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DO NOT WRITE YOUR SCHOOL/CENTRE NAME OR NUMBER ANYWHERE IN THIS BOOKLET

Candidate's Name P525/2 CHEMISTRY GUIDE

Signature ASSHU MOCK – 2024

Subject NTUNGAMO Paper code ..../......

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READ THE INSTRUCTIONS BELOW CAREFULLY BEFORE USING THIS ANSWER BOOKLET.

1. Confirm that this answer booklet has 16 pages. Do **not** accept an answer booklet with missing pages.
2. Do **not** fold, dismantle, tear and/or mishandle any part of the answer booklet. Folding, dismantling, tearing and/or any other form of mishandling of the answer booklet is a malpractice and shall lead to cancellation of results.
3. Use a blue or black ink ball pen. Work in pencil, other than graphs, maps and drawings, will **not** be marked.
4. Answer only the number of questions as instructed on the question paper. Answers to extra questions will **not** be marked.
5. Write your answers on both sides of each sheet.
6. Do your rough work in this answer booklet. Cross through any work you do not want marked. All work must be handed in.
7. Do **not** share your work with another candidate or expose your work such that another candidate can copy from it. Sharing or exposing your work shall lead to cancellation of results.
8. List the question numbers in the order attempted, in the first column of questions attempted table. Do **not** list the multiple choice questions.
9. Check to confirm that you have written your **name, signature, random number and personal number on each page** of the answer booklet(s) used.
10. Tie all the used booklets together using a white thread.

Questions attempted

Question number	For Examiners' use only	
	Mark	Examiners' initials
Total		

Write the number of answer booklets you have used here. →	

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1 (a) (i) An ideal solution is a solution in which forces of attraction between unlike molecules of the components are equal in magnitude to those between the like molecules in their pure states. The solution is formed with no heat change and obeys Raoult's law of vapour pressures.

02

(ii) Raoult's law;

The partial vapour pressure of a component of an ideal solution at a particular temperature is the product of its mole fraction and the vapour pressure it exerts in its pure state at that temperature.

01

Limitations of the law.

- No heat change when components of the liquid mixture are added to one another.
- Volume of the liquid mixture is the exact sum of the volumes of ~~and~~ the component liquids.
- Intermolecular forces within the pure separate components and those within the liquid mixture formed are the same
- Molecules of the components in the liquid mixture have the same tendency to pass into vapour phase as they have in their pure states.

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(iii) Molecular structures of the components of most liquid mixtures are different, and thus forces of different magnitude are formed between molecules of the components. These forces can be stronger or weaker than those between molecules of the pure and separate components. As a result, either a lower or higher vapour pressure than that predicted by Raoult's law is exerted as the molecules escape into vapour phase.

02

b) (i) $P_{Total} = P_A + P_B$

$= X_A P_A^\circ + X_B P_B^\circ$

$= (1/5 \times 0.674) + (4/5 \times 0.453)$

$= 0.1348 + 0.3624$

$P_{Total} = 0.4972 \text{ atm}.$

1½

(ii) The liquid mixture deviates positively from ideal behaviour.
This is because the observed vapour pressure (0.75 atm) is greater than that expected of an ideal solution (0.4972 atm)

(iii) In vapour phase, $P_A = X_A \cdot P_{Total}$

$X_A = \frac{P_A}{P_{Total}} = \frac{0.1348}{0.4972}$

01

$X_A = 0.271$

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$X_B = 1 - 0.271$
$= 0.729$ ½

c) (i) On the graph paper;
- Labelled axes
- plotted points
- Shape of graph
- labelled regions

(ii) Addition of liquid A to B results into a decrease in the boiling point of the formed liquid mixture up to formation of the azeotropic mixture where the boiling point remains constant.
This shows that the forces of attraction formed between molecules of A and B in the liquid mixture are weaker than those between molecules of pure A and B in their separate states. 03
Molecules easily escape from the liquid mixture into vapor phase, and at any given composition the exerted vapour pressure is higher than that expected of an ideal solution. The higher the vapour pressure, the lower the boiling point.

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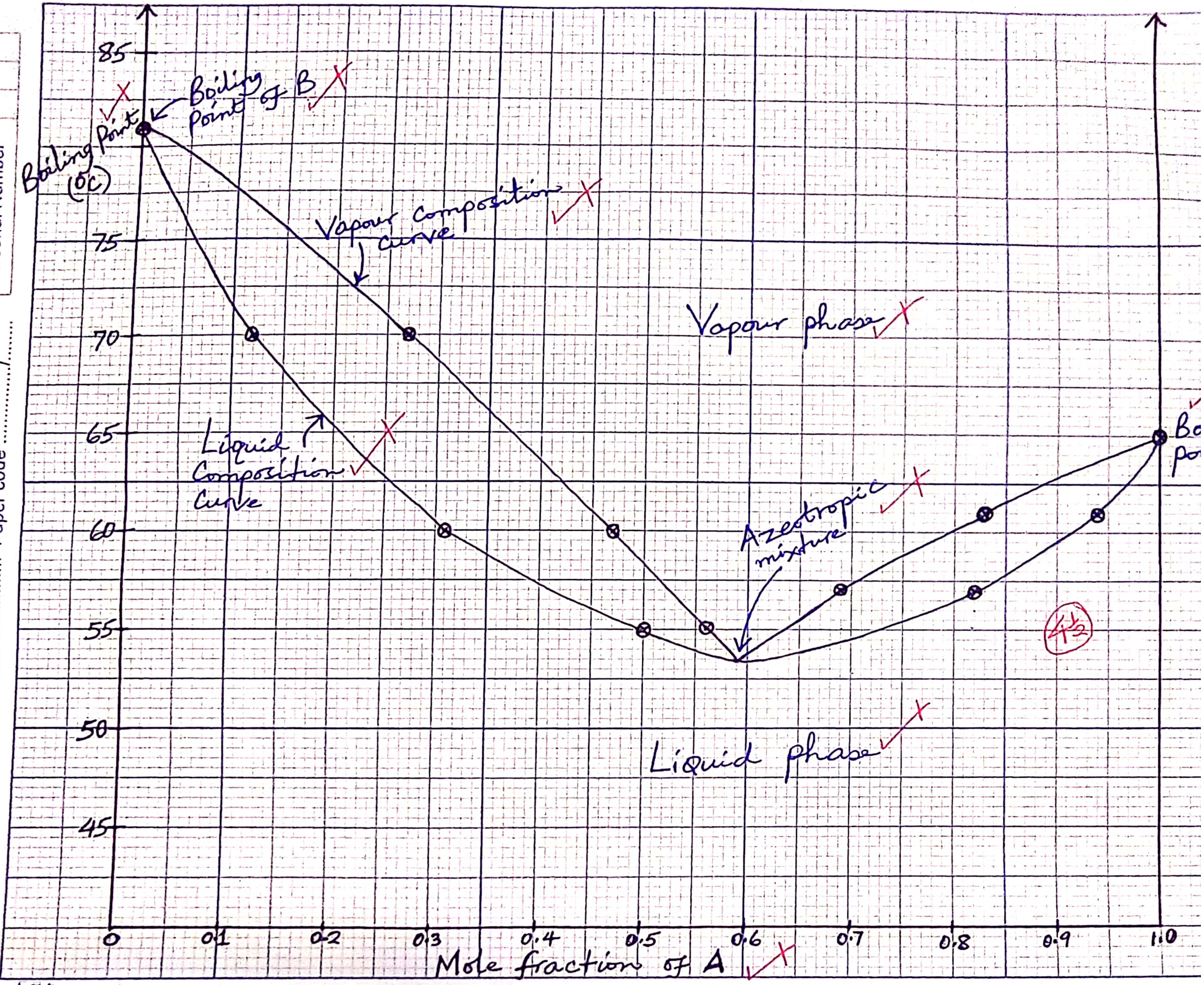

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(iii) When a liquid mixture containing 0.2 mole fraction of B is fractionally distilled, it boils to give a vapour containing 0.68 mole fraction of A and 0.32 mole fraction of B. The vapour produced is richer in B compared to the original composition of the liquid mixture.

On condensing this vapour, a liquid mixture of the same composition as the vapour is produced.

Progressive heating and condensation results into obtaining the azeotropic mixture as the distillate and pure A as the ~~dis~~ residue.

(02)

20

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2. (a) $CH_3CH_2CH_2Cl \xrightarrow[\text{Heat}]{NaOH(aq)} CH_3CH_2CH_2OH$

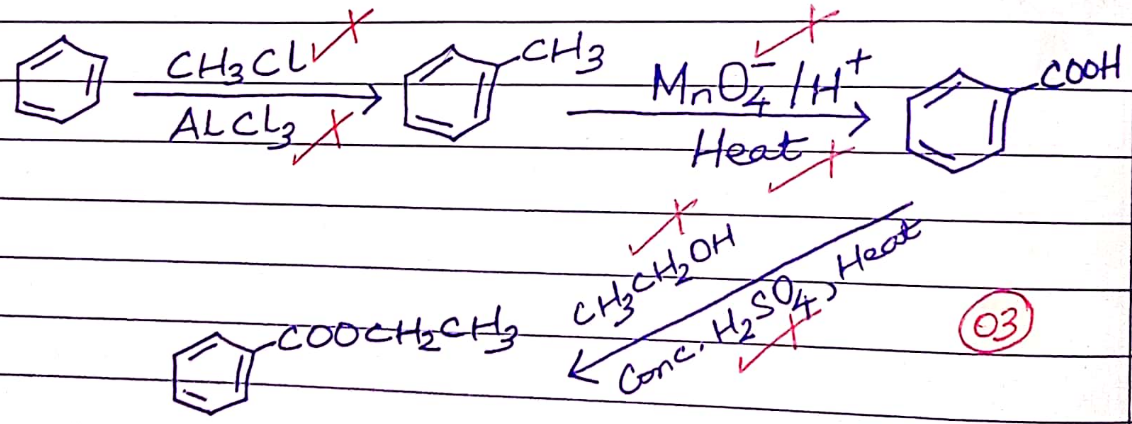
$CH_3CH_2CH_2OH \xrightarrow{\text{Conc. } H_2SO_4,\ 180^\circ C} CH_3CH=CH_2$

$CH_3CH=CH_2 \xrightarrow{HBr} CH_3CH(Br)CH_3$

$CH_3CH(Br)CH_3 \xrightarrow{CH_3NH_2} CH_3CH(NHCH_3)CH_3$

3½

(b)



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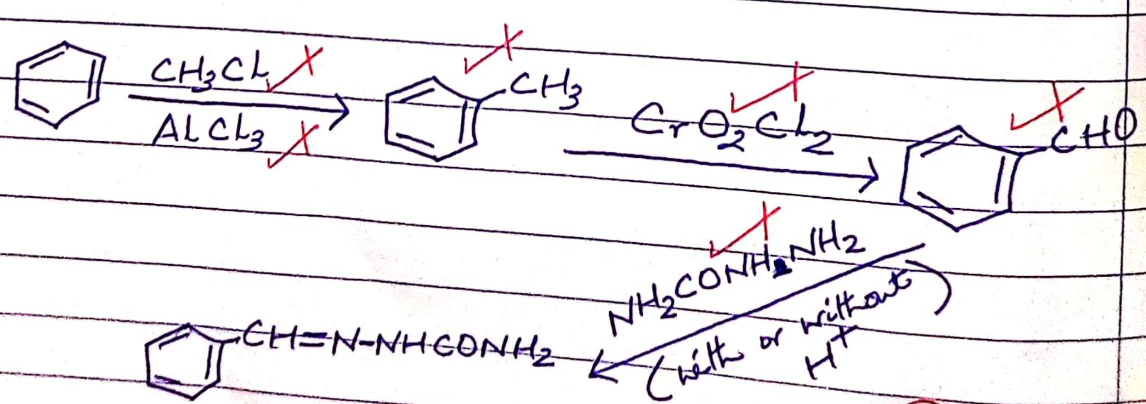
(c)



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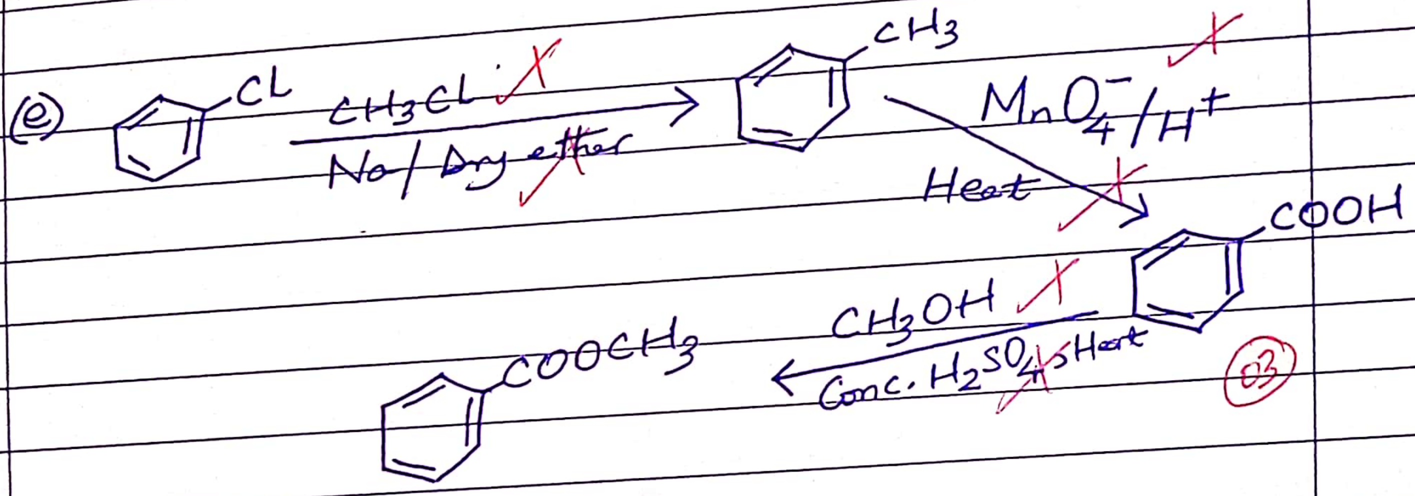
(d) $CH_3CH_2COOCH_3 \xrightarrow[Heat]{H_2O/H^+} CH_3CH_2COOH$

$CH_3CH_2COOH \xrightarrow[Heat]{(NH_4)_2CO_3} CH_3CH_2CONH_2$

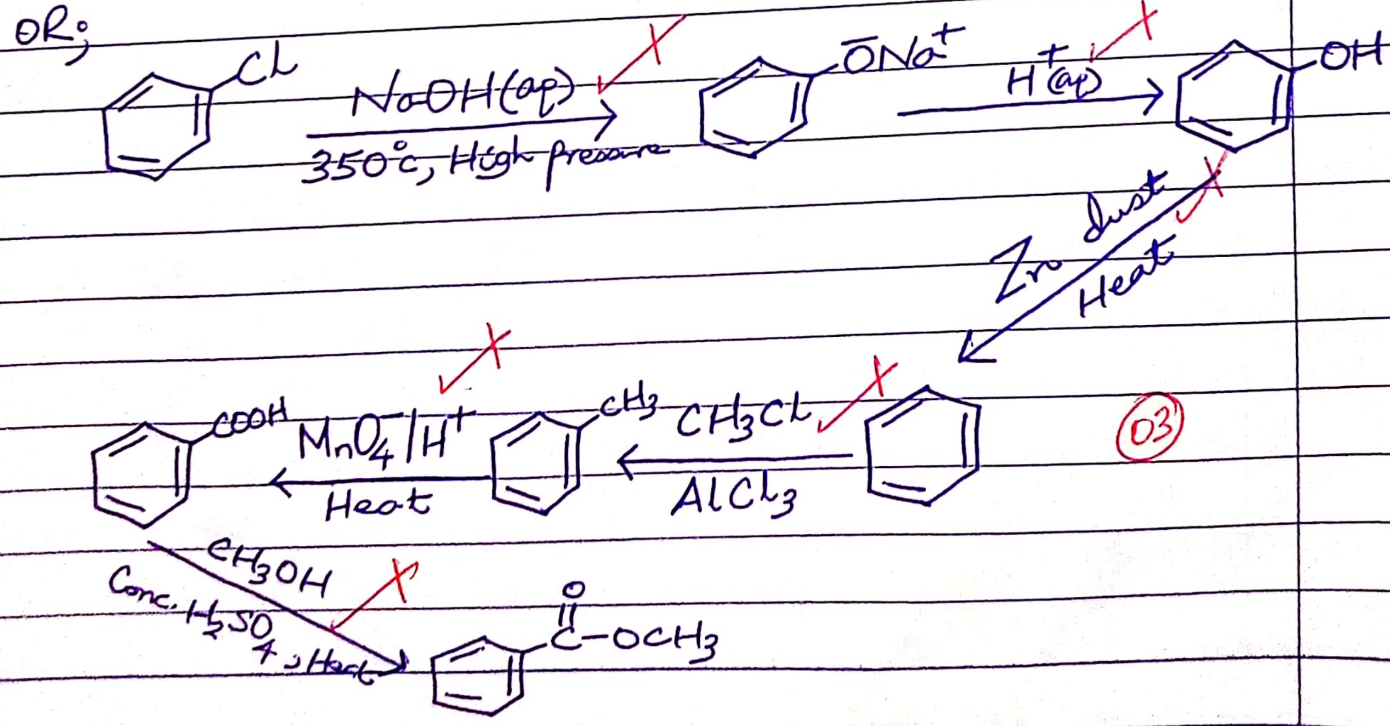
$CH_3CH_2CONH_2 \xrightarrow[Warm]{Br_2/Conc.\ NaOH} CH_3CH_2NH_2$

04

(e)



OR;



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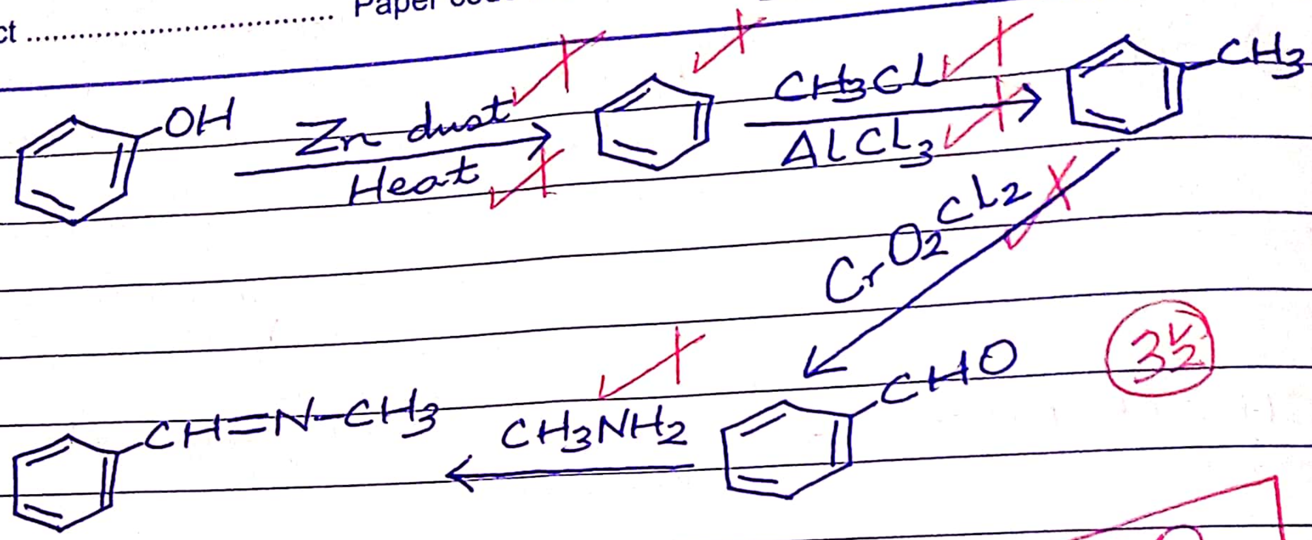
(f)



3½

20

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3 (a)(i) Electron affinity is the energy change when 1 mole of gaseous atoms or ions gains one mole of electrons to form one mole of negatively charged gaseous ions.

OR;

The energy change when an ion or gaseous atom gains an electron to form a negatively charged gaseous ion.

(ii) - Nuclear charge
- Atomic radius
- Screening effect.
- Electronic Configuration.

(iii) Nuclear charge: The greater the nuclear charge, the higher the attraction for the incoming electron. Therefore, increase in nuclear charge results into increase in electron affinity.

Atomic radius: The larger the atomic radius of an atom, the larger will be the distance between the nucleus and the attracted electron. This results into a smaller force of attraction on the incoming electron. Therefore the value of electron affinity decreases with increase in atomic radius.

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Screening effect: Within a given shell, the screening efficiency of the inner electrons decreases in the order $S > P > d > f$; implying that S- electrons are the most screening. 1½

The screening reduces attraction of outer electrons by the nucleus. Therefore, increase in screening effect results into a decrease in effective nuclear charge hence a decrease in electron affinity.

Electronic Configuration: The configurations with half-filled or completely filled sub-energy levels are relatively stable. 1½

An electron being added to such an energy level experiences greater repulsion than nuclear attraction. Therefore electron affinity becomes lower as the configuration becomes stable

b) (i) On the graph paper;

- Labelled axes 01
- plotted points. 01
- Shape of the graph. 01

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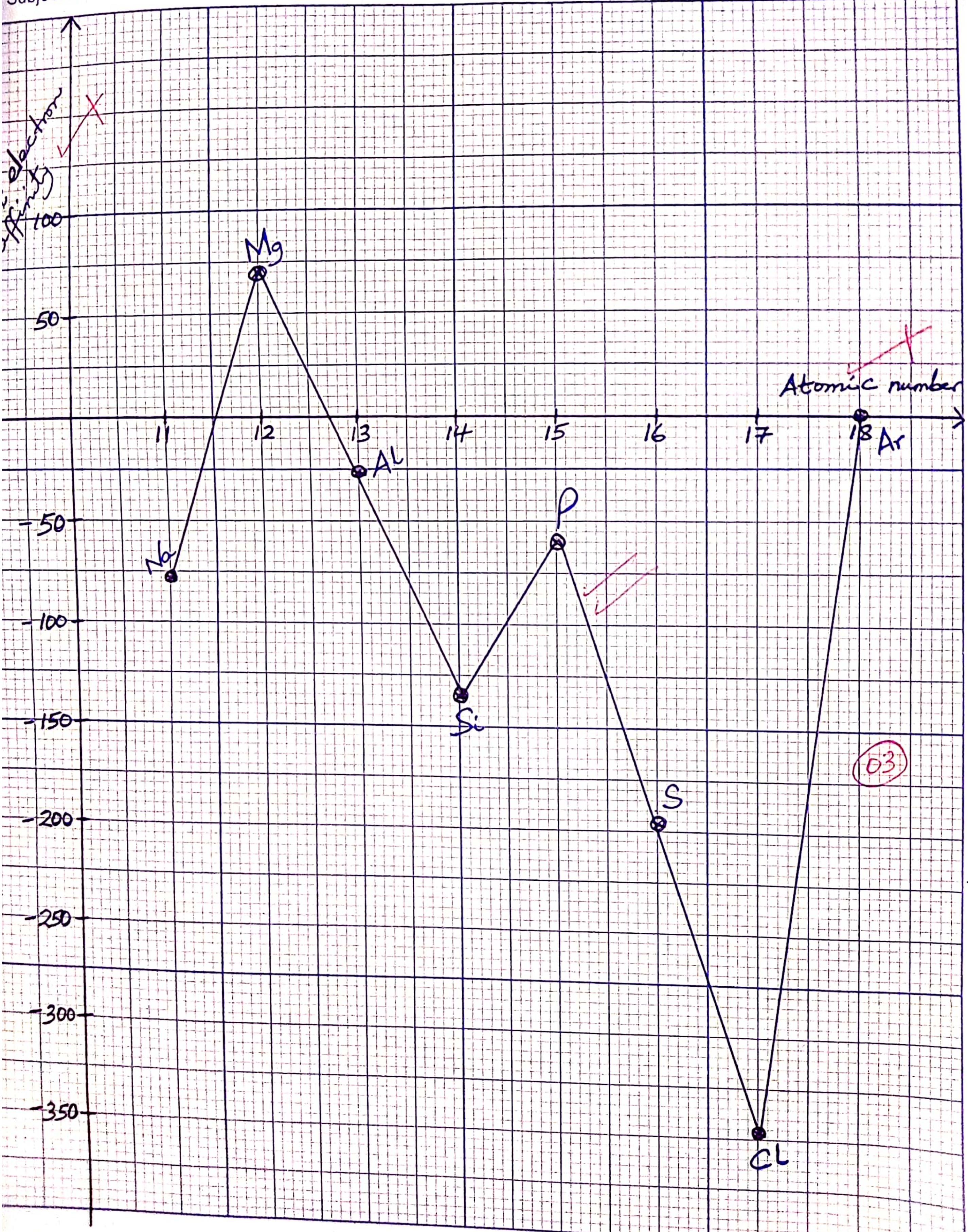

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(ii) There is a general increase in electron affinity across the period from Sodium to Argon.
Across the period, atomic radius decreases and nuclear charge increases. As a result, nuclear attraction for the incoming electron increases.
However, the first electron affinity of magnesium is lower (endothermic) than that of Aluminium.
Considering their electronic configurations;

$Al: 1S^2 2S^2 2p^6 3S^2 3p^1$

$Mg: 1S^2 2S^2 2p^6 3S^2$.

4½

Magnesium has a completely filled 3S outer sub-energy level which is stable. The added electron thus experiences greater repulsion from the existing electrons than the nuclear attraction.
Aluminium has a partially filled 3p outer sub-energy level with only one electron. The added electron thus experiences greater nuclear attraction than repulsion.

c) (i) The hydride of Silicon undergoes hydrolysis in water in the presence of an alkali to form a Silicate and hydrogen gas.

$$SiH_4(g) + 2\bar{O}H(aq) + H_2O(l) \longrightarrow SiO_3^{2-}(aq) + 4H_2(g)$$

2½

(ii) Aluminium oxide reacts with hot concentrated Sodium hydroxide solution to form Sodium aluminate solution.

$$Al_2O_3(s) + 2\bar{O}H(aq) + 3H_2O(l) \longrightarrow 2Al(OH)_4^-(aq)$$

2½

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Phosphorus (V) oxide reacts with dilute Sodium hydroxide solution to form Sodium phosphate solution and water.

$P_2O_5(s) + 6\bar{O}H(aq) \longrightarrow 2PO_4^{3-}(aq) + 3H_2O(l)$

02

20

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4.(a)

Order of reaction is the sum of the powers to which the concentrations of the reactants have been raised in an experimentally determined rate expression/equation. 01

Molecularity is the total number of species involved in the rate determining step of a chemical reaction. 01

b) (i) On the graph paper;

- Labelled axes 01
- plotted points 01
- Shape of graph 01

(ii) The reaction is First order. 01

Reason: A plot of log $[H_2O_2]$ against time is a straight line with a negative gradient. 01

c) (i) $\text{Slope} = \frac{-0.7 - 0.07}{5-0} = \frac{-0.63}{5}$

$\text{Slope} = -0.126$

and; $\text{Slope} = \frac{-K}{2.303}$ 02

~~[illegible]~~ $-0.126 \times 2.303 = -K$

Rate Constant, $K = 0.2902$

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(ii) $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

$= \frac{0.693}{0.2902}$

$= 2.388$ hours.

$1\frac{1}{2}$

d)(i) Keeping the concentration of B constant in experiments 2 and 3, when the concentration of A doubles, the rate increases four times.

Order of reaction with respect to A is 2.

Keeping the concentration of A constant in experiments 1 and 2, when the concentration of B doubles, the rate also doubles.

Order of reaction with respect to B is 1.

01

(ii) Rate $= K[A]^2[B]$

$1.00\times10^{-2} = K(2.00\times10^{-2})^2(1.00\times10^{-2})$

$K = \frac{1.00\times10^{-2}}{4\times10^{-6}}$

$= 25\times10^{6}\ mol^{-2}\ dm^{6}\ s^{-1}$

02

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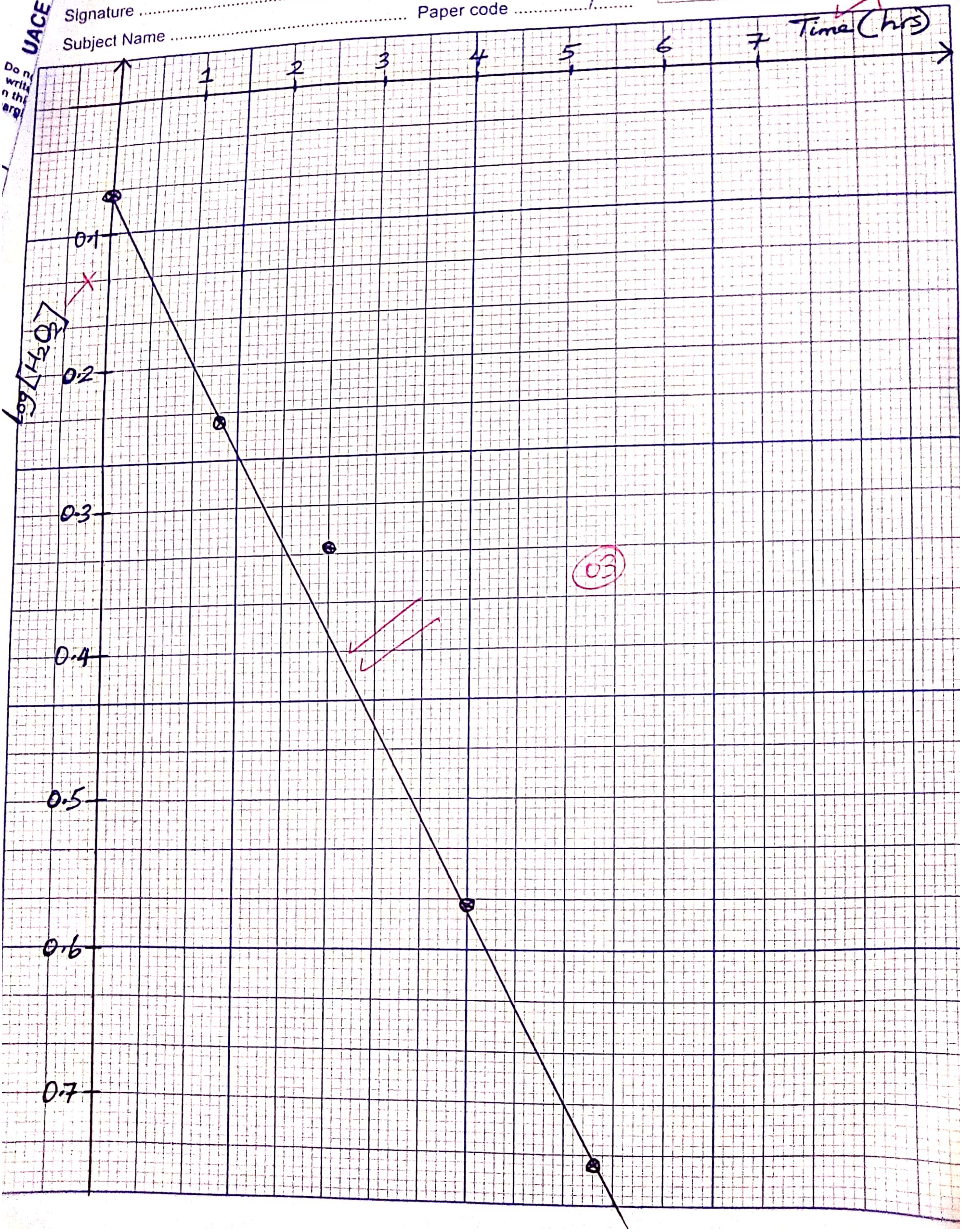

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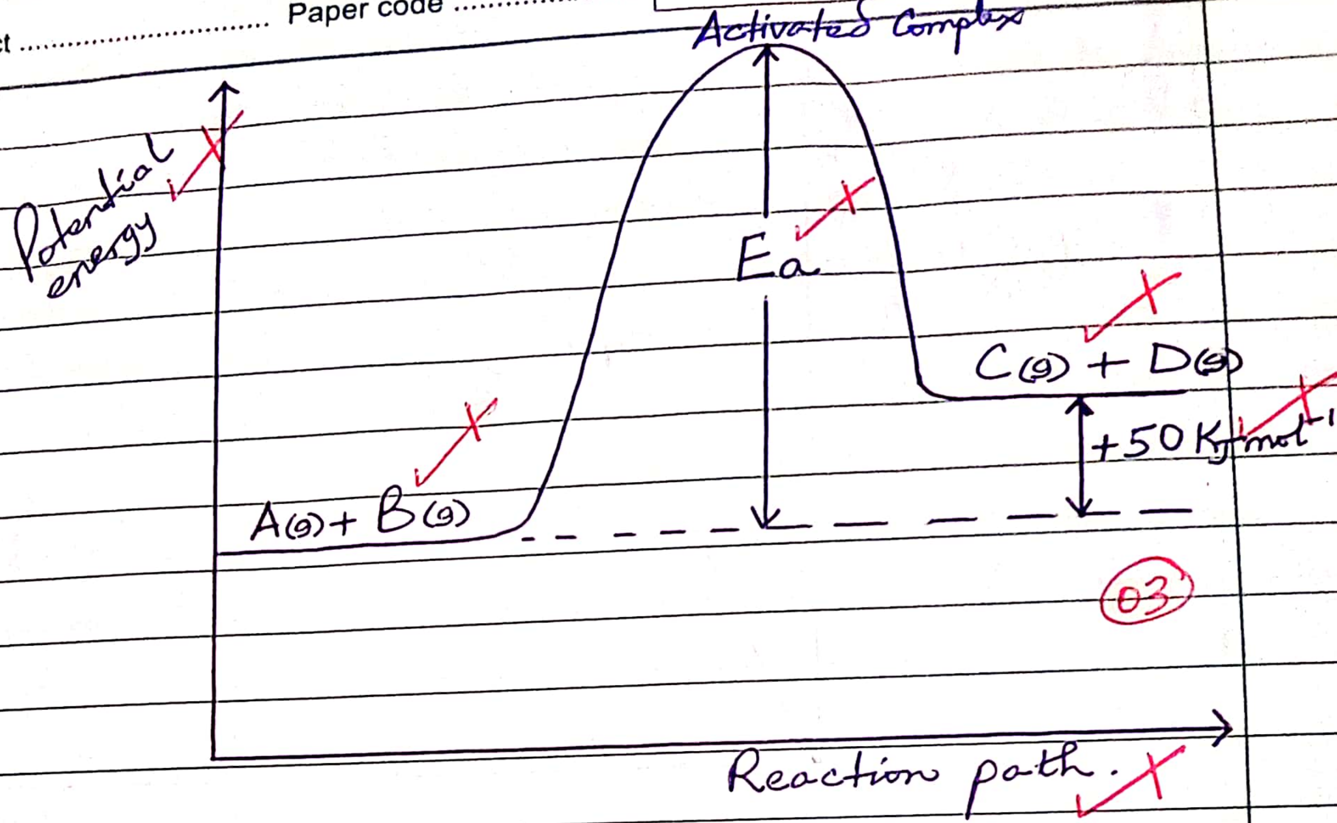
(iii)



(iv) $\Delta H = (E_a)_{forward} - (E_a)_{backward}$

$+50 = +200 - (E_a)_{backward}$

01

$-E_a = -150$

$(E_a)_{backward} = +150\,KJ\,mol^{-1}$

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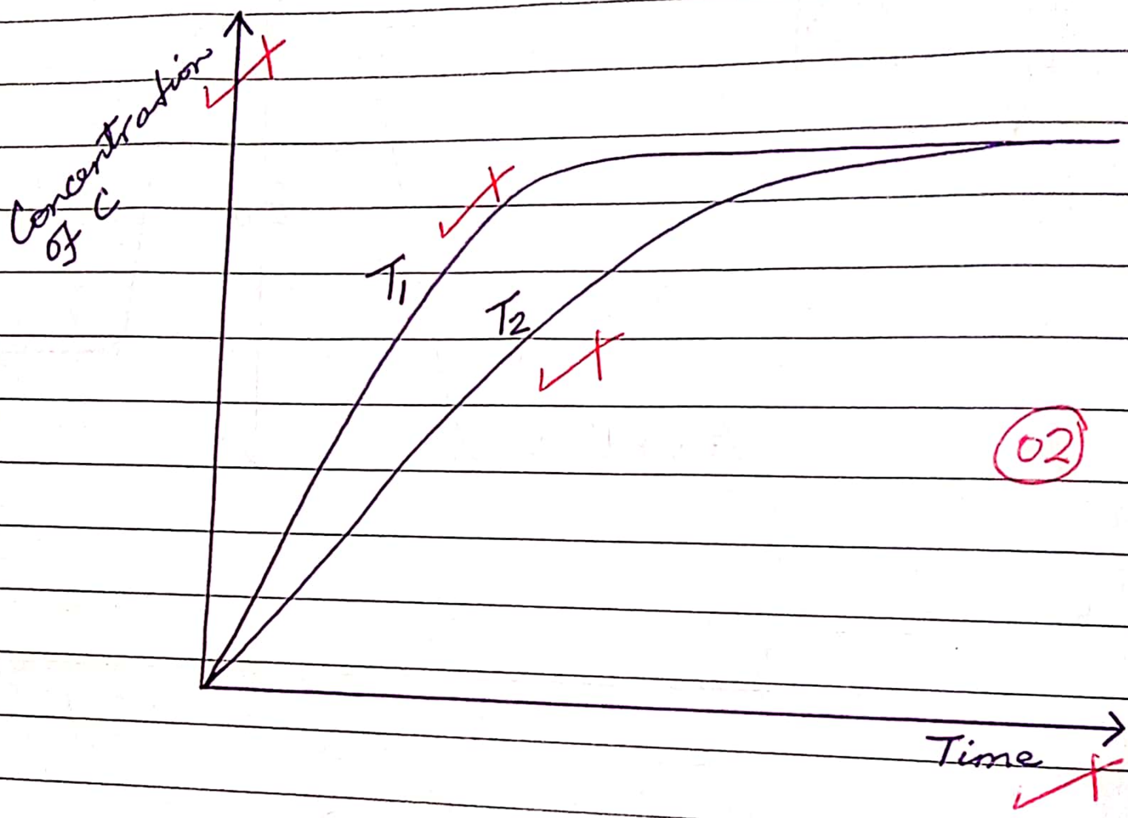
e)



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5(a) (i) Electrophilic addition reaction is a reaction in which an electrophile is added to an unsaturated compound to form a single product. 02

Example;

$CH_2{=}CH_2 + HBr \longrightarrow CH_3CH_2Br$

(ii) Nucleophilic addition reaction is a reaction in which a nucleophile is added to a carbonyl compound to form a single product. 02

Example;

$CH_3CHO + NaHSO_3 \longrightarrow CH_3\underset{\displaystyle OH}{\underset{|}{C}}HSO_3^-Na^+$

b) 2-methylpropene has a carbon to carbon double bond which contains exposed electrons. These electrons are donated to electrophiles.

In propanal, the oxygen atom in the carbon to oxygen double bond is more electronegative than the carbon atom. The oxygen atom attracts the bonding electrons towards itself leaving the carbon atom with a partial positive charge. The partially positively charged carbon atom is easily attacked by nucleophiles. 03

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$$CH_3CHO + NaHSO_3 \longrightarrow CH_3\underset{\displaystyle OH}{\underset{|}{C}}HSO_3^-Na^+$$

b) 2-methylpropene has a carbon to carbon double bond which contains exposed electrons. These electrons are donated to electrophiles.

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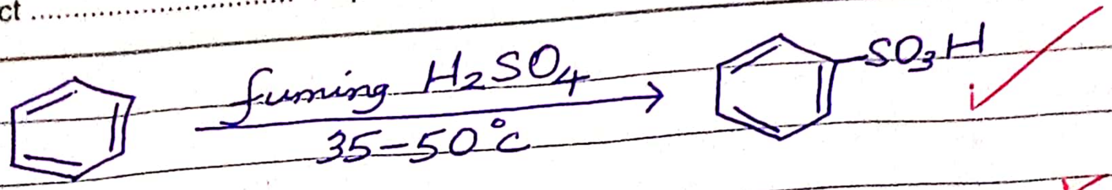
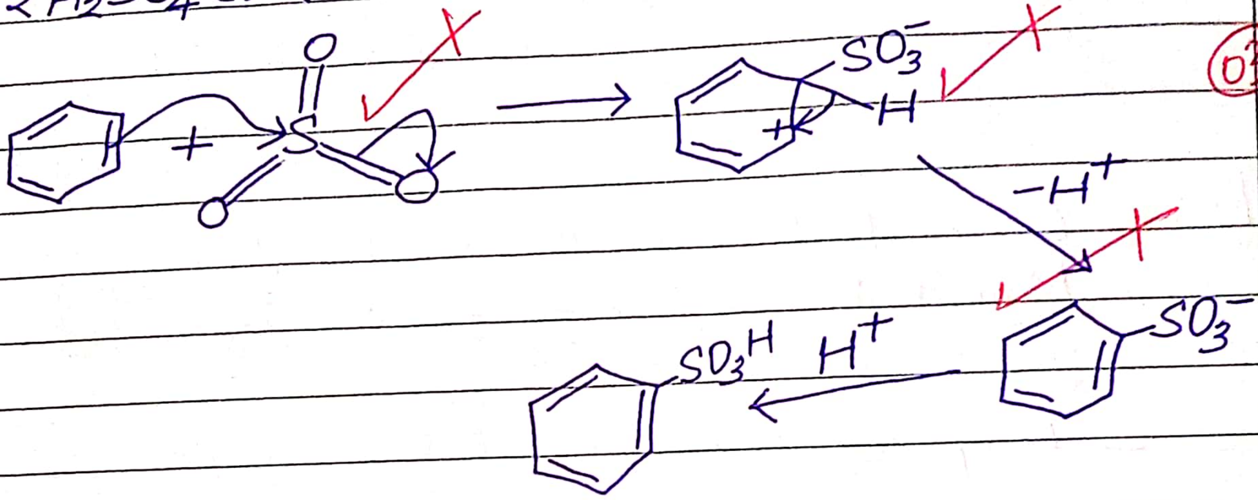
(iii) 

Mechanism.

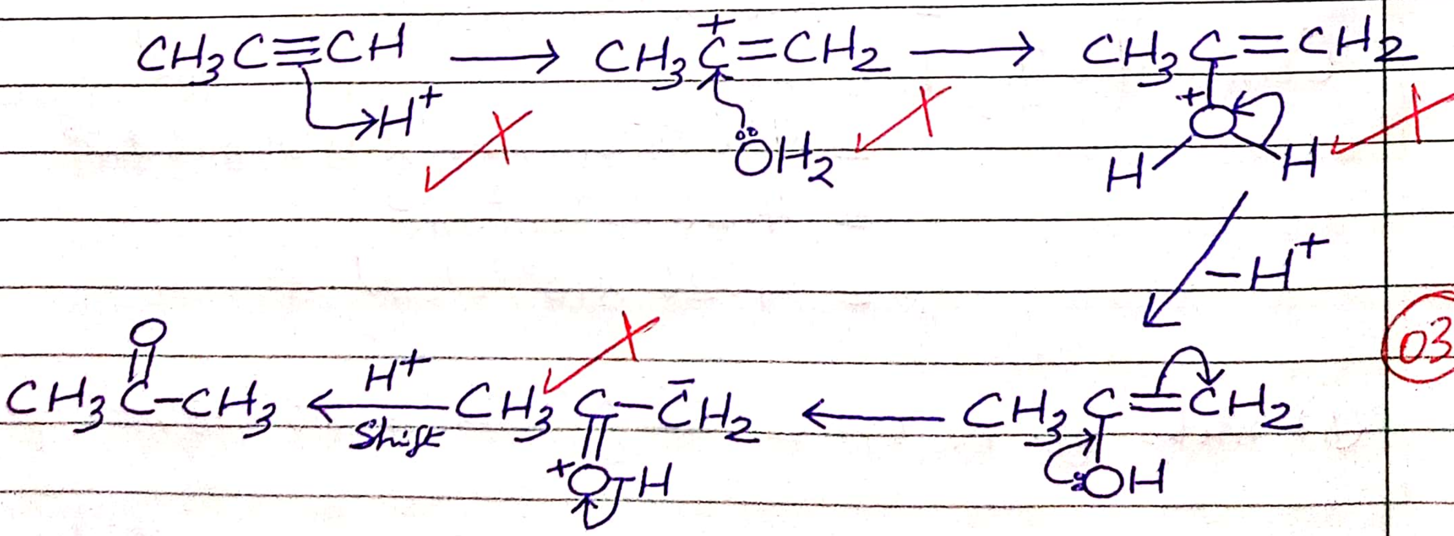
$$2H_2SO_4(l) \rightleftharpoons SO_3 + HSO_4^- + H_3O^+$$



03

(iv) $CH_3C\equiv CH + H_2O \xrightarrow[60°C]{H^+/HgSO_4} CH_3COCH_3$

Mechanism:



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6. (a) (i) Electrolytic conductivity is the conductance of an electrolyte placed between two electrodes of cross-sectional area $1m^2$ which are 1m apart. 01

(ii) Molar conductivity is the conductance of a solution containing one mole of an electrolyte placed between two electrodes of cross-sectional area $1m^2$ which are 1m apart. 01

b) – Concentration of the electrolyte.
– Magnitude of charge on the ions 1½
– Ionic radius
– Temperature of the solution of the electrolyte.

c) (i)

$$\Lambda_o(HCl) = \Lambda_o(H^+) + \Lambda_o(Cl^-)$$
$$= 350 + 76$$
$$= 426\ \Omega^{-1}cm^2mol^{-1}$$

1½

Conductivity, $K = \Lambda_o C$
$$= 426\ \Omega^{-1}cm^2mol^{-1} \times 0.01\ mol\ dm^{-3}$$
$$= 4.26\ \Omega^{-1}cm^2dm^{-3}$$
$$= 4.26 \times 10^{-3}\ \Omega^{-1}cm^{-1}.$$

(ii) moles of NaOH $= \frac{50 \times 0.01}{1000} = 5.0 \times 10^{-4}$ moles

moles of HCl $= \frac{50 \times 0.02}{1000} = 1.0 \times 10^{-3}$ moles.

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

Moles of NaCl formed = moles of NaOH reacting
$= 5 \times 10^{-4}$ moles.

Moles of excess HCl $= (1.0 \times 10^{-3} - 5 \times 10^{-4})$
$= 5 \times 10^{-4}$ moles.

Total volume of solution $= 50 + 50 = 100cm^3$.

$[HCl] = \left(\frac{1000 \times 5 \times 10^{-4}}{100}\right)$
$= 5 \times 10^{-3} M$.

Conductivity, $K_{(HCl)} = \Lambda_o C$
$= 426 \Omega^{-1} cm^2 mol^{-1} \times 5 \times 10^{-3} mol\, dm^{-3}$
$= 2.13 \times 10^{-3}\ \cancel{mol}\ \Omega^{-1} cm^{-1}$.

$\Lambda_o(NaCl) = \Lambda_o(Na^+) + \Lambda_o(Cl^-)$
$= 50 + 76$
$= 126 \Omega^{-1} cm^2 mol^{-1}$

5½

$[NaCl] = 5 \times 10^{-3} M$

Conductivity, $K_{(NaCl)} = \Lambda_o C$
$= 126 \Omega^{-1} cm^2 \cancel{mol^{-1}} \times 5 \times 10^{-3} \cancel{mol}\, dm^{-3}$
$= 0.63 \Omega^{-1} cm^2 dm^{-3}$
$= 6.3 \times 10^{-4} \Omega^{-1} cm^{-1}$.

Conductivity of solution $= K_{(HCl)} + K_{(NaCl)}$
$= 2.13 \times 10^{-3} + 6.3 \times 10^{-4}$
$= 2.76 \times 10^{-3} \Omega^{-1} cm^{-1}$.

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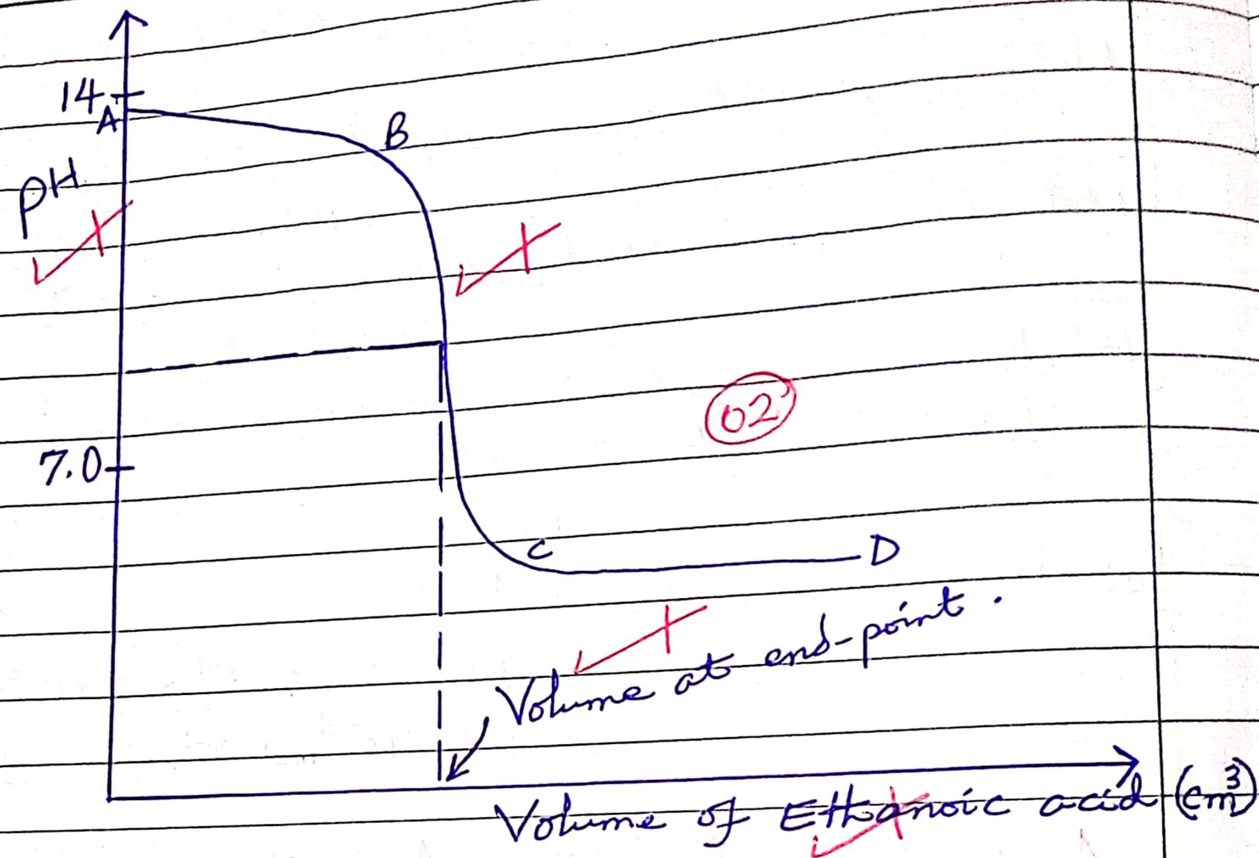
d) (i)



(ii) Initially at A, the pH is very high because of the high concentration of hydroxyl ions from Sodium hydroxide which is a strong alkali.

The pH gradually falls along AB because the hydroxyl ions are being neutralised by the acid.

At B, addition of a small amount of acid results into a sharp fall in pH showing the end-point of the reaction.

The pH of the solution formed at the end-point is greater than 7 because the salt, Sodium ethanoate undergoes hydrolysis to produce hydroxyl ions.

$CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + {}^-OH(aq)$

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After the end-point, the salt formed in the presence of excess ethanoic acid forms a buffer solution. Thus the gradual fall in pH is due to the buffer that tends to resist change in pH.

$3\frac{1}{2}$

(e) moles of NaOH $= \frac{20 \times 0.1}{1000} = 2 \times 10^{-3}$ moles

moles of $CH_3COOH = \frac{100 \times 0.1}{1000} = 1 \times 10^{-2}$ moles.

$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$

moles of Salt, CH_3COONa = moles of NaOH

$= 2 \times 10^{-3}$ moles

moles of excess $CH_3COOH = 0.01 - 0.002$

$= 0.008$ moles

Total Volume of Solution $= 100 + 20 = 120$ c

$[CH_3COONa] = \left(\frac{1000 \times 2 \times 10^{-3}}{120}\right) = 0.0167\,M$

$[CH_3COOH] = \left(\frac{1000 \times 0.008}{120}\right) = 0.067\,M$

$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$[H^+] = \frac{K_a [CH_3COOH]}{[CH_3COO^-]}$$

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$$[H^+] = \frac{1.7\times10^{-5}\times0.067}{0.0167}$$

$$= 6.82\times10^{-5}$$

04

$$pH = -\log[H^+]$$

$$= -\log(6.82\times10^{-5})$$

$$= 4.166.$$

Accept; $pH = pKa + \log\frac{[salt]}{[acid]}$

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7 (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ 01

or

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

(ii) +3 and +6. 01

b) (i) Heated chromium reacts with steam to form chromium (III) oxide and hydrogen gas.

$2Cr(s) + 3H_2O(g) \longrightarrow Cr_2O_3(s) + 3H_2(g)$ 02

(ii) Chromium reacts with dilute sulphuric acid to form chromium (II) sulphate and hydrogen.

$Cr(s) + 2H^+(aq) \longrightarrow Cr^{2+}(aq) + H_2(g)$ 04

It reacts with hot concentrated sulphuric acid to form chromium (III) sulphate, sulphurdioxide and water.

$Cr(s) + 3H_2SO_4(l) \longrightarrow Cr_2(SO_4)_3(aq) + 3SO_2(g) + 6H_2O(l)$

c) (i) An effervescence occurs and a green precipitate is formed.

Chromium (III) ions have a high charge density. They undergo hydrolysis in aqueous solution to produce hydrogen ions that make the solution acidic.

$Cr^{3+}(aq) + 3H_2O(l) \longrightarrow Cr(OH)_3(s) + 3H^+(aq)$ 3½

The solution reacts with sodium carbonate to liberate carbondioxide gas.

$CO_3^{2-}(aq) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$

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The green precipitate is the insoluble chromium (III) hydroxide ½

(ii) A green precipitate that dissolved in excess alkali to form a green solution.

The precipitate is insoluble Chromium (III) hydroxide which is amphoteric and reacts with excess alkali to form a soluble complex of chromate (III) ions.

4½

$$Cr^{3+}(aq) + 3\bar{O}H(aq) \longrightarrow Cr(OH)_3(s)$$

$$Cr(OH)_3(s) + 3\bar{O}H(aq) \longrightarrow Cr(OH)_6^{3-}(aq)$$

or;

$$Cr(OH)_3(s) + \bar{O}H(aq) \longrightarrow Cr(OH)_4^{-}(aq).$$

d) (i) The green solution changed to yellow. ½

(ii) $2Cr(OH)_4^{-}(aq) + 2\bar{O}H(aq) + 3H_2O_2(aq) \longrightarrow 2CrO_4^{2-}(aq) + 8H_2O(l)$ 1½

e) (i) The solution changed from orange to yellow ½

(ii) $Cr_2O_7^{2-}(aq) + 2\bar{O}H(aq) \longrightarrow 2CrO_4^{2-}(aq) + H_2O(l)$ 1½

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(8) (a) Ammonia is a weak base. It contains a small concentration of hydroxyl ions.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq).$$

The concentration of hydroxyl ions is enough to make the ionic product of magnesium ions and hydroxyl ions in solution exceed the solubility product, Ksp, of magnesium hydroxide so that precipitation takes place.

05

$$Mg^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s).$$

Ammonium chloride is a strong electrolyte. It provides a high concentration of ammonium ions which suppress the ionisation of ammonia.

The hydroxyl ion concentration in the solution is thus reduced and it is not enough to cause precipitation of magnesium hydroxide.

(b) Chloroethane has a polar carbon to chlorine bo[nd] because chlorine is more electronegative than carbon. The carbon atom thus acquires a partial positive charge. It is attacked by the hydroxyl ions leadin[g] to a substitution reaction and release of chloride io[ns]

$$CH_3CH_2-Cl + OH^- \longrightarrow CH_3CH_2OH + Cl^-$$

The released chloride ions react with silver ions to form insoluble silver chloride.

$$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$$

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In chlorobenzene, the lone pair of electrons on the chlorine atom interracts with the delocalised electrons of the benzene ring. This makes the carbon to chlorine bond stronger hence chlorobenzene does not undergo substitution.

05

(c) Both molecules have four electron pairs around their central atoms. In water molecule, the central oxygen atom is sorrounded by two lone pairs while the nitrogen atom in ammonia is sorrounded by one lone pair.
The two lone pairs on oxygen exert a greater repulsion on bond pairs in the water molecule compared to the one lone pair on the nitrogen in ammonia.

03

d) Although the carbon to chlorine bonds in tetrachloromet are polar, these bonds are symmetrically arranged around the central carbon atom to give the molecules a tetrahedral shape. The effect of bond polarity in the opposite directions therefore cancels out such that the net dipole moment in the whole molecule is zero.

3½

In trichloromethane, one of the carbon to chlorine bonds is directly opposite the carbon to hydrogen bond. There is a dipole moment towards the chlorine atom of this bond making the molecule to be polar.

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(e) The Iron (III) ions have a high charge density. They undergo hydrolysis in solution to form hydrogen ions in the solution that make it acidic.

$$Fe^{3+}(aq) + 3H_2O(l) \longrightarrow Fe(OH)_3(s) + 3H^+(aq)$$

On addition of Sodium hydrogen carbonate, the hydrogen ions react with hydrogen carbonate ions to liberate carbondioxide.

$$HCO_3^-(aq) + H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$$

The brown precipitate is due to formation of insoluble Iron (III) hydroxide.

$3\frac{1}{2}$

—END—

$\boxed{20}$