



**THE COPPERBELT UNIVERSITY**  
**SCHOOL OF MATHEMATICS AND NATURAL SCIENCES**  
**DEPARTMENT OF CHEMISTRY**  
**2016/17 ACADEMIC YEAR**  
**TERM II TEST ONE**  
**CHEMISTRY (CH 110/FO 130)**

**TIME ALLOWED:** Two (2) Hours.

**DATE:** 06 / 1 / 2017

**INSTRUCTIONS:**

- (i) Attempt all the four questions, each question carries 25 Marks.
- (ii) All calculated quantities must have units and reported to the correct number of significant figures.
- (iii) Do not open till instructed to do so.

**IMPORTANT DATA:**

Physical Constants		
Constant	Symbol	Value
Atomic mass unit	$Amu$	$1.660554 \times 10^{-27}kg$
Avogadro’s number	$N_A$	$6.02214 \times 10^{23} \text{ mol}^{-1}$
Gas constant	$R$	$8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$
		$0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$
$1 \text{ atm} = 760mmHg = 1.0132 \times 10^5 \text{ Nm}^{-2} = 1.0132 \times 10^5Pa$		

**QUESTION ONE (INTRODUCTION TO GENERAL CHEMISTRY) [25 marks]**

- a) Classify the following materials as a metal, non-metal or mineral by ticking the appropriate cell of the first three rows and write the symbol of the element of each material in the last row. [9]

**SOLUTIONS**

Material	Calcium	Phosphorus	Nickel	Diamond
Metal	X [1]		X [1]	
Non-metal		X [1]		X [1]
Mineral				X [1]
Symbol of elemental form of the substance	Ca [1]	P [1]	Ni [1]	C [1]

- b) Classify the following processes as chemical or physical changes [3]

**SOLUTIONS**

Process description	Type of change
1. Breaking of glass into small pieces	Physical change [1]
2. Burning of charcoal	Chemical change [1]
3. Stirring of teaspoon of mud in water	Physical change [1]

- c) State the number of elements present in each molecule of  $\text{PoCl}_2$  and  $\text{POCl}_3$  [2]

**SOLUTIONS**

- (i)  $\text{PoCl}_2$  has 2 elements [1]  
 (ii)  $\text{POCl}_3$  has 3 elements [1]

- d) Find the result of the calculation below to the proper number of significant digits and write the answer in scientific notation. [4]

$$\frac{(80.21\text{g} - 79.93\text{g})}{65.22\text{ cm}^3}$$

**SOLUTIONS**

- (i) The subtraction is done first, yielding an answer that has only two significant digits:  
 $80.21 - 79.93 = 0.28\text{ g}$  [1]

- (ii) This value is divided by  $65.22\text{ cm}^3$ , giving an answer with to two significant digits:  
 $\frac{0.28\text{ g}}{65.22\text{ cm}^3} = 0.0043 \frac{\text{g}}{\text{cm}^3}$  ([2], [1] numerical answer & [1] units)

- (iii) Answer in scientific notation is  $4.3 \times 10^{-3}\text{ g/cm}^3$  [1]

- e) A  $7.00\text{ cm} \times 3.00\text{ cm} \times 2.50\text{ cm}$  rectangular metal bar has a mass of 593 g. Will the bar float in water or mercury (density 13.6 g/mL) ? Show your work. [4]

**SOLUTIONS**

- (i) Volume of the bar is  $l \times w \times h = 52.5\text{ cm}^3$  [1]

(ii) ***Its density is  $D = \frac{\text{mass}}{\text{volume}} = \frac{593 \text{ g}}{52.5 \text{ cm}^3} = 11.3 \text{ g/cm}^3$***  [1]

(iii) ***The bar will sink in water (density is  $1.00 \text{ /cm}^3$ ) but will float in mercury*** [2]

- f) The normal body temperature in Kelvin is 310K. Convert this to the Fahrenheit Scale? Show your work. [3]

#### **SOLUTIONS**

(i) ***First convert given Kelvin temperature to Celsius using the equation***

$$t_{\text{C}} = t_{\text{K}} - 273 \quad [1]$$

(ii) ***Next convert given derived Celsius temperature to Fahrenheit using the equation***

$$t_{\text{F}} = \frac{9^{\circ}\text{F}}{5^{\circ}\text{C}} (t_{\text{C}}) + t_{\text{F}} \quad [1]$$

(iii) ***Substituting the first equation into the second putting the numerical values yields***

$$t_{\text{F}} = \frac{9^{\circ}\text{F}}{5^{\circ}\text{C}} (t_{\text{K}} - 273) + t_{\text{F}} = \frac{9^{\circ}\text{F}}{5^{\circ}\text{C}} (37^{\circ}\text{C}) + 32^{\circ}\text{F} = 98.6^{\circ}\text{F} \quad [1]$$

#### **QUESTION TWO (STOICHIOMETRY AND MOLE CONCEPT) [25 marks]**

- a) Potassium fertilizer is sometimes called Potash, a term that comes from an early production technique. Potassium phosphate and potassium nitrate are examples of potash fertilizers. Which one of the two fertilizers is a better potash fertilizer. [4 marks]

**Potassium phosphate,  $\text{K}_3\text{PO}_4$  :** [½ mark for correct formula]

$$\text{Molar mass} = (3 \times 39) + 31 + (4 \times 16) = 212\text{g/mol} \quad [½ \text{ mark}]$$

$$\% \text{ of K: } \frac{117}{212} \times 100 = 55.18\% \quad [½ \text{ mark}]$$

**Potassium nitrate,  $\text{KNO}_3$  :** [½ mark for correct formula]

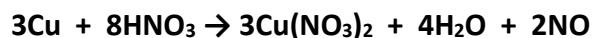
$$\text{Molar mass} = 39 + 14 + (3 \times 16) = 101\text{g/mol} \quad [½ \text{ mark}]$$

$$\% \text{ of K: } \frac{39}{101} \times 100 = 38.61\% \quad [½ \text{ mark}]$$

**Potassium phosphate (K = 55.18%) is a better potash fertilizer than potassium nitrate (K = 38.61%)** [1 mark]

- b) Copper reacts with nitric acid to give copper(II) nitrate, water and nitrogen monoxide (nitric oxide).

i) Write a balanced equation for this reaction. [1 mark]



ii) Calculate the mass of copper needed to react with 63g of nitric acid. [2 marks]



$$3 \times 64 \quad 8 \times 63$$

$$192\text{g} \quad 504\text{g}$$

$$2 \times 22.4\text{dm}^3$$

$$44.8\text{dm}^3 \text{ at STP}$$

When nitric acid is 504g, the mass of copper required is 192g.

When nitric acid is 63g, the mass of copper required is:

$$\frac{192 \times 63}{504} = 24\text{g}$$

- iii) Calculate the volume of nitric oxide at Standard Temperature and Pressure (STP) that can be collected. (One mole of a gas occupies a volume of  $22.4\text{dm}^3$  at STP). [2 marks]

When nitric acid is 504g, the volume of NO formed is  $44.8\text{dm}^3$  at STP.

When nitric acid is 63g, the amount of NO formed is:

$$\frac{44.8 \times 63}{504} = 5.6\text{dm}^3 \text{ at STP}$$

- c) An acid of phosphorus has the following percentage composition: Phosphorus, 38.27%; Hydrogen, 2.47%; Oxygen, 59.26%.

- i) Find the empirical formula of the acid. [2 marks]

Element	% by Wt	Molar mass	Number of moles	Simple ratio of atoms
P	38.27	31	$38.27 \div 31 = 1.23$	$1.23 \div 1.23 = 1$
H	2.47	1	$2.47 \div 1 = 2.47$	$2.47 \div 1.23 = 2$
O	59.26	16	$59.26 \div 16 = 3.70$	$3.70 \div 1.23 = 3$

Empirical formula =  $\text{H}_2\text{PO}_3$

- ii) Find the molecular formula of the acid if its molar mass is 162g/mol. [2 marks]

Molecular formula:

Molecular weight =  $n(\text{Empirical weight})$

$$162 = n \times 8n = 2$$

Molecular formula is:  $\text{H}_4\text{P}_2\text{O}_6$

- d) If 20g of calcium carbonate is treated with 20g hydrochloric acid, calcium chloride, water and carbon dioxide are formed.

- i) Calculate the number of moles of calcium carbonate in 20g of the sample. [1½ mark]

$$\text{Molar mass of } \text{CaCO}_3 = 40 + 12 + (3 \times 16) = 100\text{g/mol}$$

$$\text{Moles of } \text{CaCO}_3 = \frac{\text{mass}}{\text{molar mass}} = \frac{20}{100} = 0.2\text{moles}$$

- ii) Write a balanced equation for this reaction. [½ mark]



- iii) Which reactant is the limiting reagent in this reaction? [2 marks]

$$\text{Molar mass of } \text{CO}_2 = 12 + (2 \times 16) = 44\text{g/mol}$$

$$\text{Molar mass of HCl} = 1 + 35.5 = 36.5\text{g/mol}$$

**100g CaCO<sub>3</sub> produces 44g of CO<sub>2</sub>**

**20g CaCO<sub>3</sub> produces:  $\frac{20 \times 44}{100} = 8.80\text{g of CO}_2$**

**73g HCl produces 44g of CO<sub>2</sub>**

**20g HCl produces:  $\frac{20 \times 44}{73} = 12.05\text{g of CO}_2$**

**CaCO<sub>3</sub> produces the least mass of CO<sub>2</sub>. So it is the limiting reagent.**

- iv) How many grams of carbon dioxide can be generated in this reaction? **[2 marks]**

**This is determined by the limiting reagent:**

**100g CaCO<sub>3</sub> produces 44g of CO<sub>2</sub>**

**20g CaCO<sub>3</sub> produces:  $\frac{20 \times 44}{100} = 8.80\text{g of CO}_2$**

- v) Calculate the percentage yield of carbon dioxide if this reaction produced 6.6g of carbon dioxide. **[2 marks]**

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100 = \frac{6.6 \times 100}{8.8} = 75\%$$

- vi) How many molecules of carbondioxide are in 6.6g of carbon dioxide? **[2 marks]**

**44g of CO<sub>2</sub>(1mol) has  $6.022 \times 10^{23}$  molecules**

**6.6g of CO<sub>2</sub> has:  $\frac{6.6}{44} \times 6.022 \times 10^{23} = 9.033 \times 10^{22}$  molecules of CO<sub>2</sub>**

- vii) Calculate the number of atoms for both carbon and oxygen in 6.6g of carbondioxide. **[3 marks]**

**44g of CO<sub>2</sub>(1mol) has  $6.022 \times 10^{23}$  atoms of C**

**6.6g of CO<sub>2</sub> has:  $\frac{6.6}{44} \times 6.022 \times 10^{23} = 9.033 \times 10^{22}$  atoms of CO<sub>2</sub>**

**44g of CO<sub>2</sub>(1mol) has  $2 \times 6.022 \times 10^{23}$  atoms of O**

**6.6g of CO<sub>2</sub> has:  $\frac{6.6}{44} \times 2 \times 6.022 \times 10^{23} = 1.81 \times 10^{23}$  atoms of O**

### QUESTION THREE(AQUEOUS SOLUTIONS)

**[25 Marks]**

#### **REACTION IN AQUEOUS SOLUTION**

**3 (a) (i) Aqueous solution** is the solution whose solvent is water.

**(4)**

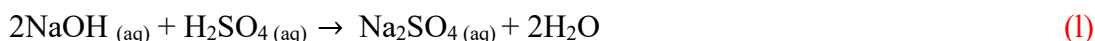
**(ii) Standard solution** is the solution whose concentration is known

**(iii) Molarity** is the number of moles of solutes per liter of solution

(iv) **Precipitation reaction** is the reaction when two solutions are mixed to form an Insoluble solid.

(b) Examples of non electrolyte are **sugars and alcohols**(2)

(c) Balance the equation first

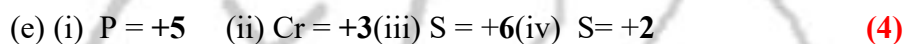
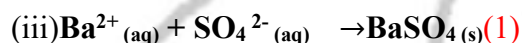
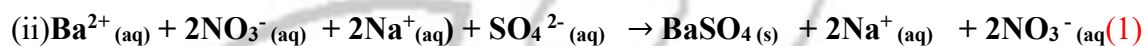
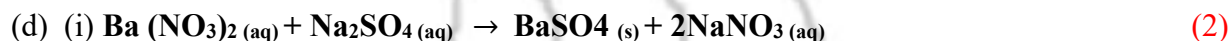


$$M_a \times V_a / M_b \times V_b = \frac{1}{2} \quad (1)$$

$$0.10 \text{ M} \times V_a / 0.125 \text{ M} \times 25 \text{ cm}^3 = \frac{1}{2}$$

$$0.2 \times V_a = 3.125$$

$$V_a = 15.625 \text{ cm}^3 (0.015625 \text{ L}) \quad (1)$$



#### QUESTION FOUR (GASES)

[25 marks]

a) True or false

i) Pressure must be exerted on a sample of a gas in order to confine it. [1 mark]

*Ans: True*

ii) Gases can be expanded without any limits [1 mark]

*Ans: True*

The density of the gas is constant as long as its temperature remains constant.

[1 mark]

*Ans: False*

b) A sample of  $\text{Cl}_2$  gas occupies 105 litres at  $27^\circ\text{C}$  under a pressure of 987 Torr.

i) What volume would it occupy at STP? [2 marks]

Given:  $v_1 = 105\text{L}$ ,  $P_1 = 985\text{ Torr}$ ,  $T_1 = 27 + 273 = 300\text{K}$ ,  $T_2 = 0 + 273 = 273\text{K}$ ,  
 $P_2 = 1.0\text{atm}$

Conversion of temperature [0.25] conversion of pressure [0.25]

Asked for  $V_2$ ?

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} \text{ [0.5]}$$

$$= \frac{985\text{Torr} \times 105\text{L} \times 300\text{K}}{760\text{Torr} \times 273\text{K}}$$

$$= 124\text{L} \text{ [1]}$$

ii) How many molecules are there in the above volume of the  $\text{Cl}_2$  gas? [3 marks]

Given:  $V = 124\text{L}$ ,  $P = 1\text{atm}$ ,  $T = 0^\circ\text{C}$

Asked for  $n$ ?

Convention factor: 1 mole of a gas STP = 22.4L

[0.5]

$$n_{(g)} = 124\text{L} \times \frac{1\text{mol}}{22.4\text{L}} = 5.536\text{ mol}$$

[1]

*solving for number of molecules of the gas:*

$$N = n \times N_A \text{ [0.5]}$$

$$N = 5.536 \times 6.02 \times 10^{23}$$

$$= 3.33 \times 10^{24} \text{ molecules of } \text{Cl}_2 (\text{g})$$

[1]

iii) Prove that  $\frac{n}{V} = \frac{d}{M}$  where  $M$  is the molar mass of a gas sample,  $d$  is density of the gas [3 marks]

Solving the Right Hand Side (RHS):

By definition density ( $d$ ) is:

$$d = \frac{m}{V} \text{ (a)}$$

*where  $m$  is the mass of the sample and  $V$  is the volume of the gas sample*

*Writing  $m$  in terms of Molecular mass ( $M$ ) and number of moles ( $n$ ) we have:*

$$m = n \times M \text{ (b)}$$

*Taking equation (b) into (a) we have:*

$$d = \frac{n \times M}{V} \text{ (c)}$$

*Dividing both sides of equation (c) we have:*

$$\frac{d}{M} = \frac{n}{V}, \text{ hence shown. [3]}$$

c) Consider a sample of  $\text{CO}_2$  gas exerting a pressure of 7.81 atm to a volume of 3.00 L at  $0.0^\circ\text{C}$ . Calculate the number of moles of  $\text{CO}_2$  gas

i) given that it is an ideal gas [3 mark]

Given:  $P = 7.81\text{ atm}$ ,  $V = 3.00\text{L}$ ,  $T = 0^\circ + 273\text{K} = 273\text{K}$  [0.5]

For an ideal gas, the ideal gas equation is applicable:

$$PV = nRT \text{ (a)}$$

*Rearranging equation (a), the number of moles is given by:*

$$n = \frac{PV}{RT} [1]$$

$$n = \frac{7.81 \text{ atm} \times 3.00 \text{ L}}{0.0821 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}} = 1.045 \text{ mol} [1.5]$$

- ii) given that is a real gas and its Van der Waal's constant  $b = 0.0427 \text{ L/mol}$  and the value of the  $\frac{an^2}{v^2} = 0.3939 \text{ atm}$ . [3 marks]

Given:  $b = 0.0427 \text{ L/mol}$ ,  $\frac{an^2}{v^2} = 0.3939 \text{ atm}$ ,  $V = 3.00 \text{ L}$ ,  $P = 7.81 \text{ atm}$ ,  $T = 0^\circ + 273 \text{ K} = 273 \text{ K}$

For a real gas the Van der Waal's equation is applicable:

$$\left(P + \frac{an^2}{v^2}\right)(V - nb) = nRT [1]$$

Substituting the Van der Waal's constants and rearranging equation (b) in terms of number of moles (n) gives:

$$7.81 \text{ atm} + 0.3939 = \frac{n(0.0821 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1} \times 273 \text{ K})}{(3.00 \text{ L} - 0.0427 \text{ L} \cdot \text{mol}^{-1} \times n)}$$

$$n = 1.098 \text{ mol} [2]$$

- iii) The molecular weight of an unknown gas is found by measuring the time required for a known volume of the gas to effuse through a small pinhole, under constant pressure. The apparatus is calibrated by measuring the time needed for the same volume of  $\text{O}_2$  (molwt =  $32.00 \text{ g/mol}$ ) to effuse through the same pinhole, under the same conditions. The time found for  $\text{O}_2$  is 60 sec, and that for the unknown gas is 120 sec. compute the molecular weight of the unknown gas. [3 marks]

Given: Molwt of oxygen =  $32.00 \text{ g/mol}$ , time for oxygen to effuse is 60sec, time for the unknown gas to effuse 120sec

The relationship between rate of effusion and molecular weight is given by:

$$\frac{R_{\text{O}_2}}{R_b} = \sqrt{\frac{M_b}{M_{\text{O}_2}}} [0.5]$$

Where  $R_b$  is the rate of effusion of the unknown gas,  $M_b$  is the molecular weight of the unknown gas.

Relating rate of effusion with time of effusion gives:

$$\frac{R_{\text{O}_2}}{R_b} = \frac{t_b}{t_{\text{O}_2}} = \sqrt{\frac{M_b}{M_{\text{O}_2}}} [0.5]$$

Where  $t_b$  is the time of effusion of the unknown gas and  $t_{\text{O}_2}$  is the time of effusion of  $\text{O}_2$  gas.

Rearranging and substituting the values given gives:

$$M_b = 128.00 \text{ g/mol} [2]$$

- d) Consider a complete decomposition of  $3.237 \text{ g}$  of  $\text{KClO}_3$  (s) to yield  $\text{KCl}_{(\text{aq})}$  and  $\text{O}_{2(\text{g})}$  which is collected over water. Taking the ideal gas condition, calculate the volume of oxygen gas generated at  $25^\circ\text{C}$  and at a total pressure of  $1.00 \text{ atm}$  when the value of vapour pressure of water at  $25^\circ\text{C}$  is  $23.8 \text{ Torr}$ . [5 marks]

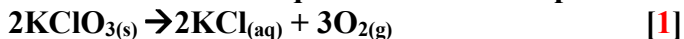
Given: mass of  $\text{KClO}_3 = 3.237 \text{ g}$ , total pressure =  $1.00 \text{ atm}$ , vapour pressure at  $25^\circ\text{C} = 23.8 \text{ Torr}$



Conversions: Temperature:  $25 + 273\text{K} = 298\text{K}$

Total Pressure:  $23.8 \text{ Torr} \times 1 \text{ atm}/760 \text{ Torr} = 0.0313 \text{ atm}/0.5/$

Balanced chemical equation for the complete decomposition of  $\text{KClO}_3$ :



Number of moles of oxygen gas:

$$n_{\text{O}_2} = \frac{\text{mass of } \text{KClO}_3}{\text{Molecular weight of } \text{KClO}_3} \times \frac{3 \text{ mol } \text{O}_2}{2 \text{ mol } \text{KClO}_3}$$

$n_{(\text{O}_2)} = 0.0396 \text{ mol}/1/$  Pressure of oxygen:  $P_{\text{O}_2} = P_{\text{tot}} - P_{\text{vap}} = 1.00 \text{ atm} - 0.0313 \text{ atm} = 0.9687 \text{ atm}/0.5/$

Volume of  $\text{O}_2$ :

From the ideal gas equation:

$$V_{\text{O}_2} = \frac{n_{\text{O}_2} RT}{P} = 0.0396 \text{ mol} \times \frac{0.0821 \text{ Latm}}{\text{Kmol}} \times \frac{298 \text{ K}}{0.969 \text{ atm}} = 1.00 \text{ L} \quad [2]$$

====THE END