1st APRIL 2023
FOOL'S DAY.

Name:…………………………………………………………………………………………COMBN…………………

Signature: ……………………………………………………………….

P525/1
Chemistry
Paper 1
MARCH 2023
2 ¾ hours

UGANDA ADVANCED CERTIFICATE OF EDUCATION

S.5 CHEMISTRY

Paper 1

2 ¾ hour's

INSTRUCTIONS TO CANDIDATES:

- *Answer* **all** *questions in section* **A** *and* **any six** *questions in section* **B**
- *All questions must be answered in the spaces provided*
- *The Periodic Table, with relative atomic masses, is supplied.*
- *Mathematical tables(3 – figure tables) are adequate or non-programmable scientific electronic calculators may be used*
- *Illustrate your answers with equations where applicable.*

Where necessary, use the following:

- *Molar gas constant* $R = 8.31\ JK^{-1}\ mol^{-1}$
- *Molar volume of a gas at s.t.p is 22.4 litres.*
- *Standard temperature = 273 K*
- *Standard pressure =* $101325\ N\ m^{-2}$

For Examiner's Use Only																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total

SECTION A

1. (a) State Graham's law of diffusion. (01 mark)

The rate of diffusion of a gas is inversely proportion to the square root of its density at constant temperature and pressure. 01

Accept; Rate of diffusion of a gas $\propto \frac{1}{\sqrt{\text{Density}}}$; at constant temp and pressure

(b) A certain volume of oxygen diffused through a porous membrane in 120s. Under the same conditions, the same volume of a gas X diffused in 112s. Calculate the formula mass of X (03 marks)

Let the volume be $V cm^3$

Rate of diffusion of $O_2 = V/120 \; cm^3s^{-1}$, Rate of diffusion of $X = V/112 \; cm^3s^{-1}$

$$\frac{\text{Rate of diffusion of } O_2}{\text{Rate of diffusion of } X} = \sqrt{\frac{Mr_x}{Mr_{O_2}}}$$

03

$$\frac{V/120}{V/112} = \sqrt{\frac{Mr_x}{32}}$$

$$Mr_x = 27.88\,g.$$

(c) State one application of diffusion of gases (01mark)

01

- In separation of isotopes of Uranium.
- In extraction of helium from natural gas.
- In air bags of steering wheels of vehicles
- Application of pesticides or teargas or perfumes.

accept any correct alternative

2. $10.0cm^3$ of a hydrocarbon P (C_xH_y) was exploded in $90.0cm^3$ of oxygen gas. On cooling to room temperature, the residual gases occupied $70.0cm^3$, when the residual gases were passed through potassium hydroxide solution, the volume reduced to $40.0cm^3$.

a. (i). Write the equation for the reaction between hydrocarbon P and oxygen gas. (01 mark)

$$C_xH_{y(g)} + \left(x+\frac{y}{4}\right)O_{2(g)} \longrightarrow xCO_{2(g)} + \frac{y}{2}H_2O_{(l)}$$ 01

(ii).Determine the molecular formula of hydrocarbon P. (03 marks)

Volume of $CO_2 = (70.0 - 40.0) = 30.0cm^3$

Volume of excess $O_2 = 40.0cm^3$

Volume of used (reacted) $O_2 = (90.0 - 40.0) = 50.0cm^3$

From the equation; $10cm^3$ of C_xH_y reacted with $50.0cm^3$ of O_2 to produce $30.0cm^3$ of CO_2

$1cm^3$ of C_xH_y reacted with $\left(\frac{50.0}{10}\right) = 5$ of O_2 to produce $\left(\frac{30.0}{10}\right) = 3$ of CO_2

On Comparison; $x + \frac{y}{4} = 5$ and $x = 3$

$3 + \frac{y}{4} = 5$

$y = 8$

03

∴ Molecular formula of P is C_3H_8

b) Write the structural formula and name of P (01 mark)

$CH_3CH_2CH_3$ propane Accept; n-propane 01

3. (a) What is meant by first electron affinity? (01 mark)

The heat energy change that occurs when a gaseous atom gains an electron to form a uninegatively charged gaseous ion at standard temperature and pressure. Accept; the definition without standard conditions 01

Accept; ......one mole of electrons added to one mole of ----

(b) Write an equation for first electron affinity of oxygen. (01 mark)

01

$O_{(g)} + e \longrightarrow O^-_{(g)}$ 1^{st} E.A = −ve

Reject; If wrong state symbol used anywhere in the equation

Reject; If state symbol is missing.

(C). The first electron affinity of oxygen is negative while the second electron affinity is positive. Explain (03 marks)

In first electron affinity, an electron is added to a neutral gaseous atom and thus it is highly attracted by the nucleus and heat is given out during the process.

$O_{(g)} + e \longrightarrow O^{-}_{(g)}$ $-ve$

In second electron affinity, an electron is being added to already negatively charged gaseous ion, thus energy is absorbed to overcome the strong repulsive force between the two negatively charged species (uninegatively charged gaseous ion and an electron)

$O^{-}_{(g)} + e \longrightarrow O^{2-}_{(g)}$ $+ve$

03

4. The combustion of a hydrocarbon P gave 8.8g of carbon dioxide and 4.5g of water, if the molecular mass of P is 58. Determine the

(a) Empirical formula of P

Mass of C in $CO_2 = \left(\frac{12}{44} \times 8.8\right) = 2.4g$

Mass of H in $H_2O = \left(\frac{2}{18} \times 4.5\right) = 0.5g$

Elements	C	H
Composition	2.4	0.5
Moles	$\frac{2.4}{12}$	$\frac{0.5}{1}$
	0.2	0.5
Mole ratio	$\frac{0.2}{0.2}$	$\frac{0.5}{0.2}$
	$2 \times (1$	$2.5)$
Simplest ratio	2	5

∴ Empirical formula of P is C_2H_5

03½

(b) Molecular formula of P

$(C_2H_5)_n = 58$

$(12 \times 2)n + (1 \times 5)n = 58$

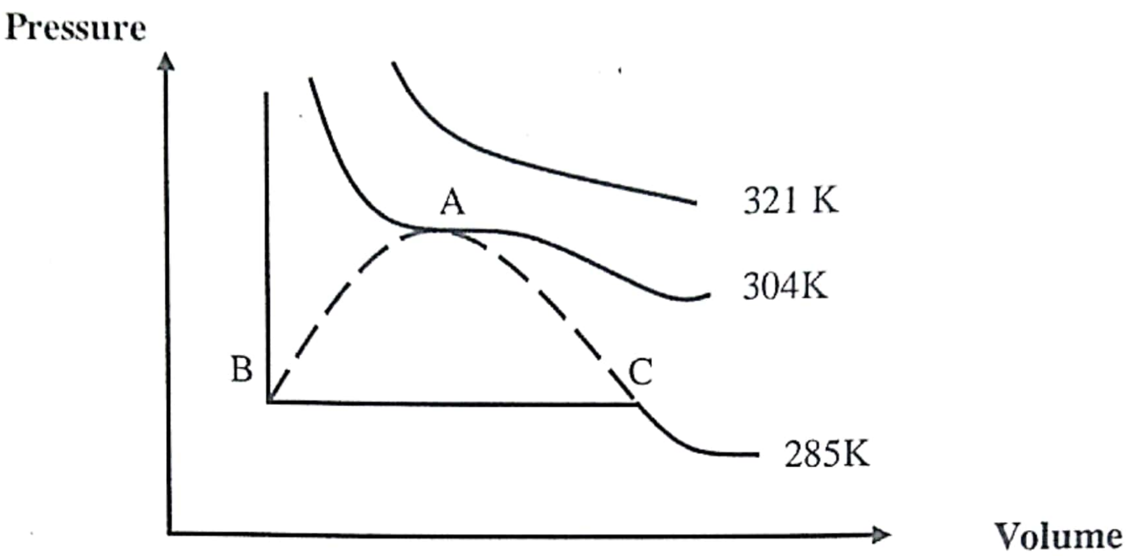
$n = 2$

$(C_2H_5)_2 = C_4H_{10}$

01½

∴ Molecular formula of P is C_4H_{10}

5. (a) The diagram below shows the isothermals of a gas.



(i) What is the critical temperature of the gas. (01 mark)

304K ✓ 01

(ii) Which isothermal almost represents an ideal gas. (01 mark)

321K ✓ 01

(iii) What does the region ABC represent. (01 mark)

The liquid is in equilibrium with its vapour. ✓ 01

(b) State two conditions for liquefying a gas. (01 mark)

A decrease in temperature ✓ (below the critical temperature)

An increase in pressure ✓ 01

6. Gas X has a vapour density of $2.615gdm^3$ at 25^0c at a pressure of 101Pa. Determine the molecular mass of gas X

From $PV = nRT$

$PV = \frac{m}{M_r}.RT$

$101 \times 1 \times 10^{-3} = \frac{2.615}{M_r} \times 8.314 \times 298$ 02½

$M_r = 64,147.04g.$

b) In another experiment gas X occupies a $225cm^3$ vessel at 7^0c and pressure of 4.8×10^5 Pa. Determine then number of moles of gas X present under those conditions

From $PV = nRT.$

$4.8 \times 10^5 \times 225 \times 10^{-6} = n \times 8.314 \times 280$ 02½

$n = 0.0464$ moles.

7. Complete the following equations for nuclear reactions.

a. $^{239}_{94}Pu + ^4_2He \longrightarrow {}^{216}_{83}Bi + ^{27}_{13}Al$ (01 mark) 01

b. $^{250}_{98}Cf + {}^{11}_{5}B \longrightarrow ^{257}_{103}Lw + 4^1_0n$ (01 mark) 01

(b). In an experiment, the rate of radioactive decay of protactinium decreased to 25% in 54 minutes. Calculate the half-life of protactinium.(03mks)

$\ln\left(\frac{N_0}{N_t}\right) = Kt$

$\ln\left(\frac{100}{25}\right) = 54K$

$K = 0.0257\ min^{-1}$

Reject Deny, without units

$t\frac{1}{2} = \frac{\ln 2}{K}$

$t\frac{1}{2} = \frac{0.693}{0.0257}$

$t\frac{1}{2} = 26.9943$ minutes.

Res; without units

03

8. (a) What is meant by the following terms

(i) A **d-block element** (01 mark)

An element whose outermost valence electrons are in the d-orbital ✓ 01

(ii)An **orbital** (01 mark)

A region in an atom where there is higher probability of finding an electron. ✓ 01

b) Write the electronic configuration of the following

(i) Boron (01 mark)

$1s^2 2s^2 2p^1$ ✓ 01

(ii) Aluminium (01 mark)

$1s^2 2s^2 2p^6 3s^2 3p^1$ ✓ 01

(i) Cobalt (01 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$ ✓ 01

(iv)Manganese (01 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$ ✓ 01

(v) Iron (01 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ ✓ 01

07

9. The table below shows the first four successive ionisation energies of elements A, B, C and D

Element	1st I.E ($KJmol^{-1}$)	2nd I.E ($KJmol^{-1}$)	3rd I.E	4th I.E
A	800	2400	3700	25000
B	900	1800	14800	21000
C	500	4600	6900	9500
D	1090	2400	4600	6200

With reasons, state the group of the periodic table to which the elements A, B and C belong

(i) A

Group (01 mark)

Group(III) 01

Reason (02 marks)

The difference between the third and fourth ionisation energies is very big compared to the difference between first and second, second and third ionisation energies 02

Emphasize; Very big

(ii) B (01mark)

Group

Group(II) 01

Reason (02 marks)

The difference between the second and third ionization energies is very big compared to the difference between first and second ionization energies, third and fourth ionization energies. 02

Emphasize; very big

CamScanner

(iii) C

Group (01 mark)

Group (I) 01

Reason (02 marks)

The difference between first and second ionisation energies is very big compared to the difference between second and third, third and fourth ionisation energies. 02

SECTION B

Attempt any *six* questions from this section.

10. (a) (i) Distinguish between an **ideal gas** and **a real gas** (02 marks)

An Ideal gas is one that obeys all gas laws accurately and has negligable intermolecular forces of attraction. 02

A real gas is one that doesnot obey gas laws accurately and has forces of attraction between its molecules. ~~and~~

(ii) State two properties of an ideal gas (01mark)

- Individual molecules of a gas have negligable volume. 01
- Molecules of the gas have negligable intermolecular forces of attraction
- Ideal gases obey gas laws.
- Can not be easily compressed.

any correct 2

(b) Explain how liquefication of a gas can be affected by

(i) Pressure. (1½ marks)

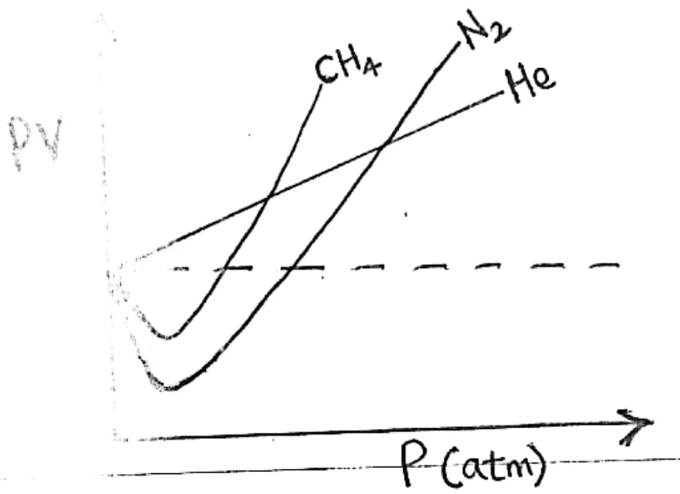
Increase in pressure favours liquefication of a gas.

This is because at increased pressures, the distance between between the gas molecules becomes much shorter, and thus molecules are more closer together forming a liquid. 01½ (ii)Temperature (02 marks)

A decrease in temperature favours liquefication of a gas. 02

This is because, at a reduced temperature, the Kinetic energy of these ~~gaseous~~ molecules of a gas reduces. This increases ~~the~~ forces of attraction between molecules, hence bring them more closer together forming a liquid.

(c). The curv... ...w deviations of some gases from the ideal behaviour



(i) ...ate why helium shows a small deviation from the ideal behaviour compared to other gases. (01 mark)

Accept; smallest

Helium has a very ~~sm~~ small atomic radius ~~and~~ has the lowest molecular weight (of 4g) hence occupies a negligable volume. This gives helium to have a weaker ~~Smaller~~ Van der waal forces of attraction compared to other molecules. 01

(ii) ... deviations of methane and nitrogen from the ideal behavio... ...eason for your answer. (1½ marks)

Nitrogen shows a greater deviation than methane. 02

This is because nitrogen has a more large molecular weight (28g) Compared to methane (16g). As a result, the Van der Waal ~~waf~~ forces of attraction will be stronger in nitrogen molecules since the strength of Van der waal forces increases with increase in molecular weight

...BUGO

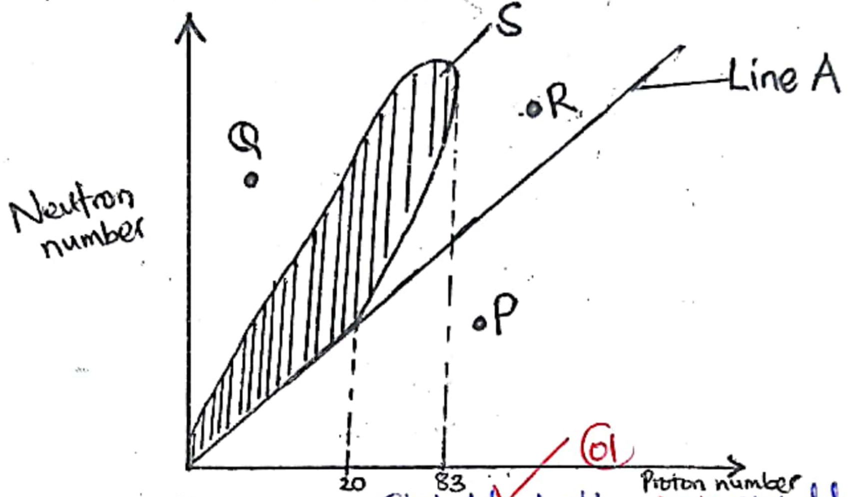
11. (a) State two factors affecting stability of a nucleus of an atom. (02mks)

- Binding energy
- Neutron to proton ratio
- Half life of the nuclide
- Atomic number
- Atomic mass.

02

accept any 2 correct alternatives

b) Below is a graph of number of neutrons against number of neutrons against number of protons for different nuclei



Identify (i) region S. Stability belt Accept; stability region or stability zone (01 mk) 01

(ii) line A. Stability line 01 (01 mk)

c). State how the following nuclide can gain stability

(i) Q (01 mark)

By beta emission 01

Since its neutron number is greater than proton number

(ii) R (01 mark)

By alpha emission. 01

It's atomic number is greater than 83 and its a heavy nuclide.

(iii) P (01 mark)

By positron emission 01 Accept; Electron capture Beta decay.

(d) State two properties of a stable nuclide Emphasize: Approximately (02 marks)

- It's neutron number is approximately equal to proton number $(\frac{n}{p} \approx 1)$
- Does not undergo Radioactivity.

02

12. Explain the following

(i) the first ionisation energy of magnesium is higher than that of aluminium. (03 marks)

Magnesium ($1s^2 2s^2 2p^6 3s^2$) has a completely filled 3s-orbital thus thermodynamically stable. More energy is required to remove this first electron, hence a higher value of first ionisation energy.

03

Aluminium ($1s^2 2s^2 2p^6 3s^2 3p^1$) has a partially filled 3p-orbital ~~thus thermodynamically unstable, Less energy is required~~ to remove this first electron, hence a lower value of first ionisation energy.

(ii) the atomic radius of sodium atom is **0.156nm** while the ionic radius of sodium ion is **0.095nm**. (03 marks)

When sodium atom loses an electron to form sodium ion, ~~this~~ the number of protons becomes greater than number of electrons. This increases the effective nuclear charge thus results in an increased nuclear attraction for the remaining electrons, pulling them closer to the nucleus leading ~~to a decrease in cationic radius.~~

03

(iii) Potassium atom has a larger atomic radius than lithium (03marks)

Potassium has extra two energy levels full of electrons than Lithium. This gives potassium to have a higher screening effect. Also, Proton number in potassium is higher than that in Lithium giving potassium to have a higher nuclear charge. In potassium, ~~the~~ effective ~~thus~~ nuclear charge will be lower than than in Lithium, and the outermost electrons will be less attracted to the nucleus thus far away from the nucleus giving it a larger atomic radius.

03

13 (a) Define the following terms

(i) Relative Atomic Mass. (01 mark)

Accept; naturally occuring element

Is a ratio of mass of an atom of an element to the twelfth mass of Carbon-12 isotope ✓ 01

(ii) Relative abundance (01 mark)

Accept; Percentage | ratio

Is the proportion of an isotope of a naturally occuring element in respect to other isotopes of that same element ✓ 01

(b) A mass spectrum of chlorine shows molecular peaks at 70, 72 and 74. Explain this observation. (02 marks)

Chlorine has two isotopes $^{35}_{17}Cl$ ✓ and $^{37}_{17}Cl$ 02

A peak is formed at 70, when two ✓ isotopes of Cl-35 combine.

A peak is formed at 72, when isotopes ✓ Cl-35 and Cl-37 combine

A peak is formed at 74, when two isotopes ✓ of Cl-37 combine.

(ii) Chlorine has two isotopes **Cl-35** and **Cl-37**. State the formula of each ion of the respective molecular peak formed. (1 ½ marks)

Molecular peak	Formula of the ion
70	$[^{35}Cl—^{35}Cl]^+$ ✓
72	$[^{35}Cl—^{37}Cl]^+$ ✓
74	$[^{37}Cl—^{37}Cl]^+$ ✓

01½

(c). (i)Determine the relative abundance of each isotope of chlorine stated above. Let the Relative abundance of Cl–35 be y and ~~that~~ of Cl–37 = 100–y (1½ marks)

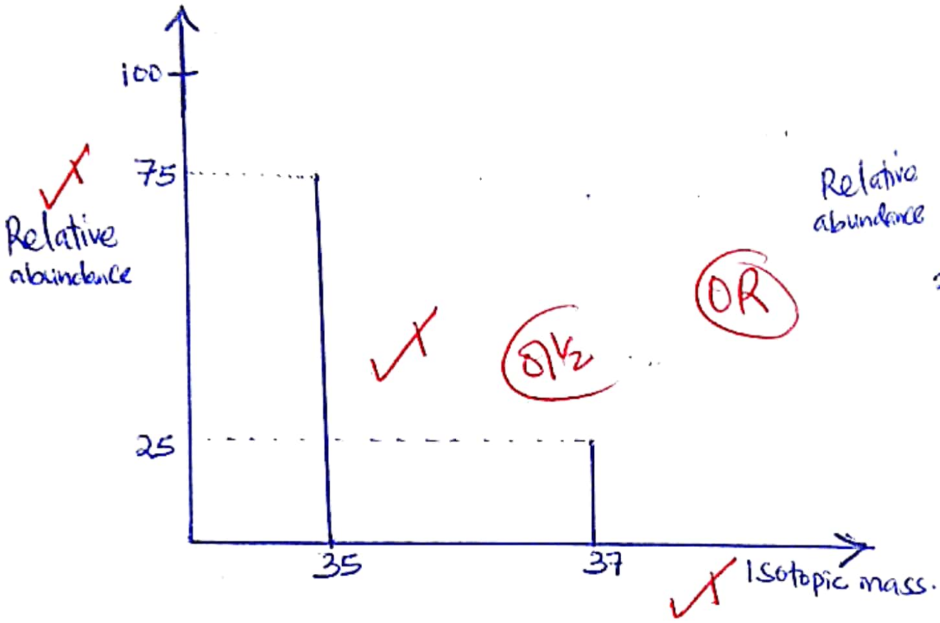
$$R\cdot A\cdot M = \frac{\sum \text{Isotopic mass} \times \text{Relative abundance}}{\text{Total Relative abundance}} \quad 0½$$

$$35.5 = \frac{(35 \times y) + (100-y)(37)}{100}$$

$y = 75$

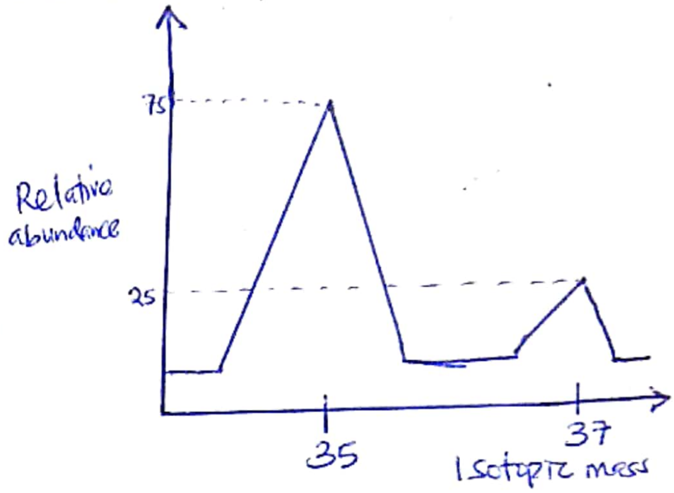
∴ Relative abundance of Cl–35 is 75% and that of Cl-37 is 25%

(iii) Draw the mass spectrum of the above two isotopes. (1½ marks)



0½

OR



(d) State one advantage and one disadvantage of determining the relative atomic mass of an element using the mass spectrometer

Advantage (0½ mark)

0½

- It is accurate
- uses a very small sample of the element
- Quick - ~~Gives details of all is~~ - Gives all isotopes of the sample.

Disadvantage (0½ mark)

- Sample should be in vapour form. 0½

14. (a)State Dalton's law of partial pressure of gases. (01 mark)

The total pressure of a mixture of gases is equal to the sum of their individual partial pressures. 01

(b) What is meant by the following terms?

(i) Partial pressure of a gas (01 mark)

Is the pressure which that gas exerts if it occupies a vessel alone which was initially occupied by a mixture of gases. 01

(ii) Mole fraction of a gas (01 mark)

Is the ratio of number of moles of a component of a gas to the total number of moles of all the component of the gases in the mixture. 01

(c) 12.0g of nitrogen, 0.4g of hydrogen and 9.0g of oxygen were put in a 1litre vessel at a pressure of 22.4atm.calculate the partial pressure of the respective gases present in the vessel. (06 marks)

Molar Mass of $H_2 = (1 \times 2) = 2g$

Molar mass of $O_2 = 16 \times 2 = 32g$

Molar mass of $N_2 = 14 \times 2 = 28g$

Moles of $H_2 = \frac{0.4}{2} = 0.2$ moles

Moles of $N_2 = \frac{12.0}{28} = 0.43$ moles

Moles of $O_2 = \frac{9.0}{32} = 0.28$ moles

Total number of moles in the mixture $= 0.2 + 0.43 + 0.28 = 0.91$ moles

Partial pressure of H_2 = Mole fraction of H_2 x Total pressure.

Partial pressure of $H_2 = \left(\frac{0.2}{0.91} \times 22.4\right) = 4.92$ atm

Partial pressure of $N_2 = \left(\frac{0.43}{0.91} \times 22.4\right) = 10.59$ atm

Partial pressure of $O_2 = \left(\frac{0.28}{0.91} \times 22.4\right) = 6.89$ atm

06

15. (a) What is meant by the term atomic radius. (01mark)

The distance of closest approach of one atom to another in any bonding situation. 01

Accept; It is half the inter-nuclear distance between atoms that are held together by a single bond.

(b)Describe how atomic radius varies

(i) Down a group. (04 marks)

Atomic radius increases down a group.
Down a group, an energy level full of electrons is being added from one atom to next. This increases the screening effect.
Also, nuclear charge increases due to the addition of protons to the nucleus of the atoms.
The increase in screening effect is more rapid than the increase in nuclear charge. This leads to a reduction in effective nuclear charge. Thus the outermost valence electrons are attracted to the nucleus ~~with~~ less ease, and are far away from the nucleus. This leads to an increase in atomic radius.

04

(i)Across a given period. (04 marks)

Atomic radius decreases across the period.
Across a given period, an extra electron is being added on the same energy level from one atom to next. The screening effect slightly increases

Accept; Almost remains constant.

Also, protons are being added in the nucleus from one atom to next. This increases the nuclear charge. However, the increase in nuclear charge is more rapid than increase in screening effect resulting into an increase in effective nuclear charge. ~~Thus~~ Consquently, the valence electrons are ~~more~~ highly attracted closer to the nucleus resulting into a decrease in atomic radius.

04

16. (a). Define the term

(i) Radioactivity. (01 mark)

The spontaneous disintergration of unstable nuclei to form a stable nuclei with emission of gamma rays or alpha, beta particle.

01

(ii). **Half life** (01mark)

Time taken for ~~half~~ of the radioactive nuclei to decay to half it's original count

01

b) The table below shows how the mass of radioactive substance **R** varies with time.

Mass of R (g)	60.0	38.5	26.0	17.2	11.1
Time (minutes)	0	40	80	120	160

Plot a graph of mass of R against time. (03 marks)

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(To be fastened together with other answers to paper)

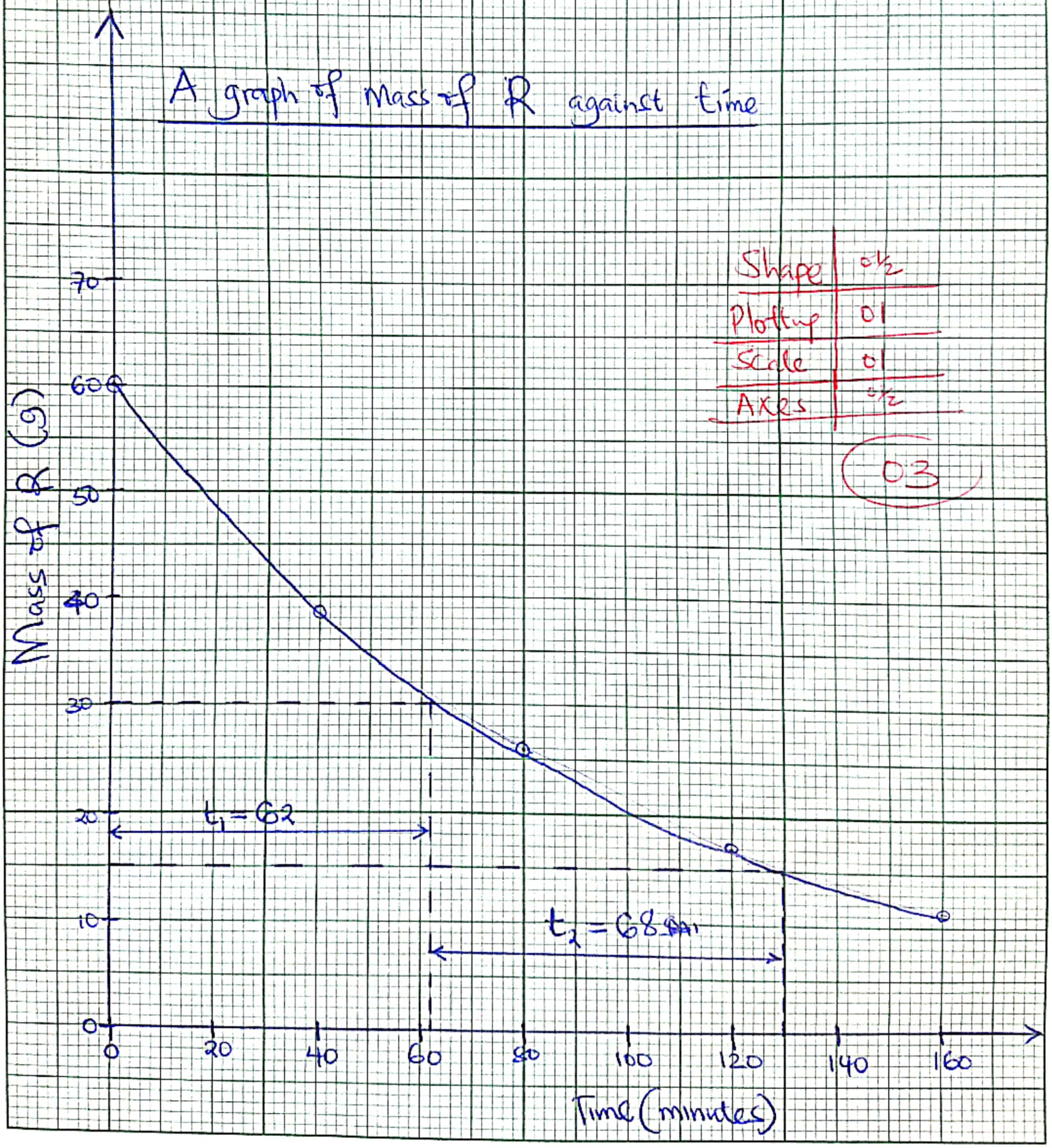
UCE

Candidate's Name ....

Signature ....

Subject Name .... Paper code ..../.......

Random No.						
Personal Number				



Shape	0½
Plotting	01
Scale	01
Axes	0½

03

(ii).Use your graph to determine the **half-life** of R. (01 mark)

$t_{\frac{1}{2}} = \frac{t_1 + t_2}{2}$ $t_1 = 62min$ $t_2 = 68min$

$= \frac{62+68}{2}$

01

$t_{\frac{1}{2}} = 65$ minutes.

(iii).Calculate the **radioactive decay constant** of R. (01 mark)

From $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ 01

$65 = \frac{\ln 2}{\lambda}$ Rej; If units are missing.

$\lambda = 0.010662\ min^{-1}$

(c) Differentiate between nuclear fission from nuclear fusion. (02 marks)

Nuclear fusion is the combination of two or more light unstable nuclides to form a heavy stable nuclide with emission of heat energy. 02

While; Nuclear fission is the process of spliting a heavy unstable nuclide to form light stable nuclide with emission of heat energy.

17. (a) What is meant by isomerism (01 mark)

The existance of compounds with same molecular formula but different structural formulae 01

(b) Write short notes on the following types of structural isomerism.

(i) Position isomerism (02marks)

The existance of compounds with same molecular formula but these differ by the position occupied by the functional group in the chain.

Example C_4H_8 for $CH_2=CHCH_2CH_3$ But-1-ene 02

and $CH_3CH=CHCH_3$ But-2-ene

(ii) Functional group isomerism (03 marks)

Existance of compounds with same molecular formula but they have different functional groups

Example C_2H_6O for CH_3CH_2OH Ethanol (02

CH_3OCH_3 Methoxymethane

Accept Dimethylether

(iii) Chain isomerism (03 marks)

Existance of compounds with the same molecular formula but the have different arrangement of atoms in the chain. Carbon chain.

Example C_4H_{10} for $CH_3CH_2CH_2CH_3$ Butane (02)

$CH_3CH(CH_3)CH_3$ 2-methylpropane

18. (a) Define the term third ionisation energy. (01 mark)

The minimum energy required to remove an electron from a divalently charged gaseous ion to form a trivalently charged gaseous ion at standard temperature and pressure. (01

Accept the definition interms of ---- one mole ---

(b) Write an equation for the third ionisation energy of magnesium.(01mk)

$Mg^{2+}_{(g)} \longrightarrow Mg^{3+}_{(g)} + e$ (01)

(c). State how the following factors affect the value of ionisation energy of an atom or ion.

(i) Electronic configuration of the atom or ion. (01 mark)

Electronic configurations with half filled or completely filled outer sub-energy levels are relatively thermodynamically stable than those with are partially filled. (01

Therefore, more energy is required to remove an electron from such atoms than those that have partially filled sub-energy levels.

Accept: The more stable the electronic configuration, the higher the ionisation energy.

(ii) Nuclear charge (01 mark)

Increase in nuclear charge (as proton number increases) results in an increase in nuclear attraction for valence electrons, hence more energy is required to remove these electrons. 01

Accept; ∴ The higher the nuclear charge of an atom, the higher the ionisation energy.

d) The table below shows the variation in first ionisation energies of elements in group (VII) of the periodic table

Element	F	Cl	Br	I
First ionisation energy($KJmol^{-1}$)	1681	1255	1142	1007

Reject; iodine

(i) State the trend in first ionisation energy of the elements. (01 mk)

First ionisation energy decreases from Fluorine to iodine

Rej; F to I

(ii) Explain your trend in (c) (i) above. (04 marks)

From Fluorine to iodine, an extra energy level full of electrons is being added from one atom to next. This increases the ~~screening~~ (shielding effect) effect. Also, a protons are added to the ~~nucleus~~ nuclei of the atoms. This increases the nuclear charge. Consquently, the increase in screening effect is more rapid than the increase in nuclear charge. This leads to a decrease in effective nuclear charge. Thus, the valence electrons are less attracted ~~towards~~ by the nucleus ~~of~~ the atoms, and are far away from the nucleus. Therefore, less energy is required to remove this first valence electron from the atom, hence a decrease in first ionisation energies. 04

END.

WELCOME TO S5 CHEMISTRY CLASS 2023.