THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

2016/17 ACADEMIC YEAR

TERM II TEST ONE

CHEMISTRY (CH 11O/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*	1.660554×10^{-27}kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
1 atm = 760mmHg = 1.0132×10^5 Nm^{-2} = 1.0132×10^5Pa		

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$PoCl_2$ and $POCl_3$ **[2]**

SOLUTIONS

(i) ***$PoCl_2$ has 2 elements*** **[1]**

(ii) ***$POCl_3$ 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 g **[1]**

(ii) ***This value is divided by 65.22 cm^3, giving an answer with to two significant digits:***

$$\frac{\mathbf{0.28\ g}}{\mathbf{65.22\ cm^3}} = \mathbf{0.0043}\frac{\mathbf{g}}{\mathbf{cm^3}} \qquad ([2], [1]\ \boldsymbol{numerical\ answer}\ \&[1]\boldsymbol{units})$$

(iii) ***Answer in scientific notation is $\mathbf{4.3 \times 10^{-3}}$ 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*** $\boldsymbol{l \times w \times h = 52.5\ cm^3}$ **[1]**

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

(iii) *The bar will sink in water (density is 1.00 /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

$$t_{°\text{C}} = t_K - 273 \qquad [1]$$

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

$$t_{°\text{F}} = \frac{9°\text{F}}{5°\text{C}}(t_{°\text{C}}) + t_{°\text{F}} \qquad [1]$$

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

$$t_{°\text{F}} = \frac{9°\text{F}}{5°\text{C}}(t_K - 273) + t_{°\text{F}} = \frac{9°\text{F}}{5°\text{C}}(37°\text{C}) + 32°\text{F} = 98.6°\text{F} \qquad [1]$$

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, K_3PO_4 : [½ mark for correct formula]

Molar mass = (3 x 39) + 31 + (4 x 16) = 212g/mol [½ mark]

% of K: $\frac{117}{212}$ **x 100 = 55.18%** [½ mark]

Potassium nitrate, KNO_3 : [½ mark for correct formula]

Molar mass = 39 + 14 + (3 x 16) = 101g/mol [½ mark]

% of K: $\frac{39}{101}$ **x 100 = 38.61%** [½ 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]

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$

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

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$

3 x 64 8 x 63 2 x 22.4dm^3

192g 504g 44.8dm^3 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:

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

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 22.4dm^3 at STP*). [2 marks]

When nitric acid is 504g, the volume of NO formed is 44.8dm^3 at STP.

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

$\frac{44.8 \times 63}{504}$ **= 5.6dm^3 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 ÷ 31 = 1.23	1.23 ÷ 1.23 = 1
H	2.47	1	2.47 ÷ 1 = 2.47	2.47 ÷ 1.23 = 2
O	59.26	16	59.26 ÷ 16 = 3.70	3.70 ÷ 1.23 = 3

Empirical formula = H_2PO_3

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

Molecular formula:

Molecular weight = n(Empirical weight)

162 = n x 8n = 2

Molecular formula is: $H_4P_2O_6$

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]

Molar mass of $CaCO_3$ = 40 + 12 + (3 x 16) = 100g/mol

Moles of $CaCO_3$ = $\frac{mass}{molar\ mass} = \frac{20}{100}$ = 0.2moles

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

$CaCO_3 + 2HCl \rightarrow CaCl_2\ H_2O + CO_2$

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

Molar mass of CO_2 = 12 + (2 x 16) = 44g/mol

Molar mass of HCl = 1 + 35.5 = 36.5g/mol

100g $CaCO_3$ produces 44g of CO_2

20g $CaCO_3$ produces: $\frac{20 \times 44}{100}$ = 8.80g of CO_2

73g HCl produces 44g of CO_2

20g HCl produces: $\frac{20 \times 44}{73}$ = 12.05g of CO_2

$CaCO_3$ produces the least mass of CO_2. 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 $CaCO_3$ produces 44g of CO_2

20g $CaCO_3$ produces: $\frac{20 \times 44}{100}$ = 8.80g of CO_2

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

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

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

44g of CO_2(1mol) has 6.022×10^{23} molecules

6.6g of CO_2 has: $\frac{6.6}{44} \times 6.022 \times 10^{23} = 9.033 \times 10^{22}$molecules of CO_2

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

44g of CO_2(1mol) has 6.022×10^{23} atoms of C

6.6g of CO_2 has: $\frac{6.6}{44} \times 6.022 \times 10^{23} = 9.033 \times 10^{22}$ atoms of CO_2

44g of CO_2(1mol) has $2 \times 6.022 \times 10^{23}$ atoms of O

6.6g of CO_2 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

$2NaOH_{(aq)} + H_2SO_{4\,(aq)} \rightarrow Na_2SO_{4\,(aq)} + 2H_2O$ (l)

Ma x Va/ Mb x Vb = ½ (1)

0.10 M x Va / 0.125M x 25 cm^{3} = ½

0.2 xVa= 3.125

Va= 15.625 cm^3(0.015625 L) (1)

(d) (i) **$Ba(NO_3)_{2\,(aq)} + Na_2SO_{4\,(aq)} \rightarrow BaSO4_{(s)} + 2NaNO_{3\,(aq)}$** (2)

(ii)**$Ba^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)} + 2Na^+_{(aq)} + 2NO_3^-{}_{(aq}$**(1)

(iii)**$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$**(1)

(e) (i) P = +**5** (ii) Cr = +**3**(iii) S = +**6**(iv) S= +**2** **(4)**

(f) (i) **Cr^+: oxidized, Sn^{4+}: reduced** **(1)**

(ii)**As: oxidized, Cl_2: reduced** **(1)**

(g) (i) **$8\,H^+ + Cr_2O_7^{2-} + 3\,C_2H_6O \quad 2\,Cr^{3+} + 7\,H_2O + 3\,C_2H_4O$(6)**

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 Cl_2 gas occupies 105 litres at 27 ^{0}C under a pressure of 987 Torr.

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

Given: v_1= 105L, P_1=985 Torr, T_1=27 + 273= 300K, T_2= 0 + 273= 273K, P_2=1.0atm
Conversion of temperature*[0.25]* conversion of pressure *[0.25]*
Asked for V_2?

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

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

$= 124L$*[1]*

ii) How many molecules are there in the above volume of the Cl_2 gas? **[3 marks]**
Given: V= 124L, P=1atm, T= 0^0C
Asked for n?
Convention factor: 1mole of a gas STP= 22.4L *[0.5]*
$n_{(g)} = 124LX \frac{1mol}{22.4L}$**= 5.536 mol** *[1]*
$solving for number of molecules of the gas$:
$N = nxN_A$*[0.5]*
N= 5.536 x 6.02 x 10^{23}
= 3.3.3 x 10^{24} molecules of $Cl_{2\,(g)}$ *[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:
$d = \frac{m}{V}$ ***(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:
$m = nxM$ ***(b)***
Taking equation (b) into (a) we have:
$d = \frac{nxM}{V}$ ***(c)***

Diving both sides of equation (c) we have:

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

c) Consider a sample of CO_2 gas exerting a pressure of 7.81 atm to a volume of 3.00 L at 0.0^{0}C. Calculate the number of moles of CO_2 gas
i) given that it is an ideal gas **[3 mark]**
Given: P=7.81 atm, V=3.00L, T= 0^0 + 273K = 273K *[0.5]*
For an ideal gas, the ideal gas equation is applicable:

$$PV = nRT(a)$$

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

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

$n = \frac{7.81 atm x 3.00 L}{0.0821 L.atm.K^{-1}.mol^{-1}}$= ***1.045 mol [1.5]***

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

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

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

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

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

$$7.81 atm + 0.3939 = \frac{n(0.0821 LatmK^{-1}mol^{-1} x 273K)}{(3.00L - 0.0427 Lmol^{-1} xn)}$$

n = 1.098 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 O_2 (molwt = 32.00g/mol) to effuse through the same pinhole, under the same conditions. The time found for 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 = 32.00g/mol, time for oxygen to effuse is 60sec, time for the unkown gas to effuse 120sec

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

$\frac{R_{O_2}}{R_b} = \sqrt{\frac{M_b}{M_{O_2}}}$*[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:

$\frac{R_{O_2}}{R_b} = \frac{t_b}{t_{O_2}} = \sqrt{\frac{M_b}{M_{O_2}}}$*[0.5]*

Where $t_b$is the time of effusion of the unknown gas and t_{o2} is the time of effusion of O_2 gas.

Rearranging and substituting the values given gives:

M_b = 128.00g/mol*[2]*

d) Consider a complete decomposition of 3.237 g of $KClO_3$ $_{(s)}$ to yield $KCl_{(aq)}$ and O_2 $_{(g)}$ which is collected over water. Taking the ideal gas condition, calculate the volume of oxygen gas generated at 25^0C and at a total pressure of 1.00 atm when the value of vapour pressure of water at 25^0C is 23.8 Torr. **[5 marks]**

Given: mass of $KClO_3$= 3.237g, total pressure = 1.00 atm, vapour pressure at 25^0C = 23.8 Torr

Conversions: Temperature: 25 + 273K= 298K
Total Pressure: 23.8 Torr X 1 atm/760 Torr= 0.0313atm*[0.5]*
Balanced chemical equation for the complete decomposition of $KClO_3$:
$2KClO_{3(s)} \rightarrow 2KCl_{(aq)} + 3O_{2(g)}$ [1]
Number of moles of oxgen gas:

$$n_{O2} = \frac{massofKClO_3}{MolecularweightofKClO_3} x \frac{3molO_2}{2molKClO_3}$$

$n_{(O2)}$ = 0.0396 mol*/1/*Pressure of oxygen:$P_{O2} = P_{tot} - P_{vap}$ = 1.00 atm – 0.0313 atm = 0.9687 atm*/0.5/*

Volume of O_2:

From the ideal gas equation:

$$V_{O2} = \frac{n_{O_2}RT}{P} = 0.0396mol \frac{x\frac{0.0821Latm}{Kmol}x298K}{0.969atm} = 1.00L \qquad [2]$$

====THE END