The Copperbelt University

CH- 110 Tutorial Sheet 2 Stoichiometry

Question 1 Mole Concept

(a) (i) Calculate the number of moles that contain 4.50×10^{24} atoms of zinc.

(ii) What amount of H is there in 5.6 mol of N_2H_4(hydrazine?)

(iii) Find the amount of penicillin,$C_{16}H_{18}N_2O_4S,$ that contains 0.10 mol C.

(iv) What mass of CO_2 contains 5.10×10^{24} molecules of CO_2?

(b) When C_2H_6 is burned in excess oxygen, the following reaction occurs:

$$C_2H_6 + O_2 \longrightarrow CO_2 + H_2O$$

(i) Balance the equation

(ii) What moles of oxygen will be formed when 1.5 mol of C_2H_6 is burned?

(ii) What volume of CO_2 at s.t.p and what mass of H_2O will be produced?

Question 2 Empirical formula and Molecular formula

(a) What is the difference between empirical formula and molecular formula of a compound?

(b) A sample of 4.24 g of copper was heated in oxygen until no further change took place. The resulting oxide had a mass of 4.77 g. Calculate its empirical formula.

(c) Combustion of a 6.38 mg of an organic compound containing only carbon, hydrogen and oxygen with excess oxygen produced 5.58 mg of water and 9.06 mg of carbon dioxide. The molar mass of the organic compound was determined as 62.02 g/ mol. Determine the empirical formula and molecular of the compound.

Question 3 Stoichiometry

(a) (i)What is stoichiometry?

(ii) List the four basic types of reaction-stoichiometry problems

(b) (i) Write a balanced chemical equation for the reduction of iron(iii) oxide in the presence of carbon monoxide

(ii) How many grams of carbon monoxide are needed to react with excess of iron (iii) oxide to produce 591 g iron?

(c) A carbonate of the metal X has a formula of X_2CO_3. The equation for the reaction of X_2CO_3 with hydrochloric acid is given below.

$$X_2CO_3\ (s)\ +\ 2HCl(aq) \longrightarrow 2XCl(aq)\ +\ CO_2(g)\ +\ H_2O(l)$$

245 g of X_2CO_3 was found to exactly neutralize 129.07 g of HCl .

(i) Calculate the number of moles of HCl

(ii) Calculate the number of moles of X_2CO_3

(iii) Calculate the relative molecular mass of X_2CO_3

(iv) What is the identity of X?

Question 4 Percent Yield

(a)(i) Distinguish between the theoretical yield and the actual yield of a chemical reaction

(ii) Why the actual yield is always not equal to theoretical yield?

(iii) Explain how percent yield is calculated

(b) Chlorobenzene (C_6H_5Cl) is used in the production of many important chemicals such as aspirin, dyes, and disinfectants. One industrial method of preparing chlorobenzene, used in the chemical industry is the reaction between benzene (C_6H_6) and chlorine, represented by the equation

$$C_6H_6(l)\ +\ Cl_2(g) \longrightarrow C_6H_5Cl(s)\ +\ HCl\ (g)$$

When 36.8 g of C_6H_6 react with excess chlorine, the actual yield of C_6H_5Cl is 38.8 g. What is the percent yield of C_6H_5Cl ?

(c)Bornite (Cu_3FeS_3) is a copper ore used in the production of copper. When heated the following reaction occur

$$2\ Cu_3FeS_3\ (s)\ +\ 7O_2(g) \longrightarrow 6Cu(s)\ +\ 2FeO\ +\ 6SO_2(g)$$

If 2.47 metric tons of bornite is reacted with excess oxygen and the process has an 82.9% yield of copper, what mass of copper is produced?

Question 5 Limiting Reactant

(a) What is meant by (i) the limiting reactant? (ii) excess reactant?

(b) Some rocket engines use a mixture of hydrazine (N_2H_4) and hydrogen peroxide (H_2O_2) as the propellant system. The reaction is given by the equation

$$N_2H_4(\mathrm{l}) + 2H_2O_2(l) \longrightarrow N_2(g) + 4H_2O(g)$$

(i) Which is the limiting reactant in this reaction when 0.750 mol of N_2H_4 reacts with 0.500 mol of H_2O_2?

(ii) How much of excess reactant, in moles, remains unchanged?

(iii) How much N_2 , in moles, is formed?

(iv) Find the volume of H_2O produced at s.t.p

Answers

Question 1

(a) (i) moles = $\frac{4.50 \times 10^{24}}{6.02 \times 10^{23}}$ = **7.47 mol**

(ii) Amount = 4 × 5.6 =**22 mol**

(iii) 1 mol $C_{16}H_{18}N_2O_4S$ —— 16 mol of C

x —— 0.10

$\times = \frac{0.10 \times 1}{16} = \mathbf{0.0063\ mol\ penicillin}$

(iv) mole = $\frac{5.10 \times 10^{24}}{6.02 \times 10^{23}} = 8.47\ mol$; mass = mol × mm = 8.47 × 44.01 = **371.75 g**

(b) (i) $2\ C_2H_6 + 7O_2 \longrightarrow 4\ CO_2 + 6H_2O$

(ii) 2moles —— 7 moles

1.5 moles —— x

X = $\frac{1.5 \times 7}{2}$ = **5.25 mol**

(ii) 2mol —— 4 mol

1.5 mol —— x

X = $\frac{1.5 \times 4}{2} = 3\ mol$ volume = 3× 22.4 $= \mathbf{67.2\ dm^3}$

2mol —— 6 mol

1.5 mol —— x

x = $\frac{1.5 \times 6}{2} = 4.5\ mol$ mass of H_2O = 4.5 × 18.02 = $\mathbf{81.02\ g}$

Question 2

(a) Empirical formula is the formula with the smallest whole-number ratio of the elements while molecular formula is the formula that specifies the actual number of atoms of each element in one molecule or formula unit of the substance

(b) mass of oxygen = 4.77 – $4.24 = 0.53\ g$

Moles Cu = $\frac{4.24}{63.5}$ = 0.067 mol Cu

Moles O = $\frac{0.53}{16.00} = 0.033\ mol\ O$

Ratio Cu to O: $\frac{0.067}{0.033} = 2$; $\frac{0.033}{0.033} = 1$

Empirical formula = $\boldsymbol{Cu_2O}$

(c) mass of C in CO_2 = 9.06 × $10^{-3} \times \frac{12.01}{44.01} = 0.0024724\ g$; moles= $\frac{0.0024724}{12.01} = 2.06$ mol

Mass of H in H_2O = $5.58 \times 10^{-3} \times \frac{2.016}{18.016} = 0.00063$ g ; moles = $\frac{0.00063}{1.008} = 0.00063\ mol$

Mass of O = (0.00638 g) – $(0.00247 + 0.00063) = 0.00328$ g; moles = $\frac{0.00328}{16} = 0.0002\ mol$

Mole ratio; C=1 ; H=3 ; O =1 Empirical formula is CH_3O

Ratio of molar mass of the molecule to that of the empirical formula is 63.02/31.02 = 2

Molecular formula = $(CH_3O)_2 = \boldsymbol{C_2H_6O_2}$

Question 3

(a) (i) Stoichiometry is the study of quantitative relationship of composition of elements in a compound and relationships between amounts of reactants used and products formed by a chemical reaction

(ii) 1. mole– mole calculations 2. mole– $mass\ calculation$

3. mass- mole calculations 4. Mass- mass calculation

(b) (i) $Fe_2O_3 + 3CO \longrightarrow$ 2Fe + 3CO_2

3 mol —— 2 mol

x —— 10.58

moles of 591 g of Fe

n=$\frac{591\ g}{55.845\ g/mol} = 10.58\ mol$

x = $\frac{3 \times 10.58}{2} = 15.87\ mol$

mass of CO = 15.87 × 28.01 = **444.52 g**

(c) (i) moles of HCl; n = $\frac{129.07\ g}{36.46\ g/mol} = \mathbf{3.54\ mol}$

(ii) moles of X_2CO_3;

X_2CO_3 ——— 2HCl

1 ——— 2

x ——— 3.54 mol

x = $\frac{1 \times 3.54}{2} = \mathbf{1.77\ mol\ of\ X_2CO_3}$

molar mass of X_2CO_3 = $\frac{245\ g}{1.77\ mol}$ = 139

molar mass of X_2CO_3 = 2x +12.01 + 48 = 139

x = 39.5

thus element X is **Potassium(K)**

Question 4

(a) (i) Theoretical yield is the maximum amount of product that can be produced from a given amount of reactant while actual yield is the measured amount of product obtained from chemical a reaction

(ii) Some of the reactant might take part in competing side reactions that reduce the amount of the desired product. Also once a product is formed it is usually collected in impure form. Often, during the purification process some of the product is lost.

(iii) Obtain the measured amount of product from the experiment (actual yield) and then calculate the theoretical yield by doing stoichiometric calculations. Finally the percent yield is calculated by finding the ratio of the actual yield to the theoretical yield expressed as a percent.

(b) Moles of36.8 g of C_6H_6 = $\frac{36.8\ g}{78.12} = 0.47\ mol$

Theoretical yied: 1 mol C_6H_6 ——— 1 mol C_6H_5Cl

0.47 mol C_6H_6 ——— x

X= 0.47 mol C_6H_5Cl

Mass of C_6H_5Cl = 112.56 × 0.47 = 52.9 g

Percent yield = $\frac{38.8\ g}{52.9\ g} \times 100 = \mathbf{73.3}\%$

(c) Relative mass of Cu_3FeS_3 = 685.37 ; relative mass of 6Cu =192.39

Theoretical yield: 685.37 ——— 192.39

2.47 metric tons ——— x

X $= \frac{2.47\ metric\ tons \times 192.39}{685.37} = 1.21\ metric\ tons$

Percent yield = $\frac{Actual\ yield}{theoretical\ yield} \times 100$

82.9 = $\frac{x}{1.21} \times 100$; x = $\frac{82.9 \times 1.21}{100} = 1.003\ metric\ tons$

Thus mass of copper produced = **1.003 metric tons**

Question 5

(a) (i) is a reactant that limits the amount of other reactants that can combine and the amount of products that formed in a chemical reaction

(ii) is a reactant not used up completely in a chemical reaction

(b) (i) $N_2H_4 + 2H_2O_2 \longrightarrow N_2 + 4H_2O$

1 molN_2H_4 ——— 2 $molH_2O_2$

0.750 mol ——— x

X = 0.750 × 2 =1.50 mol H_2O_2

The required 1.50 mol H_2O_2 is more than the available 0.500 mol H_2O_2. **Therefore $\boldsymbol{H_2O_2}$ is a limiting reactant**

(ii) 1 molN_2H_4 ——— 2 $molH_2O_2$

x ——— 0.500 mol H_2O_2.

X = 1 × 0.5/2 = 0.25 mol N_2H_4

The required 0.25 mol N_2H_4 is less than the available 0.750 mol N_2H_4 . therefore

Excess reactant remains unchanged = 0.750 – 0.25 = **0.5 mol**

(iii) Moles of N_2 : 2 $molH_2O_2$ ——— 1 mol ofN_2

0.500 mol $molH_2O_2$ ——— x

X = $\frac{0.500 \times 1}{2}$ = **0.25 mol of N_2 formed**

(iv) 2 $molH_2O_2$ ——————— 4 mol of H_2O

0.500 mol $molH_2O_2$ ——— x

X = $\frac{0.500 \times 4}{2} = 1\ mol\ H_2O$ produced

Volume of H_2O = molar volume(at s.t.p) $\times$ moles

= 22.4dm^3/mol $\times$ 1mol

= $\underline{\mathbf{22.4dm^3}}$

The end