Name.........MARKING GUIDE.........stream..................

P525/1
CHEMISTRY (theory)
Paper 1
2 ¾ Hours

MENGO SENIOR SCHOOL

S.5 END OF TERM I EXAMINATIONS 2024

Chemistry

Paper 1

Duration: 2hours 45minutes

INSTRUCTIONS TO STUDENTS:

- *Answer all questions in BOTH section A AND section B.*
- *All questions must be answered in the spaces provided.*
- *The periodic table, with relative atomic masses, is attached at the end of the paper.*
- *Mathematical tables (3 -figure tables) are adequate or non-programmable scientific electronic calculators may be used.*
- ***Illustrate your answers with equation(s) where applicable.***

Where necessary, use the following:
Molar as constant, R=8.314$Jk^{-1}mol^{-1}$ or 0.0821$atmdm^3mol^{-1}k^{-1}$
Molar volume of gas at s.t.p is 22.4dm^3.
Standard temperature = 273K.
Standard pressure = 101325Nm^{-2} / 1atm/ 760mmHg
Use; C=12, H=1, O=16, Na=23,

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
6	5	5	6	5½	6	5	4½	3	9	9	9	9	9	9	100%

46 54

SECTION A (46MARKS)

1. When 192cm^3 of excess oxygen was exploded with 12cm^3 of a gaseous hydrocarbon Q, C_xH_y followed by cooling ,the residual gases occupied 174cm^3. After bubbling the residual gases through concentrated potassium hydroxide the volume reduced by 72cm^3 when all gases were measured the same temperature and pressure.

a) Write an equation for the reaction between the hydrocarbon Q and oxygen. (1 ½ marks)

$$C_xH_{y(g)} + \left(x+\frac{y}{4}\right)O_{2(g)} \longrightarrow xCO_{2(g)} + \frac{y}{2}H_2O_{(l)}$$ 1½

b) Explain with an equation of reaction the purpose of passing the residual gases through concentrated potassium hydroxide. (1 ½ marks)

The Concentrated Potassium hydroxide helps remove/absorb Carbon dioxide gas.

$$2KOH_{(aq)} + CO_{2(g)} \longrightarrow K_2CO_{3(aq)} + H_2O_{(l)}$$ 1½

d) Calculate the molecular for of the hydrocarbon Q. (3marks)

Volume of total O_2 = 192cm^3
Volume of Q = 12cm^3
Residual gas Volume = 174cm^3
Volume of CO_2 = 72.
volume of excess O_2 = 174 − 72
= 102cm^3
volume of reacted O_2 = 192 − 102
= 90cm^3

	C_xH_y	O_2	CO_2	H_2O
mole ratio	1	$(x+\frac{y}{4})$	x	0
Volume ratios	12cm^3	90cm^3	72cm^3	0
mole ratio	$\frac{12}{12}$	$\frac{90}{12}$	$\frac{72}{12}$	0
	1	7.5	6	0

3

By Comparison:
$x = 6$

$6 + \frac{y}{4} = 7.5$
$\frac{y}{4} = 7.5 - 6$
$y = 1.5 \times 4$
$y = 6$

∴ Molecular formula of Q is C_6H_6

2. a) State

i) Pauli's exclusion principle (1mark)

It states that no two electrons in an atom can have the same set of quantum numbers.

(OR An orbital can only be occupied by a maximum ~~two~~ two electrons provided they have opposite spins.)

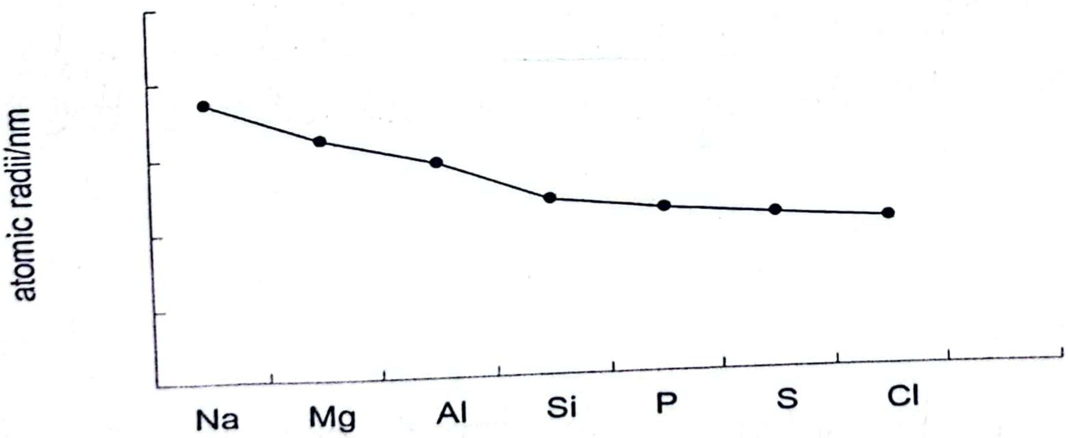
ii) Hund's rule of maximum multiplicity (1mark)

It states that within a subshell, electrons occupy the degenerate orbitals singly with parallel spins before pairing up with opposite spins occurs. 1

b) By using the spdf -notation briefly explain the significance of Pauli's exclusion principle and Hund's rule in arrangement of electrons in an oxygen atom whose atomic number 8. (3marks)

Electrons are filled in an oxygen atom starting with lower energy levels. The 1s and 2s orbitals are each occupied by two electrons each with opposite spins up and down, following Pauli's principle.
The three degenerate 2p orbitals ($2p_x$, $2p_y$ and $2p_z$) are each first filled singly according to Hund's rule ($2p_x^1$, $2p_y^1$ $2p_z^1$) with parallel spins before pairing occurs giving a more stable arrangement. 3

3. The figure below shows a sketch graph for variation of atomic radii across period 3 elements.



a) Explain what is meant by the term **atomic radius**. (1 ½ marks)

Atomic radius is half the distance between the nuclei of two similar atoms of an element in a given bonding situation.

Atomic radius $r_1 = \frac{1}{2}d$.

$1\frac{1}{2}$

b) i). State the two factors that determine the atomic radius of an element. (1mark)

- Nuclear charge
- Screening effect.

1

ii) State the trend in atomic radius across period 3 elements. ($\frac{1}{2}$ mark)

Atomic radius decreases across the period from Na to Cl

$\frac{1}{2}$

ii) Explain your answer in b) ii) above. (2marks)

This is because the increase in nuclear charge due to addition of a proton to the nucleus outweighs the slight increase in screening effect due to addition of an electron to the same shell. As a result nuclear attraction on the our electrons increases which leads to reduction in the radius of the atoms across the period.

2

4. To $25cm^3$ of sodium hydroxide solution was added $50cm^3$ of a 0.5M hydrochloric acid. The excess acid required $22.30cm^3$ of 0.25M sodium hydroxide solution for complete neutralization.

a) Write equation for the reaction. (1mark)

$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

1

b) Calculate;

i) the number of moles of excess hydrochloric acid (2marks)

$1000cm^3$ of NaOH contains 0.25 moles

$22.30cm^3$ of NaOH ~~can~~ contains $\left(\frac{0.25 \times 22.30}{1000}\right)$ moles

$= 0.005575$ moles 2

1 mole of NaOH reacts with 1 mole of excess HCl

0.005575 moles of NaOH reacts with $\left(\frac{1}{1} \times 0.005575\right)$

$= 0.005575$ moles of excess HCl

ii) the concentration in g/dm^3 of the original sodium hydroxide solution.(3marks)

$1000cm^3$ of ~~total~~ HCl contains 0.5 moles

$50cm^3$ of ~~total~~ HCl contain $\left(\frac{0.5 \times 50}{1000}\right)$

$= 0.025$ moles

Moles HCl reacted with original NaOH $= 0.025 - 0.005575$

$= 0.019425$ moles

1 mole of HCl reacted with 1 mole of NaOH

$\therefore$ Moles of original NaOH $= 0.019425$ moles

$25cm^3$ of original NaOH contains 0.019425 moles

$1000cm^3$ of original NaOH contain $\left(\frac{0.019425 \times 1000}{25}\right)$

0.777M ~~0.1694M~~ 3

RFM of NaOH $= 23+16+1$

$= 40g$

concentration of original NaOH $= 0.777 \times 40$

$= 31.08 g/dm^3$

5. a) State what is meant by the term ;

i) partial pressure of a gas (1mark)

This is the pressure that a gas would exert if it occupied an entire volume alone that was originally occupied by a mixture of gas at the same temperature.

Deny mark without condition

ii) Mole fraction of a gas (1mark)

This is the ratio of the number of moles of that gas to the total number of moles of all gases present in the mixture.

1

b) State Dalton's law of partial pressures (1mark)

It states that for a mixture of gases that do not react with each other, the total pressure is equal to the sum of the partial pressures of each individual gas in the mixture at a constant temperature.

C) A container is filled with nitrogen, oxygen and argon and the total pressure exerted is 785mmHg. If the partial pressures of Nitrogen and oxygen are 615mmHg and 125 mmHg respectively, Calculate;

i) the partial pressure of Argon. ($1\frac{1}{2}$ marks)

$P_T = P_{Ar} + P_{N_2} + P_{O_2}$

$785 = P_{Ar} + 615 + 125.$

$\therefore P_{Ar} = 785 - (615 + 125).$

$P_{Ar} = \underline{45 \text{ mmHg}}$

1

ii) mole fraction of each gas ($1\frac{1}{2}$ marks)

Mole fraction of $X_{N_2} = \frac{P_{N_2}}{P_T}$

$= \frac{615}{785}$

$X_{N_2} = 0.78344$ mole

Mole fraction of $XO_2 = \frac{P_{O_2}}{P_T} = \frac{125}{785}$

$X_{O_2} = \underline{0.15924 \text{ moles}}$

Mole fraction of Ar, $X_{Ar} = \frac{P_{Ar}}{P_T}$

$= \frac{45}{785}$

$X_{Ar} = \underline{0.05732 \text{ moles}}$

$1\frac{1}{2}$

6. When 0.870g of an organic compound Z were exploded with excess oxygen 1.980g of carbon dioxide and 0.810g of water were formed. In a victor Meyer's determination 0.058g of Z displaced 24.2cm^3 of air measured at 15°C and 98650Nm^{-2} of pressure. Calculate;

a) The empirical formula of Z . (3marks)

RMM of $CO_2 = 12+16\times2 = 44$
RMM of $H_2O = 2+16 = 18$
Mass of Carbon $= \frac{12}{44}\times 1.980$
$= 0.54g$
(OR)
Percentage of Carbon $= \frac{12}{44}\times\frac{1.980}{0.870}\times100$
$= 62.07\%$
Mass of H $= \frac{2}{18}\times 0.810$
$= 0.09g$
Percentage of H $= \frac{0.09}{0.870}\times100 = 10.34\%$
Mass of oxygen $= 0.870-(0.54+0.09)$
$= 0.24g$

Elements	C	H	O
Masses	0.54	0.09	0.24
Moles	$\frac{0.54}{12}$ $= 0.045$	$\frac{0.09}{1}$ 0.09	$\frac{0.24}{16}$ 0.015
Mole ratio	$\frac{0.045}{0.015}$:	$\frac{0.09}{0.015}$:	$\frac{0.015}{0.015}$
Simplest ratio	3	6 :	1

∴ Empirical formula is C_3H_6O

3

b) the molecular mass of Z, hence deduce the molecular formula of Z. (3marks)

$Mr = \frac{mRT}{PV}$

$= \frac{0.058\times8.314\times(15+273)}{98650\times24.2\times10^{-6}}$

$Mr = 58.2$
Thus molecular mass of Z is
58.2g

Let molecular formula be $(C_3H_6O)_n$
$n = \frac{58.2}{(12\times3+6\times1+16)}$
$n = 1$
∴ Molecular formula of Z is C_3H_6O

3

7. Sodium hydroxide and concentrated sulphuric acid cannot be used as primary standards for acid-base titration.

a) What is meant by the term primary standard? (1mark)

This is a highly pure substance of known concentration that is used to accurately determine the concentration of another substance.

1

b) State reasons why sodium hydroxide and concentrated sulphuric acid are not primary standards. (1 ½ marks)

Solid Sodium hydroxide is deliquescent and Solution readily absorbs atmospheric carbondioxide and concentrated sulphuric acid is hygroscopic. 1½

c) i) State three properties of a primary standard. (1 ½ marks)

- It is highly soluble in water or chosen solvent in all proportions
- It reacts readily with the investigated substance.
- It is highly pure
- It should be stable under all conditions.

1½

ii) Suggest two examples acid-base primary standards. (1mark)

- Borax. - Hydrochloric acid.
- Anhydrous Sodium carbonate.
- oxalic acid.

1

8. a) Define the term '**atomic orbital**'. (1mark)

This is space in an atom where there is the highest probability of finding an electron.

1

b) *p,d and f* -orbitals are said to be degenerate orbitals.

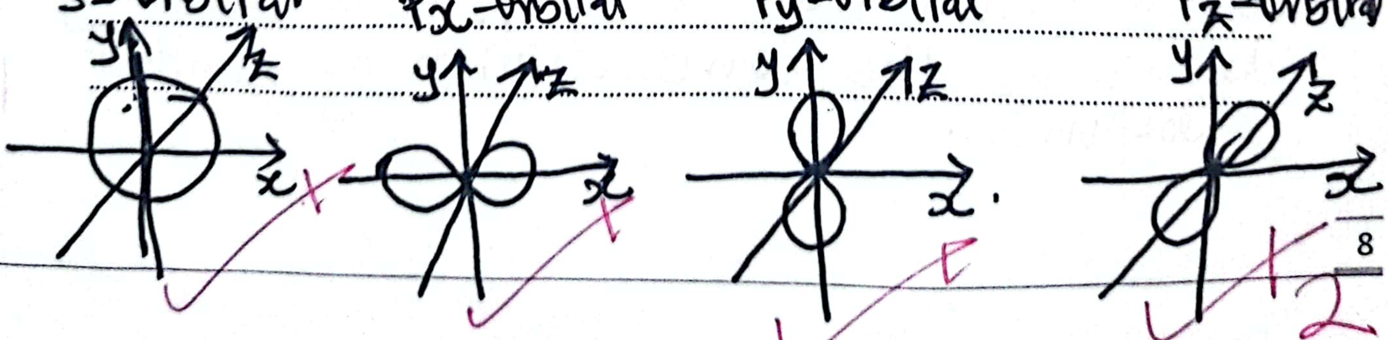
i) Explain this statement. (1mark)

These are orbitals within the same shell that have identical energies (or have same energy level) (but may differ in spartial orientation)

1

ii) Draw sketch diagrams for the shapes of the s-orbital and each of the three p-degenerate orbitals along x,y and z-axes (2marks)

S-orbital Px-orbital Py-orbital Pz-orbital



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iii) Give a reason why potassium is known as an s-block element. ($\frac{1}{2}$ mark)

It differentiating electron (or last electron) is filled in its s-orbital. ½

9. a) State the three key assumptions of a gas to be considered an ideal gas. ($1\frac{1}{2}$ marks)

① Particles of the gas have negligible intermolecular forces of attraction.

② Particles of the gas occupy a negligible volume.

③ Collisions between particles and container walls are perfectly elastic.

1½

b) State three reasons why gases like carbon dioxide deviate from ideal gas behavior. ($1\frac{1}{2}$ marks)

- Carbondioxide molecules are relatively larger compared to ideal gases.
- The molecules have significant intermolecular forces of attraction
- presence of temporary polarity in molecules as ~~temperature~~ pressure is increased.

1½

SECTION B (54MARKS)

10. a) The atomic numbers of sodium and chlorine are 11 and 17 respectively. Write the electronic configurations of sodium and chlorine

i) In their ground states (1mark)

Na: $1s^2 2s^2 2p^6 3s^1$

Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$

3rd state $1s^2 2s^2 2p^6 3s^1 3p^3 3d^2 4s^1$

ii) In the excited state (1mark)

Na : $1s^2 2s^2 2p^6 3s^0 3p^1$ or $1s^2 2s^2 2p^6 3p^1$

1st excited state Cl : $1s^2 2s^2 2p^6 3s^2 3p^4 4s^1$ or $1s^2 2s^2 2p^6 3s^2 3p_x^2 3p_y^1 3p_z^1 4s^1$

2nd state $1s^2 2s^2 2p^6 3s^2 3p^3 3d^1 4s^1$

iii) In their combined states (3marks)

In combined state the sodium atom loses one electron to become a sodium ion (Na^+) with configuration $1s^2 2s^2 2p^6$ while the chlorine atom gains the electron to form a chloride ion with configuration $1s^2 2s^2 2p^6 3s^2 3p^6$.

3

b) The atomic numbers of manganese and iron are 25 and 26 respectively.
Write the electronic configurations of;

i) Manganese and iron atoms (1mark)

Mn (25) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

Iron (26) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$.

ii) Manganese(II) ion and iron(II) ion (1mark)

Mn^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$.

Fe^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$.

c) Comment on the thermal dynamic stability of the configurations of the Manganese(II) ion and the iron(II). Explain your answer. (2marks)

Manganese (II) ion is stable because it has a half filled 3d subshell while Iron (II) ion is unstable since it has a partially filled 3d subshell with six electrons.

2

11. Carbon belongs to group IV of the periodic table but has certain unique character from the rest of the elements and is one of those few elements that undergo a process known as **hybridization**.

a) State three major reasons that enable carbon exhibit unique chemical properties. (1 ½ marks)

(i) It has the smallest atomic radius

(ii) It has the highest electronegativity

(iii) It lacks vacant orbitals.

1½

b) State three chemical properties exhibited by carbon that make it unique. (1 ½ marks)

- It has ability to form multiple bonds with itself and with other non-metals.
- It has ability to form long chains with itself.
- It forms cyclic compounds with itself and other non-metals

1½

c) i) State what is meant by the term **hybridization** as applied to chemistry. (1mark)

This is the process by which atomic orbitals mix up to form new hybrid orbitals that are well suited for bonding (or that are more energetically favourable)

ii) State three reasons why carbon undergoes hybridization process. (1 ½ marks)

(i) To optimize electron distribution.

(ii) To minimize electron repulsion

(iii) To form stronger and more stable bonds with other atoms.

1½

d) i) State two differences between compounds formed from SP^3-hybrodization and those formed from SP^2 – hybridization. (2marks)

(i) Compounds formed by sp^2 are more reactive than compounds formed by sp^3-hybrids.

(ii) Compounds formed by sp^2 are unsaturated while compounds formed by sp^3 are saturated.

2

ii) Name one group of hydrocarbons formed from each of the following type of hybridization. (1 ½ marks)

Sp³-hybridization: Alkanes

½

Sp^2-hybridization........ Alkenes ✓ 1

Sp-hybridization........ Alkynes ✓

12. a) State Graham's law of gaseous diffusion. (1 ½ marks)

At constant temperature and pressure the rate of diffusion of a gas is inversely proportional to the square root of its density. ✓ 1

b) Describe two factors that affect the rate of diffusion of gases. (2marks)

(i) When temperature is increased the kinetic energy of gas molecules increases such that the rate of diffusion increases. ✓ 2

(ii) When pressure is increased the rate of diffusion increases but decrease in pressure decreases the diffusion rate. ✓

c) State three applications of diffusion (1 ½ marks)

- Used in pharmaceuticals in drug delivery systems ✓
- used in biological systems such as transport of nutrients. ✓
- Used in food processing and preservation. ✓ 1½
- used in chemical separation such as separation of Helium.

d) $50cm^3$ of a gaseous alcohol Q, $C_nH_{2n+1}OH$ diffused through a small hole in 119.85 seconds. Under the same conditions the same volume of hydrogen diffused through the same hole in 21.85 seconds.

i) Calculate the molecular mass of Q (2 ½ marks)

$$\frac{\text{time taken by Q}}{\text{time taken by } H_2} = \sqrt{\frac{Mr_Q}{Mr_{H_2}}}$$

$$\frac{119.85}{21.85} = \sqrt{\frac{Mr_Q}{2}}$$

$$Mr_Q = 2\left(\frac{119.85}{21.85}\right)^2$$

$Mr_Q = 60$

∴ Molecular mass of Q is 60g ✓ 2½

$$Z = \frac{V_{real\ gas}}{V_{ideal\ gas}} \times \frac{P_{ideal\ gas}}{P_{real\ gas}}.$$

ii) Determine the molecular formula of Q. (1 ½ marks)

$12n + 2n + 1 + 16 + 1 = 60$
$14n + 18 = 60$
$14n = 60 - 18$
$14n = 42$
$n = \frac{42}{14}$
$n = 3$

∴ Molecular formula of Q, C_3H_7OH

1½

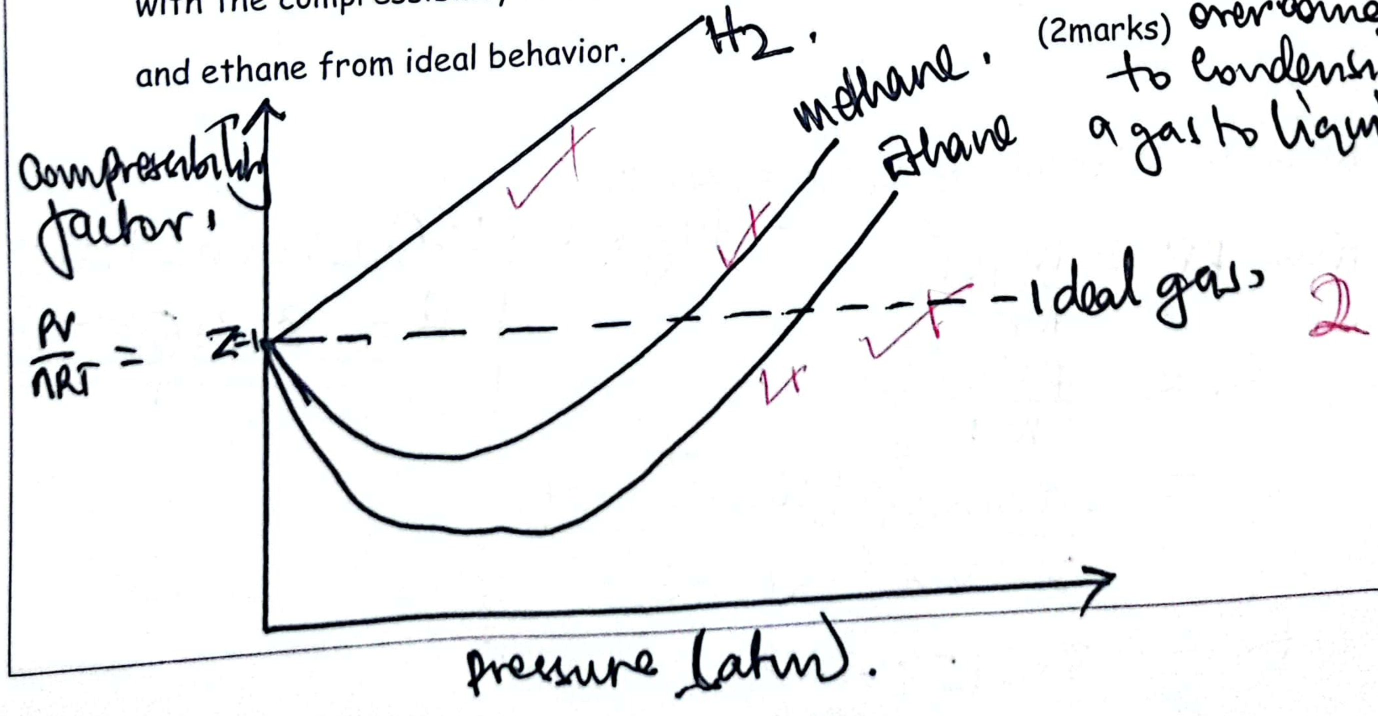
13. a) Define the term compressibility factor (Z) (1mark)

This is the ratio of the molar volume of a real gas to the molar volume predicted by an ideal gas law at the same temperature and pressure.

b) Sate and explain two conditions necessary for liquefying a gas. (3marks)

- Temperature below the critical temperature. Because below the critical temperature the intermolecular forces of attraction between molecules become stronger enough to overcome kinetic energy of the molecules causing them to condense into liquid. 1½
- Pressure above the critical pressure. Because this decreases the distance between gas molecules hence increasing the frequency of molecular collisions. this increases the forces of attraction such that thermal energy is overcome leading to condensing of a gas to liquid. 1½

d) i) On the same axes draw a sketch graph to show the variation of pressure with the compressibility factor showing the deviation of hydrogen, methane and ethane from ideal behavior. (2marks)



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ii) Explain the small deviation of hydrogen from ideal behavior (1 ½ marks)

Hydrogen molecules are very small such that they occupy little space. ~~Compar~~ As a result there are fewer intermolecular interactions, hence less deviation from ideal behaviour.

1½

iii) Explain the difference in deviation from ideal behavior of methane compared to ethane. (1 ½ marks)

Ethane molecules are heavier than methane molecules. As a result the intermolecular forces of attraction between ethane molecules are stronger than those between methane molecules. Hence ethane deviates more than methane.

1½

14.a) The ideal gas formula is given as $PV = nRT$ where R is the gas constant $0.0821 atmdm^3mol^{-1}K^{-1}$

i) State what each other later stands for and the Units of each. (2 marks)

P is pressure in atmospheres.

V is volume in cubic decimetres.

T is the temperature in Kelvin.

n is the number of moles of gas

2

ii) 2.20g of propane(C_3H_8) occupy $1,166cm^3$ at $15°C$ and exerts 1.027×10^5 Pa . Calculate the gas constant R in joules per mole kelvin. (2marks)

Molecular mass of $C_3H_8 = 12 \times 3 + 1 \times 8$

$= 44g$

From $PV = \frac{M}{Mr}RT$

$R = \frac{PV \times Mr}{MT}$

$= \frac{1.027 \times 10^5 \times 1,166 \times 10^{-6} \times 44}{2.20 \times (15+273)}$

$R = 8.315847222$

≈ 8.3

∴ Gas constant

$R = 8.31585 J/mol K$

2

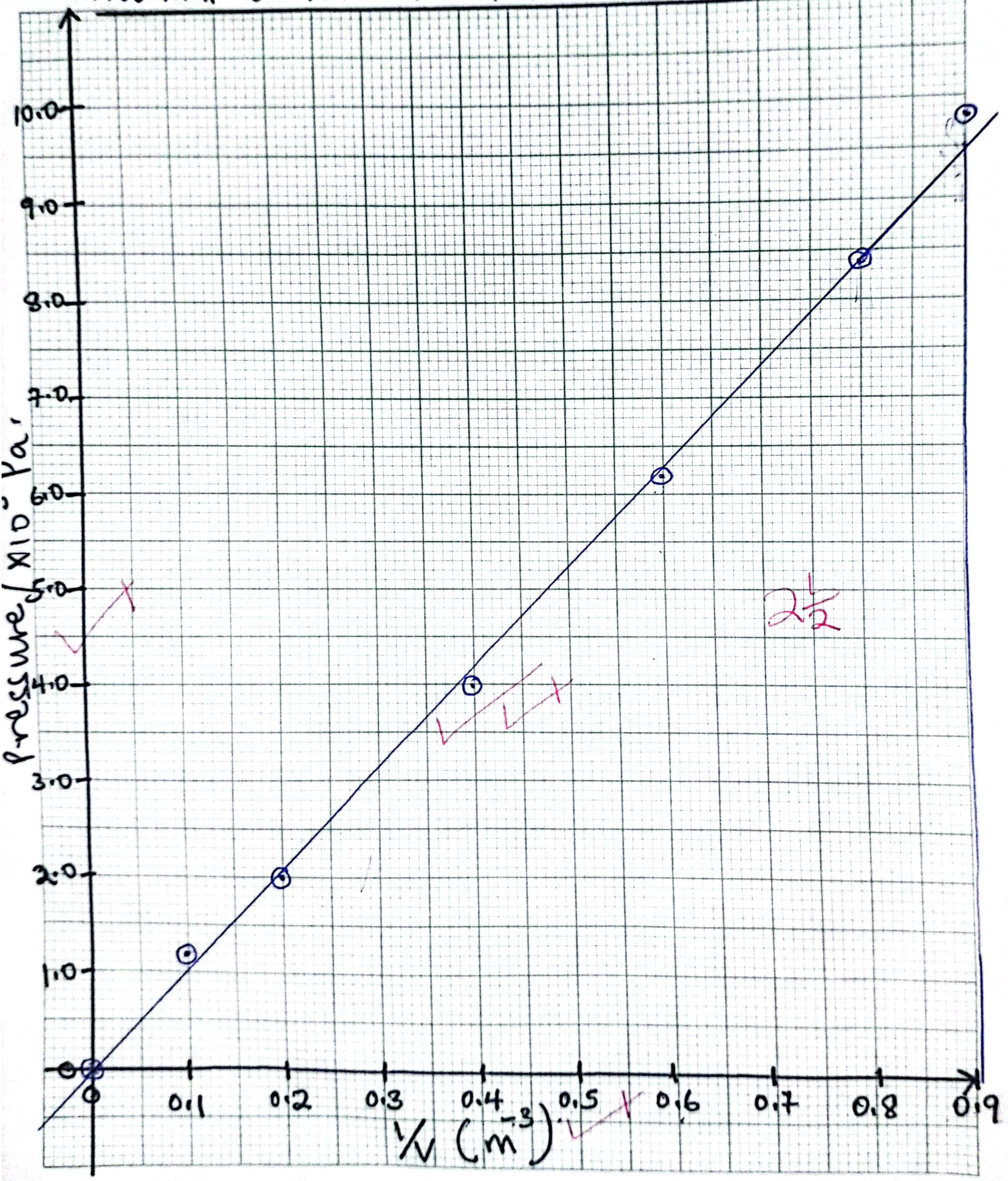
MENGO SENIOR SCHOOL

P.O. BOX 1901 KAMPALA -UGANDA

EXAMINATIONS' DEPARTMENT

NAME OF STUDENT .... DATE: ....

CLASS A GRAPH OF PRESSURE AGAINST RECIPROCAL OF VOLUME



$P = \frac{n}{V}RT$ $P = \frac{1}{V}(nRT)$

b) The table below shows experimental values obtained for an ideal gas B

Pressure/ $\times 10^5$ Pa	0	1.2	2.0	4.0	6.2	8.4	9.8
Reciprocal of volume, $\frac{1}{V}$(m^{-3})	0	0.1	0.2	0.4	0.6	0.8	0.9

i) Plot a graph of pressure against reciprocal of volume (2 ½ marks)

ii) Determine from your graph the number of moles of gas B at 5500K. (1 ½ marks)

$\text{Slope} = \frac{9.5\times10^5 - 0}{0.9 - 0}$

$= 1,055,556$

$nRT = 1,055,556$

$n = \frac{1,055,556}{RT}$

$\therefore n = \frac{1,055,556}{8.31585 \times 5500}$

$n = 23.079$ moles

∴ Number of moles is 23.079 moles

1½

iii) Hence determine the molecular mass of B if 641g were used. (1mark)

From $n = \frac{m}{Mr}$

$\Rightarrow Mr = \frac{m}{n}$

$Mr = \frac{641}{23.079}$

$Mr = 27.7742$

$\approx 28g$

∴ Molecular mass of B is 28g OR 27.8g.

1

15. a) An organic compound T consists of 49.3% carbon, 6.84% hydrogen the rest being oxygen .

i) Calculate the empirical formula of T. (C=12, H=1, O=16) (4marks)

Percentage of oxygen $= 100 - (49.3 + 6.84)$

$= 43.86\%$

Elements	C	H	O
percentages	49.3	6.84	43.86
Moles	$\frac{49.3}{12}$ $= 4.11$	$\frac{6.84}{1}$ $= 6.84$	$\frac{43.86}{16}$ $= 2.74$
Mole ratio	$\frac{4.11}{2.74}$	$\frac{6.84}{2.74}$	$\frac{2.74}{2.74}$
	1.5 :	2.5 :	1
Simplest ratio	2(1.5) :	2(2.5) :	2(1)
	3 :	5 :	2

Empirical formula is $C_3H_5O_2$

4

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ii) If 0.292g of T reacted completely with $268.8cm^3$ of hydrogen at s.t.p. Calculate the molecular mass of T. Hence deduce the molecular formula of T.
(1 mole of T reacts with 3moles of hydrogen gas.) (5marks)

$22400cm^3$ is occupied by 1mole of hydrogen

$268.8cm^3$ is occupied by $\left(\frac{1 \times 268.8}{22400}\right)$ moles

$= 0.012$ moles

3 moles of hydrogen reacted with 1mole of T

0.012 moles of hydrogen reacted with $\left(\frac{1}{3} \times 0.012\right)$ moles

$= 0.004$ moles of T

0.004 moles of T weigh 0.292 g

1 mole of T weighs $\left(\frac{0.292}{0.004}\right)$ g

$= 73g$

∴ Molecular mass of T

Let molecular formula be $(C_3H_5O_2)n$.

$n = \frac{73}{(3 \times 12 + 1 \times 5 + 16 \times 2)}$

$n = \frac{73}{73}$

$n = 1$

∴ Molecular formula of T is $\underline{\underline{C_3H_5O_2}}$

5

END