THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2022/23 ACADEMIC YEAR
TERM II TEST ONE
CHEMISTRY (CH 110)

TIME ALLOWED: Two (2) Hours.

DATE: 06 / 04 / 2023

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) Define each of the following terms applied in the scientific method:
   (i) Hypothesis (ii) theory (iii) law [3]

b) Use exponential notation to express the number 101.325 to:
   (i) One significant figure. [1]
   (ii) Five significant figures. [1]

c) State the difference between precision and accuracy. [2]

d) Perform the following mathematical operations, and express each result to the correct number of significant figures.
   (i) $(9.04 - 8.23) + 21.954 + 81.0) \div 3.1416$ [2]
   (ii) $\frac{0.470}{0.623} + \frac{80.705}{0.4326} - \frac{2.526}{3.1}$ [2]

e) Show your understanding of metric prefixes by giving the name to the unit that equals the following:
   (i) 10^{-9} gram (ii) 10^{+9} gram (iii) 10^{-15} metre [3]

f) Convert each of the following temperatures from degrees Celsius to Kelvin:
   (i) –38.9 °C (ii) 119.3 °C [4]

g) State the chemical formula of each of the following compounds:
   (i) Perchloric acid (ii) Phosphorus pentachloride [4]

h) Europium has two isotopes whose relative abundances are 48 % and 52 %. Given that the average atomic mass of Europium is 151.96 amu and the mass of an isotope with relative abundance of 52 % is 152.92 amu. Determine the mass of the isotope whose relative abundance is 48%. [3]

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

Compound A (Fe_xO_y) comprises of 30.02% oxygen.

a) Determine the actual value of x and y [4]
b) Write down the systematic name of compound A [1]
c) If 50.0 g of compound A reacts with 40.0 g of carbon monoxide to produce iron metal and carbon dioxide gas, prove that compound A is a limiting reagent in this reaction. [10]
d) 0.658 g of a compound containing only carbon, hydrogen and oxygen is burned in excess oxygen gas, 1.285 g of carbon dioxide and 0.658g of water are produced. If the molar of the compound is determined to be 90g/mol. Determine the molecular formula. [10]

QUESTION THREE (REACTION IN AQUEOUS SOLUTION) [25 Marks]

a) Predict whether mixing each pair of the following solutions will result in the formation of a precipitate. If so, identify the precipitate. [5]

i. $KOH_{(aq)}$ and $H_3PO_{4(aq)}$
ii. $K_2CO_{3(aq)}$ and $BaCl_{2(aq)}$
iii. $Ba(NO_3)_{2(aq)}$ and $Na_2SO_{4(aq)}$

b) Calculate the oxidation state of each of the following:
i. Cr in $Cr_2O_7^{2-}$ [2]
ii. S in H_2SO_4 [2]

c) Given the following reaction:

$$CuS(s) + NO_3^-{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + NO_{(g)}$$

i. Identify the oxidizing and reducing agents [4]
ii. Write the two half reaction equations specifying which one is the oxidation half reaction and which one is the reduction half reaction. [4]
iii. Balance each of the two half reaction equations. [4]
iv. Considering that the reaction is taking place in acidic medium, write the overall balanced equation for this redox reaction. [4]

QUESTION FOUR (GASES) [25 marks]

a) Gas laws help us to understand the behaviour of gases under different conditions of temperature, pressure, and volume.
i. State Boyle's Law [1]
ii. Sketch a graph of pressure against volume for the law in (i) [1]

b) If 22.5 L of nitrogen at 748 mm Hg are compressed to 725 mm Hg at constant temperature.
i. What is the new volume? [2]
ii. What is the Volume in litres at STP of 50 g of nitrogen (N_2)? [2]
iii. State the gas laws applied in (i) and (ii) above. [2]

c) A mole of a gas at 450 K has a density of 1.41 g/dm^3 at 2.0 atm. What is the density of the gas at STP? [4]

d) Dalton, a renowned scientist talked about partial pressures in the atmosphere.
i. State the Dalton's law of partial pressures. [2]
ii. What is the partial pressure in the atmosphere? [2]

e) At -18 °C, a 2L mixture of helium, nitrogen, and neon has a total pressure of 815 mmHg. What mass of neon is present in the mixture if the partial pressure of helium is 201 mmHg and the partial pressure of nitrogen is 351 mmHg? [9]

QUESTION ON (INTRODUCTION TO GENERAL CHEMITRY) [25 marks]

a) Define each of the following terms applied in the scientific method:

(i) **Hypothesis:** This is tentative explanation for a set of observations [B1]

(ii) **Theory:** This is a unifying principle that explains a body of facts and laws that are on them. [B1]

(iii) **Law:** A law is a concise verbal or mathematical statement of a relationship between phenomena that is always the same under the same conditions. [B1]

b) Use exponential notation to express the number 101.325 to:

(i) One significant figure: **Answer**: $\mathbf{1 \times 10^2}$ [A1]

(ii) Five significant figures: **Answer**: $\mathbf{1.0133 \times 10^2}$ [A1]

c) State the difference between precision and accuracy.

Answer: Precision is the degree of agreement among several measurements of the same quantity while accuracy refers to how closely a measured value agrees with the correct value. [B2]

d) Perform the following mathematical operations, and express each result to the correct number of significant figures.

(i) $(9.04 - 8.23 + 21.954 + 81.0) \div 3.1416$

$= 103.8 \div 3.1416$

$= \mathbf{33.0}$ [A2] (Deduct 1 mark if number of sig. figs is wrong)

(ii) $\frac{0.470}{0.623} + \frac{80.705}{0.4326} - \frac{2.526}{3.1}$

$= 0.754 + 186.6 - 0.81$

$= 186.544$

$= \mathbf{186.5}$ [A2] (Deduct 1 mark if number of sig. figs is wrong)

e) Show your understanding of metric prefixes by giving the name to the unit that equals the following:

(i) 10^{-9} gram ⇒ nanogram [B1]

(ii) 10^{+9} gram ⇒ gigagram [B1]

(iii) 10^{-15} metre ⇒ femtometer [B1]

f) Convert each of the following temperatures from degrees Celsius to Kelvin:

(i) –38.9 ℃ ⇒ –38.9 ℃ + 273.15 = **234.3 K** [A2] (Deduct 1 mark if number of sig. figs is wrong)

(ii) 119.3 ℃ ⇒ 119.3 ℃ + 273.15 = **392.5 K** [A2] (Deduct 1 mark if number of sig. figs is wrong)

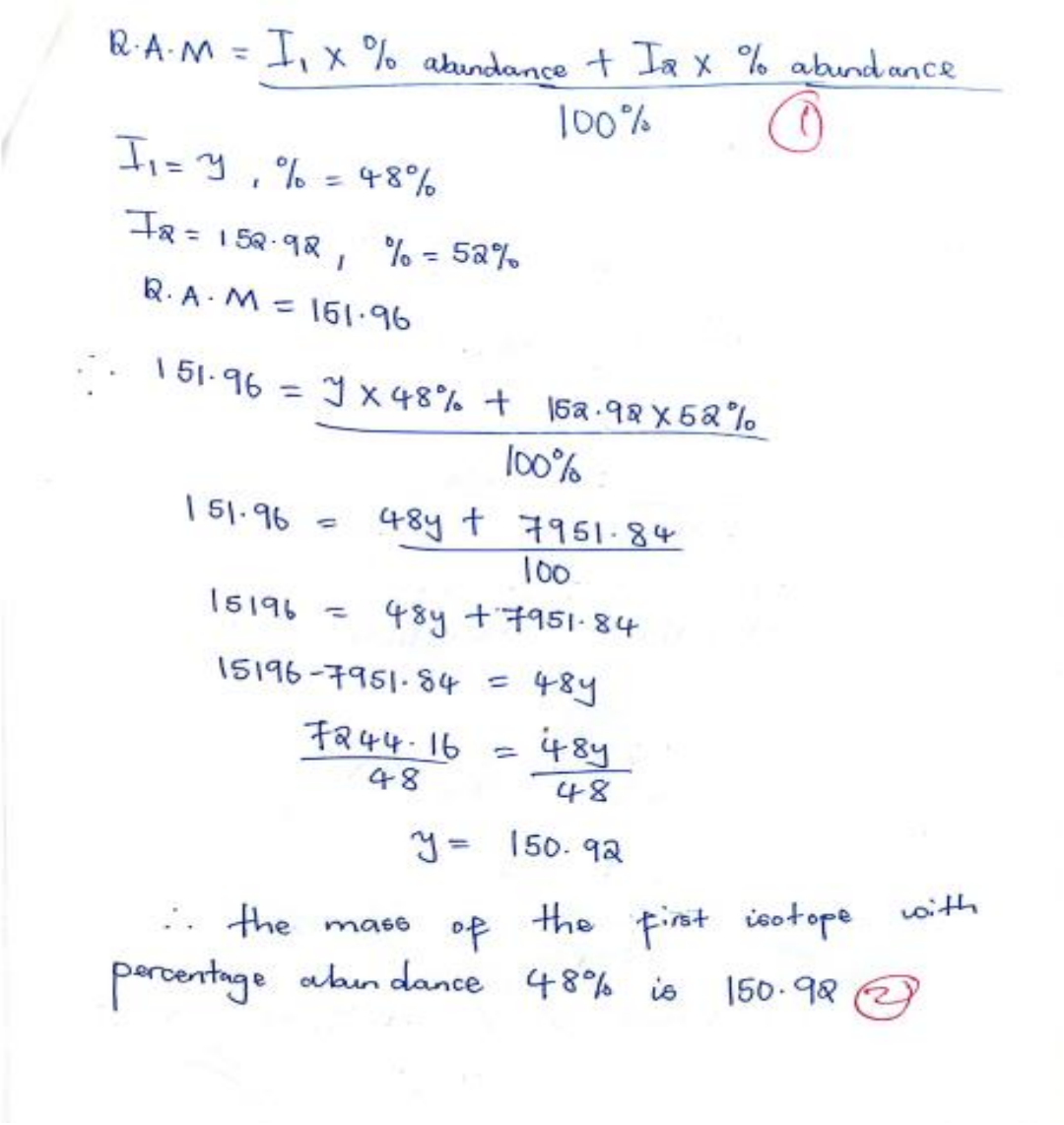
g) State the chemical formula of each of the following compounds:

(i) Perchloric acid ⇒ $HClO_4$ [B2]

(ii) Phosphorus pentachloride ⇒ PCl_5 [B2]

h) Europium has two isotopes whose relative abundances are 48 % and 52 %. Given that the average atomic mass of Europium is 151.96 amu and the mass of an isotope with relative abundance of 52 % is 152.92 amu. Determine the mass of the isotope whose relative abundance is 48%.

Answer:

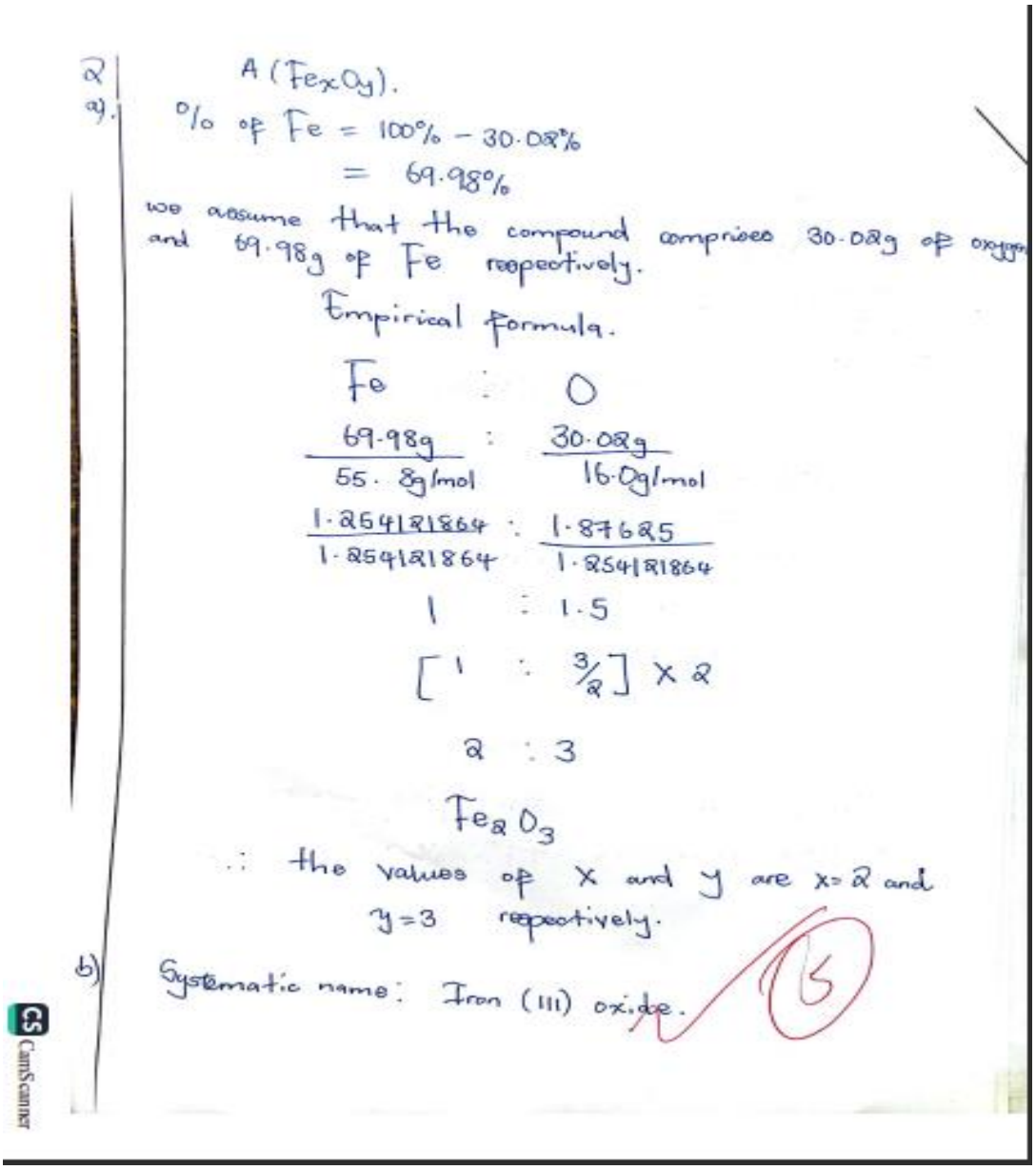


QUESTION TWO (STOICHIOMETRY AND THE MOLE CONCEPT) [25 marks]

a). Compound A (Fe_xO_y) comprises of 30.02% oxygen.

i. Determine the actual value of x and y **[4]**

Ans:



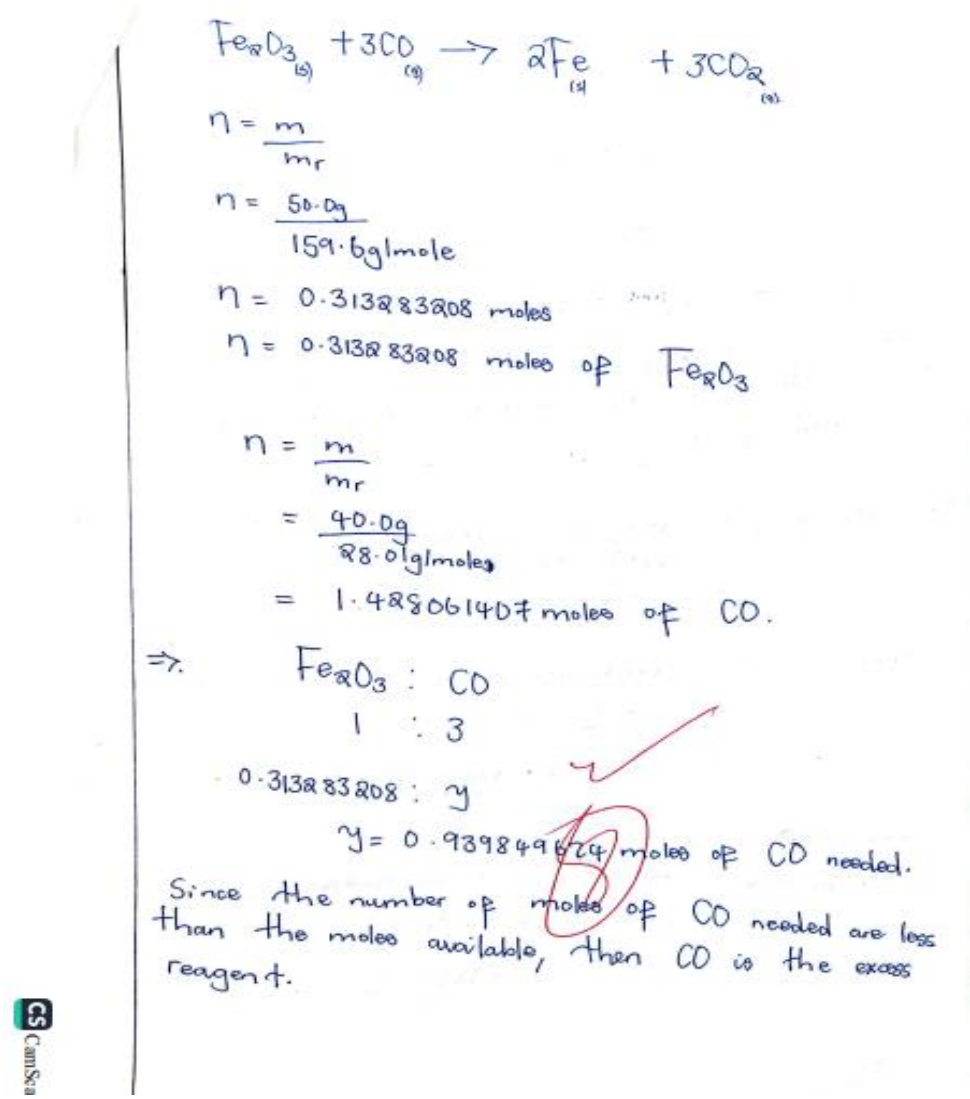
ii. Write down the systematic name of compound A **[1]**

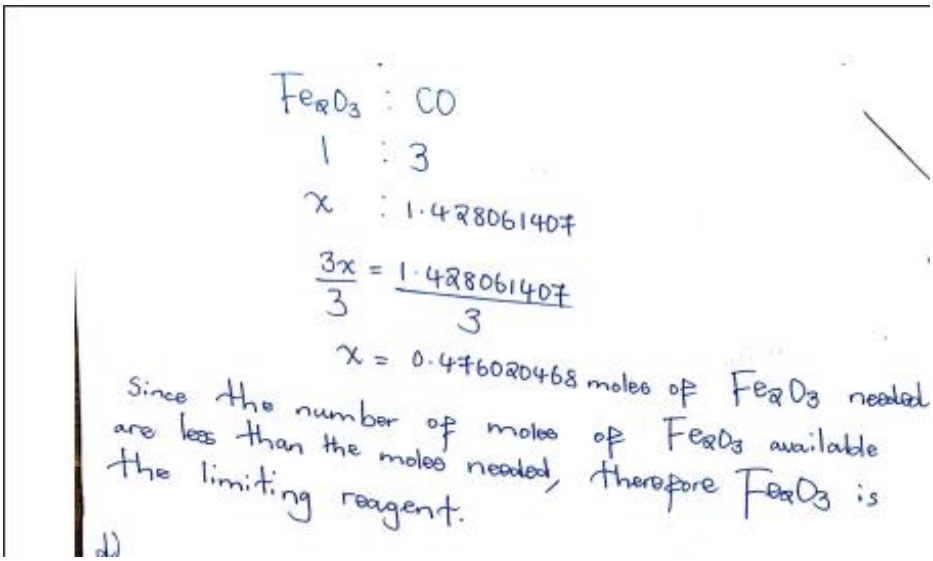
Ans:

Iron (III) oxide [1]

iii. If 50.0 g of compound A in (i) reacts with 40.0 g of carbon monoxide to produce iron metal and carbon dioxide gas, prove that compound A is a limiting reagent in this reaction. **[10]**

Ans:





a) 0.658 g of a compound containing only carbon, hydrogen and oxygen is burned in excess oxygen gas, 1.285 g of carbon dioxide and 0.658g of water are produced. If the molar of the compound is determined to be 90g/mol. Determine the molecular formula. [10]

Ans:

d). mass of C = $\frac{12.01 g/mole}{44.01 g/mole} \times 1.285 g$

= 0.350666893g of C.

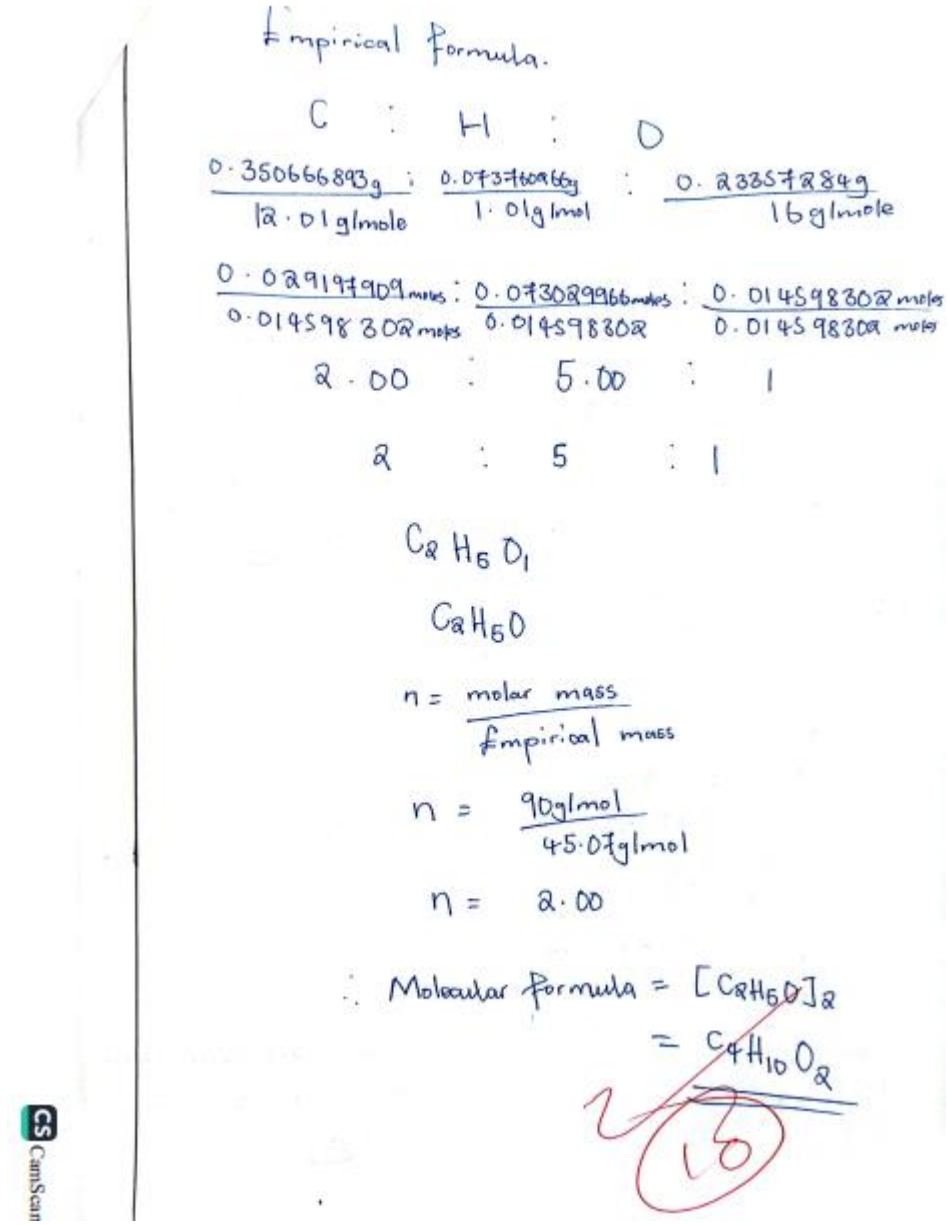
mass of H = $\frac{2.02 g/mole}{18.02 g/mole} \times 0.658 g$

= 0.073760266g of H.

Mass of O present in the sample = 0.658g − (0.350666893g + 0.073760266g)

= 0.658g − 0.424427159g

= 0.233572984g of O.



REACTIONS IN AQUEOUS SOLUTIONS (SOLUTIONS)

a) Predict whether mixing each pair of the following solutions will result in the formation of a precipitate. If so, identify the precipitate.

i. $KOH_{(aq)}$ and $H_3PO_{4(aq)}$
ii. $K_2CO_{3(aq)}$ and $BaCl_{2(aq)}$
iii. $Ba(NO_3)_{2(aq)}$ and $Na_2SO_{4(aq)}$

PAIR OF SOLUTIONS	PPT FORMS OR NOT	IDENTITY OF PPT	Marks
i. $KOH_{(aq)}$ and $H_3PO_{4(aq)}$	No ppt	-	1
ii. $K_2CO_{3(aq)}$ and $BaCl_{2(aq)}$	Precipitate forms	$BaCO_3$	2
iii. $Ba(NO_3)_{2(aq)}$ and $Na_2SO_{4(aq)}$	Precipitate forms	$BaSO_4$	2

b) Calculate the oxidation state of each of the following:

i. Cr in $Cr_2O_7^{2-}$

ii. S in H_2SO_4

Question b(i)	Question b(ii)
Cr in $Cr_2O_7^{2-}$	S in H_2SO_4
$2x + 7(-2) = -2$ $2x - 14 = -2$ $X = +6$ 2 marks	$2(+1) + x + 4(-2) = 0$ $2 + x - 8 = 0$ $X = +6$ 2 marks

c) Given the following reaction:

$$CuS(s) + NO_3^-{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + NO_{(g)}$$

i. Identify the oxidizing and reducing agents

Oxidizing Agent is NO_3^- (2 marks)

Reducing Agent is CuS (2 marks)

ii. Write the two half reaction equations specifying which one is the oxidation half reaction and which one is the reduction half reaction.

Oxidation Half-Reaction: $CuS(s) \rightarrow Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$ (2 marks)

Reduction Half-Reaction: $NO_3^-{}_{(aq)} \rightarrow NO_{(g)}$ (2 marks)

iii. Balance each of the two half reaction equations.

Balanced Oxidation Half-Reaction:

$4H_2O_{(l)} + CuS_{(s)} \rightarrow Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + 8H^+{}_{(aq)} + 8e^-$ (2 marks)

Balanced Reduction Half-Reaction

$3e^- + 4H^+{}_{(aq)} + 3NO_3^-{}_{(aq)} \rightarrow NO_{(g)} + 2H_2O_{(l)}$ (2 marks)

iv. Considering that the reaction is taking place in acidic medium Write the overall balanced equation for this redox reaction.

To balance the elections, multiply the oxidation reaction equation by 3 and the reduction reaction equation by 8 and then add the two new equations. (1 mark)

$8H^+{}_{(aq)} + 8NO_3^-{}_{(aq)} + 3CuS_{(s)} \rightarrow 3Cu^{2+}{}_{(aq)} + 3SO_4^{2-}{}_{(aq)} + 8H^+{}_{(aq)} + 8NO_{(g)} + 4H_2O_{(l)}$ (3 marks)

QUESTION 4: GASES (SOLUTIONS) (25 MARKS)

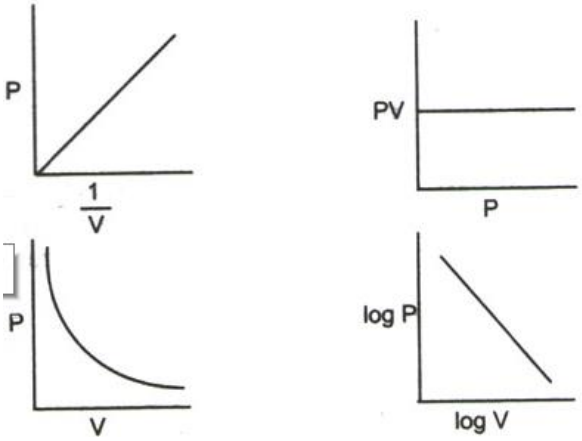
1. Gas laws help us to understand the behaviour of gases under different conditions of Temperature, pressure, and volume.

i. State Boyle's Law [1]

This law states that the pressure (P) of a fixed amount of gas is inversely proportional to the volume (V) for a given amount of gas at constant temperature

ii. Sketch a graph of pressure against volume for the law in (i) [1]

Either of the following graphs is correct;



2. If 22.5 L of nitrogen at 748 mm Hg are compressed to 725 mm Hg at constant temperature.

i. What is the new volume? [2]

$$P_1V_1 = P_2V_2$$

$$(748\ mmHg\ x\ 22.5\ L) = (725\ mmHg\ x\ V_2)$$

$$V_2 = 23.2\ L$$

ii. What is the Volume in litres at STP of 50 g of nitrogen (N_2)? [2]

Volume of one mole of any gas at STP is 22.4 L

$$50\ g\ x\ \frac{1\ mol}{28.19\ g}\ x\ \frac{22.4\ L}{1\ mol} = 39.8 \approx 40\ L$$

iii. State the gas laws applied in (i) and (ii) above. [2]

i. Boyles Law

ii. Avogadro's Law

3. A mole of a gas at 450 K has a density of 1.41 g/dm^3 at 2.0 atm. What is the density of the gas at STP? [4]

$$\frac{P_1}{T_1 d_1} = \frac{P_2}{T_2 d_2}$$

Making d_2 the subject of the formula yields

$$d_2 = \frac{T_1 d_1 P_2}{T_2 P_1} = \frac{450 \times 1.0 \times 1.41}{2 \times 273}\frac{g}{dm^3} = 1.16\ g\ dm^{-3}$$

4. Dalton, a renowned scientist talked about partial pressures in the atmosphere.

i. State the Dalton's law of partial pressures. [2]

Dalton's partial pressure law states that when two or more gases that do not react chemically are enclosed in a vessel, the total pressure equals the sum of their partial pressures

ii. What is the partial pressure in the atmosphere? [2]

At sea level, the atmospheric pressure is 760 mm Hg, the partial pressures of the various gases can be estimated to be varying for nitrogen, oxygen, argon etc.

5. At -18 ^{o}C, a 2L mixture of helium, nitrogen, and neon has a total pressure of 815 mmHg. What mass of neon is present in the mixture if the partial pressure of helium is 201 mmHg and the partial pressure of nitrogen is 351 mmHg? [9]

P_{Total} = 815 mmHg

P_{He} = 201 mmHg

P_{N} = 351 mmHg

$P_{Total} = P_{He} + P_{N} + P_{Ne}$ [1]

P_{Ne} = 815 – 201 – 351 = 263 mmHg = 0.346 atm [2]

Using the ideal gas law PV = nRT;

$T = 273 + (-18) = 255K$ [1]

$n = \frac{pV}{RT} = \frac{0.346\ atm\ x\ 2\ L}{0.082\frac{L.atm}{mol.K}\ x\ 255K}$ [2]

$n = 0.03307$ moles of Ne [1]

Converting moles into grams;

$m = n\ x\ Mr = 0.03307\ mol\ x\ 20.18\frac{g}{mol} = 0.67\ g$ [2]