

$$\text{accept} \quad 2.203 \log \left( \frac{104}{100} \right) = \lambda t$$

P525/1 CHEMISTRY

$\approx 211.77 \approx 212 \text{ minutes}$

$\lambda = \frac{0.03922738}{12 \times 60}$

$$= 0.000054473$$

$$t_{1/2} = \frac{0.693}{0.000054473}$$

SECTION A  
Answer all questions from this section

$$= 12719.55 \text{ sec}$$

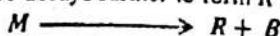
1. (a) Polonium,  $^{216}_{84}\text{Po}$  undergoes nuclear decay to give element M according to the following equation
- $$^{216}_{84}\text{Po} \longrightarrow M + \alpha$$

State

(i) The atomic number of M ..... 82 ✓ (0½)

(ii) The mass number of M ..... 212 ✓ (0½)

- (b) M decays further to form R as shown below



State

(i) The atomic number of R ..... 83 ✓ (0½)

(ii) The mass number of R ..... 212 ✓ (0½)

- (c) A sample of M had an initial activity of 104 counts per second. After 12 minutes the activity had reduced to 100 counts per second. Calculate the half-life of M. (2½ marks)

from  $\ln \left( \frac{N_0}{N_t} \right) = \lambda t$  ✓  $t_{1/2} = \frac{\ln 2}{\lambda}$  ✓ (2½)

$$\ln \frac{104}{100} = 12 \times 60 \times \lambda$$

$$\lambda = \frac{0.039221}{12 \times 60} = 0.000054473$$

$$= 12,724.55 \text{ seconds } \checkmark$$

2. State what would be observed and write equation(s) for the reaction(s) that would take place when the following pairs of substances are mixed.

- (a)  and bromine water

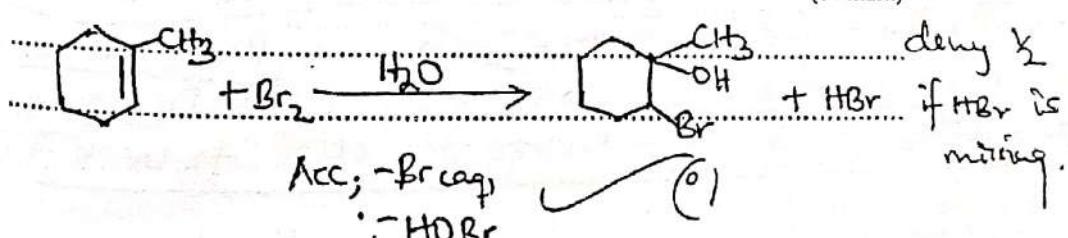
Observation

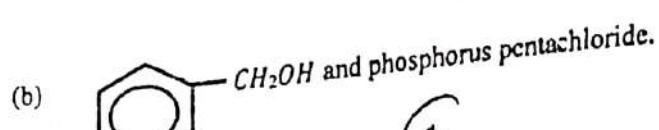


The reddish brown solution turns colourless

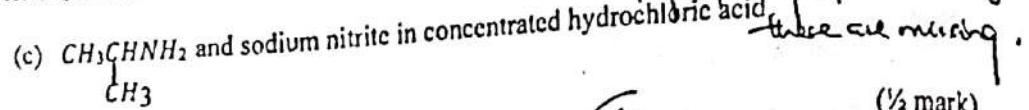
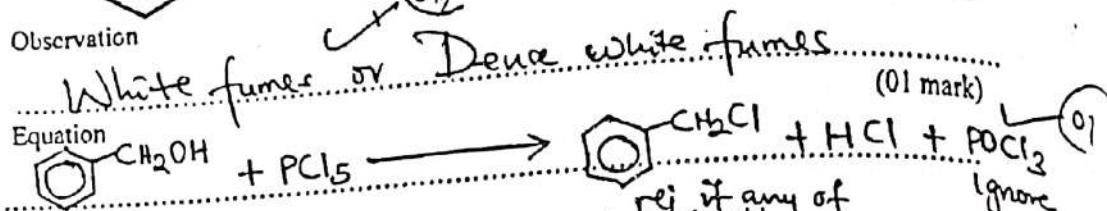
Equation

(01 mark)

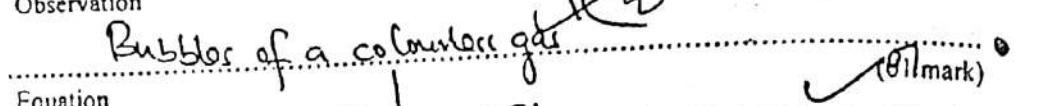




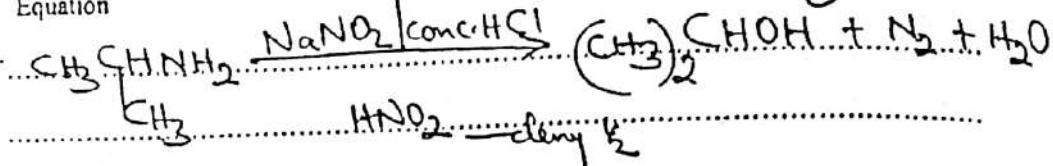
Observation



Observation



Equation

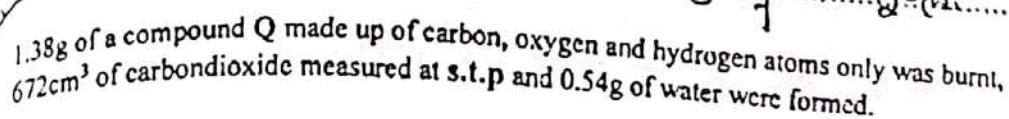
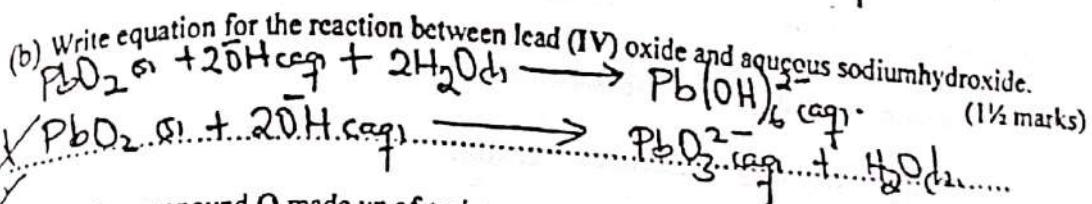
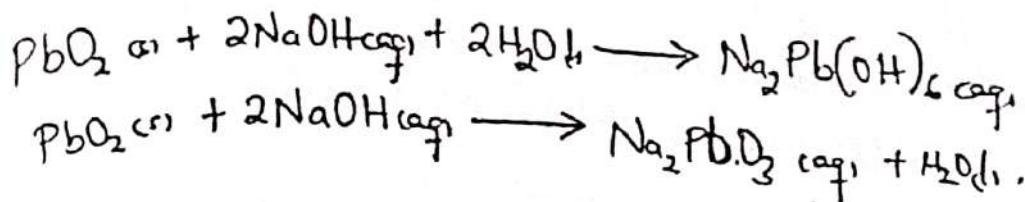


3. The table below shows the trend in the melting points of group IV dioxides.

Formula of oxide	$\text{CO}_2$	$\text{SiO}_2$	$\text{GeO}_2$	$\text{SnO}_2$	$\text{PbO}_2$
Melting points ( $^{\circ}\text{C}$ )	-18	1700	1120	1830	752

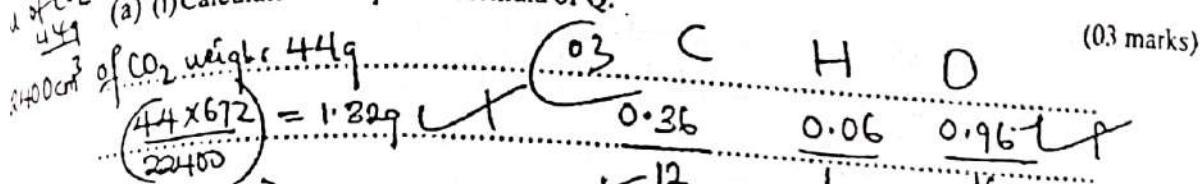
- (a) Explain the trend in melting points of the dioxides  $\checkmark$  (4½ marks)

Melting points generally increases from  $\text{CO}_2$  to  $\text{PbO}_2$  with the melting points of  $\text{GeO}_2$  and  $\text{PbO}_2$  being lower than expected. Carbon dioxide exhibit a simple molecular structure with Van der Waals forces that are so weak. Both  $\text{SiO}_2$  and  $\text{GeO}_2$  exhibit giant molecular structures with short covalent bonds between respective atoms, the atomic radius of silicon is smaller than Germanium so that the covalent bond is stronger in  $\text{SiO}_2$  than  $\text{GeO}_2$ . Tin dioxide and  $\text{PbO}_2$  exhibit giant structures so the ionic bond in  $\text{SnO}_2$  is stronger than  $\text{PbO}_2$  some more energy is needed to break it.



1.38g of a compound Q made up of carbon, oxygen and hydrogen atoms only was burnt, 672cm<sup>3</sup> of carbondioxide measured at s.t.p and 0.54g of water were formed.

(a) (i) Calculate the empirical formula of Q.



of carbon =  $\left(\frac{12 \times 1.32}{44}\right) = 0.36$

of hydrogen =  $\left(\frac{1.32 - 0.36}{18}\right) = 0.06$

of oxygen =  $1.32 - (0.36 + 0.06) = 0.96$

1	2	2
$\frac{0.06}{0.03}$	$\frac{0.06}{0.03}$	$\frac{0.96}{0.03}$

Q is CH<sub>2</sub>O<sub>2</sub>

(ii) Determine the molecular formula of Q, given that its relative molecular mass is 46.

molecular mass of Q = 46

$(\text{CH}_2\text{O}_2)_n = 46$

$46n = 46$

$n = 1$

∴ the molecular formula of Q is CH<sub>2</sub>O<sub>2</sub>

(b) Compound Q reacts with a saturated solution of sodium hydrogen carbonate liberating carbondioxide gas. Identify Q.

HCOOH or HCO<sub>2</sub>H or methanoic acid

(c) A hot solution of Q was added to acidified potassium manganate (VII) solution.

(i) State what was observed.

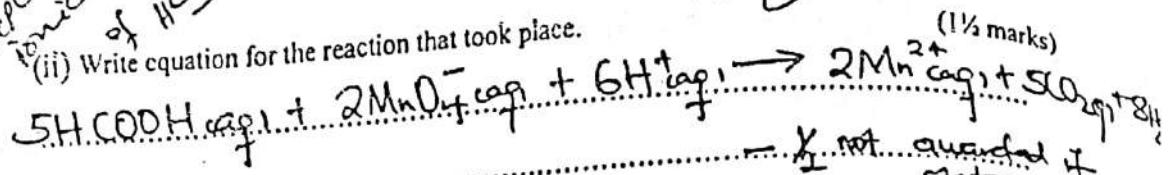
The purple solution turned colourless, bubbles of

a colourless gas

Rej; If one is missing,

accept  
ionic eqn  
of  $\text{HCOO}^-$

(ii) Write equation for the reaction that took place.



✗ not awarded if  
state mixing

5. The standard electrode potentials for some half cells are shown below: — Reg; if not balanced,



$E^\circ/V$

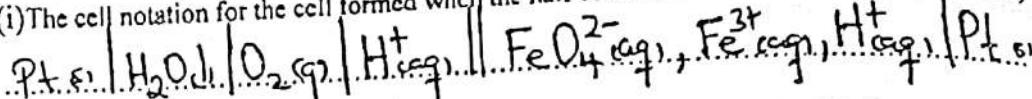
+1.23



+2.20

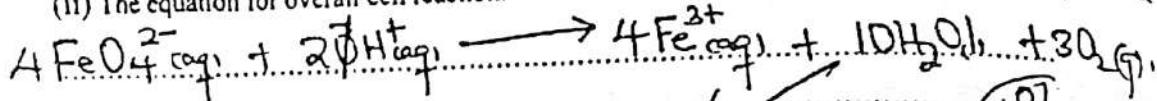
(a) Write

(i) The cell notation for the cell formed when the half cells are combined.



✗ if  $\text{H}_2\text{O}$  is included on right side. (01 mark)

(ii) The equation for overall cell reaction.



(b) (i) Calculate Gibb's free energy for the cell in (a).

$$\Delta G^\circ = -nFE^\circ \quad \text{✓} \quad E^\circ = (+2.2 - 1.23)$$

$$= -12 \times 96500 \times +0.97$$

$$= -1123260 \text{ J mol}^{-1} \quad \text{✓} \quad (01)$$

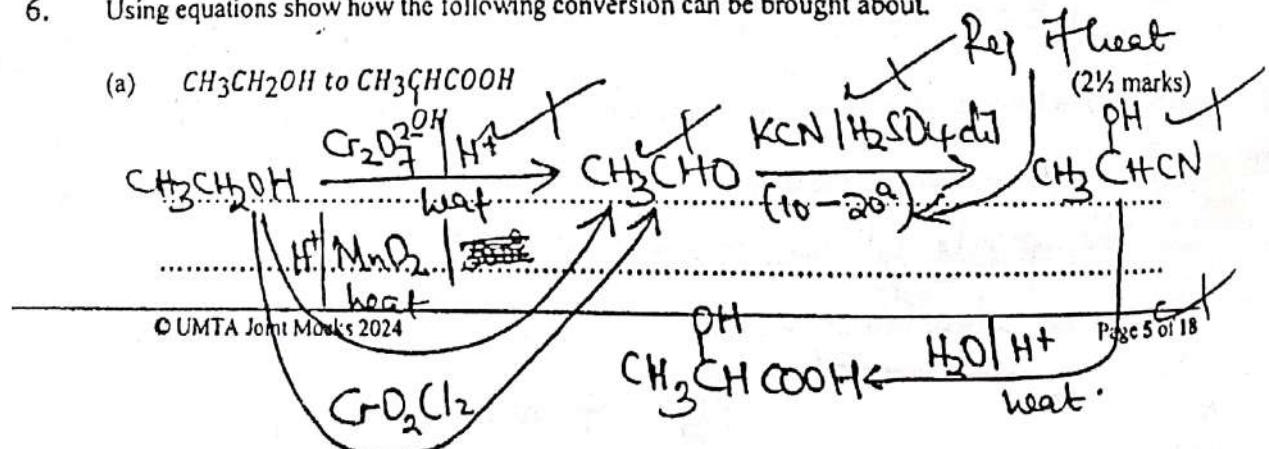
(ii) State whether the cell reaction is feasible or not. Give a reason for your answer. (01 mark)

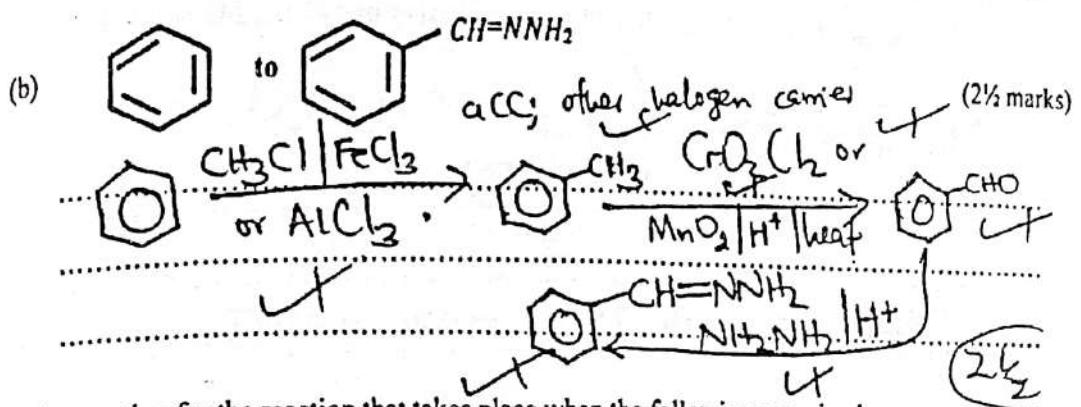
The reaction is feasible, because Gibb's free energy energy has a negative (exgn). (01)

Reg; if exothermic for negative?

6. Using equations show how the following conversion can be brought about.

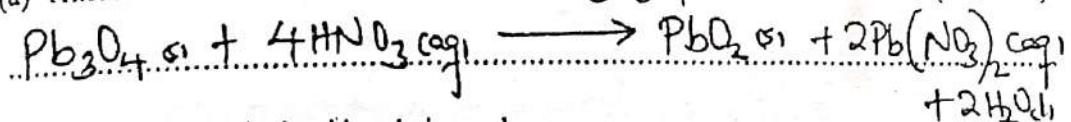
(a)  $\text{CH}_3\text{CH}_2\text{OH}$  to  $\text{CH}_3\text{CHCOOH}$





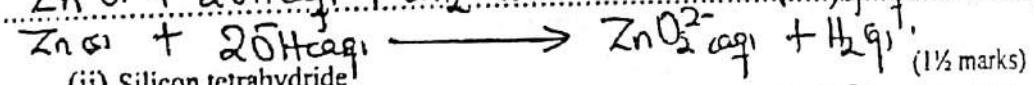
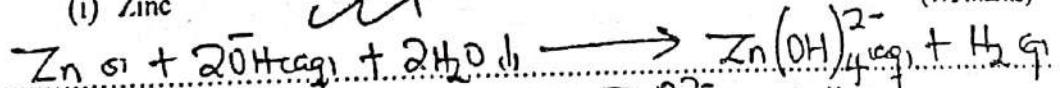
7. Write equation for the reaction that takes place when the following are mixed.

(a) Trileadtetraoxide and concentrated nitric acid. ✓ (1½ marks)

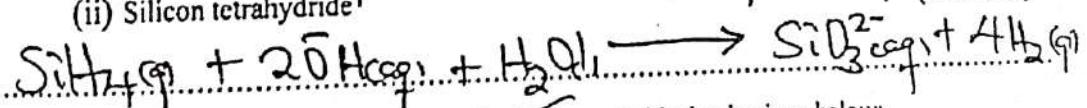


(b) Aqueous sodium hydroxide solution and

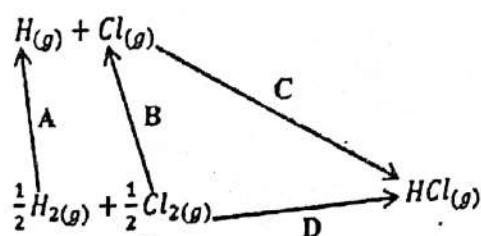
(i) Zinc ✓ (1½ marks)



(ii) Silicon tetrahydride



8. The energy diagram for the reaction between hydrogen and chlorine is given below;



- (a) Identify the energy changes
- Enthalpy of atomisation of hydrogen gas ✓ ..... (½ mark)
  - Enthalpy of atomisation of chlorine gas ✓ ..... (½ mark) (Q2)
  - Bond energy of hydrogen chloride ✓ ..... (½ mark)
  - Enthalpy of formation of hydrogen chloride ✓ ..... (½ mark)

- (b) Calculate the enthalpy change for the reaction  
 (The H - H, Cl - Cl and H - Cl bond energies are 435.9, 241.8 and 431.0 kJ/mol<sup>-1</sup>)

$\sum \text{Bonds broken} \left( \frac{1}{2} \text{H}_2 \rightarrow \text{H}; \frac{1}{2} \text{Cl}_2 \rightarrow \text{Cl} \right) \checkmark$

$$= \frac{435.9}{2} + \frac{241.8}{2} \quad \checkmark$$

$$(217.95 + 120.9) = +338.85 \text{ kJ/mol} \quad \checkmark \quad (Q2)$$

$\sum \text{Bonds formed} (\text{H}-\text{Cl}) \checkmark \quad \text{ref if sig figs needed}$

$$= -431.0 \text{ kJ} \quad \checkmark$$

Enthalpy change =  $+338.85 - 431.0$

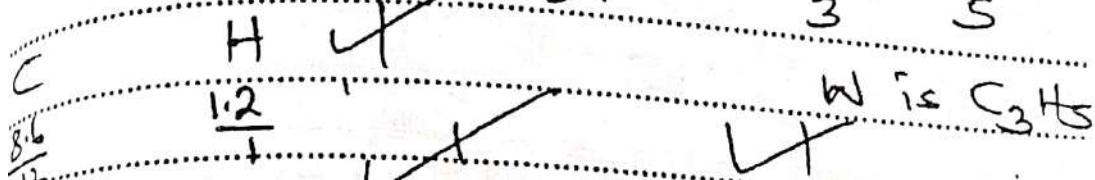
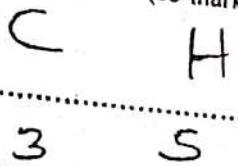
=  $-92.15 \text{ kJ/mol} \quad \checkmark$

(i) 9.8g of an organic compound W containing carbon and hydrogen only was burnt in excess oxygen, 31.55g of Carbon dioxide and 10.76g of water were formed. Determine the empirical formula of W.

$$\text{mass of carbon} = 12 \times 31.55 = 38.6$$

(03 marks)

$$\text{mass of hydrogen} = \frac{2 \times 10.76}{18} = 1.2$$



$$\frac{1.2}{12} : \frac{1.2}{1} = 1 : 1.67 \quad \text{O3}$$

(i) W was steam distilled at  $70^\circ C$  and 760 mmHg and the distillate was found to contain 8.9% by mass of water. Calculate the formula mass of W. (Vapour pressure of water at  $70^\circ C$  is 234 mmHg)

Let it be Mr<sub>W</sub>

$$\frac{\text{vap. pressure of } H_2O}{\text{vapour pressure of } W} = \frac{\text{molar } H_2O}{\text{molar } W} \quad \text{Mr}_W = 100 - 8.9$$

$$Vap. P = 760 - 234 = 526 \text{ mmHg}$$

$$\frac{234}{526} = \frac{8.9}{18} \times \frac{Mr_W}{91.1} \quad \text{molar } W = \frac{8.9}{18} = 0.494$$

$$Mr_W = \frac{91.1 \times 18 \times 234}{526 \times 8.9}$$

$$= 81.96$$

$$\approx 82.9 \quad \text{O3}$$

$$\text{molar } W = \frac{91.1}{Mr_W}$$

$$\frac{0.445}{1} = \frac{0.494 \times Mr_W}{1 \times 91.1}$$

$$Mr_W = \frac{91.1 \times 0.445}{0.494}$$

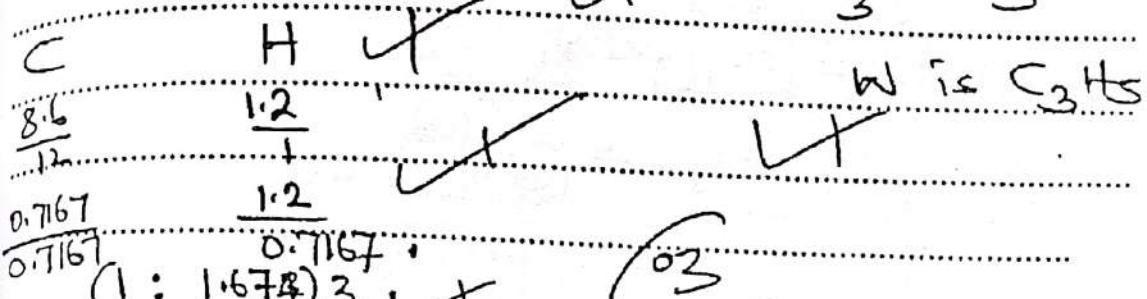
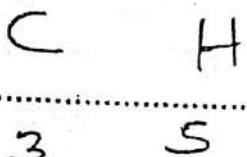
$$Mr_W = 91.127$$

4

(a) 9.8g of an organic compound  $W$  containing carbon and hydrogen only was burnt in excess oxygen, 31.55g of Carbon dioxide and 10.76g of water were formed. Determine the empirical formula of  $W$ . (03 marks)

$$\text{mass of carbon} = 12 \times 31.55 = 8.6 \text{ g}$$

$$\text{mass of hydrogen} = \frac{2 \times 10.76}{18} = 1.2 \text{ g}$$



(b)  $W$  was steam distilled at 70°C and 760 mmHg and the distillate was found to contain 8.9% by mass of water. Calculate the formula mass of  $W$ . (Vapour pressure of water at 70°C is 234 mmHg)

$$\frac{\text{vapour pressure of H}_2\text{O}}{\text{vapour pressure of } W} = \frac{\text{mole H}_2\text{O}}{\text{mole } W}$$

$$\frac{234}{526} = \frac{8.9}{18} \times \frac{\text{Mr}_W}{91.1}$$

$$\frac{1}{1} = \frac{1}{1} \times \frac{1}{1}$$

$$\text{mole } W = \frac{8.9}{18} = 0.494$$

$$\text{mole H}_2\text{O} = \frac{8.9}{18} = 0.494$$

$$\text{Mr} = \frac{91.1 \times 18 \times 234}{526 \times 8.9}$$

$$= 81.96$$

$$\approx 82 \text{ g/mol}$$



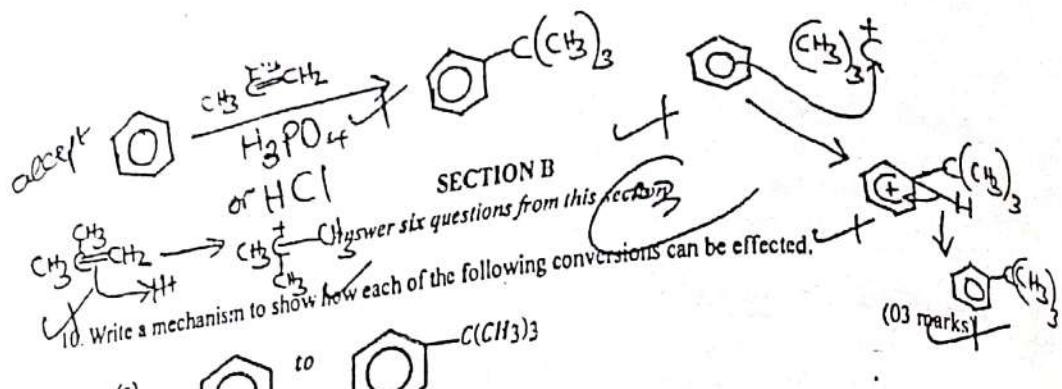
$$\text{mole of } W = \frac{91.1}{\text{Mr}}$$

$$\frac{0.445}{1} = \frac{0.494 \times \text{Mr}}{1}$$

$$\text{Mr} = \frac{91.1 \times 0.445}{0.494}$$

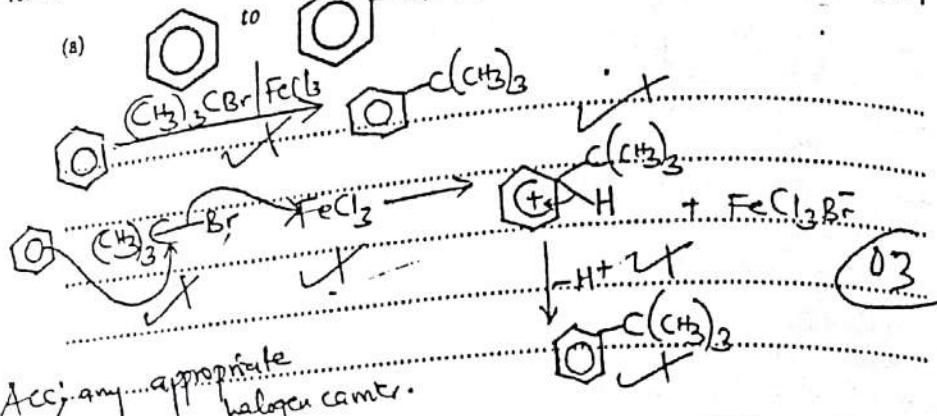
$$\text{Mr} = 91.127$$

4

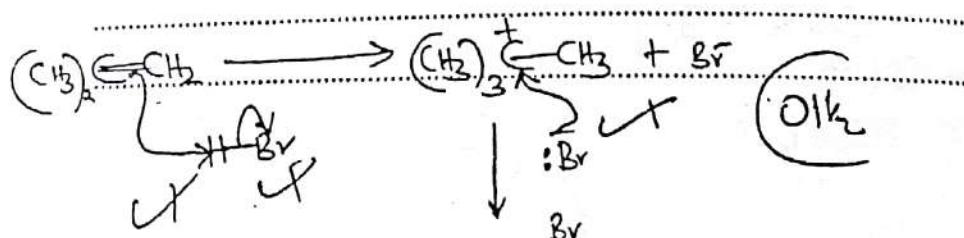
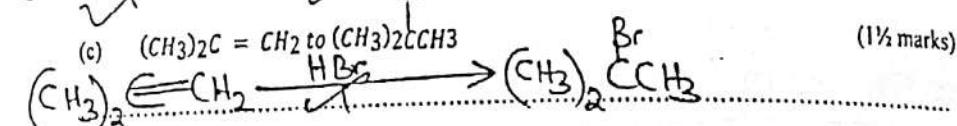
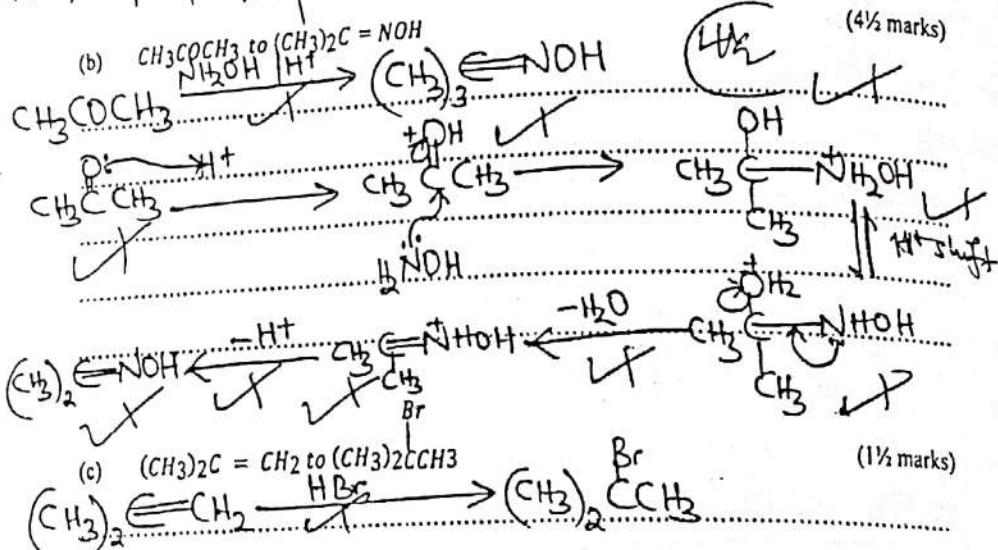


10. Write a mechanism to show how each of the following conversions can be effected.

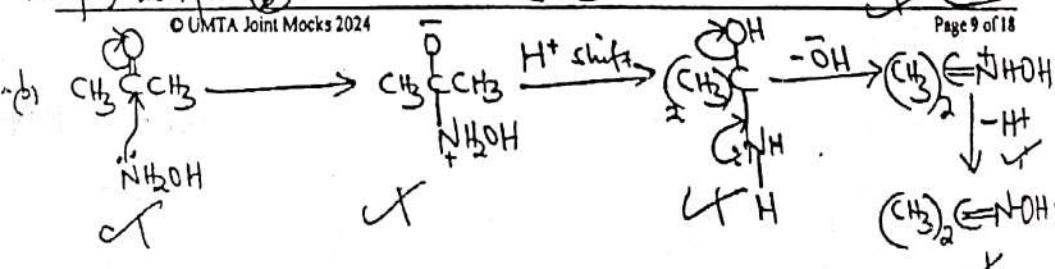
(a) to

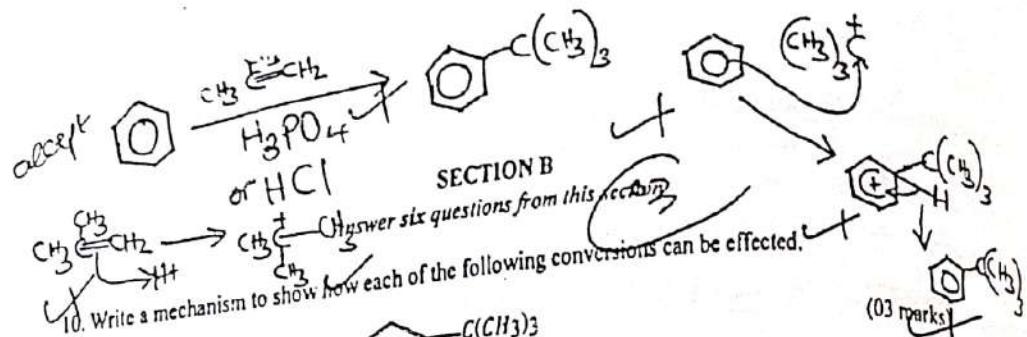


(03)

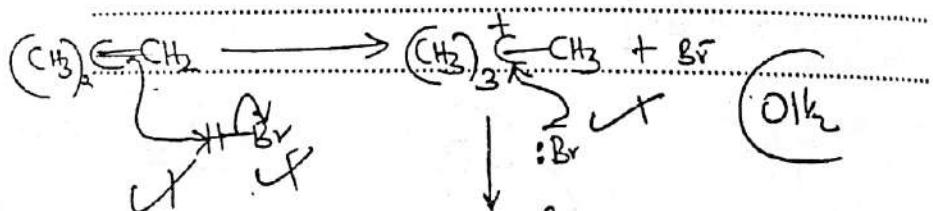
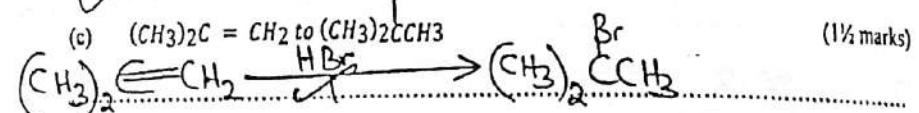
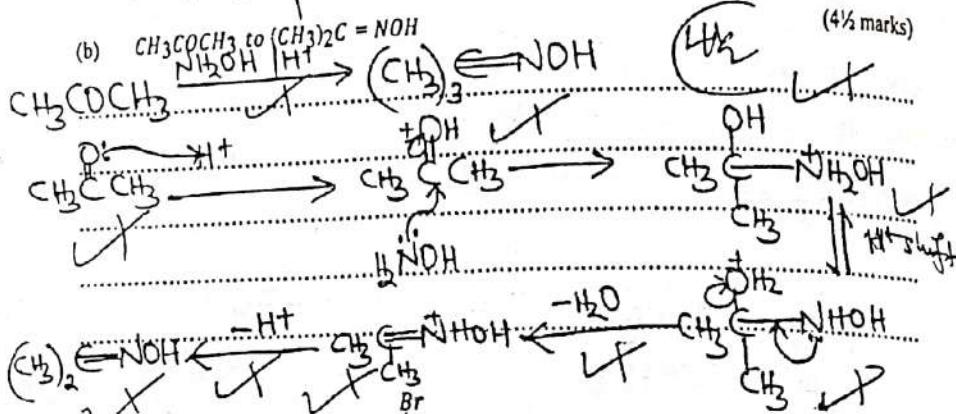
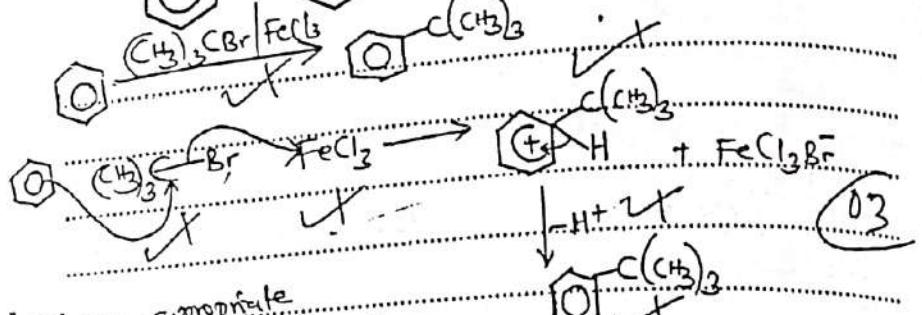


Accept; two for (c).

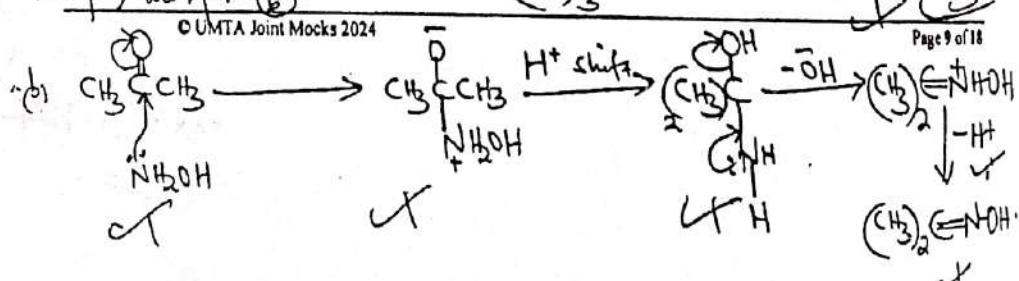




(a)  $\text{C}_6\text{H}_5\text{F} \xrightarrow{\text{C}_6\text{H}_5\text{CBr}/\text{FeCl}_3} \text{C}_6\text{H}_5\text{C}(\text{CH}_3)_3$

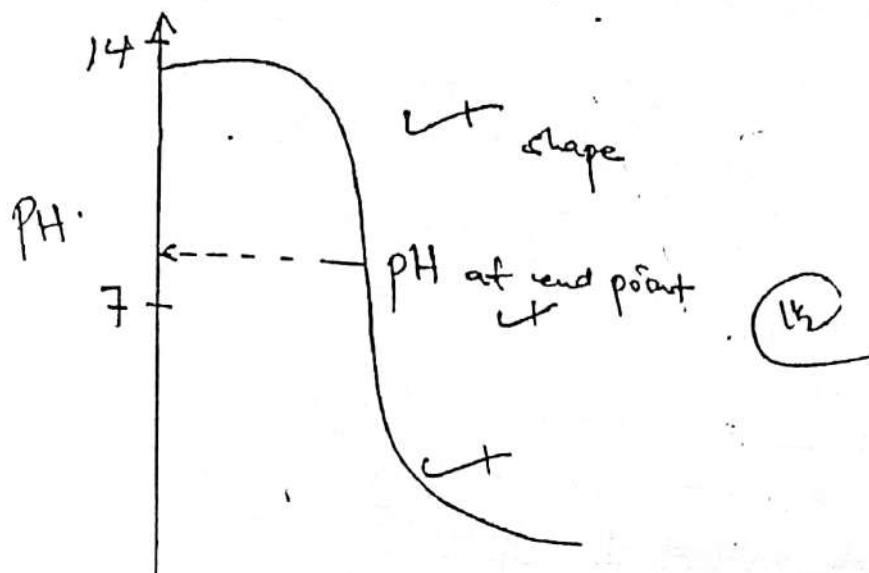


Accept; fur for ①.  $(\text{CH}_3)_3\text{C}^+\text{CH}_3$  (03)



11. (a) (i) Sketch a graph to show the pH changes that take place when Benzoic acid is titrated into Sodium Hydroxide Solution.

(1½ marks)



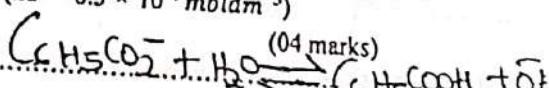
- (ii) Explain the shape of your sketch graph in (a) (i).

3½

pH initially is very high because the base is strong and it fully dissociates to form many hydroxide ions; pH gradually decreases as hydroxide ions are neutralised by the few hydrogen ions. At the end point, addition of a small amount of acid makes a sharp decrease in pH. The end point is above 7 since the salt formed hydrolyses into an alkaline solution. pH gradually decreases due to dissociation of weak acid.

(b) Calculate the pH of the resultant solution formed when 20 cm<sup>3</sup> of 0.1M potassium hydroxide solution was added to 40 cm<sup>3</sup> of 0.05M benzoic acid at 25°C, ( $K_a = 6.3 \times 10^{-5} \text{ mol dm}^{-3}$ )

$$\text{moles of KOH} = \frac{(20 \times 0.1)}{1000} = 0.002$$



$$\text{moles of } C_6H_5COOH = \frac{(40 \times 0.05)}{1000} = 0.002$$

$$K_h = \frac{[OH^-]^2}{[C_6H_5COO^-]} \quad (K_h = \frac{K_w}{K_a})$$

$$\text{Total volume} = (20+40) = 60 \text{ cm}^3$$

Molar concentration

$$KOH = \frac{0.002 \times 1000}{60} = 0.0333 \text{ M}$$

© UMTA Joint Mocks 2024

$$C_6H_5COOH = 0.0333 \text{ M}$$

$$= \frac{10^{-14}}{6.3 \times 10^{-5}} \quad (0.4)$$

$$[OH^-] = \sqrt{1.587 \times 10^{-10} \times 0.0333}$$

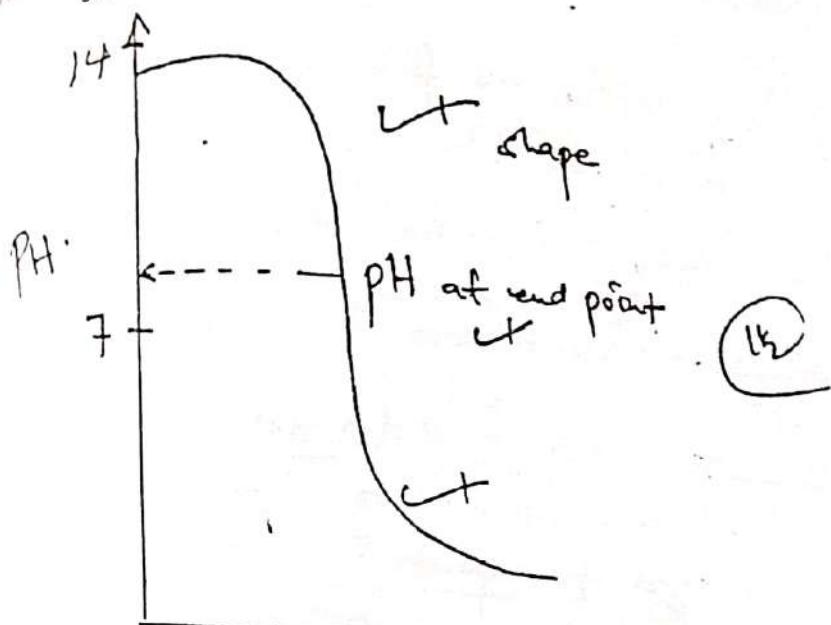
$$[OH^-] = 2.3 \times 10^{-6} \quad (Page 10 of 18)$$

$$pOH = -\log(2.3 \times 10^{-6}) = 5.6 \quad (0.4)$$

$$pH = (14 - 5.6) = 8.4 \quad (0.4)$$

11. (i) Sketch a graph to show the pH changes that take place when Benzoic acid is titrated into Sodium Hydroxide Solution.

(1½ marks)



(ii) Explain the shape of your sketch graph in (a)(i). →

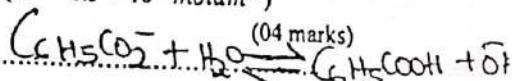
3½

pH initially very high because the base is strong and it fully dissociates to form many hydroxide ions; pH gradually decreases as hydroxide ions are neutralised by the few hydrogen ions. At the end point, addition of a small amount of acid makes a sharp decrease in pH. The end point is above 7, since the salt formed dissociates into an alkaline solution. pH gradually decreases due to dissociation of excess weak acid.

(b) Calculate the pH of the resultant solution formed when 20cm<sup>3</sup> of 0.1M potassium hydroxide

solution was added to 40cm<sup>3</sup> of 0.05M benzoic acid at 25°C, ( $K_a = 6.3 \times 10^{-5}$  mol dm<sup>-3</sup>)

$$\text{mols of KOH} = \frac{(20 \times 0.1)}{1000} = 0.002$$



$$\text{mols of } C_6H_5COOH = \frac{(40 \times 0.05)}{1000} = 0.002$$

$$K_h = \frac{[OH^-]^2}{[C_6H_5CO^-]} \quad (K_h = \frac{K_w}{K_a})$$

$$\text{Total volume} = (20+40) = 60\text{cm}^3$$

$$= \frac{10^{-14}}{6.3 \times 10^{-5}} \quad 04$$

Molar concentration

$$KOH = \frac{0.002 \times 1000}{60} = 0.0333\text{M}$$

$$[OH^-] = \sqrt{1.587 \times 10^{-10} \times 0.0333}$$

© UMTA Joint Mocks 2024

$$C_6H_5COOH = 0.0333\text{M}$$

$$[OH^-] = 2.3 \times 10^{-6} \quad \text{Page 10 of 18}$$

$$pOH = -\log(2.3 \times 10^{-6}) = 5.6$$

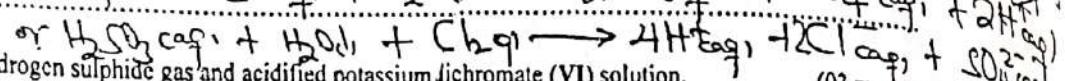
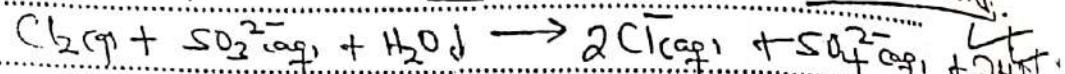
$$pH = (7 - 5.6) = 8.4$$

12. Briefly explain what would be observed when the following are mixed.

(a) Chlorine and Sulphurous acid.

(03 marks)

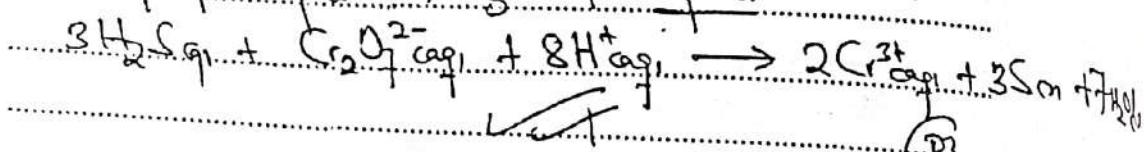
The greenish yellow gas dissolves to form a colourless solution; sulphurous acid reduces chlorine to chloride ions.



(b) Hydrogen sulphide gas and acidified potassium dichromate (VI) solution.

(03 marks)

The orange solution turns to green and a yellow solid precipitate. Hydrogen sulphide reduces dichromate (VI) to chromium (III) and hydrogen sulphide oxidized to sulphur.

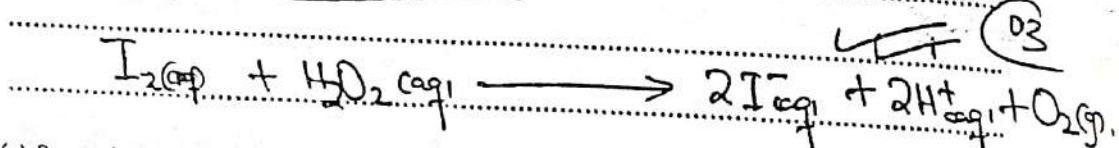


(03 marks)

(c) Acidified solution of hydrogen peroxide and iodine solution.

(03 marks)

The brown solution turned colourless and bubbles of a colourless gas. Iodine oxidizes hydrogen peroxide to oxygen and its reduced to iodide ions.



(03 marks)

3. (a) State why transition elements form complexes.

They form cations with high charge. Their cations have a small ionic radii. Their ions have empty 3d orbitals.

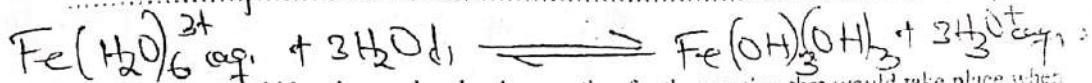
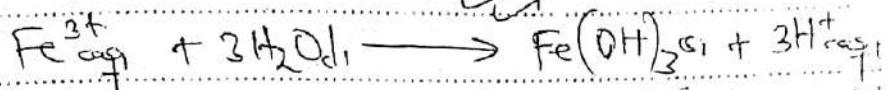
(1½ marks)

d-orbital deny.  
3d subshell.

(b) Iron (III) sulphate was dissolved in water and the resultant solution tested with litmus paper. State what was observed and explain your answer. (3½ marks)

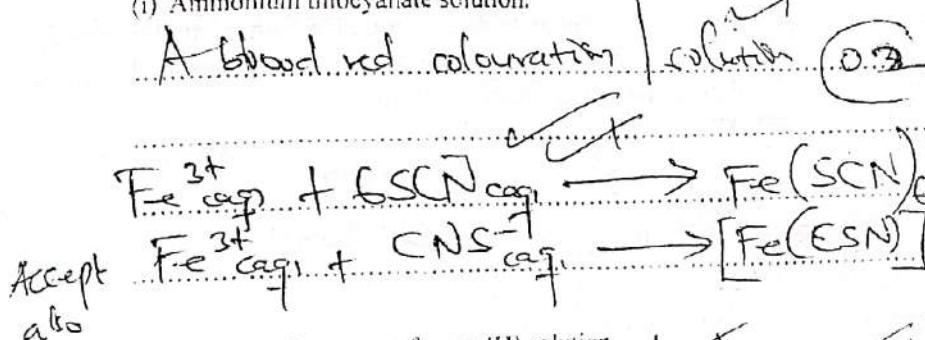
The blue litmus paper turned red. ✓ (3½)

Iron (II) ions have a high charge density and in aqueous solution get heavily hydrated so undergo hydrolysis to releases hydroxonium hydrogen ions / protonic acidic medium.

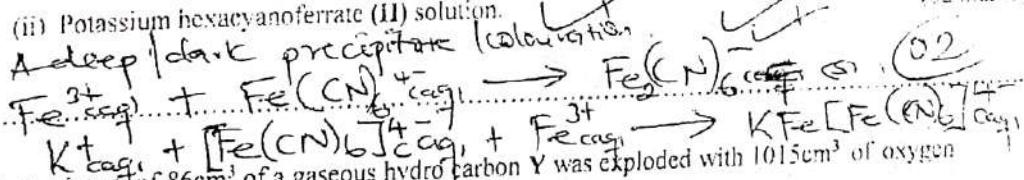


(c) State what would be observed and write equation for the reaction that would take place when the following solutions are added to the solution in (b).

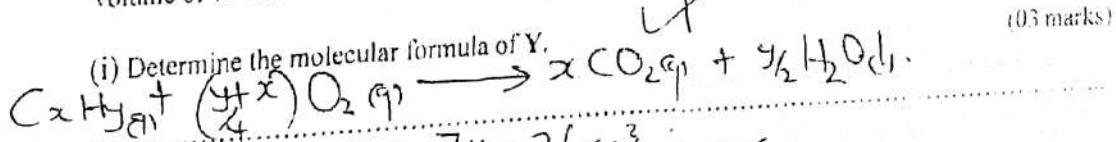
(i) Ammonium thiocyanate solution. ✓ (02 marks)



(ii) Potassium hexacyanoferrate (II) solution. ✓ (02 marks)

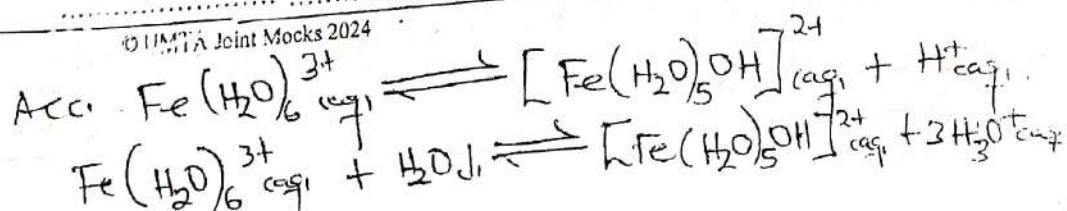


14. (a) A mixture of 86cm<sup>3</sup> of a gaseous hydrocarbon Y was exploded with 1015cm<sup>3</sup> of oxygen which was in excess. The volume after explosion and cooling to room temperature was 800cm<sup>3</sup>. After addition of concentrated potassium hydroxide solution there was a contraction in volume of 774cm<sup>3</sup>.



$$\text{unreacted O}_2 = 800 - 774 = 26\text{cm}^3$$

$$\text{used O}_2 = 1015 - 26 = 989\text{cm}^3$$



$$86x = 774 \Rightarrow x = 9$$

$$86(y/4 + 1) = 981 \Rightarrow y/4 + 1 = 11.5$$

$$y/4 = (11.5 - 1) = 2.5$$

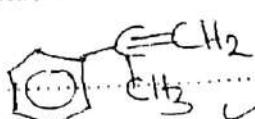
$$y = (2.5 \times 4) = 10$$

molecular  
formula



(03)

- (ii) Y burns with a sooty flame. Write the structural formulae and IUPAC names of all possible isomers of Y.



2-phenylpropene



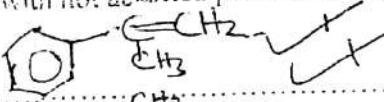
2-phenylpropene



3-phenylpropene

- (iii) When treated with concentrated sulphuric acid at 25°C compound Y formed another compound Z. When warmed with water compound Z gave compound X that gave no observable change when treated with hot acidified potassium dichromate solution.

identify

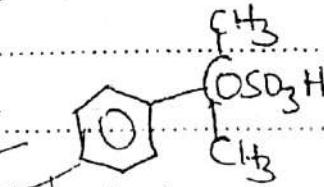
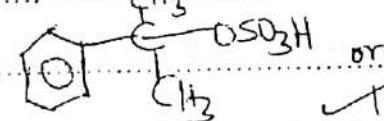


(i) Y

(01)

(01 mark)

(ii) Z



(01 mark)

- (iv) Name a reagent that can be used to identify the functional group in compound X and state what is observed when this reagent is reacted with X.

(02 marks)

Any carboxylic acid

(02)

Trifluoroacetic acid and concentrated sulphuric acid and heat

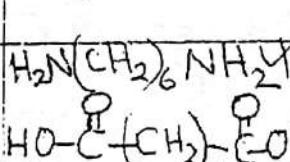
A sweetly fruity smell

15. (a) Define the term solubility product.

(01 mark)

The product of equilibrium molar concentrations of the ions in a saturated solution of a sparingly soluble salt with each ion raised to the appropriate powers at a constant temperature.

(01)

- | Polymer          | Structural formula of monomer   | Method of formation of polymer | Structural formula of polymer  |
|------------------|---|--------------------------------|--|
| Polyphenylethene |  $\text{CH}=\text{CH}_2$ ✓                         | Addition polymerisation        | $(-\text{C}_6\text{H}_5-\text{CH}_2-)_n$   |
| Nylon - 6, 6     | $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$<br> | Condensation polymerisation    | $(-\text{HN}(\text{CH}_2)_6-\text{C}(=\text{O})-\text{CH}_2-\text{CH}_2-\text{C}(=\text{O})-\text{NH}-)_n$ |

Reject: Additional & Condensational

- (b) State one use of

(i) polyphenylethene

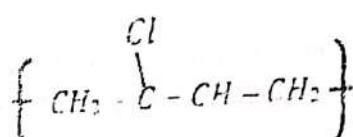
## Polyphenylethene Packaging materials

( $\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$ )

- (ii) Nylon - 6,6

ii) Nylon - 6,6  
Fishing nets, fabric/clothes, mosquito nets, ropes, curtains

- (c) Neoprene is an addition polymer of structure



(0)  $\text{m}^{-1}$

- (i) Define the term addition polymer.

(i) Define the term addition polymer.  
A high molecular weight compound formed from combination of small unsaturated molecules with no loss of small molecules.

(ii) A solution containing 1.4% of neoprene was found to exert an osmotic pressure of  $3.5 \times 10^{-4}$  atmospheres at  $25^\circ\text{C}$ .

Calculate the relative molecular mass of neoprene.  
( $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ )

From  $\Pi V = \frac{MRT}{Mr}$ ,  $Mr = \frac{\Pi RT}{V} = \frac{1.4 \times 0.0821 \times 298}{3.5 \times 10^{-4} \times 100 \times 10^{-3}} = 978.63$

Acc  $Mr = \frac{1.4 \times 8.314 \times 298}{3.5 \times 10^{-4} \times 100 \times 10^{-3}} = 978.069$

(iii) Determine the number of monomers ( $n$ ) that formed neoprene.

$n(\text{CH}_2=\text{C}-\text{CH}=\text{CH}_2) = 978.069$  or  
 $88.4n = 978.069 \quad 88.4n = 978.632$   
 $n = 11,064$  monomers       $n = 11,070$

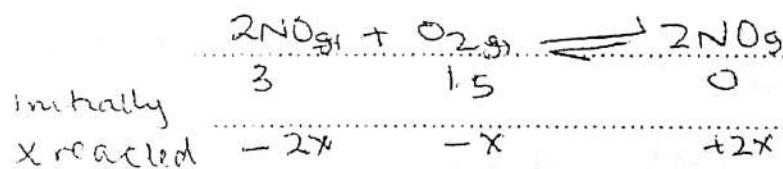
Nitrogen monoxide combines with oxygen to form nitrogen dioxide according to the equation:



(a) Write the expression for the equilibrium constant,  $K_c$ .

$$K_c = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 [\text{O}_2]}$$

(b) (i) 3 moles of nitrogen monoxide and 1.5 moles oxygen were put into a vessel which was heated to  $40^\circ\text{C}$ . When equilibrium was established the vessel found to contain 0.5 moles of oxygen. Calculate the value of  $K_c$  at this temperature. (02 marks)



Eqm moles  $3 - 2x \quad 1.5 - x \quad 2x$

$$1.5 - x = 0.5$$

$$x = 1 \text{ mole}$$

$$K_c = \left( \frac{2^2}{1^2 \times 0.5} \right) = 8.0 \text{ mol}^{-1} \text{ O}_2$$

Equilibrium moles:  
 $\text{NO} = 3 - (2x) = 1 \text{ mole}$   
 $\text{NO}_2 = (2x) = 2 \text{ moles}$

(ii) When the temperature was raised to  $500^{\circ}\text{C}$  the mixture in (i) was found to contain 25% of the initial nitrogen monoxide. Calculate the equilibrium constant at this temperature.

$$\text{moles NO} = \left( \frac{25}{100} \times 3 \right) = 0.75$$

$$K_c = \frac{(2.25)^2}{(0.75)^2} \times 0.375 \quad (03 \text{ marks})$$

$$3 - 2x = 0.75 \rightarrow x = 1.125 \text{ mole}$$

Concentration of

$$\text{NO} = 0.75 \text{ mole} \quad \checkmark$$

$$\text{O}_2 = 1.5 - 1.25 = 0.375 \text{ mole}$$

$$\text{NO}_2 = 2x = 2.25 \text{ mole} \quad \checkmark$$

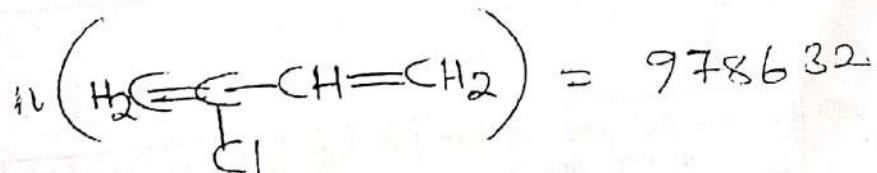
$$K_c = 24 \text{ mol}^{-1} \quad (03)$$

(c) From your answer to (b) (i) and (ii) deduce whether the process is endothermic or exothermic and explain how you arrive at this deduction.  $\checkmark$  (02 marks)

The process is Endothermic for the forward reaction  
Because an increase in temperature leads to an increase in value of  $K_c$ .  $\checkmark$  (02)

(d) What would be the effect on  $K_c$  when a catalyst is added to the reaction mixture? (01 mark)

The value of  $K_c$  remains constant as a catalyst has no effect on  $K_c$  value.  $\checkmark$  (01)



$$88.4n = 978632$$

$$\underline{n = 11,070 \text{ monomers.}}$$

## THE PERIODIC TABLE

P525/2 CHEMISTRY  
MARKING GUIDE  
SECTION A

1. (a) Define the terms;

(i) activation energy

The minimum energy required to be possessed by the reactants in order to react to form products.

(ii) molecularity

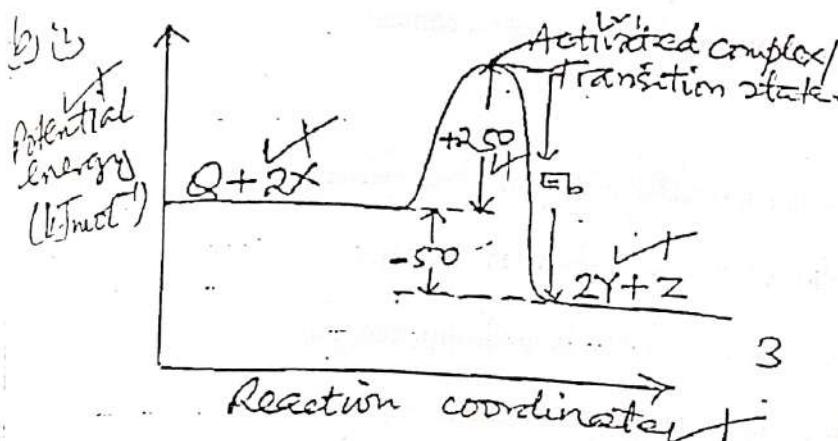
The total number of atoms or molecules or ions or species involved in the rate determining step of a reaction

(b) Q and X react to form Y and Z according to the equation;



The enthalpy change for the above reaction is  $-50\text{ kJ mol}^{-1}$  and activation energy of forward reaction is  $+250\text{ kJ mol}^{-1}$ .

(i) Draw a well labelled energy diagram for the reaction.



3

(ii) Calculate the activation energy for the backward reaction.

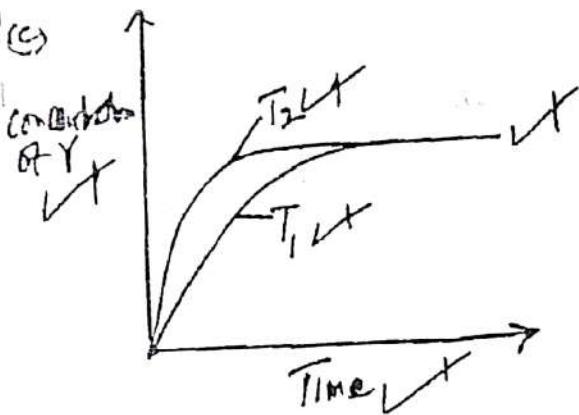
$$\Delta H_{rxn} = -50$$

$$+250 - 50 = E_b$$

$$E_b = +200\text{ kJ mol}^{-1}$$

for missing units deny  $\frac{1}{2}$  mark or a sign

(c) For the reaction in (b) above, draw a sketch graph to show the change in concentration of Y with time at two temperatures  $T_1$  and  $T_2$  where  $T_1 > T_2$



(d) Propanone reacts with iodine in the presence of an acid catalyst according to the

equation;



Describe an experiment to show that the order of reaction with respect to iodine is zero.

An aqueous solution of propanone, a solution of iodine in potassium iodide and a solution of

Sulphuric acid, all of known concentration are prepared and kept at a constant temperature

A known volume of propanone solution is pipetted into a conical flask followed by a known volume of sulphuric acid to catalyze the reaction.

A known volume of iodine solution is added and a stop clock started simultaneously.

The mixture is shaken and allowed to settle at a constant temperature for some few minutes.

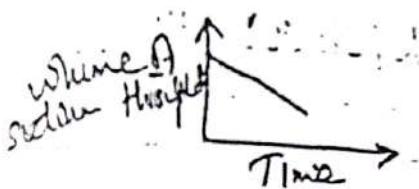
After the few minutes, a known volume of the mixture is pipetted into a beaker containing sodium hydrogen carbonate solution to stop or quench the reaction.

The time at which the reaction stops is recorded.

The resultant solution is titrated against a standard solution of a known concentration of sodium thiosulphate solution using starch indication to determine the amount of iodine remaining.

The reacting mixture is analyzed several times by changing the time taken for the reaction to take place before adding it to the sodium hydrogen carbonate solution. The original iodine is also pipetted and titrated with standard solution of sodium thiosulphate to obtain the volume of sodium

A graph of volume of sodium thiosulphate solution used against time is plotted.



The graph is a straight line with a negative gradient indicating that the reaction is zero order with respect to iodine.

- (e) The following experimental data was obtained about the rate of the reaction in (c) above.

Experiment No.	$[CH_3COCH_3]$	$[H^+]$	$[I_2]$	Rate ( $mole^{-1}s^{-1}$ )
1	0.60	0.50	-	-
2	0.80	0.50	0.02	$9.0 \times 10^{-5}$
3	0.60	1.00	0.04	$1.2 \times 10^{-4}$
4	0.80	1.00	0.02	$1.8 \times 10^{-4}$
			0.02	$2.4 \times 10^{-4}$

- (i) Determine the order of reaction. Explain your answer.

Let order w.r.t to  $CH_3COCH_3$  be  $q$

Let order w.r.t to  $H^+$  be  $r$  and order w.r.t to  $I_2$  be  $x$  considering experiments 1 and 2.

$$\text{Rate} = k[CH_3COCH_3]^q[H^+]^r[I_2]^x$$

$$9 \times 10^{-5} = k \times 0.6^q \times 0.5^r \times 0.02^x$$

$$1.2 \times 10^{-4} = k \times 0.8^q \times 0.5^r \times 0.04^x$$

(ii) : (i) yields

$$\frac{1.2 \times 10^{-4}}{9 \times 10^{-5}} = \left(\frac{0.8}{0.6}\right)^q \left(\frac{0.04}{0.02}\right)^x$$

$$1.3333 = 1.3333^q \times 2^x$$

$$2^x = 1.3333^{(1-q)}$$

Considering experiments 3 and 4

$$\frac{2.4 \times 10^{-4}}{1.8 \times 10^{-4}} = \left(\frac{0.8}{0.6}\right)^q$$

$$1.3333 = 1.3333^q > q = r$$

For (iii)  $2^x = 1.3333^0 \rightarrow 2^x = 1 = 2^0 \rightarrow x = 0$

Order of reaction =  $1 + 1 + 0 = 2$

NB: Allow inspection method

For order of rxn wrt propanone refer to expt 38.)

Reason: Propanone concentration was increased by a factor of 4 far thirds;

While keeping conc of iodine &  $H^+$  ie constant

R.O.R also increased by four thirds hence first order.

For hydrogen ion, refer to expt 1 & 3, when  $[H^+]$  is doubled keeping  $[CH_3COCH_3]$  and  $[I_2]$  constant.

R.O.R also doubled. Hence first order w.r.t to hydrogen ions. For order of rxn with respect to iodine use calculations method only . Overall order

- (ii) Write the rate equation.

$$\text{Rate} = k[CH_3COCH_3][H^+]$$

**(iii) Calculate the rate constant.**

Consider experiment 1:

$$9.0 \times 10^{-5} = k \times 0.6 \times 0.5$$

$$k = \frac{9.0 \times 10^{-5} \text{ mol}^{-1} \text{ s}^{-1}}{0.6 \times 0.5 \text{ (mol}^{-1})^2}$$

$$k = 3 \times 10^{-4} \text{ mol}^{-1} \text{ s}^{-1}$$

2. The elements aluminium, silicon, phosphorus, sulphur and chlorine belong to Period 3 of the Periodic Table. The table below shows the melting points of the above elements and the values of their first electron affinities.

Element	Al	Si	P	S	Cl
Atomic number	13	14	15	16	17
Melting point (°C)	660.3	1414	44.2	115.2	-101.5
First electron affinity (kJmol <sup>-1</sup> )	-44	-135	-72	-200	-364

- (a) State and explain the trend in melting points of the elements.

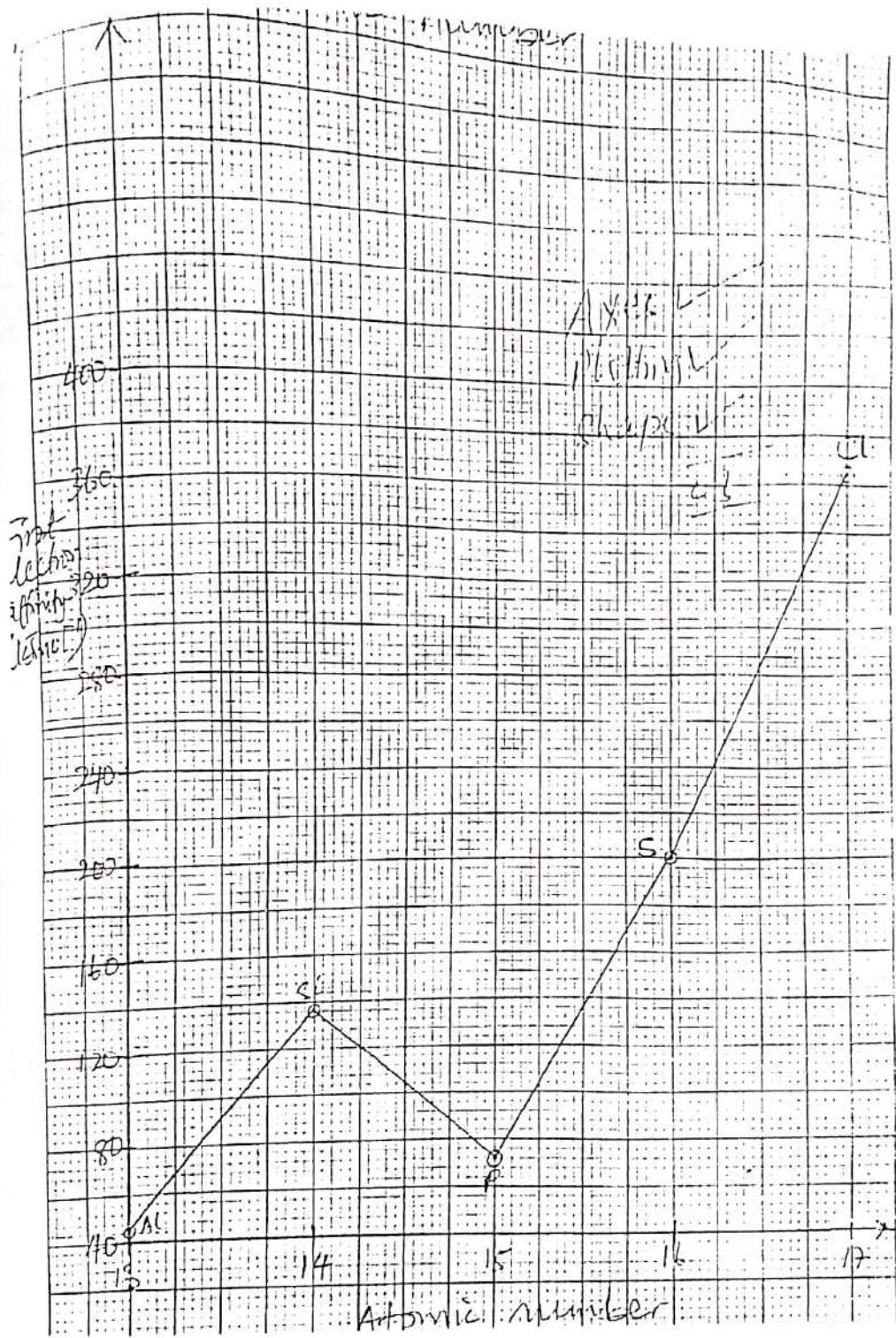
Melting point increases from aluminium to silicon and then generally decreases from silicon to chlorine.

Aluminum has a giant metallic structure in which the atoms are held by metallic bonds. Silicon has a giant molecular structure in which the atoms are held by very many strong covalent bonds which are stronger and require higher amount of energy to break than metallic bonds in aluminum.

Phosphorus sulphur and chlorine have simple molecular structures in which the molecules are held by weak vander waal forces whose strength decreases with decreasing molecular mass sulphur being octatomic has a higher molecular mass and stronger vander waal forces than phosphorous which is tetra atomic and chlorine which is diatomic.

- (b) (i) Plot a graph of first electron affinity of the elements against atomic number.

### A GRAPH OF FIRST ELECTRON AFFINITY AGAINST ATOMIC NUMBER



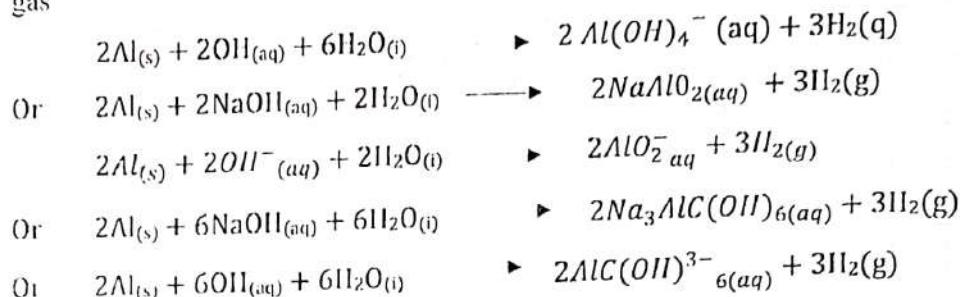
(ii) Explain the general trend in first electron affinity using the graph in b (i) above.

First electron affinity generally increases from aluminum to chlorine because from one element to

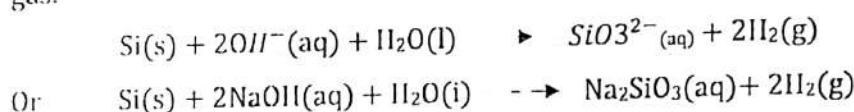
another nuclear charge increases since a proton added to the nucleus. Screening effect remains almost constant / slightly increases because an extra electron is added to the same energy level. Effective nuclear charge increases atomic radius decreases and the incoming electron experiences greater / an increasing nuclear attraction.

**(c) Describe the reactions of the elements with hot concentrated sodium hydroxide.**

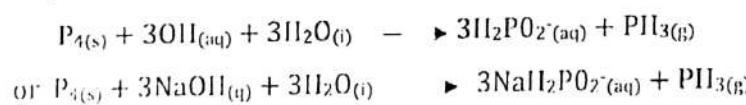
Aluminium reacts with hot concentrated sodium hydroxide to form sodium aluminate and hydrogen gas



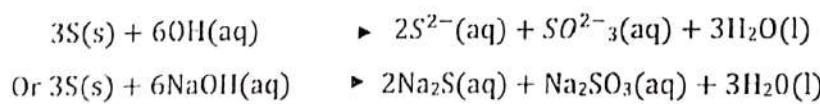
Silicon reacts with hot concentrated sodium hydroxide to form sodium silicate and hydrogen gas.



Phosphorous reacts with hot concentrated sodium hydroxide to form sodium phosphinate and phosphine.

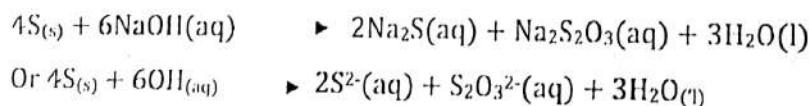


Sulphur reacts with hot concentrated sodium hydroxide to form sodium sulphide and sodium sulphite.

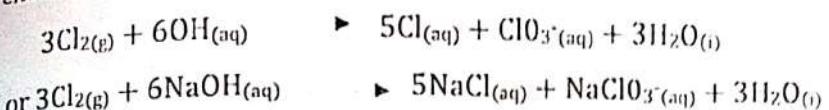


OR:

Excess Sulphur reacts with hot concentrated sodium hydroxide to form sodium sulphide, sodium thiosulphate and water.



Chlorine reacts with hot concentrated sodium hydroxide to form sodium chloride sodium chlorate(V) and water.

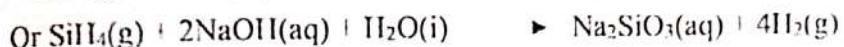
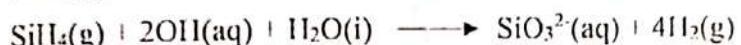


(d) Write the;

(i) formula of the hydride formed by each of the elements above.



(ii) equations for the reaction for each of the hydrides in d (i) above with water.



3. An organic compound G, contains 31.4% oxygen and 9.8% hydrogen. When  $29.58\text{cm}^3$  of G was dissolved in  $520\text{cm}^3$  of ether, the solution boiled at  $307.849\text{K}$ .

$$(i) \% \text{ of C} = 100 - 31.4 - 9.8 = 58.8 \checkmark$$

Elements	C	H	O
moles	$\frac{58.8}{12} = 4.9$	$\frac{9.8}{1} = 9.8$	$\frac{31.4}{16} = 1.9625$
simplest mole ratio	$\frac{4.9}{1.9625}$	$\frac{9.8}{1.9625} = \frac{1.9625}{1.9625}$	
	(2.5 : 5 : 1)		$\checkmark$

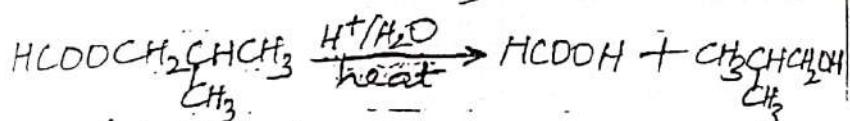
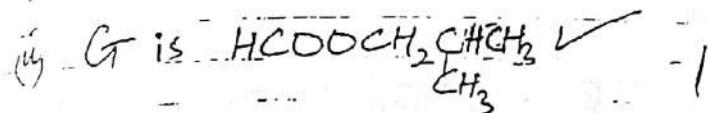
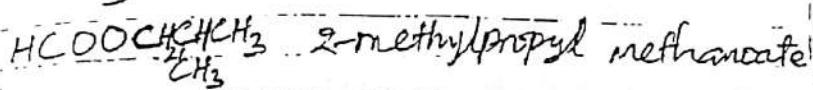
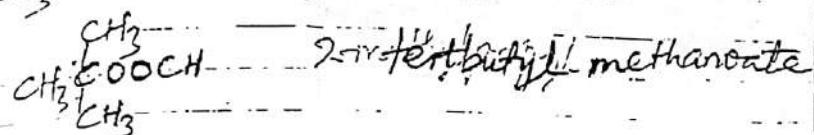
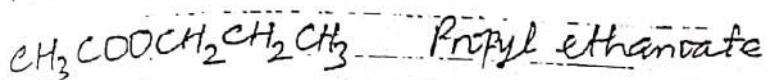
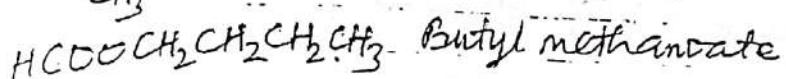
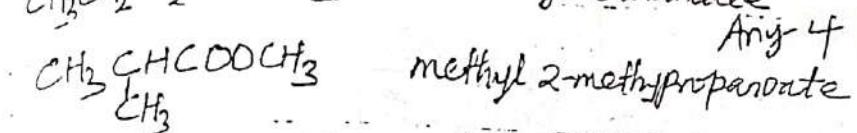
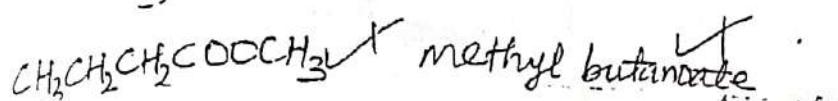
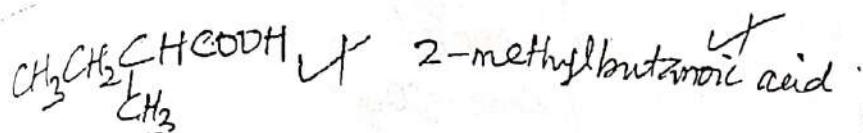
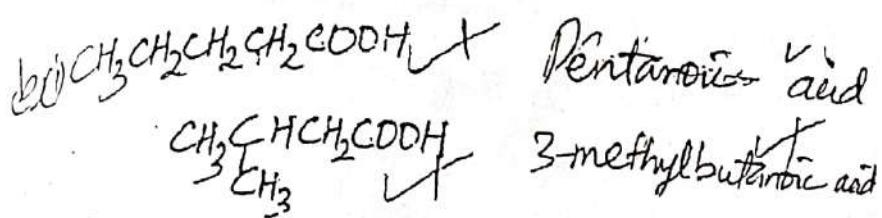
Empirical formula is  $C_5H_{10}O_2 \checkmark$   $\checkmark$

$$ii) \text{ Mass of ether} = (520 \times 1) = 520 \text{ g}$$

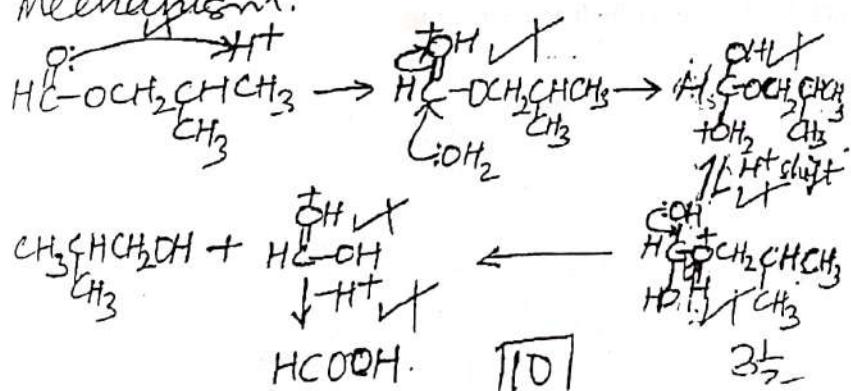
$$\begin{aligned} 520 \text{ g dissolve } 29.58 \text{ g} \\ 1000 \text{ g dissolve } \left( \frac{1000}{520} \times 29.58 \right) \checkmark \\ = 56.8846 \text{ g.} \end{aligned}$$

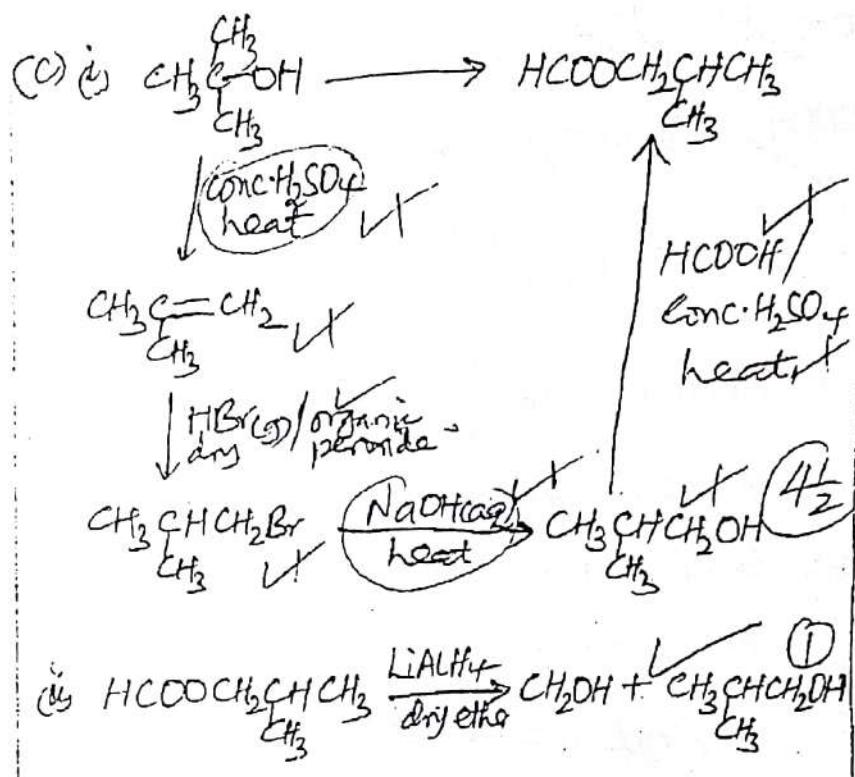
$$\begin{aligned} \text{Boiling point elevation} &= 307.849 - (3.46 + 2.23) \\ 0.249 \text{ K} &\text{ is elevation caused by } 56.8846 \text{ g} \\ 0.446 \text{ K} &\text{ is caused by } \left( \frac{0.446 \times 56.8846}{0.249} \right) \checkmark \\ &= 101.889 \approx \underline{\underline{102}} \text{ g} \end{aligned}$$

$$\begin{aligned} (C_5H_{10}O_2)_n &= 102 \checkmark \\ (60+10+32)n &= 102 \\ 102n &= 102 \\ n &= 1 \checkmark \end{aligned} \quad \begin{array}{l} \text{Molecular formula is} \\ C_5H_{10}O_2 \frac{1}{2} \underline{4\frac{1}{2}} \end{array}$$



Mechanism:



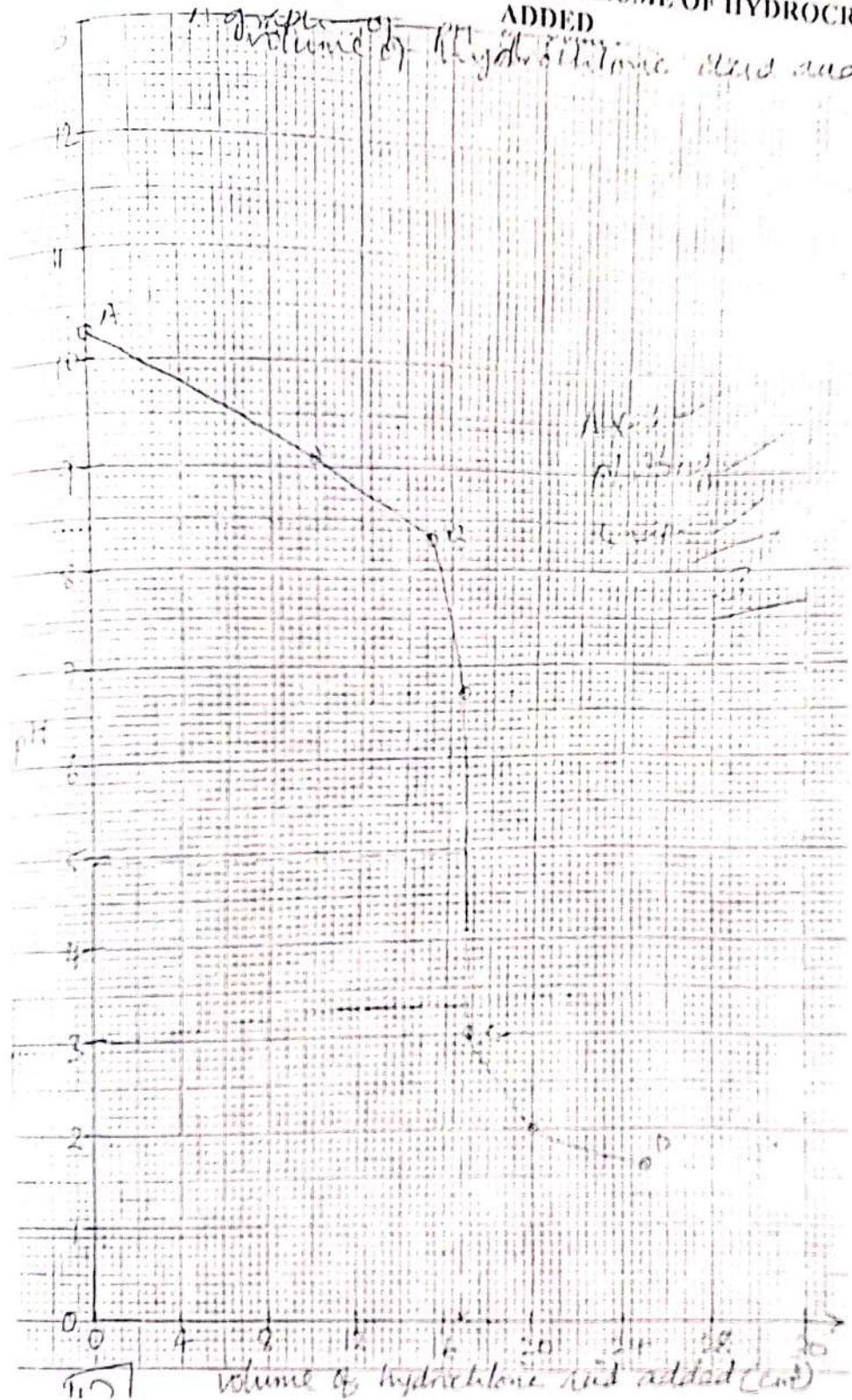


4. (a) The table below shows the pH of the solution when measured volumes of hydrochloric acid is added to  $25\text{cm}^3$  of 0.1M ammonia solution.

Volume of hydrochloric acid ( $\text{cm}^3$ )	0	10.0	15.0	16.5		17.0	20.0	25.0
pH of solution	10.25	9.08	8.30	6.70		2.97	1.96	1.60

- (i) Plot a graph of pH against volume of hydrochloric acid.

A GRAPH OF PH OF SOLUTION AGAINST VOLUME OF HYDROCHLORIC ACID ADDED



(ii) Explain the shape of the graph.

Initially, pH is above seven, because ammonia is as a weak base that partially ionizes to form few hydroxide ions.

pH gradually decreases along AB as hydrochloric acid is added due to the excess ammonia still present which together with the ammonium chloride salt forms constitute a buffer solution that resists a decrease in pH. Also some of the ammonia solution is being neutralized by hydrochloric acid.

pH sharply decreases along BC even with a little hydrochloric acid added because the end point is reached pH at endpoint is below 7 because the ammonium chloride salt formed undergoes hydrolysis to form an acidic solution.

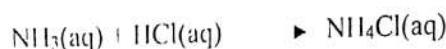
Along CD, pH gradually decreases due to excess hydrochloric acid added.

(b) Using the graph in (a) above, calculate the:

(i) molarity of hydrochloric acid.

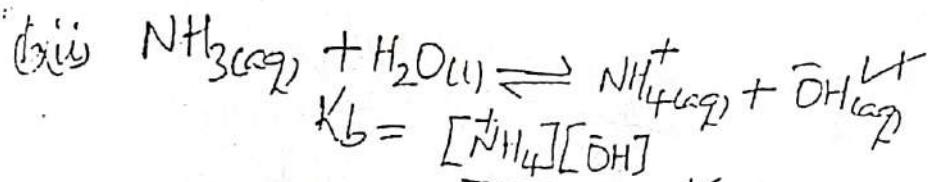
$$\text{Volume of HCl at endpoint} = 16.80 \text{ cm}^3$$

$$\text{Moles of NH}_3 \text{ neutralised} = \frac{25 \times 0.1}{1000} = 2.5 \times 10^{-3}$$



$$\text{Moles of NH}_3 = \text{moles of HCl} = 2.5 \times 10^{-3}$$

$$\text{Molar concentration of HCl} = \frac{1000 \times 2.5 \times 10^{-3}}{16.80}$$
  
0.1488M



At equilibrium;  $\frac{[\text{NH}_3]}{[\text{NH}_4^+]} = \frac{[\text{OH}^-]}{[\text{NH}_3]} = 0.1 \text{M}$

$$K_b = \frac{[\text{OH}^-]^2}{[\text{NH}_3]} = 0.1 \text{M}$$

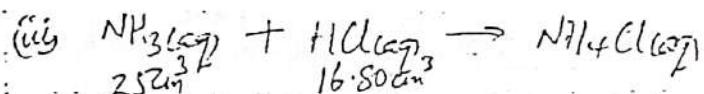
But  $\text{pH} = \frac{0.1}{10.25}$

$$\text{pOH} = 14 - \text{pH} = 14 - 10.25 = 3.75$$

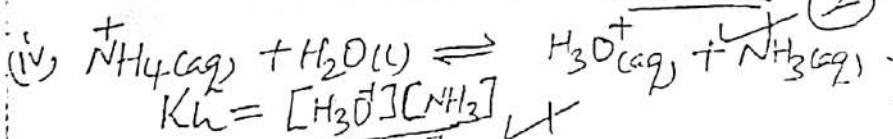
$$\text{pOH} = -\log_{10}[\text{OH}^-] = 3.5$$

$$[\text{OH}^-] = 10^{-3.5} = 3.162 \times 10^{-4} \text{ M}$$

$$K_b = \frac{(3.162 \times 10^{-4})^2}{0.1} = 9.998 \times 10^{-7} \text{ mol dm}^{-3}$$



Mole ratio of  $\text{NH}_3 : \text{NH}_4\text{Cl} = 1:1$   
 moles of  $\text{NH}_4\text{Cl}$  formed =  $2.5 \times 10^{-3}$   
 Total volume after complete neutralisation  
 $= 25 + 16.80 = 41.80 \text{ cm}^3$   
 molar concentration of  $\text{NH}_4\text{Cl} = \frac{1000 \times 2.5 \times 10^{-3}}{41.80}$   
 $= 0.0598 \text{ M}$



At equilibrium  $[\text{H}_3\text{O}^+] = [\text{NH}_3]$

$$K_h = \frac{[\text{H}_3\text{O}^+]^2}{[\text{NH}_4^+]} = \frac{[\text{H}_3\text{O}^+]^2}{0.0598}$$

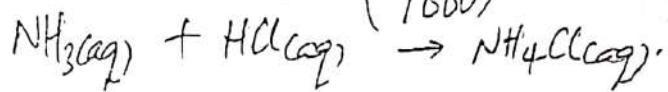
$$\text{pH at endpoint} = 4.95 = -\log_{10}[\text{H}_3\text{O}^+]$$

$$[\text{H}_3\text{O}^+] = 10^{-4.95} = 1.122 \times 10^{-5} \text{ M}$$

$$K_h = \frac{(1.122 \times 10^{-5})^2}{0.0598} = 2.105 \times 10^{-9} \text{ M}$$

$$(c) \text{ moles of HCl} = \frac{5 \times 0.1}{1000} = 5 \times 10^{-4} \checkmark$$

$$\text{moles of } \text{NH}_3\text{(aq)} = \left( \frac{2.5 \times 0.1}{1000} \right) = 2.5 \times 10^{-3}$$



$$\begin{aligned} \text{moles of } \text{NH}_3\text{(aq)} &= \text{moles of HCl that reacted} \\ &= 5 \times 10^{-4} = \text{moles of } \text{NH}_4\text{Cl formed.} \end{aligned}$$

$$\text{moles of unreacted ammonia} = (2.5 \times 10^{-3}) - (5 \times 10^{-4})$$

$$\begin{aligned} \text{Total volume} &= 25 + 5 = 30 \text{ cm}^3 \\ [\text{NH}_3] &= \frac{1000 \times 0.002}{30} = 6.667 \times 10^{-2} \text{ M} \end{aligned}$$

$$[\text{NH}_4\text{Cl}] = \frac{1000 \times 5 \times 10^{-4}}{30} = 1.667 \times 10^{-2} \text{ M}$$

$$\text{pOH} = \text{pK}_b + \log \left( \frac{[\text{NH}_4\text{Cl}]}{[\text{NH}_3\text{(aq)}]} \right) \checkmark$$

$$\text{pOH} = -\log_{10}(1.8 \times 10^{-5}) + \log \left( \frac{1.667 \times 10^{-2}}{6.667 \times 10^{-2}} \right) \quad (4)$$

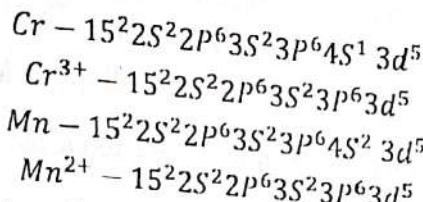
$$\text{pOH} = 4.745 + (-0.602) = 4.143 \checkmark$$

$$\text{pH} = 14 - \text{pOH} = 14 - 4.143 = 9.857 \approx 9.9$$

## SECTION B

*Answer two questions from this section.*

5. (a) Chromium (Cr = 24) and manganese (Mn = 25) are both d-block and transition elements. Explain this statement.



Both chromium and manganese atoms have their outermost electrons filling the 3d subenergy level and also form atleast one stable ion that has a partly filled 3d sub energy level.

(b) State the possible oxidation states exhibited by both chromium and manganese in their compounds.

Both Cr and Mn exhibit the oxidation states of +2, +3, and +6.

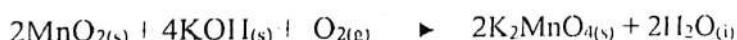
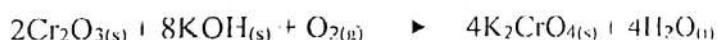
(c) An oxide of chromium Q, and that of manganese, R, were separately fused with potassium hydroxide in presence of oxygen to form a yellow solid and a green solid respectively.

(i) Identify Q and R.

Q is  $Cr_2O_3$  allow chromium(III) oxide

R is  $MnO_2$  allow manganese (IV) oxide

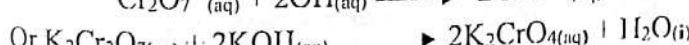
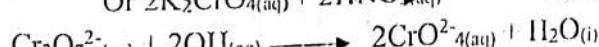
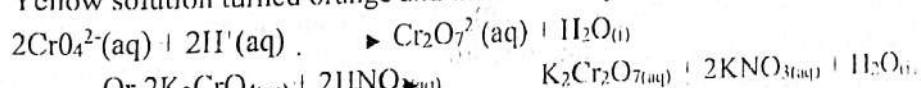
(ii) Write equations for formation of the yellow solid and the green solid respectively.



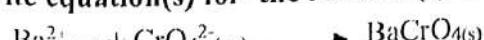
(d) A sample of the yellow solid in (c) (i) above was shaken with water and the resultant solution was divided into two portions. To the first portion dilute nitric acid was added followed by sodium hydroxide solution.

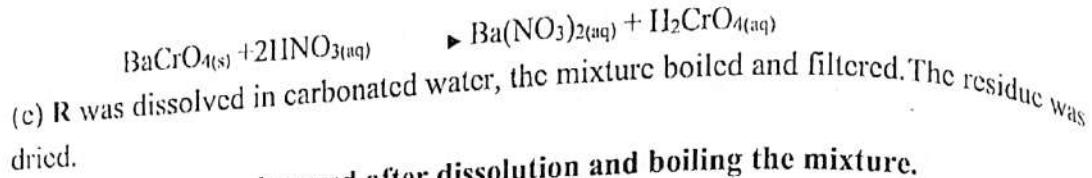
(i) State what was observed and write equation(s) for the reaction(s) that took place on treatment of the first portion as stated above.

Yellow solution turned orange and then back to yellow.



(ii) To the second portion barium nitrate solution was added followed by dilute nitric acid. Write equation(s) for the reaction(s) that took place.



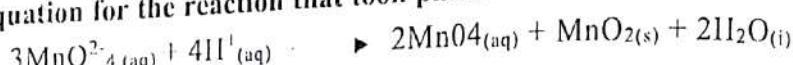


(i) State what was observed after dissolution and boiling the mixture.

Green solution turned purple and brown solid formed.

(ii)

Write equation for the reaction that took place.



(f) State one application of the residue from I above as;

(i) a reagent in organic synthesis.

Manganese (IV) oxide is acidic medium is used to oxidise aldehydes to carboxylic acids, secondary alcohols to ketones, primary alcohols to aldehydes or methylbenzene to benzaldehyde.

(ii) a catalyst

Manganese (IV) oxide catalyzes the decomposition of hydrogen peroxide to oxygen and water.

(g) State one reagent that can be used to distinguish the following pairs of ions in aqueous solution. State what is observed in each case.

(i)  $\text{Cr}^{3+}$  and  $\text{Mn}^{2+}$

Sodium hydroxide solution

$\text{Cr}^{3+}$  green precipitate

$\text{Mn}^{2+}$  - white precipitate turns brown on standing.

(ii)  $\text{MnO}_4^-$  and  $\text{MnO}_4^{2-}$

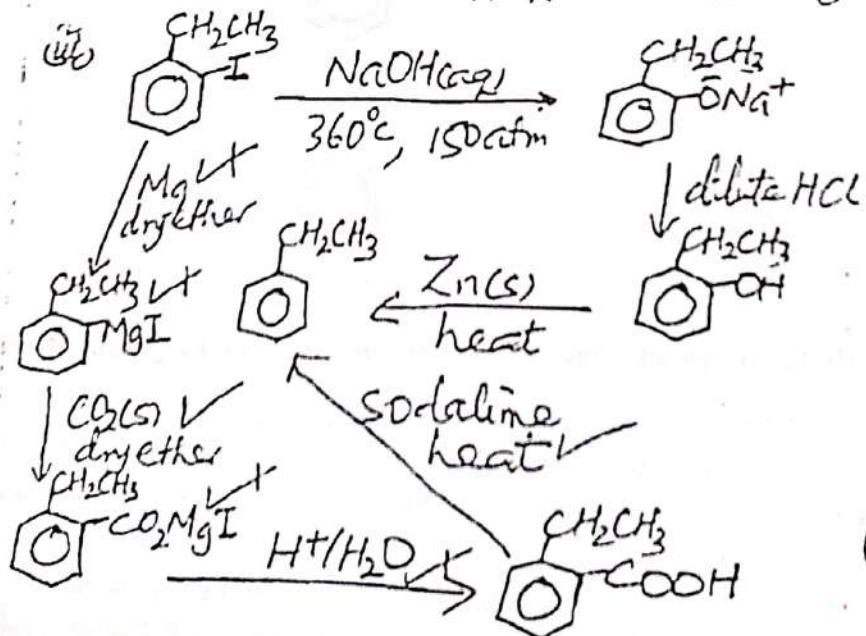
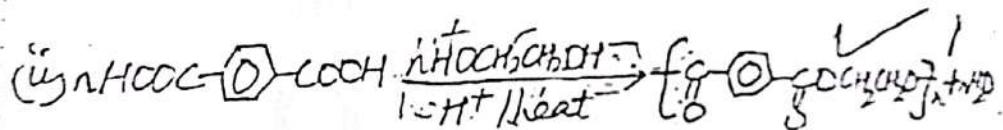
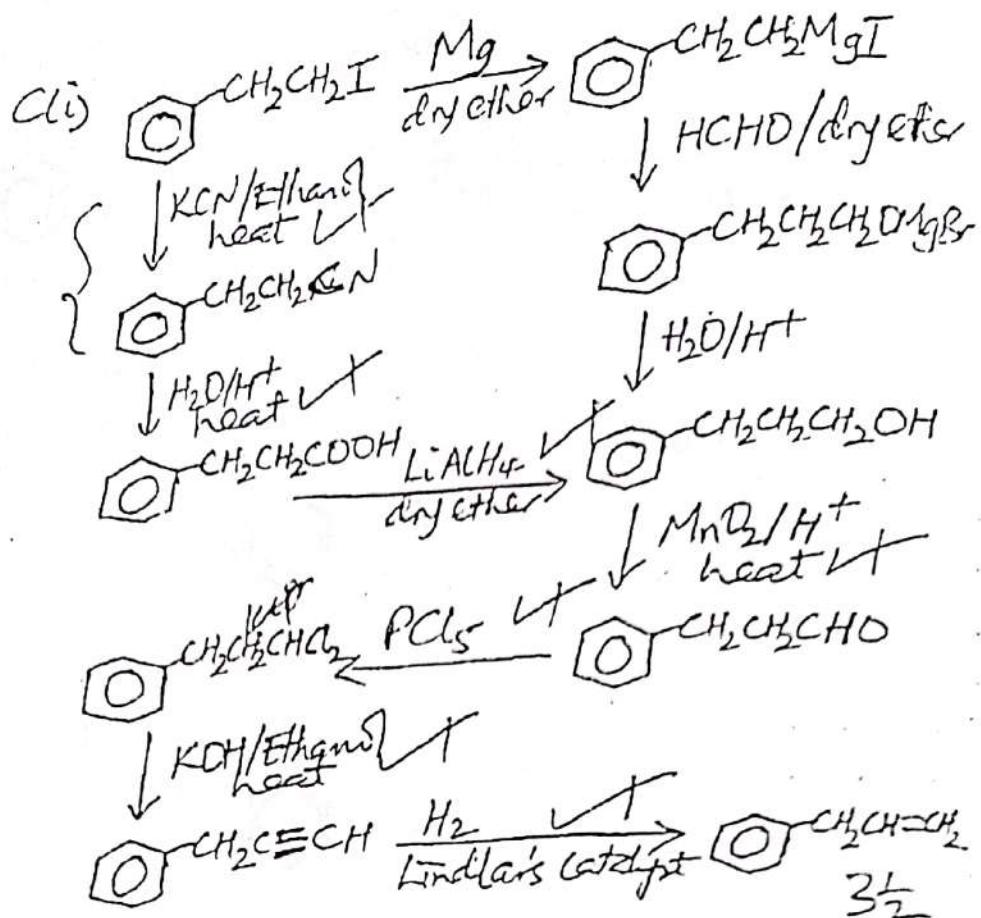
Dilute Sulphuric acid

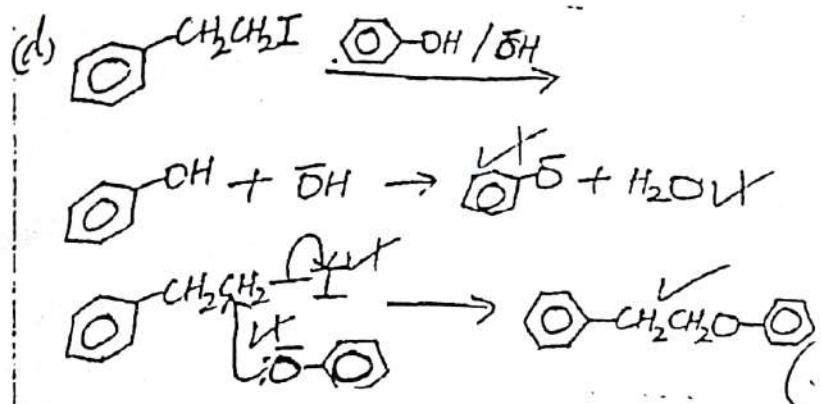
$\text{MnO}_4^-$  No observable change

$\text{MnO}_4^{2-}$  green solution turns purple and a brown precipitate.

Accept other correct alternatives.

5. An organic compound with molecular formula;  $C_8H_9I$ , has three isomers P, Q and R which all burn with a sooty flame. When each of the isomers was separately treated with hot aqueous sodium hydroxide solution followed by dilute nitric acid and then silver nitrate solution, P and Q gave no observable change whereas R formed a yellow precipitate. Q can undergo a reaction scheme shown below to form compound T.





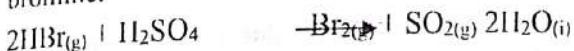
7. Explain each of the following observations.

(a) Hydrogen fluoride is a liquid at room temperature while hydrogen chloride is a gas at room temperature.

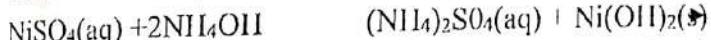
Fluorine is more electronegative and has a smaller atomic radius than chlorine. This makes the hydrogen-fluorine bond more polar than hydrogen-chlorine bond. The molecules of hydrogen fluoride therefore are held by stronger intermolecular hydrogen bonds that keep them close together than the weaker vander waal forces between molecules of hydrogen chloride that keep molecules further apart.

(b) Pure hydrogen bromide is not readily obtained by action of concentrated Sulphuric acid on sodium bromide.

Due to the large atomic radius of bromine, hydrogen bromide is a strong reducing agent hence reduces concentrated sulphuric acid to sulphur dioxide and water as itself is oxidized to bromine.



(c) When aqueous ammonia was added to Nickel (II) sulphate solution, a pale green precipitate was formed which dissolved in excess to form a blue solution. Nickel(II) ions react with hydroxide ions to form nickel(ii) hydroxide which is insoluble in water. Allow

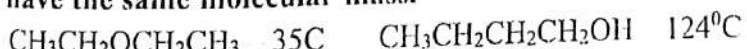


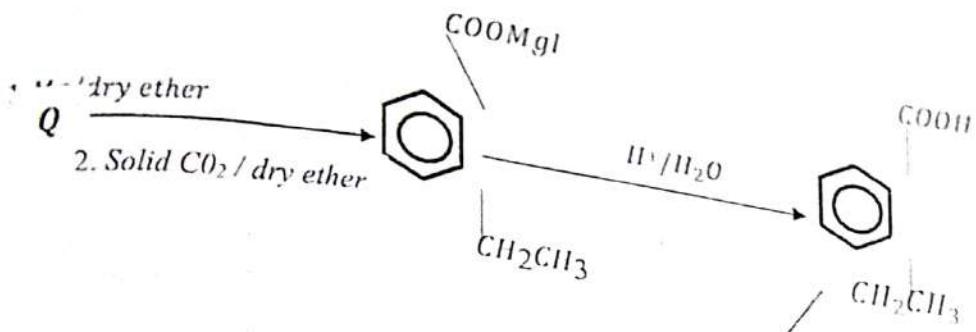
Nickel(II) hydroxide excess ammonia molecules to form hexaammine nickel ions a soluble complex.



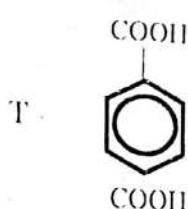
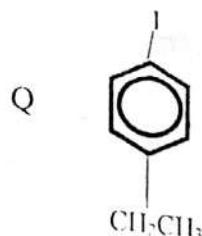
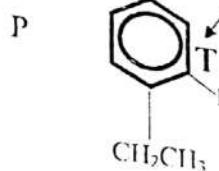
(d) Diethyl ether boils at  $35^\circ\text{C}$  whereas butan-1-ol boils at  $124^\circ\text{C}$  yet the two compounds

have the same molecular mass.





(a) Identify P, Q, R and T.



(b) Explain the differences in reactivity of the isomers in P, Q and R above with the reagent used.

In P and Q, the lone pair of electrons on the iodine atom interacts with the delocalized  $\pi$ -electrons of the benzene ring. This strengthens the carbon-iodine bond making it very difficult to break,

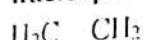
However, the iodine atom is more electronegative than the carbon atom and therefore attracts the bonding electrons more towards itself gaining a partial negative charge and the carbon atom gains a partial positive charge. This makes the carbon-iodine bond polar and easy to break.

(c) Write equation(s) to show how;

(i) R can be converted to 3-phenylpropene.

Molecules of diethyether interact only through weak vander waal forces that are easy to break. However molecules of butan -1-ol interact more strongly through intermolecular hydrogen bonds that require a higher amount of energy to break due to the polar oxygen hydrogen bonds in them.

(e) Ethene undergoes electrophilic addition reactions whereas ethanal undergoes nucleophilic addition reactions.



Ethene has a carbon Carbon double bond which is a source of  $\pi$  electrons. The C-C double bond is a centre of high electron density and readily attacked by electrophiles.

In ethanol, the oxygen atom on the Carbonyl Carbon is more electronegative than the carbon atom, attracting bonding electrons more towards itself, becoming partial negative whereas the carbon atom is partial positive and the carbon oxygen double bond is polar. The partial positive carbon atom is therefore readily attacked by a nucleophile which adds itself to the carbonyl group forming a dingle product.

8. (a) Define the terms:

(i) **molar conductivity**

The conductance of a solution containing 1 mole of an electrolyte placed between two parallel electrodes, each of cross sectional area  $2 \text{ m}^2$  and separated by a distance of 1m apart

Or

The electrolytic conductivity divided by concentration

Or

$\lambda c = \frac{k}{c}$  where K is electrolytic conductivity and c is concentration and  $\lambda c$  is molar conductivity.

(ii) **electrolytic conductivity**

The conductivity of a solution of an electrolyte placed between two parallel electrodes, each of cross sectional area  $1\text{m}^2$  and separated by a distance of 1m apart.

Or

The reciprocal of resistivity

Or

$K = \frac{1}{\rho}$  where  $\rho$  is resistivity and k is electrolytic conductivity

(iii) **conductance**

Conductance is the reciprocal of resistance of an electrolytic solution

Or

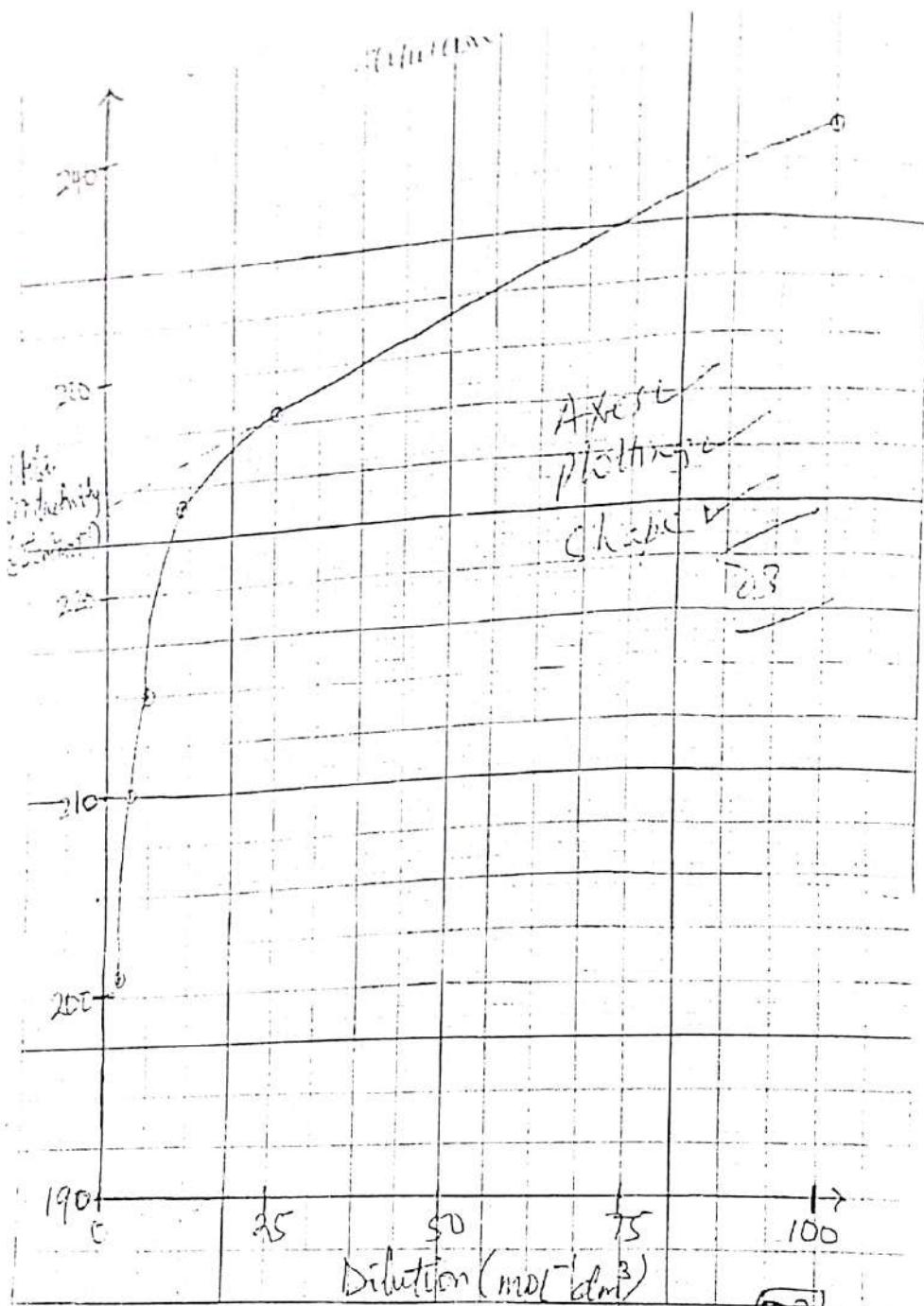
$C = \frac{1}{R}$  where C is conductance and R is resistance.

(b) The table below shows the molar conductivities of aqueous potassium hydroxide at given dilutions.

Dilution( $\text{mol}^{-1}\text{dm}^3$ )	100	25	11.11	6.25	4.0	2.8
Molar conductivity( $\text{ohm}^{-1}\text{cm}^2\text{mol}^{-1}$ )	239	228	224	215	210	201

(i) Plot a graph of molar conductivity against dilution.

### A GRAPH OF MOLAR CONDUCTIVITY AGAINST DILUTION



- (ii) Use the graph to determine the molar conductivity of potassium hydroxide at infinite dilution.

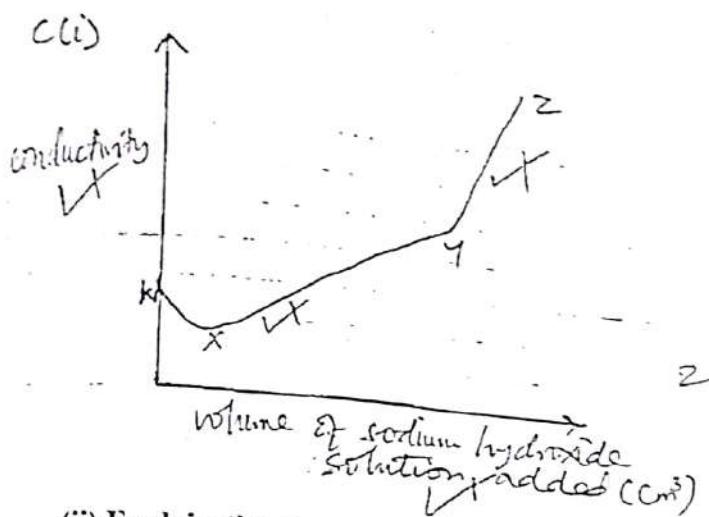
$$\lambda_0 = 224.5 \text{ ohm}^{-1} \text{cm}^2 \text{mol}^{-1}$$

- (iii) Explain the shape of the graph.

Molar conductivity increases as dilution increases

Potassium hydroxide is a strong electrolyte that completely dissociates in solution. As dilution increases inter ionic distance increases ionic interference decreases and ionic mobility increases

(c) (i) Draw a sketch graph to show the change in the conductivity with volume of aqueous sodium hydroxide when  $25\text{cm}^3$  of a  $0.1\text{M}$  propanoic acid is titrated with  $0.1\text{M}$  sodium hydroxide solution.



(ii) Explain the shape of the graph.

Initially, conductivity is low at W due to very few conductivity hydrogen ions from the weak partially ionized propanoic acid.

Conductivity slightly decreases along WX as sodium hydroxide solution is added because the few conducting hydrogen ions are being neutralized to form water and being replaced by the slow moving less conducting sodium ions along YZ, conductivity rapidly increases because of excess fast moving hydrogen ions being added.

Also, the propanoate ions from completely ionized sodium propanoate formed suppress the ionization of propanoic acid

Conductivity gradually increases along XY due to increase in number of propanoate ions and sodium ions from sodium propanoate formed.

At Y, endpoint is reached and conductivity is only due to sodium propanoate formed.

Along YZ, Conductivity rapidly increases because of excess fast moving hydroxide ions being added

(d) The conductivity of a saturated solution of silver phosphate at  $25^\circ\text{C}$  is  $2.65 \times 10^{-6}\text{ohm}^{-1}\text{cm}^{-1}$  and that of pure water is  $1.52 \times 10^{-6}\text{ohm}^{-1}\text{cm}^{-1}$ . If the molar ionic conductivities of phosphate ions and silver ions are 240 and 62  $\text{ohm}^{-1}\text{cm}^2\text{mol}^{-1}$  at infinite dilution at  $25^\circ\text{C}$  respectively, calculate the:

(i) solubility of silver phosphate at  $25^\circ\text{C}$ .

$$K_{\text{Ag}_3\text{PO}_4} = K_{\text{solution}} / K_{\text{water}}$$

$$(2.65 - 1.52) \times 10^{-6}$$

$$1.13 \times 10^{-6} \text{ ohm}^{-1} \text{ cm}^{-1}$$

$$\lambda o \Lambda g_3 PO_4 = 3\lambda o \Lambda g^+ + \lambda o PO_4^{3-}$$

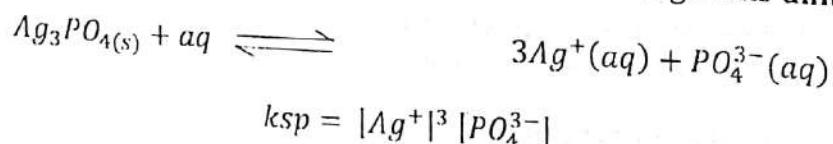
$$= 3(62) + 240 = 426 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$$

Assuming  $\lambda o = \lambda c$  and  $C$  is solubility in  $\text{mol dm}^{-3}$

$$\lambda c = \frac{1000 K_{\Lambda g_3 PO_4}}{c} > C \quad \frac{1000 K_{\Lambda g_3 PO_4}}{\lambda c}$$

$$C = \frac{1000 \times 1.13 \times 10^{-6}}{426} = 2.653 \times 10^{-6} \text{ M}$$

(ii) solubility product of silver phosphate at  $25^\circ\text{C}$  and give its units.



But  $[\Lambda g^+] = 3[\Lambda g_3 PO_4]$  and  $[PO_4^{3-}] = [\Lambda g_3 PO_4]$

Hence  $k_{sp} = (3 \times 2.653 \times 10^{-6})^3 (2.653 \times 10^{-6}) \text{ mol}^4 \text{ dm}^{-12}$

$$K_{sp} = 1.338 \times 10^{-12} \text{ mol}^4 \text{ dm}^{-12}$$

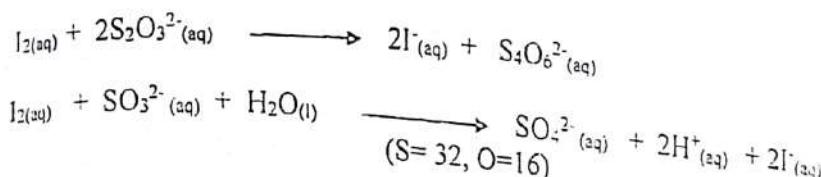
**END**

PS25/3 CHEMISTRY

- You are provided with
- FA<sub>1</sub> which is 0.1M sodium thiosulphate solution
  - FA<sub>2</sub> which is iodine solution of unknown concentration
  - Solid P which is a metal sulphite M<sub>2</sub>SO<sub>3</sub>

You are required to determine:

- The concentration of FA<sub>2</sub> using FA<sub>1</sub>
- The relative atomic mass of M using FA<sub>1</sub> and FA<sub>2</sub>



### PROCEDURE 1

Pipette 25cm<sup>3</sup> or 20cm<sup>3</sup> of FA<sub>2</sub> into a conical flask and titrate with FA<sub>1</sub> until the brown solution just turns yellow. Add five drops of starch and continue the titration until the blue colour just turns colourless. Repeat the titration until you obtain consistent values. Record your values in the table below:

Volume of pipette ..... 25/25.0 cm<sup>3</sup>

Titre	1	2	3
Final burette reading /cm <sup>3</sup>	25.10	35.00	45.00
Initial burette reading / cm <sup>3</sup>	0.00	10.00	20.00
Volume of use FA <sub>1</sub> /cm <sup>3</sup>	25.10	25.00	25.00

✓ ✓ ✓

Volume of FA<sub>1</sub> used to calculate average: ..... 25.00 and 25.00 cm<sup>3</sup> (4½ marks)  
✓ ✓ ✓ ✓ ✓ ✓ (½ marks)

Average volume of FA<sub>1</sub> used ..... 25.00 ± 0.1 cm<sup>3</sup> (2½ marks)

(a) Calculate

(i) Moles of S<sub>2</sub>O<sub>3</sub><sup>2-</sup> in FA<sub>1</sub> that reacted with I<sub>2</sub> in FA<sub>2</sub> (1½ marks)

1000cm<sup>3</sup> of FA<sub>1</sub> Contains 0.1 moles of S<sub>2</sub>O<sub>3</sub><sup>2-</sup> ✓

25.00cm<sup>3</sup> of FA<sub>1</sub> contains  $\frac{(0.1 \times 25.00)}{1000}$  moles of S<sub>2</sub>O<sub>3</sub><sup>2-</sup> ✓

$$= 2.5 \times 10^{-3} \text{ moles. } \checkmark \quad 1\frac{1}{2}$$

(03 marks)

Molarity of FA<sub>2</sub>

2 moles of  $S_2O_3^{2-}$  reacted with 1 mole of  $I_2$   
 $2 \times 5 \times 10^{-3}$  moles of  $S_2O_3^{2-}$  reacted with  $\frac{(1 \times 2.5 \times 10^{-3})}{2}$  mole =  $1.25 \times 10^{-3}$  mole

25.0 cm<sup>3</sup> of FA<sub>2</sub> contains  $1.25 \times 10^{-3}$  moles of  $I_2$

1000 cm<sup>3</sup> of FA<sub>2</sub> contains  $(\frac{1.25 \times 10^{-3} \times 1000}{25})$  moles of  $I_2$

$$= 0.05M$$

## PROCEDURE 2

Weigh accurately 1.6g of P into a beaker and dissolve it in about 100cm<sup>3</sup> of water. Transfer this solution into a 250cm<sup>3</sup> volumetric flask and make it up to the mark with distilled water. Label this solution FA<sub>3</sub>.

Pipette 40cm<sup>3</sup> of FA<sub>3</sub> into a flask followed by 25cm<sup>3</sup> of FA<sub>2</sub>. Then add two spatula endful of sodium hydrogen carbonate. Titrate the excess iodine with FA<sub>1</sub> from the burette using starch indicator. Repeat the titration until consistent values. Record the values in the table below:

Values of FA <sub>2</sub> used	.....	25.0 / 25 cm <sup>3</sup>	(½ marks)
Mass of P + beaker	.....	21.60 g	(½ mark)
Mass of beaker only	.....	20.00 g	(½ mark)
Mass of P used	.....	1.60 g	(½ mark)
Volume of FA <sub>3</sub> used	.....	10.0 / 10 cm <sup>3</sup>	(½ mark)

Titre	1	2	3
Final burette reading/cm <sup>3</sup>	14.80	24.80	34.80
Initial burette reading/cm <sup>3</sup>	0.00	10.00	20.00
Volume of use FA <sub>1</sub> /cm <sup>3</sup>	14.80	14.80	14.80

Centre range  
± 3

4½

(4½ marks)

Volume of FA<sub>1</sub> used to calculate average:

14.80 and 14.80 ✓  $\frac{1}{2}$  cm<sup>3</sup> (½ mark)

Average volume of FA<sub>1</sub> used .....  $14.80 \pm 0.1$  cm<sup>3</sup> (2½ marks)

± 0.2 ✓  
 ± 0.3 ✓  
 ± 0.4 ✓  
 ± 0.5 ✓

(b) Calculate  
(i) Moles of excess iodine that reacted with  $S_2O_3^{2-}$  in FA<sub>1</sub> from the burette. (02 marks)

1000 cm<sup>3</sup> of FA<sub>1</sub> contains 0.1 moles of  $S_2O_3^{2-}$

14.80 cm<sup>3</sup> of FA<sub>1</sub> contains  $\frac{0.1 \times 14.80}{1000}$  moles of  $S_2O_3^{2-}$

2 moles of  $S_2O_3^{2-}$  reacted with 1 mole of  $I_2$

$1.48 \times 10^{-3}$  moles of  $S_2O_3^{2-}$  reacted with  $\frac{1 \times 1.48 \times 10^{-3}}{2}$  moles of  $S_2O_3^{2-}$

(ii) Moles of  $SO_3^{2-}$  in 250 cm<sup>3</sup> of FA<sub>3</sub> =  $7.4 \times 10^{-4}$  moles of  $I_2$  (02 marks)

Moles of  $I_2$  added =  $\frac{(25 \times 0.05)}{1000}$  moles =  $1.25 \times 10^{-3}$  moles

Moles of  $I_2$  that reacted with  $SO_3^{2-}$  =  $(1.25 \times 10^{-3} - 7.4 \times 10^{-4})$  =  $5.1 \times 10^{-4}$

Molar ratio of  $I_2 : SO_3^{2-}$  is 1:1, moles of  $SO_3^{2-}$  =  $5.1 \times 10^{-4}$  moles

10 cm<sup>3</sup> of FA<sub>3</sub> contains  $5.1 \times 10^{-4}$  moles of  $SO_3^{2-}$

250 cm<sup>3</sup> of FA<sub>3</sub> contains  $\frac{(5.1 \times 10^{-4} \times 250)}{10}$  moles =  $1.27 \times 10^{-2}$  moles

(iii) Relative atomic mass of M in  $M_2SO_3$

$1.27 \times 10^{-2}$  moles of P weighs 1.6g

1 mole of P weighs  $\frac{(1.6 \times 1)}{(1.27 \times 10^{-2})}$  g =  $125.9 \approx 126$

$M_2SO_3 = 126$

$2m + 32 + (16 \times 3) = 126$

$$2m + 80 = 126$$

$$2m = 126 - 80$$

$$M = \frac{46}{2}$$

$$2m = 46$$

$$M = 23$$

2. You are provided with substance Y which contains two cations and two anions. You are required to carry out the following tests and identify the ions in Y. Identify any gases that may be evolved. (03 marks)

TEST	OBSERVATION	DEDUCTION
(a) Heat 2 spatula endfuls of Y in a testtube strongly until no further change.	<ul style="list-style-type: none"> <li>- Y is a white powdery substance</li> <li>- Colourless gas that turns moist blue litmus paper red and forms white precipitate with calcium hydroxide.</li> <li>- Yellow residue when hot and white on cooling.</li> <li>- Purple fumes that settles as black sublimate</li> <li>- Colourless liquid that turns colourless copper(II) sulphate from white to blue.</li> </ul>	<p>Non-Transition metal ions present or (<math>Zn^{2+}, Ca^{2+}, Mg^{2+}</math>)</p> <p><math>CO_3^{2-}, CO_3^{2-}</math> present</p> <p><math>Zn^{2+}, Zn^{2+}</math></p> <p><math>I^-</math></p> <p>Y contains water of crystallisation</p> <p>or Y is hydrated.</p>

(b) To one spatula endful of Y in a test tube add concentrated sulphuric acid and heat	Purple forms that settle as black Sublimate.	$I^-$ oxidises to $I_2$
(c) To two spatula endful of Y in a test tube add $3\text{cm}^3$ of water shake well and then filter. Keep the residue divide the filtrate into four portions	- White suspension - White residue - Colourless filtrate	Non-transition metal ions present or $Zn^{2+}$ , $Al^{3+}$ $C_{2T}$ Non-transition metal ions present or $Zn^{2+}$ , $C_{2T}$ Non-transition metal ions present or $Zn^{2+}$ , $C_{2T}$ $Mg^{2+}$
(i) To the first portion add silver nitrate solution followed by aqueous ammonia	Pale yellow precipitate insoluble in aqueous ammonia.	$I^-$ present
(ii) To the second portion add lead (II) nitrate solution.	Yellow precipitation	$I^-$
(iii) To the third portion add bleaching powder and 2M sulphuric acid. Then add carbon tetrachloride and allow to stand	Purple Solution in the organic layer. or The organic layer is purple	$I^-$ confirmed.
(d) Dissolve the residue in (c) in dilute nitric acid then add sodium hydroxide drop wise until in excess filter and keep both the residue and filtrate.	Effervescence bubbles of colourless gas that turns moist blue litmus paper red and lime water milky. - colourless solution - white precipitate insoluble - white residue - colourless filtrate	$CO_2$ ; $CO_3^{2-}$ contained. Non-transition metal ions $Ba^{2+}$ , $Ca^{2+}$ or $Mg^{2+}$ $Ba^{2+}$ , $Ca^{2+}$ or $Mg^{2+}$ $Zn^{2+}$ , $Al^{3+}$ or $Pb^{2+}$
(e) To the filtrate in (d) add dilute nitric acid until the solution is just acidic. Divide the acid solution in three portions	White precipitate soluble forming colourless solution.	$Zn^{2+}$ , $Al^{3+}$ , $Pb^{2+}$ or $Sn^{2+}$
To the first portion add aqueous ammonia drop wise until in excess	White precipitate soluble in excess forming colourless solution.	$Zn^{2+}$

To the second portion add dilute sulphuric acid	No observable change	$\text{Pb}^{2+}$ absent $\text{Zn}^{2+}$ present
(iii) To the third portion add potassium chromate (VI) solution and then excess sodium hydroxide solution	No observable Change	$\text{Zn}^{2+}$ present
(f) Dissolve the residue in (d) in dilute hydrochloric acid divide the solution into three portions	Colourless Solution	$\text{Ba}^{2+}$ , $\text{Ca}^{2+}$ or $\text{Mg}^{2+}$
(i) To the first portion add aqueous ammonia drop wise until in excess	No observable change	$\text{Ca}^{2+}$
(ii) To the second portion add dilute sulphuric acid	No observable change	$\text{Cu}^{2+}$
(iii) To the third portion add ammonium chloride solid then disodiumhydrogenphosphate solution and then excess aqueous ammonia	White precipitate insoluble in excess ammonia	$\text{Ca}^{2+}$ present

Cations are .....  $\text{Zn}^{2+}$  ..... and .....  $\text{Ca}^{2+}$  .....  
 Anions are .....  $\text{I}^-$  ..... and .....  $\text{CO}_3^{2-}$  .....

3. You are provided with substances S which is an organic compound. You are required to determine the nature of S. Carry out the following tests on S and record your observations and deductions in the table below.

(14 marks)

TEST	OBSERVATION	DEDUCTIONS
Burn a small amount of S on a spatula endful or on a crucible	S burns with a yellow sooty flame	S is an aromatic compound or alicyclic compound of high carbon content
To a spatula endful of S in a test tube, add 2cm <sup>3</sup> of sodium hydroxide and shake	S dissolves in sodium hydroxide forming colourless Solution	Acidic organic compound probably phenol or carbonylic acid

(c) To a spatula endful of S in a test tube, add about 3cm <sup>3</sup> of water. Warm the mixture and test the solution with litmus. Divide the hot solution into two parts	Dissolves in water on warming forming colourless solution solution turns blue litmus paper red.	Polar organic compound of high molecular mass. Carboxylic acid or phenol.
(i) To the first part of the warm solution, add sodium carbonate	No effervescence or No observable change	Carboxylic acid absent.
(ii) To the second part of the warm solution, add neutral iron (III) chloride solution	Purple/violet & Solution formed	Phenol present.
(iii) To the third part of the warm solution, add acidified potassium dichromate solution and heat	The orange solution turns green.	aldehyde, primary alcohol or secondary alcohol.
(iv) To the fourth part of the warm solution, add Brady's reagent	Orange precipitate or yellow precipitate	aldehyde present.
(v) To the fifth part of the warm solution, add tollens reagent and heat	Silver mirror formed.	Aldehyde confirmed.
(vi) To the sixth part of the warm solution, add Fehling's reagent and heat	No red precipitate	Aldo group directly attached to benzene ring.

(c) Comment on the nature of S

S is Phenol with an aldo group attached to it.

or S is an aromatic aldehyde with the hydroxyl group attached to the benzene ring.

END