Candidate's Name: MARKING GUIDE .....Signature.....

P525/1

CHEMISTRY

Paper1

NOV.2022

2¾ hours

UGANDA ADVANCE CERTIFICATE OF EDUCATION

S5 END OF YEAR EXAMINATIONS 2022

CHEMISTRY

(THEORY)

Paper 1

2 hours 45 minutes

INSTRUCTION TO CANDIDATES:

Answer **all** *questions in section* **A** *and* **six** *questions from 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 gas constant, $R = 8.31\ JK^{-1}\ mol^{-1}$

Molar volume of gas at s.t.p is 22.4 l.

Standard temperature = 273K.

Standard pressure = $101325Nm^{-2}$.

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

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SECTION A: (46 MARKS)

Answer **all** *questions from this section.*

1. (a) Complete the following equations for nuclear reactions.

(i) $^{27}_{14}Si \longrightarrow {}^{27}_{13}Al + \ldots {}^{0}_{+1}e \ldots$ *(01 mark)* 1

(ii) $^{236}_{92}U + {}^{1}_{0}n \longrightarrow 2{}^{1}_{0}n + \gamma + {}^{147}_{60}Nd + \ldots {}^{88}_{32}Ge \ldots$ *(01 marks)* 1

(b) When a radioactive isotope was left to stand, it decayed by 12.5% of its original value in 45 days. Calculate the half-life of the radioactive isotope. *(2½ marks)*

$N_o = 100\%$, $N_t = 100 - 12.5 = 87.5\%$

$2.303 \log\left(\frac{N_o}{N_t}\right) = \lambda t$ ✓

$\lambda = \frac{2.303 \log\left(\frac{100}{87.5}\right)}{45}$ ✓

$\lambda = 2.968 \times 10^{-3} day^{-1}$ ✓

$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

$\lambda = \frac{0.693}{2.968 \times 10^{-3}}$ ✓

$\lambda = 233.5 days.$ ✓ 2½

04½

2. (a) State **three** factors that can affect electron affinity. *(1½ marks)*

- Atomic radius. ✓
- Nuclear charge / Effective nuclear charge. ✓
- Screening effect / shielding effect ✓
- Electron structure / Electronic configuration.

1½

(b) Write equation for the first electron affinity of sulphur. *(01 mark)*

$S(g) + e \longrightarrow S^{-}(g)$ ✓ 1

(c) The first and second electron affinities of sulphur are -200 and $+649\ kJ\ mol^{-1}$ respectively. Explain the difference in the electron affinities of sulphur. *(04 marks)*

The first electron affinity is exothermic because an electron is added to a neutral atom where there is less repulsion between electrons in the atom and the added electron. The second electron affinity is endothermic because an electron is added to a negatively charged ion and there 4

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is greate repulsion between the ion and the electron being added.

06½

3. Polystyrene is formed by polymerization of phenylethene.

(a) (i) Write the structural formula of polystyrene. *(01 mark)*

1

(ii) Name the type of polymerization involved in the formation of polystyrene. *(½ mark)*

Addition polymerisation ½

(b) The osmotic pressure of a solution containing 5.5 g of polystyrene in 1 dm^3 of benzene is 1.0×10^{-3} atmospheres at 20^0C.

(i) Calculate the relative molecular mass of polystyrene.

($R = 0.082\ atm\ dm^3\ K^{-1}mol^{-1}$) *(02 marks)*

$\pi V = \frac{mass}{RMM} RT$

$RMM = \frac{5.5 \times 0.082 \times 293}{1.0 \times 10^{-3} \times 1}$

$= 132143$ 2

(ii) Determine the number of monomers that formed the polystyrene. *(1½ marks)*

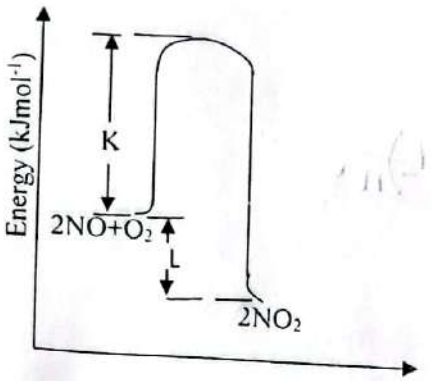
Rfm of monomer $= (12 \times 8) + 1 \times 8 = 104$

Number of monomers $= \frac{132143}{104}$

$= 1271$ 1½

05

4. (a) The figure below shows the energy diagram for the reaction between nitrogen monoxide and oxygen.



(i) Identify K and L.

K. Activation energy for forward reaction (½ mark) ½

L. Enthalpy change for the reaction (½ mark) ½

(ii) State whether the reaction is endothermic or exothermic. (½ mark)

Exothermic ½

(iii) Give a reason for your answer in (a) (ii). (½ mark)

Enthalpy of products are at lower energy than reactants. ½

(b) The experimental results in the table below were obtained for the reaction in (a).

Initial concentration ($mol\ dm^{-3}$)		Rate of reaction ($mol\ dm^{-3}s^{-1}$)
NO	O_2	
0.03	0.03	2.7×10^{-5}
0.03	0.06	5.4×10^{-5}
0.06	0.03	10.8×10^{-5}

(i) Deduce the order of the reaction with respect to;

nitrogen monoxide... (01 mark)

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order 2. ✓ 1

Oxygen. *(01 mark)*

order 1. ✓ 1

(ii) Write the rate equation for the reaction. *(01 mark)*

Rate = $K[NO]^2[O_2]$ ✓, K - rate constant 1

(c) Calculate the

(i) rate constant (k) for the reaction and state its units. *(1½ marks)*

$K = \frac{Rate}{[NO]^2[O_2]} = \frac{2.7 \times 10^{-5}}{(0.03)^2(003)}$ ✓ ✓ 1½

$= 1.0 \, mol^{-2} dm^6 s^{-1}$ ✓ ½

06½

5. When compound **Q** was steam distilled at 95^{0}C and at 760mmHg, the distillate contained 77.1% by mass of **Q**. Calculate the molecular formula of **Q**.
[The vapourpressure of water at 95^{0}C is 526mmHg] *(04 marks)*

Vapour pressure of Q = 760 - 526 = 234mmHg ✓

Percentage by mass of Q = 100 - 77.1 = 22.9% ✓

$\frac{\text{Mass of Q in distillate}}{\text{Mass of water in distillate}} = \frac{\text{V.P of Q} \times \text{RMM of Q}}{\text{V.P of } H_2O \times \text{MM of } H_2O}$ ✓

$\frac{77.1}{22.9} = \frac{234 \times \text{RMM of Q}}{526 \times 18}$ ✓

$\text{MM of Q} = \frac{77.1 \times 526 \times 18}{22.9 \times 234}$

$= 136$ ✓ or 136.2. 04

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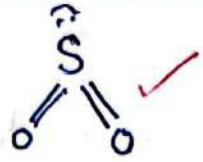
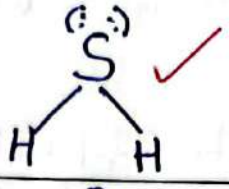
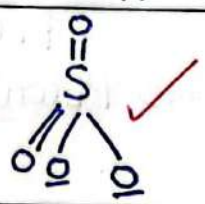
6. Draw the structures and name the shapes for the following species.

(4½ marks)

species	Structure	Name
(i) SO_2	 ✓	V-shape ✓ OR Bent shape
(ii) H_2S	 ✓	V-shape ✓ OR Bent shape
(iv) SO_4^{2-}	 ✓	Tetrahedral shape ✓

$4\frac{1}{2}$

7. (a) Explain what is meant by the term an **ideal solution.** *(1½ marks)*

Is a solution in which the intermolecular forces between the like and unlike molecules are equal. The solution is formed with no enthalpy change and no change in volume. The solution obeys Raoult's law of vapour pressure. $1\frac{1}{2}$

(b) A mixture of liquids **A** and **B** behaves as an ideal solution. The vapour pressures of A and B are 473.2Pa and 139.8Pa respectively at 20°C. Calculate the composition of the vapour from a mixture containing 0.6 mole fraction of liquid **A** at 20°C. *(03 marks)*

$P_A = X_A P_A^\circ$ ✓

$P_A = 0.6 \times 473.2 = 283.92\ Pa$ ✓

$P_B = 0.4 \times 139.8 = 55.92\ Pa$ ✓

Vapour pressure of solution $= P_A + P_B$

$= 283.92 + 55.92$

$= 339.84\ Pa$ ✓

Composition of A in vapour $= \frac{283.92}{339.84} \times 100$

$= 83.5\%$ ✓

Composition of B in vapour $= 100 - 83.5$

$= 16.5\%$ ✓

3

$04\frac{1}{2}$

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8. State what would be observed and write equation(s) for the reaction(s) that would take place when sodium hydroxide solution is added drop-wise until in excess to:

(a) lead nitrate solution. *(03 marks)*

Observation.

White precipitate soluble in excess to give a colourless solution.

Equation(s).

$Pb^{2+}_{(aq)} + 2\bar{O}H_{(aq)} \longrightarrow Pb(OH)_{2(s)}$

$Pb(OH)_{2(s)} + 2\bar{O}H_{(aq)} \longrightarrow Pb(OH)^{2-}_{4(aq)}$

OR $Pb^{2+}_{(aq)} + 4\bar{O}H_{(aq)} \longrightarrow Pb(OH)^{2-}_{4(aq)}$ 3

(b) Iron(II) chloride solution. *(02 marks)*

Observation.

Green precipitate insoluble in excess

Equation.

$Fe^{2+}_{(aq)} + 2\bar{O}H_{(aq)} \longrightarrow Fe(OH)_{2(s)}$ 2

05

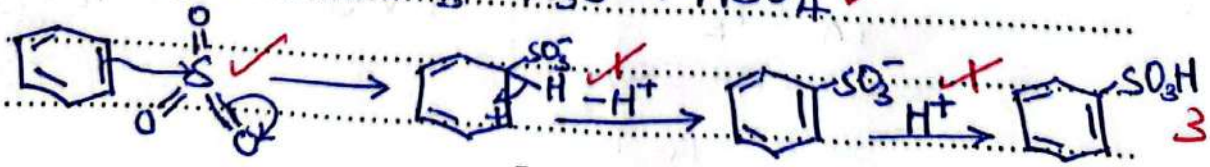
9. (a) (i) State the conditions for the reaction between benzene and sulphuric acid. *(01 mark)*

Fuming sulphuric acid and warm (reflux) or (35–50°c)

OR Concentrated sulphuric acid and heat. 1

(ii) Outline a mechanism for the reaction in (a) (i). *(03marks)*

$2H_2SO_4 \rightleftharpoons SO_3 + H_3O^+ + HSO_4^-$



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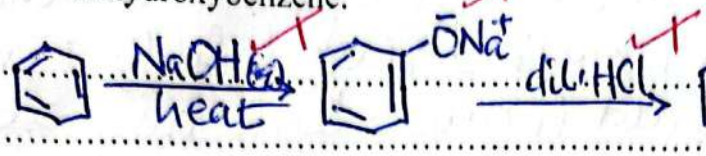
(b) Write equation(s) to show how the products in (a) (ii) can be converted to hydroxybenzene. *(1½ marks)*



1½

05½

SECTION B (54 MARKS)

Answer **six** *questions from this section.*

10. (a) State what is meant by the term **enthalpy of solution.** *(01 marks)*

Is the enthalpy change that takes place when one mole of a solute dissolves in a solvent to form an infinitely dilute solution. 1

(b) The table below shows the heats of hydration and lattice energies of lithium chloride and sodium chloride.

Salt	Enthalpy of hydration (kJ mol^{-1})	Lattice energy (kJ mol^{-1})
LiCl	−882	+848
NaCl	−765	+788

Calculate the heat of solution of

(i) lithium chloride *(1½ marks)*

$\Delta H_{solution} = \Delta H_{lattice\ energy} + \Delta H_{hydration\ energy}$

$= +848 + (-882)$

$= -34\ KJ\ mol^{-1}$ 1½

(ii) sodium chloride. *(01 marks)*

$\Delta H_{solution} = +788 + (-765)$

$= +23\ KJ\ mol^{-1}$ 1

(iii) State how you would expect the solubility of the two salts to vary with temperature and give reasons for your answers. *(2½ marks)*

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The solubility of lithium chloride would decrease with increase in temperature because the enthalpy of solution is negative. The solubility of sodium chloride would increase with increase in temperature because the enthalpy of solution is positive. 2½

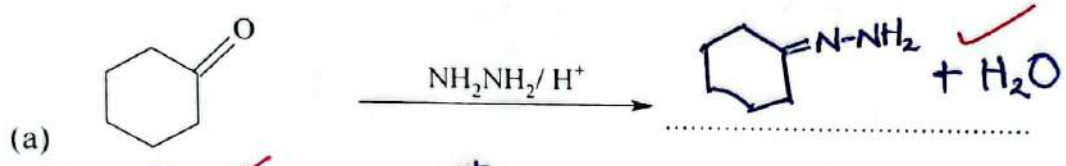
(c) Explain how hydration energy affects the solubility of salts in water. *(03 marks)*

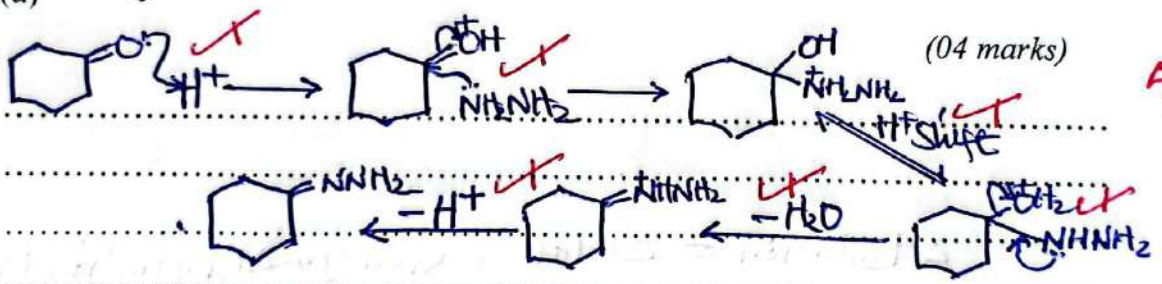
The more exothermic the hydration energy the more soluble the salt will be because the overall enthalpy of solution will be more exothermic. 3

09

11. Complete the following equations and in each case write the accepted mechanism.

(a)

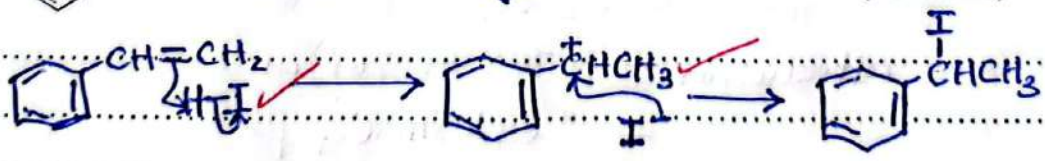




(04 marks) 4

(b)

(03 marks)



3

(c) $(CH_3)_2\overset{Cl}{C}CH_2CH_3 \xrightarrow[Heat]{NaOH(aq)} (CH_3)_2\overset{OH}{C}CH_2CH_3 + NaCl$ *(02 marks)*

$(CH_3)_2\overset{Cl}{C}CH_2CH_3 \rightleftharpoons (CH_3)_2\overset{+}{C}CH_2CH_3 + Cl^-$ 2

$(CH_3)_2\overset{+}{C}CH_2CH_3 \longrightarrow (CH_3)_2\overset{OH}{C}CH_2CH_3$

09

12. (a) State how the following anhydrous chlorides can be prepared.

(i) Aluminium chloride. *(01mark)*

Dry chlorine is passed over heated aluminium. 1

(ii) Phosphorous(III) chloride. *(01½mark)*

Limited dry chlorine is passed over heated Phosphorous. ½

(b) Write equations for the reaction between water and the chlorides in (a).

(i) Aluminium chloride. *(1½ marks)*

$AlCl_3(s) + 3H_2O(l) \longrightarrow Al(OH)_3(s) + 3HCl(aq)$ ½ ½

(ii) Phosphorous(III) chloride. *(1½ marks)*

$PCl_3(l) + 3H_2O(l) \longrightarrow H_3PO_3(aq) + 3HCl(aq)$ ½ ½

(c) Dilute sodium hydroxide solution was added drop-wise until in excess to a solution of aluminium chloride in water.

(i) State what was observed. *(1 mark)*

White precipitate soluble in excess forming a colourless solution. 1

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(ii) Write equation(s) for the reaction (s) that took place. *(2½ marks)*

$Al^{3+}_{(aq)} + 3\bar{O}H_{(aq)} \longrightarrow Al(OH)_{3(s)}$ ✓

$Al(OH)_{3(s)} + \bar{O}H_{(aq)} \longrightarrow Al(OH)_{4\ (aq)}^{-}$ ✓✓ 2½

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13. A hydrocarbon **Y** contains 85.7% carbon and has a density of $2.5 gl^{-1}$ at s.t.p.

(a) Calculate the empirical formula of **Y**. *(02 marks)*

Percentage of hydrogen = 100 − 85.7 = 14.3 ✓

Element:	C	H
Moles	85.7/12	14.3/1
	= 7.142	14.3 ✓
	7.142/7.142	14.3/7.142 ✓
Simplest ratio	1	2

∴ Empirical formula of Y is CH_2 ✓ 2

(b) Determine the molecular formula of **Y**. *(02 marks)*

RFM = 2.5 × 22.4 = 56 ✓

$(CH_2)n = 56$ ∴ Molecular formula of Y

$14n = 56$ is C_4H_8 ✓ 2

$n = 4$ ✓

(c) Write the structural formulae of all the possible open chain isomers of **Y**. *(1½ marks)*

$CH_3CH_2CH=CH_2$ ✓

$CH_3CH=CHCH_3$ ✓ 1½

$CH_3C(CH_3)=CH_2$ ✓

(d) (i) Ozonolysis of **Y** and subsequent work-up gave one compound. Identify **Y**. *(½ marks)*

$CH_3CH=CHCH_3$ ✓ OR But-2-ene. ½

(ii) Write an equation to show how **Y** can be synthesized from butan-2-ol and indicate a mechanism for the reaction. *(03 marks)*

$CH_3CH(OH)CH_2CH_3 \xrightarrow[\text{heat}]{\text{conc } H_2SO_4} CH_3CH=CHCH_3 + H_2O$ ✓

$CH_3CH(OH)CH_3 \longrightarrow CH_3CHCH_2CH_3 \xrightarrow{-H_2O} CH_3\overset{+}{C}HCH_2CH_3$ ✓✓ 3

$CH_3\overset{+}{C}HCH_2CH_3 \xrightarrow{-H^+} CH_3CH=CHCH_3$ ✓✓

09

14. (a) Define the term **partition coefficient**. *(01 mark)*

Is the ratio of the concentration of a solute between two immiscible liquid solvents in the same container at constant temperature. ✓ 1

(b) Copper(II) ions forms a complex $Cu(NH_3)_n^{2+}$ with ammonia. The table below shows the results of partition of ammonia between 0.1M copper(II) ions and trichloromethane.

$[NH_3]$ (0.1M $Cu^{2+}(aq)$)	0.88	1.08	1.34	1.56	1.80
$[NH_3]$ $(CHCl_3)$	0.02	0.03	0.04	0.05	0.06

(i) Plot a graph of $[NH_3]$ (0.1M Cu^{2+} (aq)) against $[NH_3]$ $(CHCl_3)$. *(03 marks)*

(ii) Determine the value of n in the complex. *(2½ marks)*

$[NH_3]$ complexed = $0.4 mol dm^{-3}$ ✓

0.1 moles of Cu^{2+} complexed with 0.4 moles of NH_3

1 mole of Cu^{2+} complexed with $\left(\frac{0.4 \times 1}{0.1}\right)$ moles of NH_3 2½

= 4 moles

∴ value of $n = 4$ ✓

(c) (i) Determine the partition coefficient, K_D of ammonia between aqueous copper(II) ions and trichloromethane. *(1½ marks)*

K_D = slope

$= \frac{1.78 - 0.82}{0.06 - 0.018}$ ✓

$= 22.86$ ✓ $(22.70 - 23.20)$ 1

(ii) State how the value of K_D you have determined indicates about the distribution of ammonia. *(01 mark)*

It indicates that ammonia is more soluble in aqueous copper(II) sulphate than in trichloromethane. 1

09

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(To be fastened together with other answers to paper)

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Candidate's Name .....

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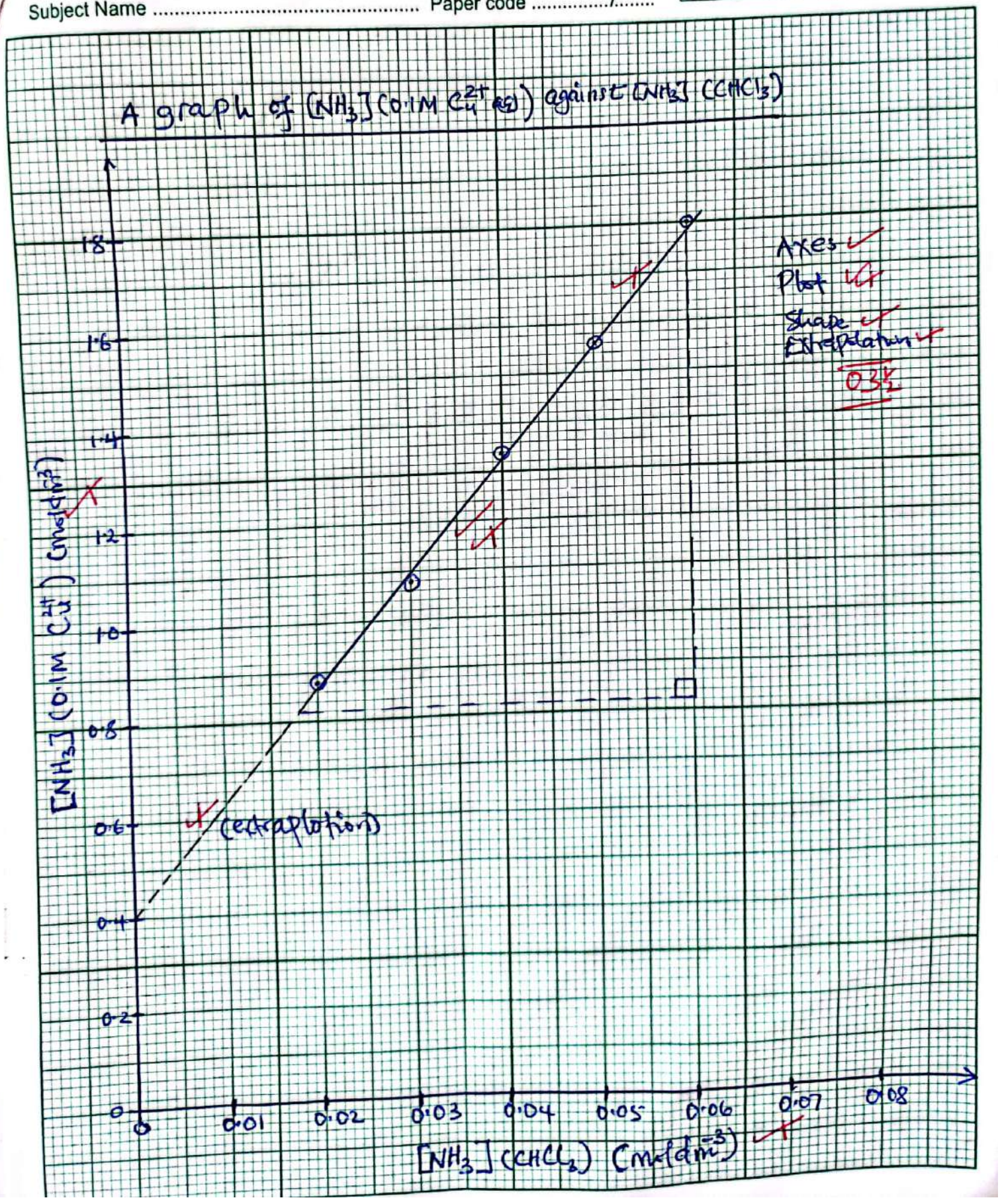
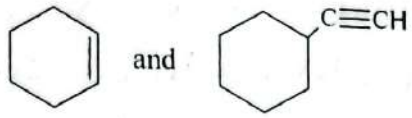


15. Name the reagent(s) that can be used to distinguish between the following compounds. In each case state what would be observed when each compound is separately treated with the reagent.

(a)  and *(03 marks)*

Reagent(s)

Ammoniacal silver nitrate solution ✓

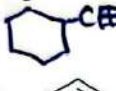
OR Ammonical copper(I) chloride solution

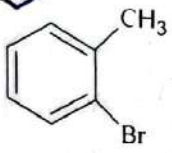
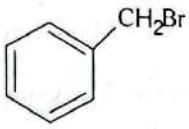
Observation:

 - No observable change. ✓

 - White precipitate. ✓ 3

OR  - No observable change.

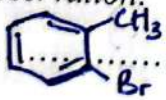
 - Red precipitate.

(b)  and  *(03 marks)*

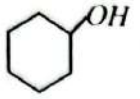
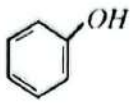
Reagent(s)

Hot sodium hydroxide solution followed by dilute nitric acid and silver nitrate solution. ✓

Observation:

 - No observable change. ✓

 - Pale yellow precipitate. ✓ 3

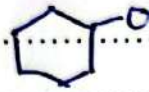
(c)  and  *(03 marks)*

Reagent(s)

Neutral iron(III) chloride solution. ✓

3

Observation:

 — No observable change. ✓

 Purple/violet colouration. ✓

09

16. The table below shows the atomic radius and the first ionization energy of some elements in period(III) of the Periodic Table.

Element	Na	Mg	Al	Si	P	S	Cl
Atom radius (nm)	0.186	0.160	0.143	0.117	0.110	0.104	0.099
First ionization energy (kj mol^{-1})	496	738	577	787	1060	1000	1251

(a) (i) State how atomic radius of the elements varies across the period. *(01 mark)*

Atomic radius decreases ✓ across the period from sodium to chlorine.

1

(ii) Explain your answers in (a) (i). *(03 marks)*

Across the period electrons are added to the same energy level ✓ and Protons to the nucleus. ✓ Both screening effect and nuclear charge ✓ increases but the increase in nuclear charge outweighs the screening effect therefore the effective nuclear charge increases ✓ hence attraction for the outermost electrons by the nucleus increases ✓ resulting in decrease ✓ in atomic radius.

3

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(b) (i) Explain how atomic radius affects the first ionization energy.

(02marks)

First ionisation energy increases with decrease in atomic radius because electrons are greatly attracted by the nucleus. 2

(ii) Why is the first ionization energy of aluminium lower than that of magnesium?

(03 marks)

Mg; $1s^2 2s^2 2p^6 3s^2$ Al; $1s^2 2s^2 2p^6 3s^2 3p^1$

for magnesium electron is removed from 3s subshell which is half filled and very stable while in aluminium electron is removed from 3p subshell which is partially filled and less stable. 3

09