PSI AP Chemistry Name _____

Chapter Problems Parts A and B: The Mole and Formulas

PART A: The mole concept and empirical and molecular formulas

1. Bauxite is an aluminum rich ore that is approximately 23.7% aluminum ion by mass. How many ions of aluminum are in a 24.5 gram sample of bauxite?

2. Silver ions react with chloride ions in aqueous solution to form a silver chloride solid (precipitate).

   a. How many silver ions would be present in a 0.36 gram sample of solid silver sulfate (Ag_2SO_4)?

   b. How many mL of 0.34 M aqueous aluminum chloride ($AlCl_3$) will be needed to react with the silver ion amount found in part "a" assuming the product of the reaction of silver and chloride ions is AgCl(s)?

3. For each, determine which contains the greater number of moles of each ion/element listed:

   a. [NO_3- ion] 3×10^{23} formula units of $Mg(NO_3)_2$ or 100 mL of 2 M $Al(NO_3)_3$

   b. [NH_3(g)] 0.76 L of NH_3 @STP or 670 mg of NH_3

4. Write the empirical formula for:

   a. $C_2H_4O_2$

   b. $H_2NCH_2CH_2NH_2$

5. A nitrogen oxide is created when 5.6 L of N_2 gas reacts with O_2 gas at STP to produce 11 grams of product.

   a. How many grams of nitrogen gas reacted?

   b. How many grams of oxygen gas reacted?

   c. What is the empirical formula of the oxide?

6. An organic compound containing carbon, hydrogen and chlorine was combusted in air and found to produce 0.225 grams of carbon dioxide and 0.0921 grams of water. Assuming the initial mass of the organic compound was 0.43 grams:

   a. How many grams of carbon and hydrogen were in the organic compound?

   b. What is the % by mass of chlorine in the compound?

   c. What is the empirical formula of the compound?

7. Propylene (a precursor compound for plastics we make on earth) was recently discovered in the atmosphere of Saturn's moon Titan. When analyzed, the sample of propylene was found to be 85.7% carbon by mass with a molecular weight of 42 u. What are the empirical and molecular formulas of propylene?

8. The mass spectrum of an unknown organic compound indicated prominent peaks on the mass spectrum at 216 and 218 u of roughly equal intensity. The compound, consisting of C, H, O, and Br was assessed to be 73% bromine by mass. When a 31.2 gram sample was combusted in air, 6.44 L of CO_2 gas was produced @STP along with 3.22 L of water.

   a. What is the mass of bromine in the sample?

b. What is the mass of C, H, and O in the sample?
c. What is the empirical and molecular formula of the organic compound?
d. Propose why there are two peaks produced in the mass spectra for this compound of relatively equal intensities?

PART B: Chemical Reactions and Reaction Stoichiometry

1. A hydrocarbon with an unknown formula produces carbon dioxide and water in a 2:1 ratio when 1 mole of the hydrocarbon combusts with excess oxygen gas.
    a. What must be the empirical formula of the hydrocarbon?
    b. If the molecular weight of the hydrocarbon is 26 u, what is the molecular formula?
    c. Write the balanced equation for the combustion of this hydrocarbon in oxygen gas.
    d. If the reaction is carried out at a 23% yield:
        i. How many moles of the hydrocarbon would need to be burned to produce 11.2 L of water @STP?
        ii. How much water would have been produced if the same amount of hydrocarbon reacted as burned in "I" but if the reaction was carried out at a 50% yield instead of a 23% yield?
2. Cadmium ions will react with fluoride ions to make a precipitate as shown below.

    $Cd^{2+}(aq) + 2F^{-}(aq) \rightarrow CdF_2(s)$

    The solid precipitate formed is typically filtered from the rest of the aqueous solution and then dried before massing. If 30 mL of 0.3 M aqueous $Cd(NO_3)_2$ is mixed with 10 mL of 0.5 M NH_4F:

    a. How many grams of precipitate would be expected to be produced?
    b. If 0.31 grams of precipitate were produced in the laboratory, what would be the % yield?
    c. Propose a reason, based on the laboratory procedure involved:
        i. How the % yield could be higher than 100
        j. What step could be taken to minimize this source of error?
    d. What will be the concentration of the following ions in the aqueous mixture after the reaction is complete?
        i. $Cd^{2+}(aq)$
        ii. $NO_3^{-}(aq)$
        iii. $NH_4^{+}(aq)$

3. Balance the following reactions:

a. The formation of ammonia from it's elements (nitrogen and hydrogen gas)
b. The combustion of propene (C_3H_6) in oxygen gas to produce CO_2 and H_2O
c. C_2H_3Br combusts in air (O_2) to produce CO_2, H_2O, and Br_2

4. The following data was obtained when aluminum metal was reacted with aqueous HCl to produce Al^{3+} ion and hydrogen gas (H_2).

$$2Al + 6H^+ \rightarrow 3H_2 + 2Al^{3+}$$

	Mass of Aluminum (g)	mL of HCl reacted	volume H_2 produced
Exp. 1	2.5	20	3.11 L
Exp. 2	5.0	20	6.22 L
Exp. 3	5.0	40	6.22 L
Exp. 4	5.0	15	5.33 L

a) Which substance is the limiting reactant in Exp. 1? Justify your answer using evidence from the other experiments.
b) Which substance is the limiting reactant in Exp. 2? Justify your answer using evidence from the other experiments.
c) Which substance is the limiting reactant in Exp. 3? Justify your answer using evidence from the other experiments.

Answers

PART A

1. Bauxite is an aluminum rich ore that is approximately 23.7% aluminum ion by mass. How many ions of aluminum are in a 24.5 gram sample of bauxite?

24.5 g ore x 0.237 = 5.81 g of Al = 0.215 mol Al = 1.29 x 10^{23} ions of Al

2. Silver ions react with chloride ions in aqueous solution to form a silver chloride solid (precipitate).

a. How many silver ions would be present in a 0.36 gram sample of solid silver sulfate (Ag_2SO_4)?

0.36 g silver sulfate/ 310 g*mol-1 = 0.00116 mol Ag_2SO_4 x 2 = 0.0023 mol Ag+
0.0023 mol = 1.39 x 10^{21} ions

b. How many mL of 0.34 M aqueous aluminum chloride ($AlCl_3$) will be needed to react with the silver ion amount found in part "a" assuming the product of the reaction of silver and chloride ions is AgCl(s)?

1 mol Cl- needed for every 1 mol Ag+ so 1.39 x 10^{21} ions of Cl- needed
1.39 x 10^{21} ions Cl- = 0.00232 mol Cl- / 3 = 0.000774 mol $AlCl_3$ needed
= 0.00228 L $AlCl_3$ = 2.28 mL

3. For each, determine which contains the greater number of moles of each ion/element listed:

a. [NO_3- ion] 3 x 10^{23} formula units of $Mg(NO_3)_2$ or 100 mL of 2 M $Al(NO_3)_3$

3 x 10^{23} formula units $Mg(NO_3)_2$ = 0.5 moles x 2 = 1.0 moles NO_3- ions
0.1 L x 2 = 0.2 moles $Al(NO_3)_3$ x 3 = 0.6 moles NO_3- ions

b. [NH_3(g)] 0.76 L of NH_3 @STP or 670 mg of NH_3

0.76 L = 0.034 mol NH_3
670 mg = 0.670 g = 0.039 mol NH_3

4. Write the empirical formula for:

a. $C_2H_4O_2$

CH_2O

b. $H_2NCH_2CH_2NH_2$

H_4CN

5. A nitrogen oxide is created when 5.6 L of N_2 gas reacts with O_2 gas at STP to produce 11 grams of product.

a. How many grams of nitrogen gas reacted?

7.0 grams

b. How many grams of oxygen gas reacted?

4.0 grams

c. What is the empirical formula of the oxide?

0.25 mol N_2 = 0.50 mol N/0.25 = N_2
0.125 mol O_2 = 0.25 mol O/0.25 = O_1
N_2O

6. An organic compound containing carbon, hydrogen and chlorine was combusted in air and found to produce 0.225 grams of carbon dioxide and 0.0921 grams of water. Assuming the initial mass of the organic compound was 0.43 grams:

a. How many grams of carbon and hydrogen were in the organic compound?

0.061 g C, 0.010 g H

b. What is the % by mass of chlorine in the compound?

0.43 g total - 0.061 g C - 0.010 g H = 0.359 g Cl/0.43 = 0.834 = 83.4%

c. What is the empirical formula of the compound?

CH_2Cl_2

7. Propylene (a precursor compound for plastics we make on earth) was recently discovered in the atmosphere of Saturn's moon Titan. When analyzed, the sample of propylene was found to be 85.7% carbon by mass with a molecular weight of 42 u. What are the empirical and molecular formulas of propylene?

85.7 g C = 7.14 mol C

14.3 g H = 14.3 mol H

Empirical Formula = CH_2

Molecular Formula = 42/14 = 3 → C_3H_6

8. The mass spectrum of an unknown organic compound indicated prominent peaks on the mass spectrum at 216 and 218 u of roughly equal intensity. The compound, consisting of C, H, O, and Br was assessed to be 73% bromine by mass. When a 31.2 gram sample was combusted in air, 6.44 L of CO_2 gas was produced @STP along with 3.22 Liters of water.

a. What is the mass of bromine in the sample?

31.2 g x 0.73 = 22.78 g Br

b. What is the mass of C, H, and O in the sample?

3.45 g C, 0.288 g H

31.2 - 22.78 g Br - 3.45 g C - 0.288 g H = 4.682 g O

c. What is the empirical and molecular formula of the organic compound?

Empirical = CHOBr Molecular = 217/109 = 2 so…. $C_2H_2O_2Br_2$

d. Propose why there are two peaks produced in the mass spectra for this compound of relatively equal intensities?

Bromine has two naturally occurring isotopes that are stable with masses of 79 and 81 respectively. Both occur almost equally in nature.

PART B

1. A hydrocarbon with an unknown formula produces carbon dioxide and water in a 2:1 ratio when 1 mole of the hydrocarbon combusts with excess oxygen gas.
    a. What must be the empirical formula of the hydrocarbon?

    CH

    b. If the molecular weight of the hydrocarbon is 26 u, what is the molecular formula?

C_2H_2

c. Write the balanced equation for the combustion of this hydrocarbon in oxygen gas.
$C_2H_2 + 2O_{2(g)} \rightarrow 2CO_{2(g)} + H_2O_{(g)}$

d. If the reaction is carried out at a 23% yield:
   i. How many moles of the hydrocarbon would need to be burned to produce 11.2 L of water @STP?
   2.17 Moles
   ii. How much water would have been produced if the same amount of hydrocarbon reacted as burned in "i" but if the reaction was carried out at a 50% yield instead of a 23% yield?
   1.09 Moles or 24.3L

2. Cadmium ions will react with fluoride ions to make a precipitate as shown below.

$Cd^{2+}(aq) + 2F^-(aq) \rightarrow CdF_2(s)$

The solid precipitate formed is typically filtered from the rest of the aqueous solution and then dried before massing. If 30 mL of 0.3 M aqueous $Cd(NO_3)_2$ is mixed with 10 mL of 0.5 M NH_4F:

a. How many grams of precipitate would be expected to be produced?
0.4 g (0.376g)

b. If 0.31 grams of precipitate were produced in the laboratory, what would be the % yield?
82%

c. Propose a reason, based on the laboratory procedure involved:
   i. How the % yield could be higher than 100
   Reasons could include:
   - **The sample was not fully dried.**
   - **Not all of the ammonium flouride filtered out and when you dried the sample it remained.**
   - **The reactants were possibly contaminated and the resulting side reaction was not water soluable.**
   - **The starting mass was measured to be lower than its actual value.**

   ii. What step could be taken to minimize this source of error?
   Steps could include:
   - **Using a gravity oven for drying and then immediately massing the result.**
   - **Washing the filtrate thoroughly with water**

- **Performing a melting point depression analysis to ascertain the severity of the contamination of the starting materials**
- **Use the same balance for the starting and ending masses.**

d. What will be the concentration of the following ions in the aqueous mixture after the reaction is complete?
   i. $Cd^{2+}(aq)$ **0.163 M**
   ii. $NO_3^-(aq)$ **0.45M**
   iii. $NH_4^+(aq)$ **0.125M**

3. Balance the following reactions:
   a. The formation of ammonia from it's elements (nitrogen and hydrogen gas)
   $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$
   b. The combustion of propene (C_3H_6) in oxygen gas to produce CO_2 and H_2O
   $2C_3H_{6(g)} + 9O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$
   c. C_2H_3Br combusts in air (O_2) to produce CO_2, H_2O, and Br_2
   $4C_2H_3Br + 11O_{2(g)} \rightarrow 8CO_{2(g)} + 6H_2O_{(g)} + 2Br_{2(l)}$

4. The following data was obtained when aluminum metal was reacted with aqueous HCl to produce Al^{3+} ion and hydrogen gas (H_2).

$$2Al + 6H^+ \rightarrow 3H_2 + 2Al^{3+}$$

	Mass of Aluminum (g)	mL of HCl reacted	volume H_2 produced
Exp. 1	2.5	20	3.11 L
Exp. 2	5.0	20	6.22 L
Exp. 3	5.0	40	6.22 L
Exp. 4	5.0	15	5.33 L

a) Which substance is the limiting reactant in Exp. 1? Justify your answer using evidence from the other experiments.
Aluminum, when the mass of Aluminum is doubled and the HCl left unchanged, the volume of gas produced doubles.
b) Which substance is the limiting reactant in Exp. 2? Justify your answer using evidence from the other experiments.
Aluminum, when the volume of HCl is doubled and the Aluminum left unchanged, the volume of gas produced remains unchanged.
c) Which substance is the limiting reactant in Exp. 3? Justify your answer using evidence from the other experiments.
Aluminum, assuming Aluminum is the limiting reagent in experiment 2, increasing the amount of HCl will not affect the limiting reagent.