</tbody>
</table>

A) -508
B) 64
C) 137
D) -137
E) -64
1. If the rate of formation of NH₃ under a given set of conditions is 0.35 M/s, then what is the rate of disappearance of H₂ under the same conditions?

\[ \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \]

A) 0.23 M/s  
B) 0.35 M/s  
C) 0.53 M/s  
D) 0.70 M/s  
E) 1.1 M/s

2. A first-order reaction is 38.5% complete in 520 s. What is the value of the rate constant?

A) 1.83 x 10⁻³ s⁻¹  
B) 9.35 x 10⁻⁴ s⁻¹  
C) 3.07 x 10⁻³ s⁻¹  
D) 1.18 x 10⁻³ s⁻¹  
E) 1.20 x 10⁻³ s⁻¹

3. Data collected in a laboratory experiment was used to create a graph of ln k versus 1/T (T in Kelvin). The slope of the resulting line is m. Which answer option represents the activation energy for the reaction used to collect the data?

A) \( \frac{E_a}{R} \)  
B) \(-\frac{E_a}{R}\)  
C) mR  
D) \(-mR\)  
E) ln A

4. \( K_c = 0.00392 \)

Phosgene, COCl₂, was used as a chemical weapon during World War I and is currently used as a starting material for the synthesis of other chemical compounds. Phosgene decomposes into carbon monoxide and chlorine gas.

\[ \text{COCl}_2(g) \rightleftharpoons \text{CO}(g) + \text{Cl}_2(g) \]

Suppose that 0.250 mol COCl₂ decomposes in a sealed 1.00 L container at 1000 K to give 0.0294 mol CO at equilibrium.

a. Determine the equilibrium constant for the decomposition of phosgene at 1000 K.
Consider the following equilibrium:

\[ 2 \text{NOCl}(g) \rightleftharpoons \text{Cl}_2(g) + 2 \text{NO}(g) \]

Determine the relative values of \(Q\) and \(K\) when the following changes are made to the system, and determine the direction in which the reaction shifts after these changes are made:

a. Increasing the concentration of \(\text{Cl}_2\)

b. Decreasing the concentration of \(\text{NO}\)

c. Removing \(\text{NOCl}\) from the system
Answers
1. \([\text{H}_3\text{O}^+] = 2.5 \times 10^{-3} \text{ M}, \text{pH} = 2.60\)
2. \(K_a = 7.84 \times 10^{-7} \text{ M}\)
3. 13.7mL
4. Redox:
   a. \(5 \text{SO}_3^{2-} (aq) + 2 \text{MnO}_4^{-} (aq) + 6 \text{H}^+ (aq) \rightarrow 5 \text{SO}_4^{2-} (aq) + 2 \text{Mn}^{2+} (aq) + 3 \text{H}_2\text{O} (l)\)
   b. \(2 \text{I}^- (aq) + 2 \text{NO}_2^- (aq) + 4 \text{H}^+ (aq) \rightarrow \text{I}_2 (s) + 2 \text{NO} (g) + 2 \text{H}_2\text{O} (l)\)
   c. \(\text{Al} (s) + \text{MnO}_4^- (aq) + 2 \text{H}_2\text{O} (l) \rightarrow \text{MnO}_2 (s) + \text{Al(OH)}_4^- (aq)\)
5. Standard Cells
   a. \(E^{\circ}_{\text{cell}} = 1.97\text{ V}, \text{spontaneous}\)
   b. \(E^{\circ}_{\text{cell}} = 0.55\text{ V}, \text{spontaneous}\)
   c. \(E^{\circ}_{\text{cell}} = -0.40\text{ V}, \text{non-spontaneous}\)
1. a. SiH₄ < HCl < H₂O  
b. F₂ < Cl₂ < Br₂  
c. CH₄ < C₂H₆ < C₃H₈

2. a. Gas to solid to liquid  
b. Gas to liquid  
c. Gas to solid (to liquid, maybe)

3. 113.4 kJ

4. 2 atoms per unit cell. Body-centered cubic unit cell.

5. +29.0 kJ/mol