

# A LEVEL CHEMISTRY QUESTIONS AND ANSWERS

**525/1**

## **S6 CHEMISTRY**

### **Exam 1**

### **PAPER 1**

**DURATION: 2 HOUR 45 MINUTES**

#### **Instructions**

- This paper consists of two sections A and B
- Section A is compulsory
- Attempt only six questions in section B
- Answers must be written in the spaces provided only.

Where necessary use the following:

Molar gas constant, R =  $8.31\text{JK}^{-1}\text{mol}^{-1}$

Molar volume of a gas at s.t.p = 22.4litres

Standard temperarue = 273K

Standard pressure =  $10125\text{Nm}^{-2}$

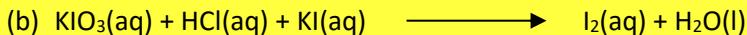
# Kampala Mathematics Club

For Examiner's Use Only

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

## SECTION A

1. Write a balanced overall ionic equation for the following reactions:



2. The osmotic pressure of an aqueous solution of a non-electrolyte containing 5.43 gdm<sup>-3</sup> of solution is  $7.093 \times 10^4 \text{ Nm}^{-2}$  at 25°C. Calculate the freezing point of solution. ( $K_f$  for water = 18.6°C per 100gmol<sup>-1</sup>)

Solution

First we find the formula mass of the solute

From  $PV = nRT$

$$7.093 \times 10^4 \times 1 \times 10^{-3} = \frac{5.43}{mr} \times 8.31 \times (273 + 25)$$

$$\text{Mr} = 190$$

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Then find freezing point depression

190g cause a freezing point depression of  $1.86^{\circ}$  per mole per 1000g of solvent

$$5.43\text{g of solute will cause } \frac{1.86 \times 5.43}{190} = 0.05^{\circ}$$

Freezing point of solution = freezing point of water – freezing point depression

$$= 0 - 0.05$$

$$= -0.05^{\circ}$$

3. (a) Define the term “disproportionation.”

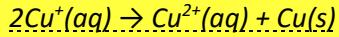
*Disproportionation, is a redox reaction in which one compound of intermediate oxidation state converts to two compounds, one of higher and one of lower oxidation states.*

- (b) Write the ionic equation for the disproportionation of the following species.

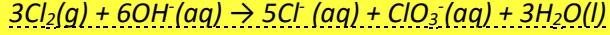
- (i)  $\text{MnO}_4^{2-}$  in acidic media.



- (ii) Copper (I) in aqueous solution.



- (iii) Chlorine in hot concentrated sodium hydroxide solution



4. The following data was obtained for the reaction between hydrogen peroxide and iodine ions and hydrogen ions

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Expt. No.	Concentration (mol dm <sup>-3</sup> )			Rate of reaction (mol dm <sup>-3</sup> s <sup>-1</sup> )
	I-(aq) ion	H <sub>2</sub> O <sub>2</sub> (aq)	H <sup>+</sup> (aq) ions	
1	0.010	0.010	0.010	1.76 × 10 <sup>-6</sup>
2	0.010	0.030	0.010	5.25 × 10 <sup>-6</sup>
3	0.020	0.030	0.010	1.05 × 10 <sup>-5</sup>
4	0.020	0.030	0.020	1.05 × 10 <sup>-5</sup>

(i) State the order of reaction with respect to



*It is first order because when the concentration of I<sup>-</sup> and H<sup>+</sup> are kept constant while the concentration of H<sub>2</sub>O<sub>2</sub> is multiplied by 3 in experiments 1 and 2, the rate multiplies by 3.*



*Experiments 2 and 3 show that it is first order because when the concentration of H<sub>2</sub>O<sub>2</sub> and H<sup>+</sup> are kept constant while the concentration of I<sup>-</sup> is multiplied by 2 the rate multiplies by 2.*



*Experiments 3 and 4 show that it is zero order because when the concentration of H<sub>2</sub>O<sub>2</sub> and I<sup>-</sup> are kept constant while the concentration of H<sup>+</sup> is multiplied by 2 the rate remain unchanged; therefore the rate is independent of the concentration of H<sup>+</sup>.*

(ii) Write the rate equation for the reaction:

$$\text{Rate} = K[\text{H}_2\text{O}_2][\text{I}^-]$$

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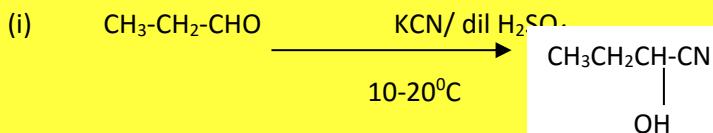
- (iii) Calculate the rate constant (K) for the reaction and indicate its units.

Substituting terms of experiment 1 in rate equation

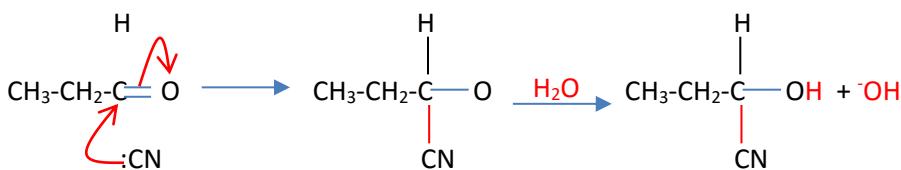
$$1.76 \times 10^{-6} = K \times 0.01 \times 0.01$$

$$K = 1.76 \times 10^{-2} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

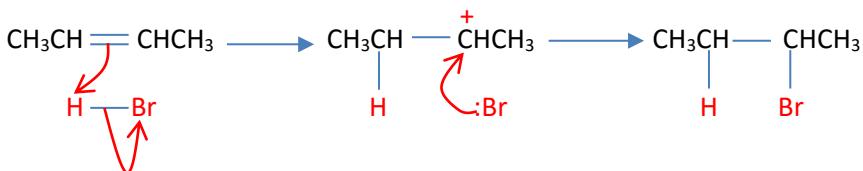
5. Complete each of the following equations and write the accepted mechanism.



Mechanism



Mechanism



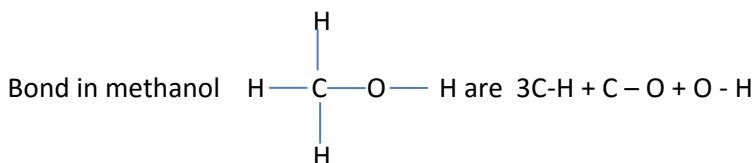
6. (a) Define the term “standard enthalpy of atomization”

Standard enthalpy of atomization is enthalpy change when 1 mole of gaseous atoms are formed from an element at 298K and 1 atmosphere.

(b) Bond energies for some bonds are given below.

Bond	Bond energy
C-O	358
C-H	413
O-H	464

Calculate the standard enthalpy of atomization of methanol



$$\text{Bond energies} = 3 \times 413 + 358 + 464 = 2061$$

(d) Explain why ammonium nitrate is readily soluble in water even though the standard enthalpy of solution has a positive value.

Because increase in entropy offsets the positive enthalpy of solution to make Gibb's free energy negative

7. Name the reagent that can be used to distinguish between  $\text{Co}^{2+}$  and  $\text{Mn}^{2+}$  ions. State what is observed when the aqueous solution of each ion is separately treated with the reagent.

Reagent: Sodium hydroxide

Observations:

$\text{Co}^{2+}$  (aq): forms a blue precipitate insoluble in excess which turns pink on standing

$\text{Mn}^{2+}$  (aq): form a white precipitate insoluble in excess which rapidly turns brown

(b) Cobalt forms a complex of formula  $\text{Co}(\text{NH}_3)_n^{3+}3\text{Cl}^-$ .

$5 \times 10^{-3}$  moles of a complex were heated in excess alkali and the ammonia liberated was absorbed in 50 cm<sup>3</sup> of dilute sulphuric acid of concentration 0.5M. The excess acid remaining after the absorption required 20.00cm<sup>3</sup> of 1M sodium hydroxide for complete neutralization. Calculate the value of n in the formula of the complex.

**Solution**

**Moles sodium hydroxide that reacted with excess sulphuric acid.**

1000cm<sup>3</sup> of sodium hydroxide solution contain 1 mole

20.0cm<sup>3</sup> of sodium hydroxide contain  $\frac{1 \times 20}{1000} = 0.02 \text{ moles}$

Moles of excess sulphuric acid =  $\frac{1}{2}$  the moles sodium hydroxide that reacted =  $\frac{1}{2} \times 0.02 = 0.01$  moles.

**Total moles of sulphuric acid**

1000cm<sup>3</sup> of sulphuric acid contain 0.5moles

50 cm<sup>3</sup> of the acid contains  $\frac{0.5 \times 50}{1000} = 0.025 \text{ moles}$

Moles of sulphuric acid that reacted with ammonia = total moles – excess moles of the acid

$$= 0.025 - 0.01$$

$$= 0.015$$

Moles of ammonia that reacted = twice the moles of sulphuric acid reacted =  $0.015 \times 2 = 0.03$  moles

$$n = \frac{\text{moles of ammonia}}{\text{moles of complex}} = \frac{0.03}{0.005} = 6$$

**8(a) Explain what is meant by the term “condensation polymerization?”**

A condensation polymerization is a form of step-growth polymerization in which monomers and/or oligomers react with each other to form larger structural units while releasing smaller molecules as a byproduct such as water or methanol.

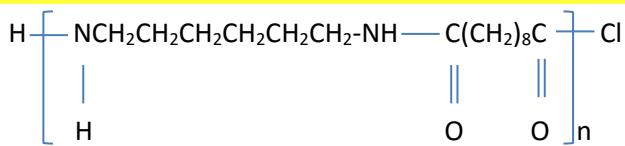
**(b) Nylon 6, 10 can be made by reacting 1, 6-diaminohexane with decanedioyl chloride  $\text{ClOC}(\text{CH}_2)_8\text{COCl}$ .**

Write the structural formula of:

(i) 1,6-diaminohexane



(ii) Nylon 6,10



**(c) State one use of nylon 6, 10.**

Packing material, clothes, water pipes

**9. Ammonium carbamate ( $\text{NH}_4\text{CONH}_2$ ) decomposes according to the following equation:**



**(a) Write the expression for the equilibrium constant ( $K_p$ )**

$$K_p = P_{\text{NH}_3}^2 \times P_{\text{CO}_2}$$

**(b) At equilibrium, the total pressure of the system is 0.36 atm. at  $40^\circ\text{C}$ . Calculate the value of  $K_p$  for the reaction at  $40^\circ\text{C}$  (indicate units).**

**Solution**

$$P_{NH_3} = \frac{2}{3} \times 0.36 = 0.24 \text{ atm}$$

$$P_{CO_2} = \frac{1}{3} \times 0.36 = 0.12 \text{ atm}$$

$$K_p = P_{NH_3}^2 \times P_{CO_2} = 0.24^2 \times 0.12 = 0.006912 \text{ atm}^3$$

(c) State what happens to the  $K_p$  calculated in (a)(i) if

(i) More solid ammonium carbamate is added to the equilibrium mixture.

The concentration of the carbamate has no effect on the value of  $K_p$

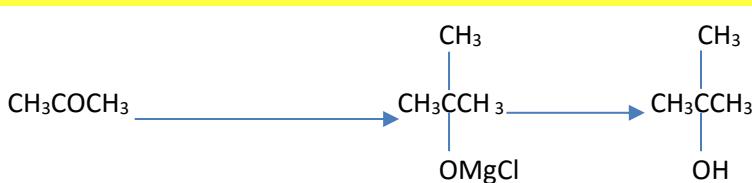
(ii) The temperature is increased to  $80^\circ\text{C}$ .

Increasing temperature increases the value of  $K_p$  because the reaction is endothermic.

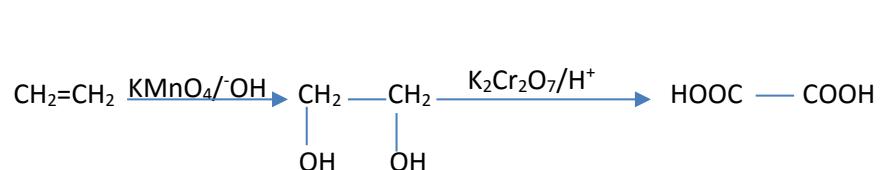
**SECTION B**

10 Show how the following organic conversions can be effected. (Indicate suitable reagents and conditions of reaction's n each). (3marks each)

(a)  $(CH_3)_3COH$  from  $CH_3COCH_3$



(b)  $H_2C_2O_4$  from  $CH_2=CH_2$



(c)  $\text{CH}_3\text{NH}_2$  from  $\text{CH}_3\text{COOH}$



11. Explain the following observations

(a) Silicon and phosphorus are both covalent substances, but the melting of silicon is much higher than that of phosphorus. (3marks)

*Silicon forms big molecules of 3 dimensional array of silicon atoms in which each silicon atom is bonded to 4 silicon atoms by strong covalent bonds whereas phosphorus molecules ( $P_4$ ) are bonded by weak Van der Waal forces.*

(b) Magnesium oxide ( $\text{MgO}$ ) has the same crystalline structure as sodium chloride ( $\text{NaCl}$ ) but the lattice energy of  $\text{MgO}$  is more exothermic than that of  $\text{NaCl}$ . (3marks)

*Magnesium ion have a valence of +2 while sodium ion has a valence of +1. The force of attraction between  $\text{Mg}^{2+}$  and  $\text{O}^{2-}$  are thus stronger than those between  $\text{Na}^+$  and  $\text{O}^{2-}$ .*

(c) A concentrated solution of calcium chloride forms a precipitate with sodium hydroxide but no precipitate form with aqueous ammonia. (3marks)

*Sodium hydroxide is a strong base while ammonia solution is a weak base. Therefore ammonia does not produce enough hydroxide ion to exceed  $K_{\text{sp}}$  of calcium hydroxide.*

12.(a) Phenylamine was mixed with concentrated hydrochloric acid and sodium nitrite at  $0-5^\circ\text{C}$ . The resultant solution Y was then treated with a mixture of phenol in aqueous sodium hydroxide. State what is observed and write the equation of reaction that takes place between:

(i) Phenylamine and a mixture of concentrated hydrochloric acid and sodium nitrite.

Observation

(½ mark)

No observable change

Equation:

(1½ marks)



(ii) Y and phenol in aqueous sodium hydroxide

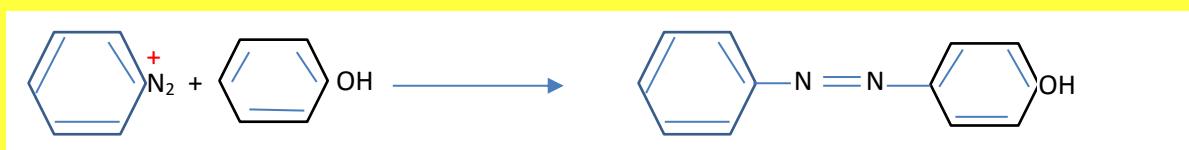
Observation

(½ mark)

Orange solution

Equation:

(1 ½ marks)



(b) 20 cm<sup>3</sup> of 0.05M aqueous phenylamine was mixed with 50cm<sup>3</sup> of 1M sodium bromide and electrolyzed at current of 0.2A. The first permanent bromine color was observed after 49.93 minutes; then electrolysis was stopped. (Faradays constant =96500Cmol<sup>-1</sup>).

(i) Calculate the moles of bromine that reacted with 1 mole of phenylamine

(3 ½ marks)

Solution

$$\text{Charge } Q = It = 0.2 \times 49.93 \times 60 = 599 \text{ C}$$

Mole of bromine

$96500\text{C} \times 2$  liberate 1mole od Br<sub>2</sub>

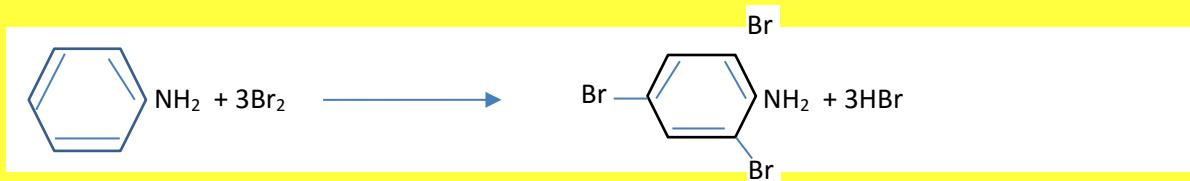
$$599\text{C} \text{ will liberate } \frac{1 \times 599}{2 \times 96500} = 0.003 \text{ moles}$$

$$\text{Moles of phenylamine} = \frac{20 \times 0.05}{1000} = 0.001 \text{ moles}$$

$$\text{Moles of bromine that react with 1 mole of phenylamine} = \frac{0.003}{0.001} = 3$$

(iii) Hence write equation of the reaction between bromine and phenylamine. Name the product

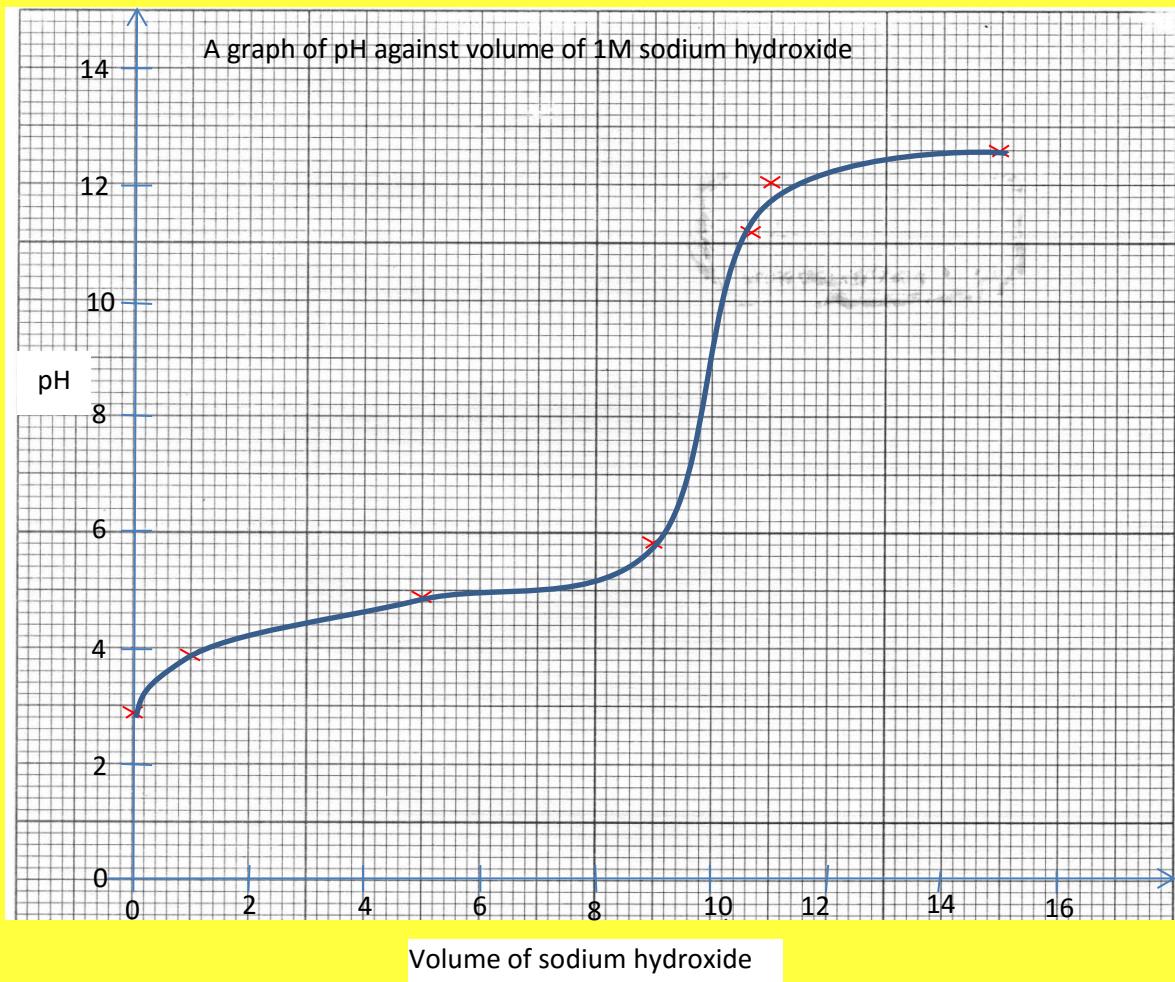
(1 ½ marks)



13. The table below gives data obtained when 100cm<sup>3</sup> of propanoic acid was titrated with 1.0M sodium hydroxide solution.

Volume of 1M NaOH added/ cm <sup>3</sup>	0.0	1.0	5.0	9.0	10.5	11.0	15.0
pH of solution	2.94	3.92	4.87	5.82	11.70	12.00	12.70

(a) (i) Plot a graph of pH against volume of 1M sodium hydroxide (3marks)



- (ii) Using the graph determine the pH and volume 1.0M sodium hydroxide used at equivalent point (1mark)

10cm<sup>3</sup>

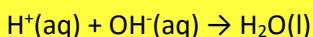
- (iii) Name the suitable indicator that can be used for the titration (½ mark)

Phenolphthalein with pH range 8-10

- (b) Explain the shape of the graph.

- Initially the pH is relatively high because propanoic acid is a weak acid that partially ionizes to liberate few hydrogen ions.

pH increase as the volume of sodium hydroxide added due to removal of hydrogen ions by hydroxyl ions.



- The end point occurs at PH above 7 due to hydrolysis of propanoate ions at a volume of sodium hydroxide = 10cm<sup>3</sup> to produce hydroxyl ions.



- After the end point pH increases due to excess hydroxyl ions.

14. The table below shows formulae of oxides of silicon, Aluminium and phosphorus. (Indicate the chemical nature, bonding type and the structure adopted by the oxide)

Oxide	Chemical nature	Bonding	Structure
SiO <sub>2</sub>	acidic	Covalent bond	3-dimension covalent solid
Al <sub>2</sub> O <sub>3</sub>	amphoteric	Ionic bond	Ionic solid
P <sub>4</sub> O <sub>10</sub>	acidic	covalent	molecular

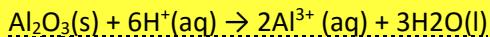
(c) Write equations of reaction to illustrate the chemical nature of

(i) P<sub>4</sub>O<sub>10</sub>

Equation



Equation



Or



15 (a) Define the term “Phase” (1mark)

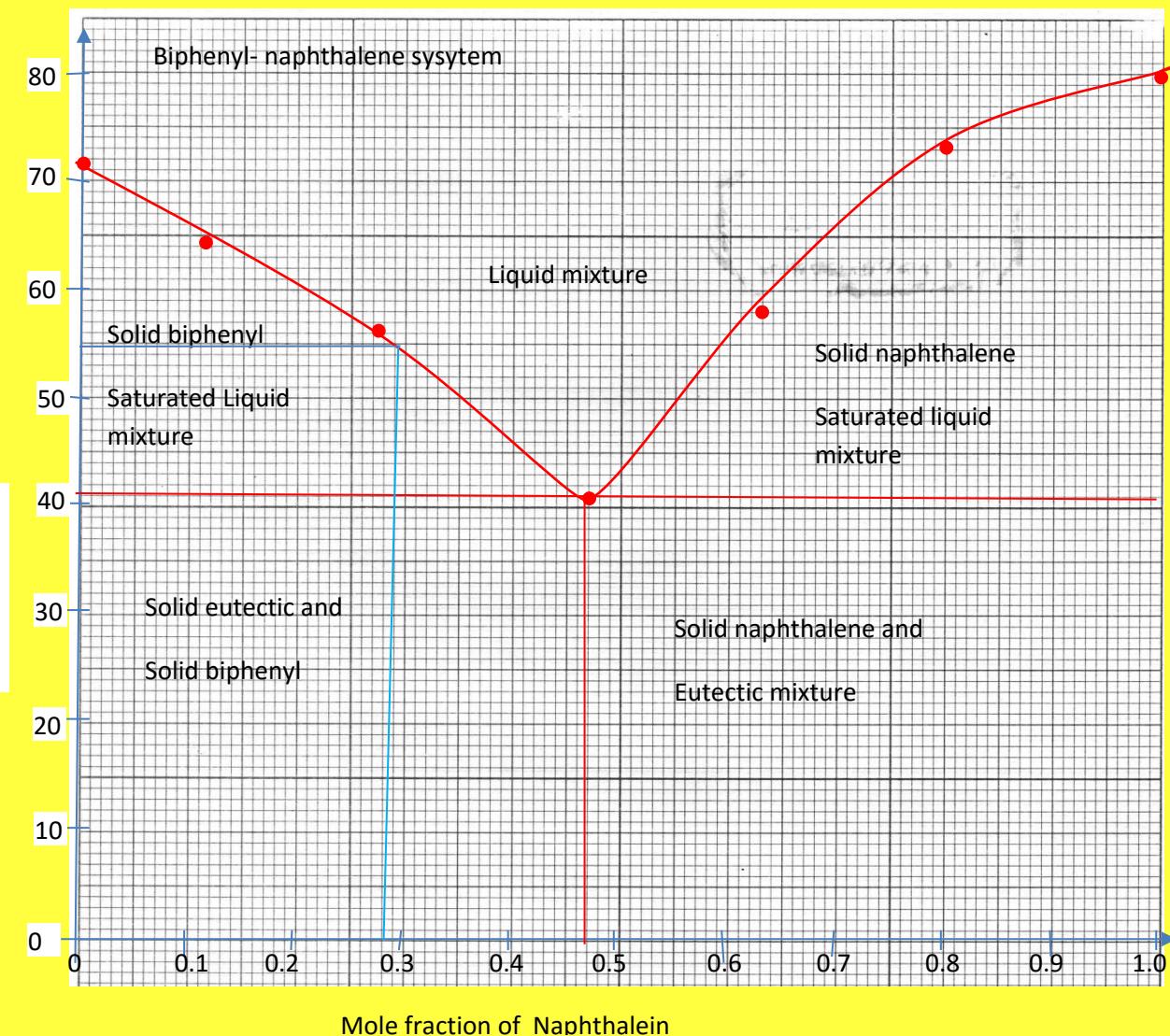
*A phase is a homogeneous state into which a substance can exist i.e. solid, liquid or gas.*

(b) The melting points of various composition of Naphthalene-biphenyl system are given below:

Mole fraction of Naphthalene	0.800	0.625	0.275	0.125
Melting points/ $^{\circ}\text{C}$	72.6	58.0	56.0	64.5

Naphthalene-biphenyl system form a eutectic mixture of composition of 0.47 mole fraction of naphthalene at temperature of  $41.0^{\circ}\text{C}$

(i) Plot a phase diagram for naphthalene-biphenyl system and label all regions. Melting point pure Naphthalene =  $80^{\circ}\text{C}$  and mpt. Of biphenyl =  $71^{\circ}\text{C}$  (5marks)



- (ii) Describe what happens when a mixture containing 0.70 mole fraction of biphenyl is cooled. (2marks)
- Solution freezes at  $55^{\circ}\text{C}$ .
  - Solid biphenyl separates out
  - The concentration of biphenyl decreases to 0.59 mole fraction by  $41^{\circ}$
  - At  $41^{\circ}$ , temperature remains constant as both biphenyl and naphthalene freeze together to form a solid of constant composition.

- After all the liquid has solidified at 410, the temperature of the solid falls to that of room temperature.

(c) State one application of eutectic mixture (½ mark)

To make alloys.

16. 3.70g of an organic compound Q containing carbon, hydrogen and oxygen was exploded in excess oxygen, 4.50g of water and 6.48dm<sup>3</sup> of gaseous substance were passed through sodium hydroxide solution, 2.0dm<sup>3</sup> of oxygen was found unreacted. (All volumes of gaseous substances were measured at stp).

(a) (i) Determine the empirical formula of Q: (4marks)

Mass of hydrogen atoms in the compound

18g of water contain 2g of hydrogen

4.50g of water contain  $\frac{4.5 \times 2}{16} = 0.5\text{g of hydrogen}$

Volume of carbon dioxide =  $6.48 - 2 = 4.48\text{dm}^3$  at stp

Mass of carbon in the compound

22.4dm<sup>3</sup> of carbon dioxide contain 12g of carbon

4.48dm<sup>3</sup> of carbon dioxide contain  $\frac{12 \times 4.48}{22.4} = 2.4\text{g}$

Mass of oxygen =  $3.70 - 0.5 - 2.4 = 0.8$

Elements	hydrogen	Carbon	hysrogen
Symbols	H	C	O
Mass	0.5	2.4	0.8
Atomic mass	1	12	16
Mole	0.5	0.2	0.05
Mole ratio	10	4	1

Empirical formula:  $C_4H_{10}O$

- (iii) If the vapor density of Q is 37, determine the molecular formula of Q (1½ marks)

$$\text{Molecular formula} = 2 \times 37 = 74$$

$$[C_4H_{10}O]n = 74$$

$$[12 \times 4 + 1 \times 10 + 16]n = 74$$

$$n = 1$$

$$\text{molecular formula} = C_4H_{10}O$$

- (d) Q reacts with a mixture of sodium hydroxide and iodine solution to give a yellow precipitate

- (i) Identify Q (1mark)

Butan-2-ol

- (ii) Name the reagent(s) used to confirm the functional group in Q. (½ marks)

Sodium gives effervescence of hydrogen gas

17. (a) Explain what is meant by the term “salt hydrolysis” (1½ marks)

Hydrolysis is the reaction of a salt with water to give either alkaline or acidic solution

(b) Sodium sulphide undergoes hydrolysis. Write the

(i) Equation for hydrolysis of sodium sulphide



(iii) expression for hydrolysis constant ( $K_h$ ), for sodium sulphide.

$$K_h = \frac{[HS^-][OH^-]}{[S^{2-}]}$$

(c)(i) Calculate the pH of solution containing 3.9gdm<sup>-3</sup> of sodium sulphide (Hydrolysis constant at 25°C of sodium sulphide =  $1.25 \times 10^{-10}$  moldm<sup>-3</sup>) (4marks)

Formula mass of NaS = 23 + 32 = 55

$$\text{Molarity of sodium sulphide} = \frac{3.9}{55} \text{ 0.071 moldm}^3$$

Let the concentration of OH<sup>-</sup> be x

$$\frac{x^2}{0.071} = 1.25 \times 10^{-10} \Rightarrow x = 3 \times 10^{-6}$$

$$\text{Concentration of hydrogen ion} = \frac{10^{-14}}{[OH^-]} = \frac{10^{-14}}{3 \times 10^{-6}} 3.3 \times 10^{-9} \text{ moldm}^3$$

$$pH = -\log[H^+] = 8.47$$

(iv) State whether the resultant solution in (a)(i) is basic, neutral or acid (Give a reason for your answer) (1marks)

It is alkaline because it has pH above 7

**525/1**

## **S6 CHEMISTRY**

### **Exam 2**

### **PAPER 1**

**DURATION: 1 HOUR**

#### **INSTRUCTIONS TO CANDIDATES**

Attempt All questions

1. (a) Name three radiations emitted by radioisotopes (1 ½ marks)

Alpha particles, Gamma rays, Beta particles

(b) What is meant by the following terms?

(i) Decay constant. (1 mark)

This is a constant ratio of the number of radioactive atoms disintegrating in any specified short unit interval of time to the total number of atoms of the same kind still intact at the beginning of that interval

Or

It is the average probability per nucleus of decay occurring per unit time

(ii) Half life

(1mark)

Half-life is the time taken for radioactive substance to decay to half its original mass.

(c) The half-life for  $^{223}_{88}Ra$  is 1620 years. Calculate the time taken for 90% of radium to disintegrate. (2 ½ mark)

$$\text{Radioactive constant, } K = \frac{\ln 2}{\text{half-life}} = \frac{\ln 2}{1620} \text{ yr}^{-2}$$

$$\ln \frac{N_o}{N} = Kt$$

$$\ln \frac{100}{10} = \frac{\ln 2}{1620} t$$

$$t = \ln \frac{100}{10} / \frac{\ln 2}{1620} = 5376 \text{ years}$$

2. (a) What is meant by the term first electron affinity. (1mark)

*Electron affinity is the enthalpy change when 1 mole of electrons are added to gaseous atoms or anions to form gaseous anions.*

(b) The first electron affinities of some elements of period 3 are given below

Element	Al	Si	P	S
First electron affinity (kJmol <sup>-1</sup> )	-44	-134	-71.7	-200

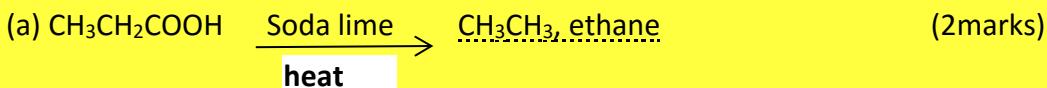
(i) State how the electron affinities vary (1mark)

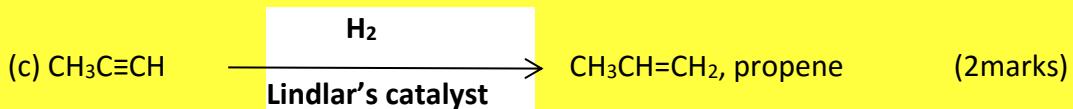
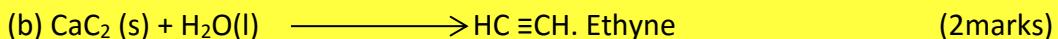
*It generally increases from Al to Si to S. the electron affinity of P is abnormally low.*

(ii) Explain your answer in (i) (3marks)

*Electron affinity generally increase from Al to S due to increase in electronegativity. The electron affinity of Sulphur is abnormally low because it has relatively stable half shell electron configuration that opposes addition of electron.*

3. Complete the following reactions and name the main product.





4. (a) What is meant by the term boiling point elevation constant . (1marks)

Boiling point elevation constant is an increase in boiling point of solution caused by 1 mole of solute in 1000g of solvent.

(b) (i) The boiling point of benzene under certain pressure condition is  $80.0^\circ\text{C}$ . Calculate the boiling point of a solution containing 5g of 2, 4, 6-trinitrophenol ( $\text{HOOC}_6\text{H}_2(\text{NO}_2)_3$ ) in 100g of benzene under these pressure conditions.  $\text{K}_b = 2.6^\circ\text{C}$  per 1000g of benzene) (3mks)

#### **Solution**

Formula mass of 2, 4, 6-trinitrophenol ( $\text{HOOC}_6\text{H}_2(\text{NO}_2)_3$ ) = 229

Mass of 2, 4, 6-trinitrophenol ( $\text{HOOC}_6\text{H}_2(\text{NO}_2)_3$ ) in 1000g of benzene =  $\frac{5 \times 1000}{100} = 50\text{g}$

Boiling point elevation

229g of 2, 4, 6-trinitrophenol ( $\text{HOOC}_6\text{H}_2(\text{NO}_2)_3$ ) cause  $2.6^\circ\text{C}$

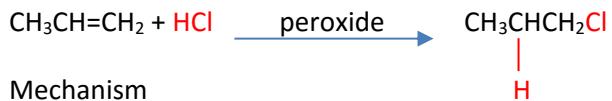
50g of 2, 4, 6-trinitrophenol ( $\text{HOOC}_6\text{H}_2(\text{NO}_2)_3$ ) cause  $\frac{2.6 \times 50}{229} = 0.56^\circ\text{C}$

Boiling point of solution =  $80 + 0.56 = 80.56^\circ\text{C}$

(iii) State any three assumptions made in the calculation (1 ½ mark)

- solution is dilute
- the solute does not associate
- the solute does not react with the solvent

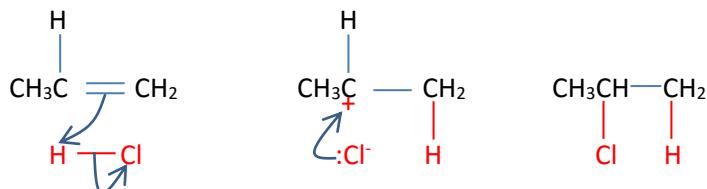
5. (a) When prop-1-ene was reacted with hydrogen chloride in the presence of a peroxide, 1-chloropropane is formed but when the reaction occurs in absence of a peroxide, 2-chloropropane is the main product. Write the mechanisms leading to the formation of the two products.



Mechanism



Mechanism



(b) Explain why the products are different in (a)

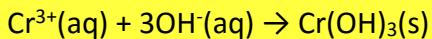
(2marks)

1-Chloropropane is formed by free chain reaction mechanism whereas 2-chloropropane is formed by electrophilic addition reaction mechanism.

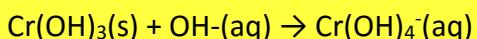
6 State what's observed and write equation for the reactions when

(a) Dilute sodium hydroxide is added drop wise to a solution of chromium (III) sulphate (3mks)

A green precipitate soluble in excess is formed



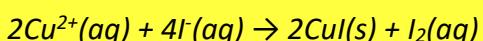
Then



(b) Potassium iodide is added to aqueous copper (II) sulphate

(2 ½ marks)

*White precipitate and brown solution*



# Kampala Mathematics Club

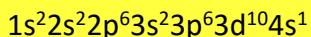
7 (a) (i) Explain what is meant by the term electronic configuration; (01mark)

*Electron configuration is the placement of electron in electron shells within an atom.*

(ii) State two deductions that can be made from electronic configurations (2marks)

*Electron configuration enable us to tell the group and period into which an atom of an element exist.*

(iv) Write electronic configuration of copper (Cu atomic number 29) (2marks)



8. Name one reagent(s) that can be used to differentiate between the following species. In each case state what is observed if each species is separately treated with the reagent.

(a)  $\text{H}_2\text{C}=\text{CH}_2$  and  $\text{HC}\equiv\text{CH}$

Reagent: ammoniacal silver nitrate

Observations

$\text{H}_2\text{C}=\text{CH}_2$ : no observable change

$\text{HC}\equiv\text{CH}$ : white precipitate

$\text{Al}^{3+}$  and  $\text{Pb}^{2+}$

Reagent: potassium iodide

Observations

$\text{Al}^{3+}$  : no observable change

$\text{Pb}^{2+}$ : yellow precipitate

9. 100cm<sup>3</sup> of concentrated hydrochloric acid were diluted to 1dm<sup>3</sup> with distilled water. 26.8cm<sup>3</sup> of the diluted solution required 25cm<sup>3</sup> of 0.5M sodium carbonate solution, with methyl orange indicator for complete neutralization. Calculate the molar concentration of the concentrated hydrochloric acid. (3 marks)

Solution

Mole of sodium carbonate

1000cm<sup>3</sup> contain 0.5moles of sodium carbonate

$$25\text{cm}^3 \text{ contain } \frac{0.5 \times 25}{1000} = 0.0125 \text{moles}$$

Moles of hydrochloric acid in 26.8cm<sup>3</sup> that reacted =  $2 \times 0.0125 = 0.025$ moles

Moles hydrochloric acid in 1000cm<sup>3</sup> of dilute acid

26.8cm<sup>3</sup> of dilute acid contain 0.025moles

$$1000\text{cm}^3 \text{ of dilute acid contains } \frac{0.025 \times 1000}{26.8} = 0.93 \text{mole}$$

Molarity of concentrated acid

100cm<sup>3</sup> contain 0.93 moles

$$1000\text{cm}^3 \text{ contain } \frac{0.93 \times 1000}{100} = 9.3\text{M}$$

10. (a) Explain what is meant by the term colligative property. (2marks)

*Colligative property is a property of dilute solution that depend on the number rather chemical nature of the solute particles.*

(c) 0.72g of a compound M was dissolved in 80g of water and the resultant solution had a freezing point of -0.14°C. When 2.9g of the same compound was dissolved in 111g of benzene the freezing point was depressed by 0.6°C.

(K<sub>f</sub> for water =  $1.86^{\circ}\text{Cmol}^{-1}\text{kg}^{-1}$  and K<sub>f</sub> for benzene is  $5.5^{\circ}\text{Cmol}^{-1}\text{kg}^{-1}$ )

(i) Calculate the apparent molecular mass of M in  
Water

(2 ½ mark)

*Solution*

*Freezing point depression =  $0 - (-0.14) = 0.14$*

*Mass of M in 1000g of water*

80g of water contain 0.72g

$$1000\text{g of water contain } \frac{0.72 \times 1000}{80} = 9\text{g}$$

Formula mass of M

0.14<sup>0</sup>C is caused by 9g of M

1.86<sup>0</sup>C is causes by RFM of M

$$\text{RFM of M} = \frac{1.86 \times 9}{0.14} = 120$$

Benzene

(2 ½ marks)

*Solution*

Freezing point depression = 0.6<sup>0</sup>C

Mass of M in 1000g of benzene

111g of benzene contain 2.9g

$$1000\text{g of benzene contain } \frac{2.9 \times 1000}{111} = 26.13\text{g}$$

Formula mass of M

0.6<sup>0</sup>C is caused by 26.13g of M

5.5<sup>0</sup>C is causes by RFM of M

$$\text{RFM of M} = \frac{5.5 \times 26.13}{0.6} = 240$$

(ii) Explain why the molecular mass of M differs in the solvents.

(2 mark)

*M is associated in benzene or dissociated in water*

**525/1**

## **S6 CHEMISTRY**

### **Exam 3**

### **PAPER 1**

**DURATION: 2 HOUR 45 MINUTES**

### **INSTRUCTIONS**

Attempt all questions in Section A and only six in Section B.

#### **SECTION A**

1. (a) Explain why an azeotrope is a mixture and not a compound
  - they can be separated by physical means
  - components react independently for example water in rectified spirit react with calcium oxide while ethanol does not, in solder tin reacts with dilute hydrochloric acid while lead does not.
  - Composition of azeotropes vary with pressure
  - In crystal the components of azeotropes are seen in the microscope as heterogeneous

(b) Name three methods for separating azeotropic mixtures

- (i) Adding a substance that reacts and removes one component. e.g. CaO reacts and removes water from azeotrope of ethanol and water
- (ii) distillation with a third substance e.g. benzene in rectified spirit
- (iii) Fractional crystallization
- (iv) solvent extraction
- (v) adsorption

(c) Naphthalene ( $C_{10}H_8$ ) distils in steam at  $98.3^{\circ}C$  under a pressure of 753mmHg. The vapor pressure of water at this temperature is 715mmHg. Calculate the percentage by mass of Naphthalene in the distillate.

### **Solution**

$$\text{Vapour pressure of naphthalene} = 753 - 715 = 38$$

$$\text{Formula mass of naphthalene } (C_{10}H_8) = 12 \times 10 + 1 \times 8 = 128$$

$$\text{Formula mass of water } (H_2O) = 2 + 16 = 18$$

Let the percentage of naphthalene be  $x$ ; that of water =  $(100 - x)$

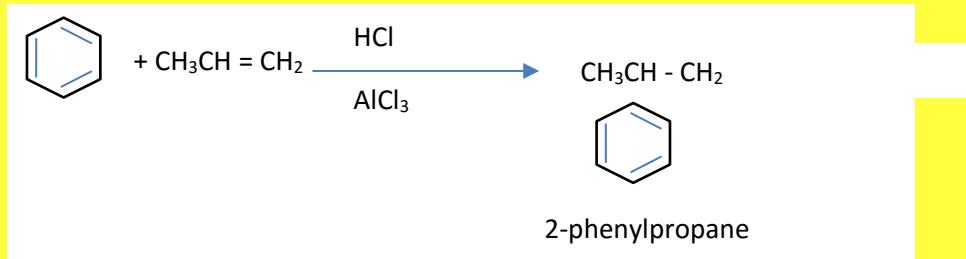
$$\frac{\% \text{ of naphthalene}}{\% \text{ of water}} = \frac{V.P \text{ of naphthalene} \times \text{RFM of naphthalene}}{V.P \text{ of water} \times \text{RFM of water}}$$

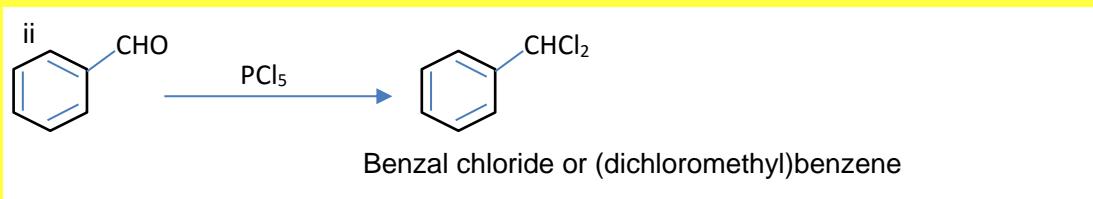
$$\frac{x}{(100-x)} = \frac{38 \times 128}{18 \times 715}$$

$$x = 27.4\%$$

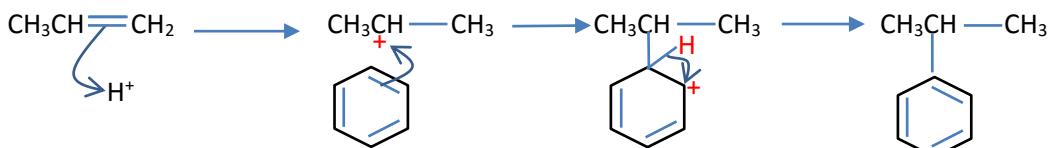
therefore the percentage of naphthalene = 27.4%

2. (a) Complete the following equations and name the major product.





(b) Write the mechanism for the reaction in a (i)

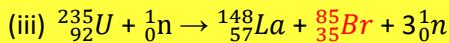
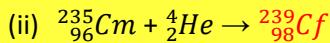
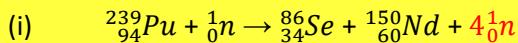


3. (a) State three properties of beta particles.

- bear negative charge
- have negligible mass
- attracted to the positive terminal
- have penetrating power

(b) Complete the following nuclear transformations

Note the sum of atomic mass and atomic numbers of the left hand side are equal to those on the right hand side



(c) Francium isotope ( $^{223}_{87}\text{Fr}$ ) emits beta particles. The rate of emission reduces from 14.0 to 7.5 counter in 80 second. Calculate the half-life of isotopes.

Solution

$$\text{From } \ln \frac{N_0}{N} = \lambda t$$

$$\ln \frac{14}{7.5} = 80\lambda$$

$$\lambda = 0.0078 \text{s}^{-1}$$

$$\text{half-life, } t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{0.0078} = 88.87 \text{s}$$

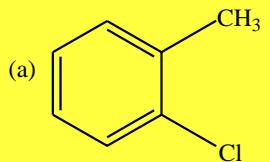
4. (a) Draw the structures and name the shapes of the following species

Species	Structure	Shape
$\text{HCO}_3^-$		Triangular planar
$\text{NO}_2^-$		V-shaped
$\text{SO}_3^{2-}$		Triangular pyramidal

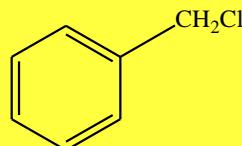
- (b) Explain why the nitrite ion ( $\text{NO}_2^-$ ) adopts the shape you have named in (a)

**The lone pair of electron strongly repel the bond pairs to one side forming a v-shaped molecule.**

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

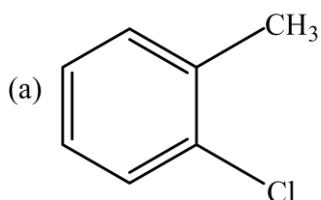


and

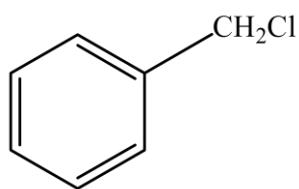


Reagents: **hot concentrated sodium hydroxide followed by acidified silver nitrate**

Observations(s)



and



No observable change

White precipitate

(b)  $\text{CH}_3\text{COCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CHO}$

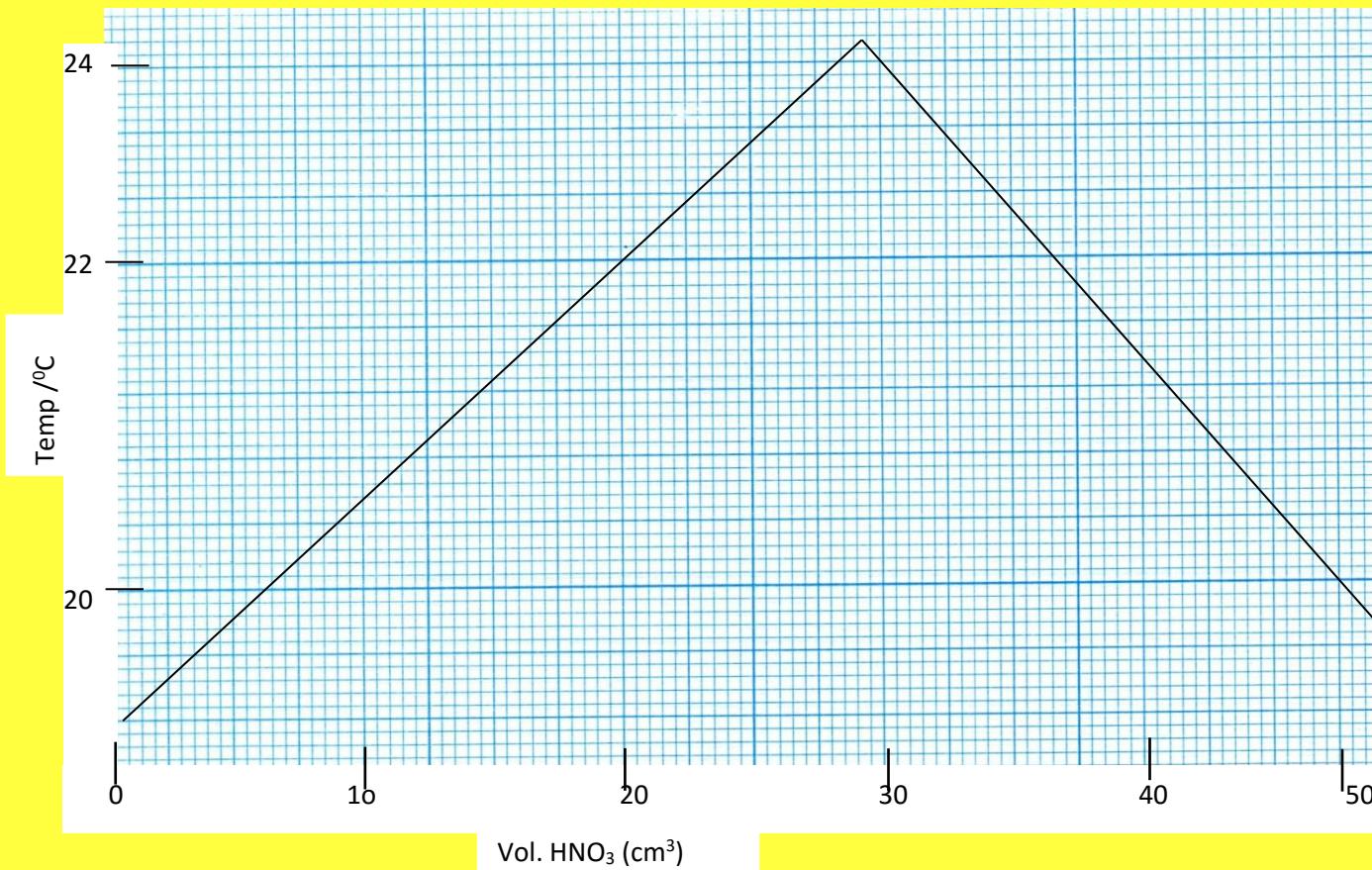
Reagents: **iodine in sodium hydroxide solution ( $\text{I}_2/\text{OH}^-$ )**

Observations(s)

$\text{CH}_3\text{COCH}_3$ : **yellow precipitate**

$\text{CH}_3\text{CH}_2\text{CHO}$ : **no observable change**

6. The graph below was obtained when nitric acid was gradually added to  $50\text{cm}^3$  of  $0.72\text{M}$  potassium hydroxide in a calorimeter of negligible heat capacity



- (a) Determine the volume of nitric acid required to neutralize potassium hydroxide?

28.5cm<sup>3</sup>

- (b) Calculate

(i) Molarity of nitric acid

Mole of potassium hydroxide

1000 cm<sup>3</sup> contain 0.72 moles

$$50 \text{ cm}^3 \text{ contain } \frac{50 \times 0.72}{1000} = 0.036 \text{ moles}$$

Moles of nitric acid that reacted = moles of potassium hydroxide = 0.036moles

Molarity of nitric acid

28.5cm<sup>3</sup> of nitric acid contain 0.036mole

$$1000\text{cm}^3 \text{ of nitric acid contain } \frac{1000 \times 0.036}{28.5} = 1.26\text{moles}$$

Therefore, molarity of nitric acid = 1.26M

- (ii) Heat of neutralization of nitric acid by potassium hydroxide (Density of solution = 1.0gcm<sup>3</sup>)

Temperature change,  $\theta = 24.26 - 18.67 = 5.6^{\circ}\text{C}$

Total volume of solution = 50 + 28.5 = 78.5cm<sup>3</sup>

Mass of solution = 78.5 x 1 = 78.5g

Heat liberated = MCθ = 78.5 x 4.2 x 5.6 = 1846J

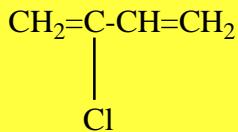
Heat of neutralization per mole

0.036 mole of nitric acid liberate 1846J

1Mole of nitric acid liberate  $\frac{1846 \times 1}{0.036} = 51,287\text{J}$

Therefore, heat of neutralization of nitric acid = 51, 287J per mole

7. (a) A synthetic rubber, Z, was made from (n) monomers with structure



- (i) State the condition for the reaction

- In solution polymerization, the monomer or monomers are dissolved in a hydrocarbon solvent, usually hexane or cyclohexane, and polymerized, using an organometallic catalyst such as butyllithium. Polymers made in solution generally have more linear molecules (that is, less branching of side chains from the main polymer chain), and they also have a narrower distribution of molecular weight (that is, greater length) and flow more easily. In addition, the placement of the monomer units in the polymer molecule can be controlled more precisely when polymerization is conducted in solution.
- In emulsion polymerization, the monomer (or monomers) is emulsified in water with a suitable soap (e.g., sodium stearate) employed as a surfactant, and a water-soluble free-radical catalyst (e.g., potassium persulfate, peroxides, a redox system) is added to induce

polymerization. When emulsion polymerization of SBR is carried out “hot” (i.e., at 50 °C, or 120 °F), the polymer molecules are more branched. When polymerization is carried out “cold” (i.e., at 5 °C, or 40 °F), they are more linear and generally higher in molecular weight—features that improve the rolling resistance and wear resistance of tires. In some cases polymerization is continued in order to give products of such high molecular weight that they would normally be intractable. In these cases about 30 percent of a heavy oil is added before coagulation to yield “oil-extended” elastomers with superior wear resistance.

***In brief conditions for formation of rubber include solvents, organocatalyst, surfactants***

- (ii) Write the equation leading the formation of Z.



- (iii) Name the type reaction in a (i).

Polymerization

- (b) A solution containing 5.0g of Z in 200cm<sup>3</sup> of benzene is found to have an osmotic pressure of 34kPa at 17°C. Calculate the:

- (i) Molar mass of Z

From PV = nRT

$$34 \times 1000 \times 200 \times 10^{-6} = \frac{5}{M_r} \times 8.31 \times (273+17)$$

$$M_r = 3140$$

- (ii) Number of moles of monomers

Formula mass of monomer (C<sub>4</sub>H<sub>5</sub>Cl) = (12 × 4 + 1 × 5 + 35.5) = 88.5

$$\text{Number of monomers} = \frac{3140}{88.5} = 35.5$$

8. (a) State Raoult's law of relative lowering of vapour pressure.

Raoult's law of relative lowering of vapour pressure states that

- (a) the relative lowering of vapour pressure is equal to mole fraction of solute
- (b) the vapor pressure of the solution is equal to mole fraction of the solvent
- (c) the relative lowering of vapour pressure is proportional to amount of solute
- (d) the lowering of vapor pressure is equal to the mole fraction of solute in solution

- (b) (i) Calculate the vapour pressure of a solution containing 18g of glucose ( $C_6H_{12}O_6$ ) in 50g of water at  $60^{\circ}C$ . (Vapour pressure of water at  $60^{\circ}C$  is 150mmHg.)

Solution

$$\text{Formula mass of glucose } (C_6H_{12}O_6) = 6 \times 12 + 12 \times 1 + 16 \times 6 = 180$$

$$\text{Moles of glucose} = \frac{18}{180} = 0.1$$

$$\text{Formula mass of water } (H_2O) = 1 \times 2 + 16 = 18$$

$$\text{Moles of water} = \frac{50}{18} = 2.8$$

$$\text{Total moles} = 2.8 + 0.1 = 2.9$$

$$\text{Mole fraction of water} = \frac{2.8}{2.9}$$

$$\text{Vapor pressure of solution} = \text{mole fraction of water} \times \text{V.P of water}$$

$$= \frac{2.8}{2.9} \times 150 = 144.8 \text{ mmHg}$$

- (ii) State any assumptions made in (b)(i)

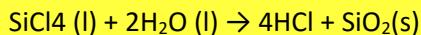
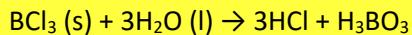
- The solution is dilute
- The solute does not react with solvent
- Solute does not associate or dissociate

# Kampala Mathematics Club

9. (a) State three properties in which boron resembles silicon (1 ½ mark)

- Both are nonmetals
- They react with oxygen to form acid oxide
- Form salts e.g., borides  $MgB_2$  and  $CaB_6$ , and silicides, e.g.,  $Mg_2Si$ , with metal

(b) Write equation(s) for the reaction of the chloride of boron and silicon with water (3marks)

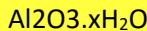


## SECTION B

Attempt any six questions from this section

10. Bauxite is the principal ore used for the extraction of aluminium.

(a) (i) Write the formula of bauxite. (1 ½ mark)



Name **two** impurities in bauxite (1mark)

Silica or  $SiO_2$

Iron salts

(b) Briefly explain how pure aluminium can be obtained from bauxite.

(Include appropriate equations where necessary) (3marks)

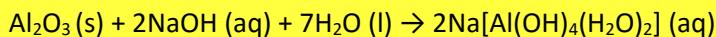
Steps in extraction of Aluminium

(i) The ore is heated

- to remove water and,
- To convert iron salts to iron III oxide

(ii) The powdered ore is heated with concentrated sodium hydroxide to dissolve aluminium oxide and silica such that the insoluble iron oxide is filtered off.

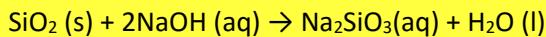
Aluminium oxide form aluminate



Or the ionic form



Silica also dissolves forming sodium silicate.

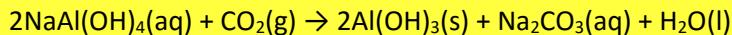


# Kampala Mathematics Club

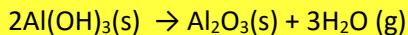
(iii) To the filtrate a little aluminium hydroxide is added to precipitate Aluminium hydroxide,(seeding).



Alternatively carbon dioxide bubbled through the filtrate to precipitate aluminium hydroxide as follows



(iv) The precipitated aluminium hydroxide is filtered off, washed and ignited to give pure aluminium oxide (alumina).



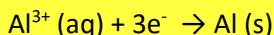
Alumina

(v) Aluminum is obtained from aluminium oxide by electrolysis.

Cryolite,  $\text{Na}_3\text{AlF}_6$ , is added to

- lower the melting point of alumina from  $2050^{\circ}\text{C}$  to  $900^{\circ}\text{C}$
- and improve conductivity of aluminium oxide

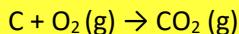
At the cathode (carbon) aluminium is liberated



At the anode (carbon) oxygen is liberated



The anode is eaten up by oxygen



(c) Sodium carbonate solution was added to an aqueous solution of aluminium chloride

(i) State what was observed (1mark)

**White precipitate with effervescence**

(ii) Write equation of the reaction that took place (1 ½ mark)



11. (a) State three reasons why fluorine differs in some of its properties from the rest of group (VII)

elements. (3marks)

- Has small atomic radius
- Has high electronegativity
- Has abnormally low F-F bond energy (158kJ/mol) due to high electron repulsion of nonbonding electron pairs.

(b) Write equation for ionization of hydrogen fluoride in aqueous solution that are

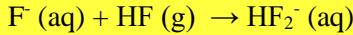
(i) Dilute (1 ½ marks)



(ii) Concentrated (1 ½ marks)



then



(c) Explain why hydrogen fluoride is a weaker acid than hydrogen chloride (3marks)

**H-Cl bond is weaker than H-F bond. The HCl thus easily ionizes to liberate H<sup>+</sup>.**

12. (a) State three characteristics of a chemical equilibrium

- Occurs at constant temperature
- Occurs in closed system
- It is dynamic equilibrium

(b) Hydrogen and iodine react according to the following equations



Write the expression for the equilibrium constant K<sub>c</sub>.

$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$$

(c) 0.5 molar quantities of hydrogen and iodine were sealed in a glass bulb at 445°C until equilibrium was reached. The glass bulb was then rapidly cooled and broken under alkali.

(i) Explain why the glass bulb was rapidly cooled and broken under alkalis.

**To react the formed HI with sodium hydroxide**

(ii) The equilibrium mixture was found to contain 0.78 moles of hydrogen iodide. Calculate the value of the equilibrium constant, K<sub>c</sub> for the reaction at 445°C.

**Solution**

$$\text{Moles of iodine or hydrogen} = \frac{0.78}{2} = 0.39$$

$$\text{Moles of unreacted iodine or hydrogen} = 0.5 - 0.39 = 0.11$$

$$K_C = \frac{0.39^2}{0.11 \times 0.11} = 12.57$$

(d) State what would happen to the position of equilibrium of the reaction in (b) when

- (i) Sodium thiosulphate solution is added to the equilibrium mixture.

**Equilibrium shift to the left due to removal of iodine from the mixture**

- (ii) Argon gas is added at constant volume.

**Equilibrium remains unchanged even when pressure increases because there no change in number of moles of a gas from left to right**

13. (a) A compound Z contain 19.1% nitrogen, 43.6% oxygen and rest manganese.

- (i) Calculate the empirical formula of Z.

$$\text{Percentage of manganese} = 100 - (19.1 + 43.6) = 37.3\%$$

Elements	Nitrogen	Oxygen	manganese
percentages	19.1	43.6	37.3
RAM	14	16	55
Moles	1.36	2.725	0.678
Mole ratio	2	4	1



- (ii) 10g of Z in 1000g of water lowered the freezing point by  $0.127^\circ\text{C}$ . Calculate the molecular formula of Z . ( $k_f$  for water is  $1.86^\circ\text{Cmol}^{-1}\text{kg}^{-1}$ ).

**$0.127^\circ$  is caused by 10g of Z**

$$1.86^\circ \text{ is caused by } \frac{1.86 \times 10}{0.127} = 146$$

**Therefore formula mass of Z = 146**

$$n(\text{MnN}_2\text{O}_4) = 146 \Rightarrow n = 1$$

**molecular formula of Z =  $\text{MnN}_2\text{O}_4$**

- (b) When Z was strongly heated brown fumes were given off. Z dissolved in water to form a pink solution which decolorizes acidified potassium permanganate (VII). Identify Z.

**Z iz Mn(NO<sub>2</sub>)<sub>2</sub> manganese nitrite**

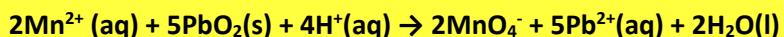
- (c) State what would be observed and write equation(s) for the reaction(s) that took place in the reaction in (b) when:

- (i) Concentrated nitric acid and lead (IV) oxide was added and the mixture boiled.

Observation

**Purple color is observed**

Equation

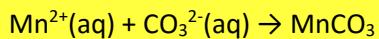


- (ii) Sodium carbonate solution was added

Observation

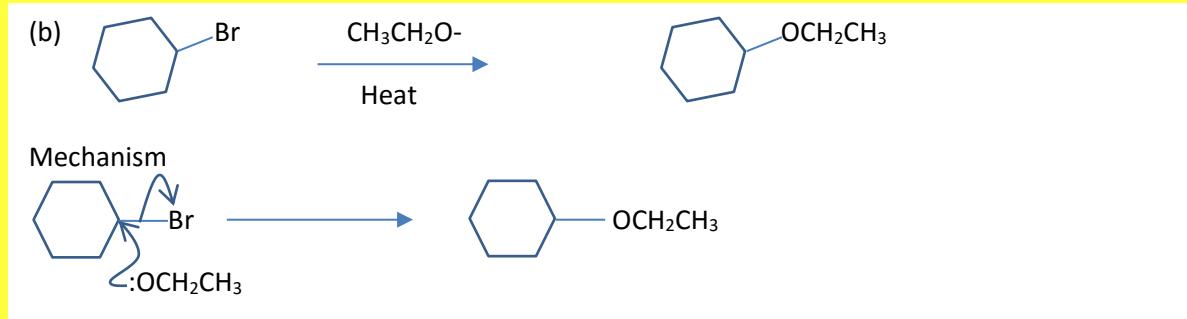
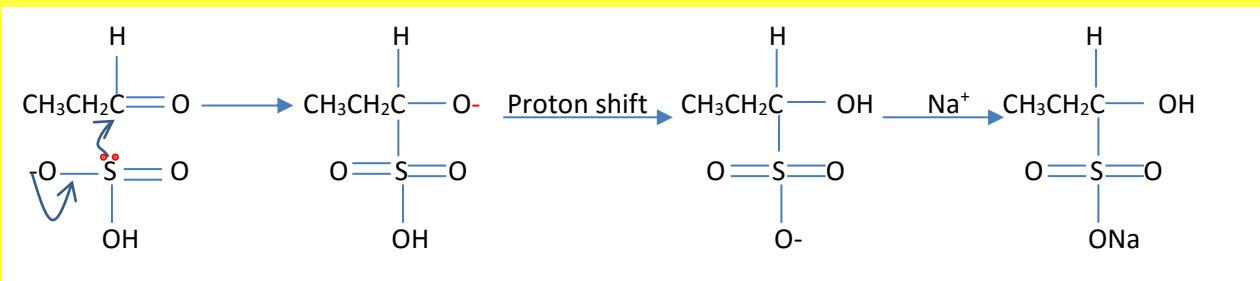
**White precipitate**

- (iii) Equation

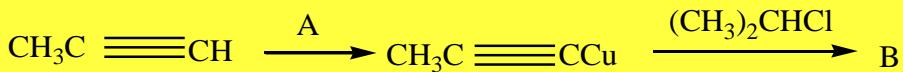


14. Complete the following equations and in each case write acceptable mechanism of the reaction.

(3marks each)



(c) Identify condition and reagent A and product B in the following equation



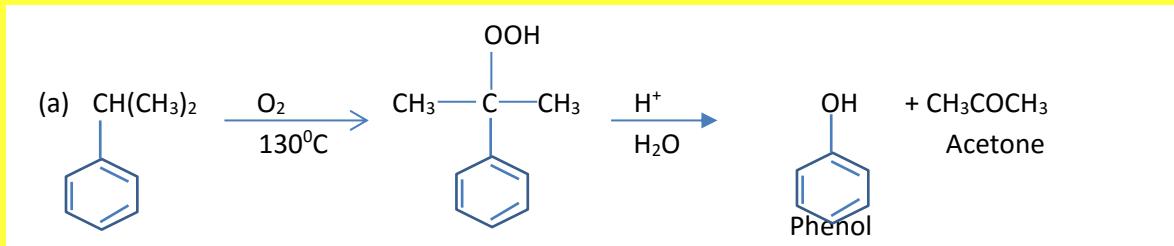
Reagent A: ammoniacal copper I chloride

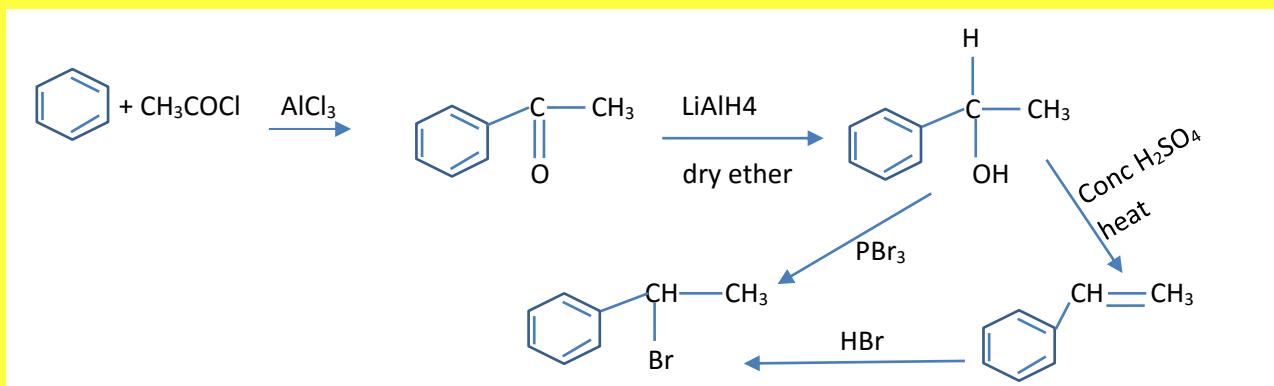
Product B: 4- methylpent-2-ions

15. Show how the following conversions can be attained. In each case indicate the reagent and conditions

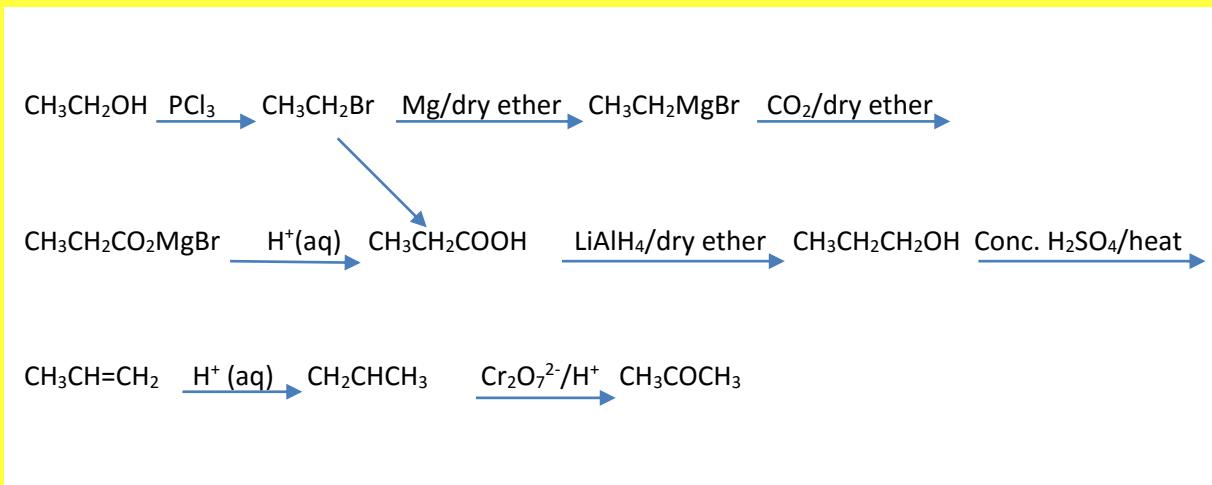
for the reaction.

(3marks each)





(a)  $(\text{CH}_3)_2\text{CO}$  from  $\text{CH}_3\text{CH}_2\text{OH}$



16. (a) The solubility of lead (II) iodide is 0.122g in 100cm<sup>3</sup> of water at 40°C.

(i) Write equation for the solubility of lead (II) iodide in water.



(ii) Write expression for the solubility product of lead (II) iodide.

$$K_s = [\text{Pb}^{2+}][\text{I}^-]^2 \text{ mol}^3\text{dm}^{-9}$$

(iii) Calculate the solubility product of lead (II) iodide.

Formula mass of  $\text{PbBr}_2 = 207 + 2 \times 127 = 461$

# Kampala Mathematics Club

$$\text{Concentration in grams per dm}^3 = \frac{0.122 \times 1000}{100} = 1.22$$

$$\text{Concentration of PbBr}_2 \text{ in mole per litre} = \frac{1.22}{461} = 0.0026$$

$$\text{Concentration of Pb}^{2+} \text{ in mole per litre} = 0.0026$$

$$\text{Concentration of Br}^- \text{ in mole per litre} = 0.0026 \times 2 = 0.0052$$

$$K_s = 0.0026 \times 0.0052^2 = 7 \times 10^{-8} \text{ mol}^3 \text{dm}^{-9}$$

- (d) 50cm<sup>3</sup> of 0.001M lead (II) nitrate was mixed with 50cm<sup>3</sup> of 0.001M potassium iodide. Deduce whether lead (II) iodide will be precipitated or not. Show your working.

Volume doubles and concentration is halved

$$[\text{Pb}^{2+}] = 0.0005 \text{ mol dm}^{-3}$$

$$[\text{I}^-] = 0.0005 \text{ mol dm}^{-3}$$

$$K_s = 0.0005 \times 0.0005^2 = 1.25 \times 10^{-10} \text{ mol}^3 \text{dm}^{-9}$$

Precipitation does not occur because ionic product is less than  $K_s = 7 \times 10^{-8} \text{ mol}^3 \text{dm}^{-9}$

17. (a) State factors that can affect standard electrode potential of an element.

- **Atomization energy**
- **Ionization energy**
- **Hydration energy**

- (b) The standard electrode potential M<sup>2+</sup>(aq)/M(s) for group II elements are given in the table below:

Element	Be	Mg	Ca	Sr	Ba
S.E.P M <sup>2+</sup> (aq)/M(s)	-1.85	-2.37	-2.87	-2.89	-2.91

- (i) State and explain the trend in the variation of standard electrode potential

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**SEP increases from Be to Ba because from Be to Ba, atomization energy, ionization and hydration energies decrease but atomization and ionization energies decrease more rapidly than hydration energy**

- (ii) Explain why the values of standard electrode potentials are negative.

**Hydration energy is higher than the sum of atomization and ionization energies.**

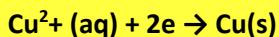
- (c) Electrode potential for some cells are given below

Half cell	$E^0/V$
Pt(s)/SO <sub>4</sub> <sup>2-</sup> , SO <sub>3</sub> <sup>2-</sup>	-0.90
Cu <sup>2+</sup> (aq), Cu(s)	+0.34

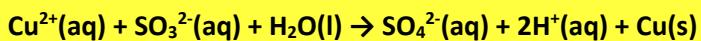
- (i) Write the equation of reaction that takes place at the Anode



Cathode



Overall equation



- (ii) Calculate the emf of the cell.

$$Emf = E_{LHE} - E_{RHE}$$

$$= 0.34 - 0.90$$

$$= 1.24V$$

- (iii) State whether the reaction in (a)(ii) above is feasible or not. Give a reason for your answer.

**The reaction is feasible because emf is positive.**

END

525/1

## S6 CHEMISTRY

Exam 5

**PAPER 1**

DURATION: 2 HOUR 45 MINUTES

*Instructions to candidates:*

- Attempt all questions in section A and any six from section B
- All questions are to be answered in the spaces provided
- A periodic table with relevant atomic masses is supplied at the end of the paper.

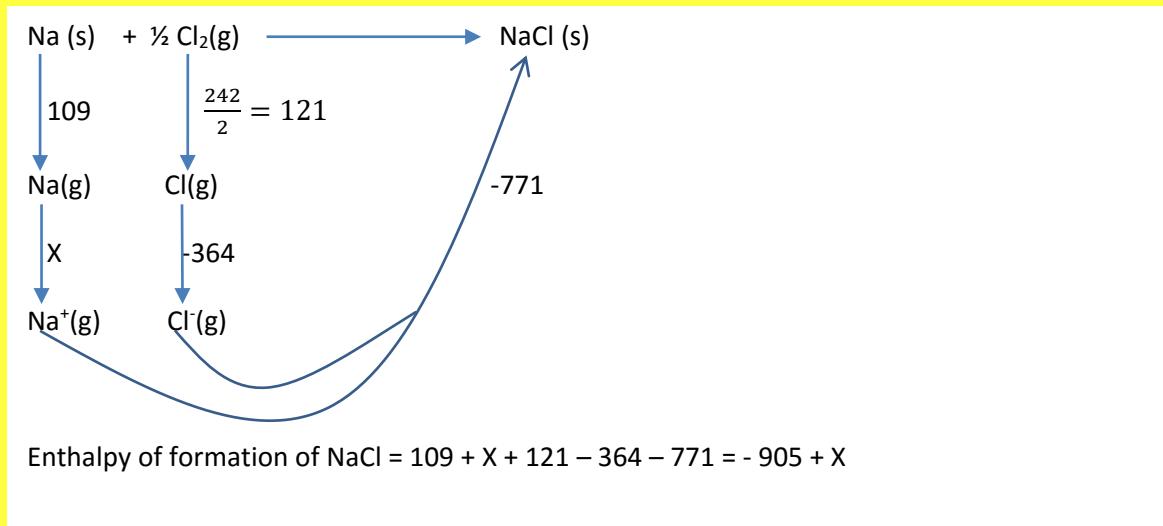
FOREXAMINER'S USE ONLY																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	TOTAL

1. (a) Define the term enthalpy of formation. (1 mark)  
**Enthalpy change when 1 mole of a substance is formed from its element at 298K and 1 atmosphere.**

(b) Calculate the enthalpy of formation sodium chloride from the following data.

$$\Delta H^\theta \text{ (kJmol}^{-1}\text{)} \quad (3 \text{ marks})$$

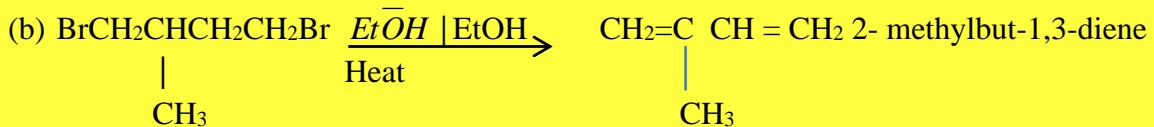
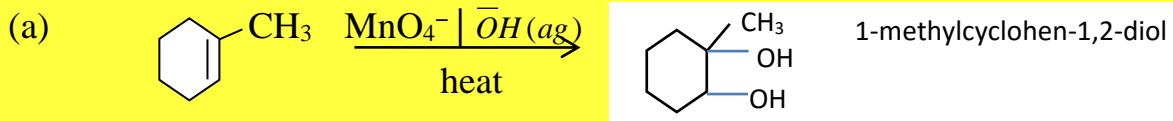
$\text{Na(s)} \longrightarrow \text{Na(g)}$	+109
$\text{Cl}_2(\text{g}) \longrightarrow 2\text{Cl(g)}$	+242
$\text{Na}^+(\text{g}) + \text{Cl}^-(\text{g}) \longrightarrow \text{NaCl(s)}$	-771
$\text{Cl(g)} + \text{e}^- \longrightarrow \text{Cl}^-(\text{g})$	-364

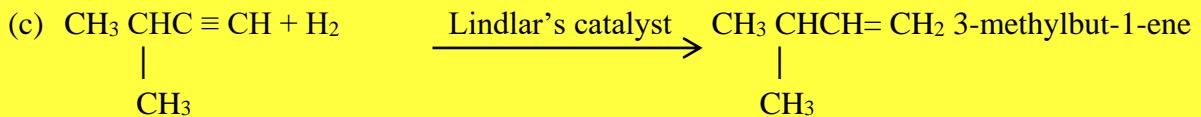


- (c) Comment on the stability of sodium chloride. Give a reason for your answer. (1 mark)

**Stable enthalpy change is negative**

2. Complete the following reactions and in each case write the 1UPAC names of the major organic product. (1 ½ marks each)





3. 0.02M methylamine solution is 4% ionized at 25°C.

(a) Write ;

(i) an equation for the ionization of methylamine in water. (1 mark)



(ii) an expression for the base ionization constant  $K_b$  for methylamine. (1 mark)

$$K_b = \frac{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}{[\text{CH}_3\text{NH}_2]}$$

(b) Calculate the

(i) pH of the methylamine solution ( $K_w = 1.0 \times 10^{-14} \text{ mol}^2\text{dm}^{-6}$ )

$$[\text{OH}^-] = \alpha C = \frac{4}{100} \times 0.02 = 0.0008\text{M}$$

$$[\text{H}^+] = \frac{10^{-14}}{0.0008} = 1.25 \times 10^{-11}$$

$$\text{pH} = -\log \text{H}^+ = 10.9$$

(ii) base ionization constant;  $K_b$  for methylamine. (1 ½ marks)

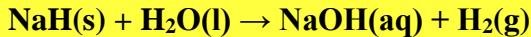
$$K_b = \frac{0.0008^2}{0.02} = 3.2 \times 10^{-5} \text{ mol dm}^{-3}$$

4. (a) Write the formula of the hydrides of sodium and sulphur, in each case state the type of bonds present in the compounds. (2 marks)

Elements	Formula of hydride	Type of bond
Sodium	NaH	ionic
Sulphur	H <sub>2</sub> S	covalent

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(b) Write equations to show how the hydrides react with water. (3 marks)



5. (a) Define the term Osmotic pressure. (1 mark)

**Osmotic pressure of the solution is the minimum pressure which must be applied to the solution to balance the tendency of the solvent to flow from the solvent to the solution side of a semipermeable membrane.**

(b) A polysaccharide has the formula  $(\text{C}_{12}\text{H}_{12}\text{O}_{11})_n$ . A solution containing 5.00gdm<sup>-3</sup> of the sugar has an osmotic pressure of  $7.12 \times 10^2 \text{ Nm}^{-2}$  at 20°C. Find the value of n. (3 ½ marks)

**From PV = nRT**

$$712 \times 10^{-3} = \frac{5}{Mr} \times 8.31 \times (273 + 20)$$

$$Mr = 17098$$

$$(\text{C}_{12}\text{H}_{12}\text{O}_{11})_n = 17098$$

$$n = 51.5$$

(c) State any two assumptions made in (b) above. (1 mark)

- The solution is dilute
- The solute does not react with solvent
- The solute does not associate or dissociate

6. A powdered element T was investigated as shown in the table below

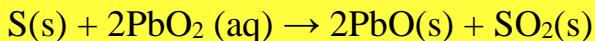
Experiment	Results
(a) A mixture of T and lead (IV) oxide was heated	A colorless gas with a choking smell and turned acidified potassium dichromate from orange to green was evolved.

(b) Concentrated nitric acid is added to heated T, the products were diluted and barium nitrate solution added.	T dissolved in nitric acid with effervescence of a brown gas. On addition of barium nitrate solution a white precipitate was formed
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- (i) Identify T (1 mark)

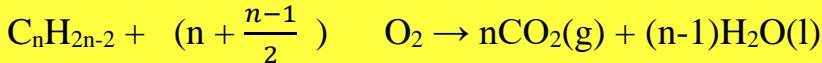
### Sulphur

- (ii) Write equations for the reactions in experiments (a) and (b) (4 marks)



7. (a) 20cm<sup>3</sup> of hydrocarbon Q with general formula C<sub>n</sub>H<sub>2n-2</sub> were mixed with 100cm<sup>3</sup> of oxygen. The mixture was ignited and the residual gaseous product at room temperature bubbled through concentrated potassium hydroxide solution. The final volume was found to be 20cm<sup>3</sup>.

- (i) Calculate the value of n in Q. (2 marks)



Mole of oxygen

$$n + \frac{n-1}{2} = \frac{100-20}{20} = 4$$

$$n = 3$$

- (ii) Deduce the molecular formula of Q. (½ mark)



- (b) Q has two isomers X and Y. X decolorizes bromine water but it does not react with ammoniacal silver nitrate solution. Y forms a white precipitate with ammoniacal silver nitrate solution.

- (i) Identify isomers X and Y (1 mark)



- (ii) Write an equation for the reaction between X and bromine water (1 mark)

X and bromine water



Y and ammoniacal silver nitrate solution. (1 mark)



8. Name the reagent(s) that can be used to distinguish between each of the following compounds. State what would be observed in each case.

(a) KI(aq) and KCl(aq) (1 ½ marks)

Reagent(s)

**Lead (II) nitrates solution**

Observations

**KI – yellow precipitate**

**KCl- white precipitate**

(b)  COONa and  (1 ½ marks)

Reagent(s): neutral iron III chloride

Observations



COONa

**white precipitate**



**purple solution**

(c) PbCO<sub>3</sub>(s) and BaCO<sub>3</sub>(s) (1 ½ marks)

Reagent(s)

HCl

Observations

PbCO<sub>3</sub>(s): **effervescence + white residue**

BaCO<sub>3</sub>(s): **effervescence + colorless solution**

9. The electrode potentials of  $\text{S}_2\text{O}_8^{2-}(\text{aq}) \mid \text{SO}_4^{2-}(\text{aq})$  and  $\text{I}_2(\text{aq}) \mid \text{I}^-(\text{aq})$  are +2.01V and +0.54V respectively.

(a) Write an equation for the reaction that occurs at the;

(i) anode (1 mark)



(ii) cathode (1 mark)



(i) Overall cell reaction (1 mark)



- (b) (i) calculate the e.m.f of the cell generated from the cell reaction in b(ii) above.

$$E_{\text{cell}} = E_{\text{LHE}} - E_{\text{RHE}}$$

$$= 2.01 - 0.54$$

$$= 1.47\text{V}$$

(ii) State whether the above cell reaction is feasible or not. Give a reason for your answer (1 mark)

**It is feasible emf is positive**

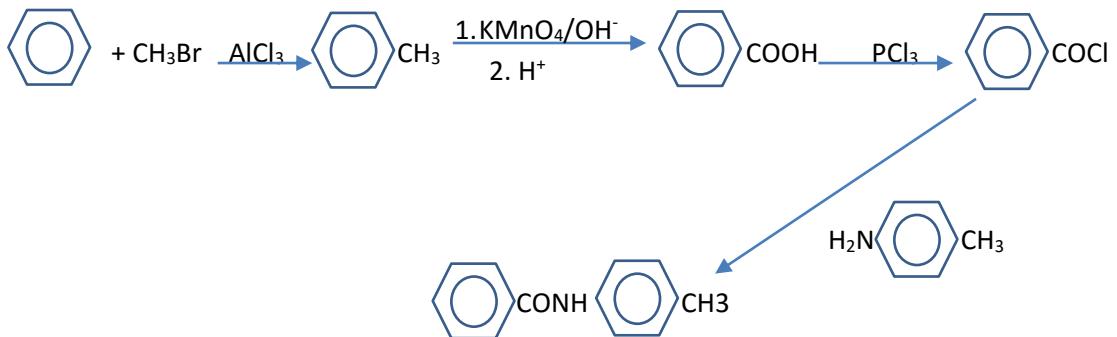
## SECTION B: (54 MARKS)

**Answer only six questions from this section**

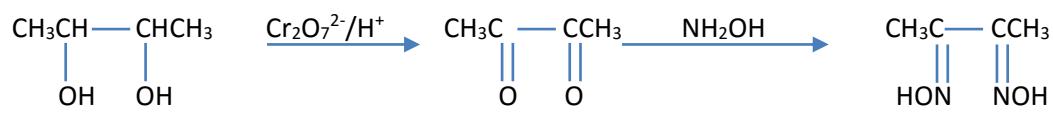
10. Write equations to show how the following conversions can be effected.  
Indicate all reagents and conditions necessary for each reaction.

(a) 1 – methylcyclobutene to 2 – methylcyclobutanol. (3 marks)





(c) Butane – 2, – diol to 2, 3-Butanedione, dioxime. (2 marks)



11. (a) Be(OH)<sub>2</sub>, Mg(OH)<sub>2</sub>, Ca(OH)<sub>2</sub> and Ba(OH)<sub>2</sub> are the hydroxides of group II elements. Briefly describe how the hydroxides react with;

(i) sodium hydroxide solution (2 marks)

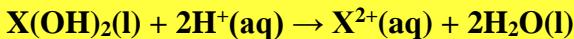
Beryllium hydroxide react to form complex ion



**Mg(OH)<sub>2</sub>, Ca(OH)<sub>2</sub> and Ba(OH)<sub>2</sub> do not react with sodium hydroxide**

(ii) hydrochloric acid solution (2 marks)

**The react to form chloride and water**



(b) The solubilities of the hydroxides of group II elements of the periodic table at 25°C are given below

Hydroxide	Be(OH) <sub>2</sub>	Mg(OH) <sub>2</sub>	Ca(OH) <sub>2</sub>	Sr(OH) <sub>2</sub>	Ba(OH) <sub>2</sub>
Solubility g/100g of water	Insoluble	0.002	0.150	0.900	4.000

(i) State and explain the trend in solubility of the hydroxides.

**Solubility increases from Be(OH)<sub>2</sub> to Ba(OH)<sub>2</sub> because both lattice energy and hydration energy decrease, but lattice energy decreases more rapidly than hydration energy.**

(ii) Different masses of solid Ca(OH)<sub>2</sub> and Ba(OH)<sub>2</sub> containing the **same number of moles** were separately shaken with the same volume of water at 25°C.

Identify the solution with higher pH value. Give a reason for your answer

(1 ½ marks)

**Barium hydroxide because it is more soluble in water to produce more hydroxyl ion**

12. (a) The partition coefficient of ammonia between water and trichloromethane at 25°C is 25.0.

(i) Define the term partition coefficient. (1 ½ marks)

**Partition coefficient is the ratio of concentration of ammonia in trichloromethane over concentration of ammonia in water**

(ii) State two conditions under which the partition coefficient ( $K_D = 25.0$ ) is valid other than constant temperature. (1 mark)

- **none of the solvents is saturated**
- **temperature is constant**
- **the solute (ammonia) is in the same molecular conditions in both solvents.**

(b) 25cm<sup>3</sup> of 0.0056M nickel (II) sulphate solution were added to an **equal** volume of ammonia solution at 25°C. The mixture was shaken with 50cm<sup>3</sup> of trichloromethane and allowed to stand until equilibrium was established. The trichloromethane layer required 32cm<sup>3</sup> of 0.0025M hydrochloric acid for complete neutralization. 7.060cm<sup>3</sup> of the aqueous layer required 20cm<sup>3</sup> of 0.002M hydrochloric acid. Nickel (II) ions react with ammonia according to the equation;

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Calculate

- (i) Molar concentration of the free ammonia in the aqueous layer.(2 ½ marks)

Solution

Moles of hydrochloric acid that reacted with ammonia in organic layer

1000cm<sup>3</sup> contain 0.0025moles

$$32 \text{ cm}^3 \text{ contain } \frac{32 \times 0.0025}{1000} = 0.00008 \text{ moles}$$

$$\text{Moles of ammonia in organic layer} = 0.00008 \text{ mole}$$

Moles of free ammonia in aqueous layer

$$K_D = \frac{\text{Moles of free ammonia in aqueous layer}}{\text{mole of ammonia in organic layer}}$$

$$\text{Moles of free ammonia} = 0.00008 \times 25 = 0.002 \text{ moles}$$

- (ii) Molar concentration of ammonia that reacted with nickel (II) ions (2 marks)

Moles of HCl that reacted with ammonia in 20cm<sup>3</sup> in aqueous solution

1000 cm<sup>3</sup> contain 0.02moles

$$20\text{cm}^3 \text{ contains } \frac{0.02 \times 20}{1000} = 0.0004 \text{ moles}$$

Moles of ammonia in 50cm<sup>3</sup> of aqueous layer

7.060cm<sup>3</sup> contain 0.004 moles

$$50\text{cm}^3 \text{ contain } \frac{0.0004 \times 50}{7.060} = 0.00283$$

$$\text{Mole of complexed with Ni}^{2+} = 0.00283 - 0.002 = 0.00083 \text{ moles}$$

- (iii) Use your answer b (II) above to determine the value of n in  $[\text{Ni}(\text{NH}_3)_n]^{2+}$

Moles of  $\text{Ni}^{2+}$

1000cm<sup>3</sup> contain 0.0056 moles

$$25 \text{ cm}^3 \text{ contain } \frac{0.0056 \times 25}{1000} = 0.00014 \text{ moles}$$

$$n = \frac{\text{moles of ammonia}}{\text{moles of nickel}} = \frac{0.00083}{0.00014} = 6$$

- 13.(a) Describe a simple chemical test to distinguish between  $\text{CH}_3\text{COCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CHO}$  (2 marks)

**Reagent: iodine in sodium hydroxide solution**

**Observations**

$\text{CH}_3\text{COCH}_3$  **yellow precipitate**

$\text{CH}_3\text{CH}_2\text{CHO}$  **no observable change**

Or

**Reagent: Hot Fehling's solution**

**Observations**

$\text{CH}_3\text{COCH}_3$  **no observable change**

$\text{CH}_3\text{CH}_2\text{CHO}$  **red precipitates**

Or

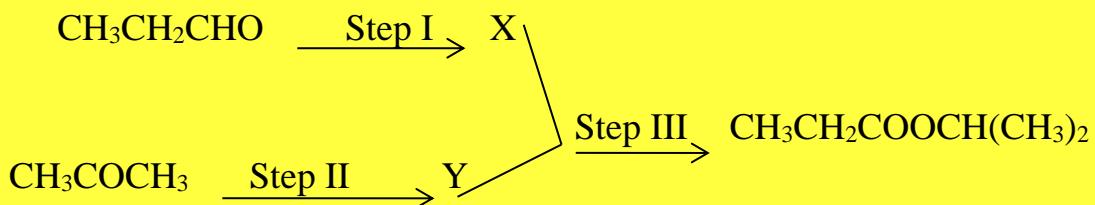
**Reagent: ammoniacal silver nitrate**

**Observations**

$\text{CH}_3\text{COCH}_3$  **no observable change**

$\text{CH}_3\text{CH}_2\text{CHO}$  **silver mirror**

- (b) Compound Z can be synthesized by the reaction between X and Y as shown below



- (i) Identify compounds X and Y

**X-  $\text{CH}_3\text{CH}_2\text{COOH}$ , propanoic acid**

**Y- CH<sub>3</sub>CHOHCH<sub>3</sub> propan-2-ol**

- (ii) Name the type of reaction that occurs in steps I and II (1 mark)

**Step I - oxidation**

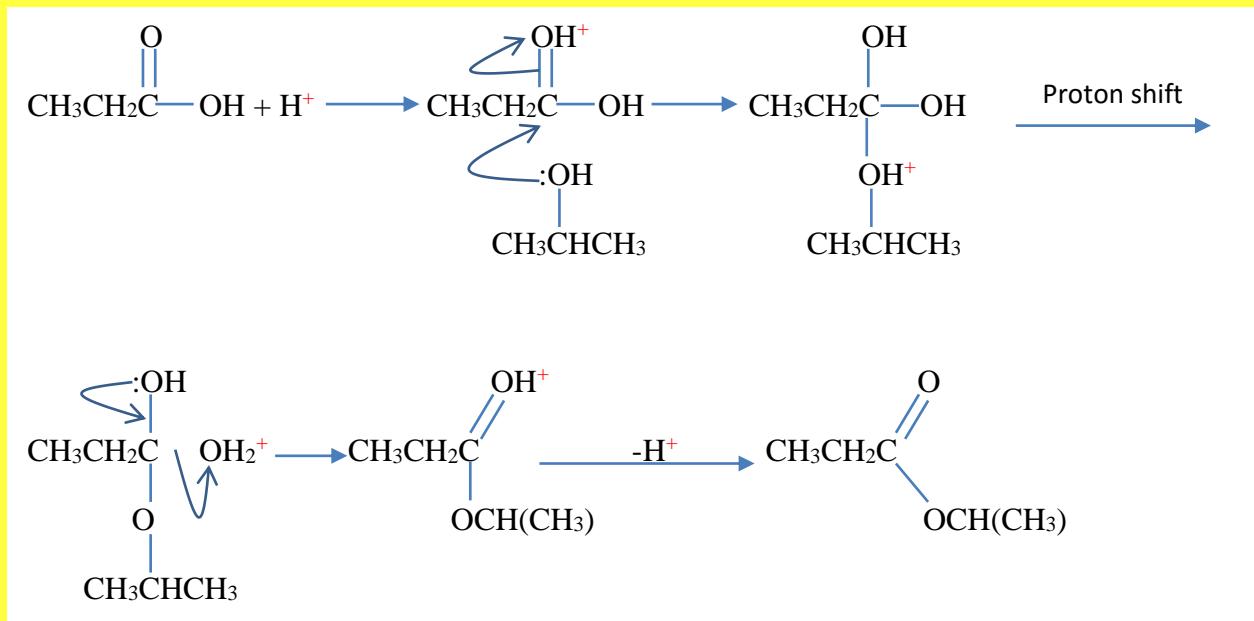
**Step II - reduction**

- (c) Identify the reagents and state the conditions necessary for the reaction in

- (i) step I : Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>/H<sup>+</sup> (1 mark)

- (ii) Step III: LiAlH<sub>4</sub>, dry ether (2 marks)

- (d) Write the mechanism for the reaction that occurs in step III

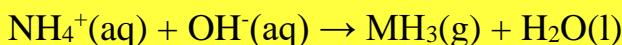
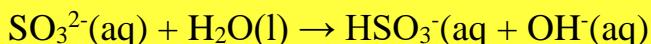


14. Explain each of the following observations.

- (a) An aqueous solution sodium sulphite when mixed with ammonium chloride produce a colourless gas that forms dense white fumes with concentrated hydrochloric acid on warming. (3 marks)

**Solution**

Sulphite ions hydrolyses to form hydroxide ions that react with ammonium ions to form ammonia



- (b) The acid dissociation constant ( $K_a$ ) of chloric (I) acid is lower than the  $K_a$  for chloric (VII) acid at  $25^\circ\text{C}$ , (2 marks)

**The four oxygen atoms in chloric acid (VII) strongly withdraw electron from H-O bond leading to release of  $\text{H}^+$ .**

- (c) When refluxed with aqueous potassium hydroxide followed by acidified silver nitrate solution. Chloroethane forms a white precipitate which chlorobenzene gives no observable change. (4 mark)

Solution

**The chloride ions from chloroethane is substituted by hydroxide ions and forms white precipitates with silver ions. The chloride atom on chlorobenzene is held to benzene ring by hybridized electrons that it is not easily substituted by hydroxide ions**

15. HF, HCl, HBr and HI are hydrides of group VII elements

- (a) Explain the variation in boiling points of the hydrides. (3 marks)

**Boiling points increase from  $\text{HF} < \text{HCl} < \text{HBr} < \text{HI}$  due to increase in molecular mass that increases the van der Waal forces.**

- (b) Aqueous solutions of the hydrides of the same concentration at constant temperature have different pH values.

(i) Identify the hydride whose solution in water has the lowest pH (1 mark)

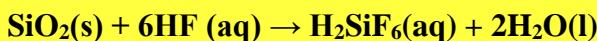
**HF**

(ii) Give a reason for your answer in b(i) above. (2 marks)

**H-F has the strongest covalent bond due to high electronegativity of F. the H-F bond does not break to release  $\text{H}^+$**

- (c) Write an equation for the reaction between

(i) The hydride of fluorine and excess silicon (IV) oxide (1 mark)

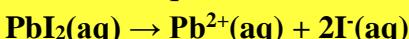


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- (ii) Potassium manganate (VII) solution and the hydride of chlorine. (1 mark)
- $$2\text{KMnO}_4(\text{aq}) + 16\text{HCl}(\text{aq}) \rightarrow 2\text{MnCl}_2(\text{aq}) + 5\text{Cl}_2(\text{g}) + 2\text{KCl}(\text{aq}) + 8\text{H}_2\text{O}(\text{l})$$
- (iii) Concentrated sulphuric acid and the hydride of bromine. (1 mark)
- $$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{Br}^-(\text{aq}) \rightarrow \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \text{Br}_2(\text{aq})$$

16. Lead (II) iodide is a sparingly soluble salt.

- (a) Write an equation for the solubility of lead (II) iodide in water (1 mark)



- (b) The concentration of a saturated solution of lead (I) iodide at 40°C is 0.122g per 100cm<sup>3</sup> of solution

State whether a mixture of 50cm<sup>3</sup> of 0.01M lead (II) nitrate and 50cm<sup>3</sup> of 0.001M potassium iodide forms a yellow precipitate of lead (II) iodide or not. (Show your working clearly) (6 marks)

Formula mass of PbI<sub>2</sub> = 207 + 127 x 2 = 461

Concentration in moles per litre

100cm<sup>3</sup> contain 0.122g

1000cm<sup>3</sup> contain  $\frac{0.122 \times 1000}{100} = 1.22\text{g}$

Molar concentration =  $\frac{1.22}{461} = 0.00265$

$$[\text{Pb}^{2+}] = 0.00265$$

$$[\text{I}^-] = 0.0053$$

$$K_s = 0.00265 \times 0.0053^2 = 7.44 \times 10^{-8}\text{mol}^3\text{dm}^{-9}$$

When 50cm<sup>3</sup> of 0.01M lead (II) nitrate and 50cm<sup>3</sup> of 0.001M potassium iodide are mixed, the volume is double and thus concentration halved.

Ionic product becomes  $0.005 \times 0.0005^2 = 1.25 \times 10^{-9}\text{ mol}^3\text{dm}^{-9}$

**Yellow precipitate does not occur because ionic product is less than solubility product.**

(c) The saturated solution of lead (II) iodide of concentration 0.122g per 100cm<sup>3</sup> of solution was heated to 60°C in a closed system

(i) State whether the solution remains saturated at 60°C (½ mark)

**The solution become unsaturated**

(ii) Give a reason for your answer. (1 ½ marks)

**Solubility of lead iodide increases with temperature**

17. A mixture of methanol and water at 50°C is an ideal solution. The partial vapour pressure of methanol in the vapour above the solution varies according to Raoult's law as shown in the table below.

Partial vapour pressure of methanol (mmHg)	40.0	100.0	200.0	260.0	320.0
Mole fraction of methanol in solution	0.10	0.25	0.50	0.65	0.80

(a) (i) Define the term ideal solution. (1 mark)

**Ideal solution is a solution that obeys Raoult's law, its formation does not cause change in temperature nor volume**

(ii) State Raoult's law (1 mark)

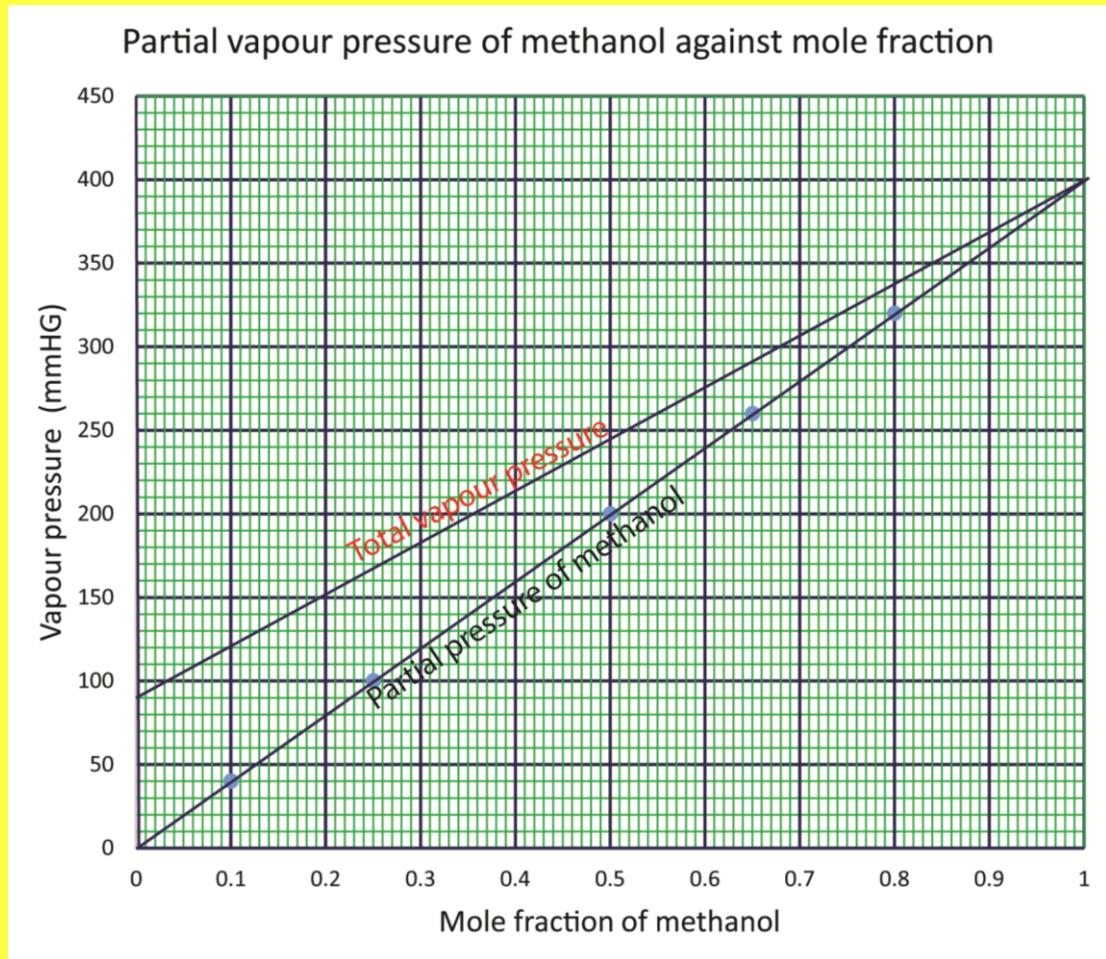
**Raoult's law state that the partial vapour pressure of a component in a mixture is proportional to the concentration of the component.**

(b) On the same axes, plot a graph of;

(i) Partial vapour pressure of methanol

(ii) Total vapour pressure above the solution against mole fraction of methanol.

(The composition of methanol in the vapour is 50% when its mole fraction in solution is 0.19)



(c) Use your graphs in (b) above to determine the

- (i) Saturated vapour pressure of methanol at 50°C. (1 mark)  
**400mmHg**

- (ii) Saturated vapour pressure of water at 50°C

Let the vapour pressure of water be  $x$

From  $P_t = X_{\text{water}} + X_{\text{methanol}}$

At mole fraction of methanol = 0.19

$$P_t = 0.19 \times 400 + 0.81x = 76 + 0.81x$$

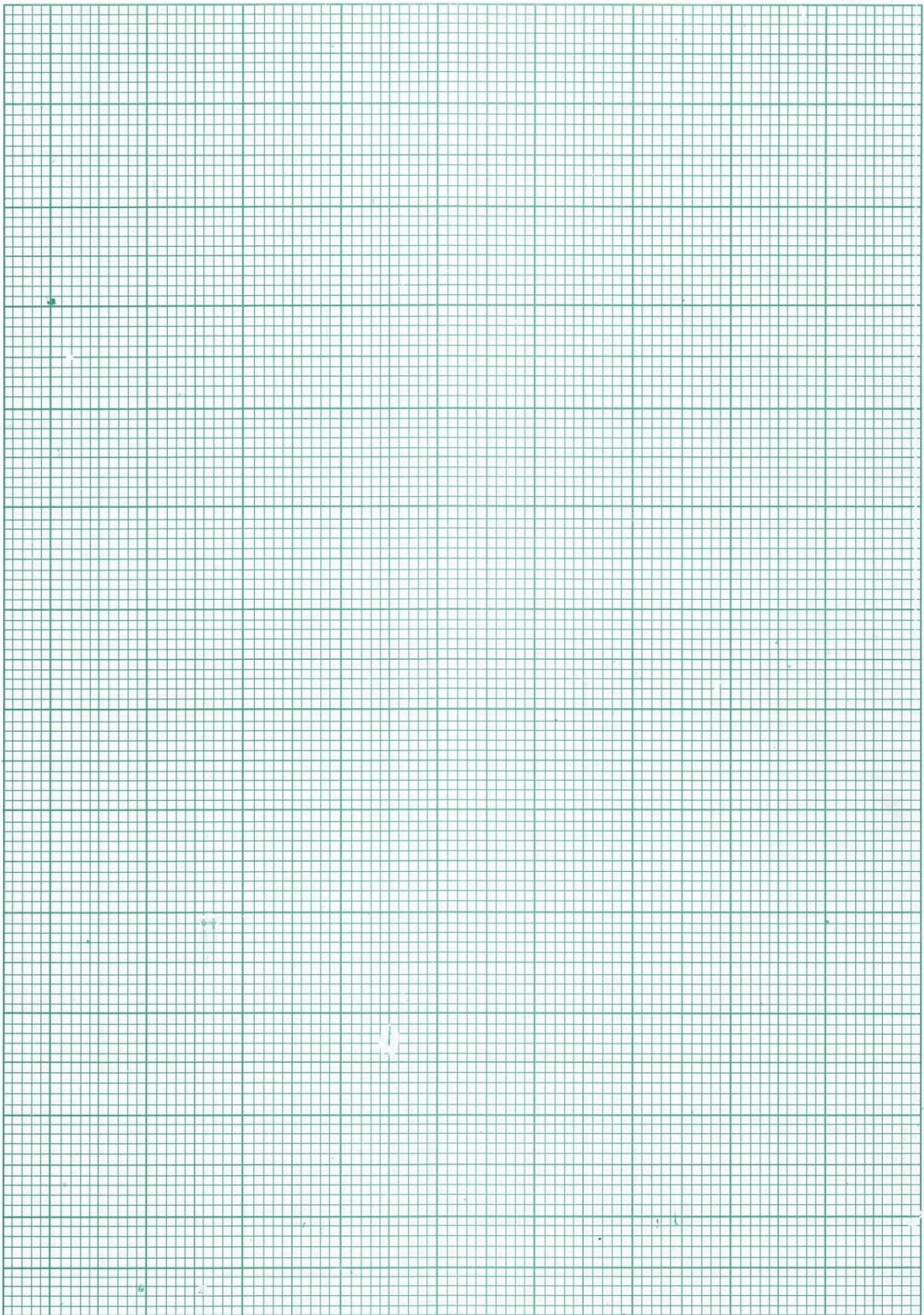
$$\text{Vapour pressure of methanol} = \frac{50}{100} = \frac{76}{76+0.81x}$$

$$\text{Vapour pressure of water, } x = 93.8 \text{ mmHg}$$

- (d) Compare the volatility of methanol and water at 50°C. Give a reason for your answer. (1 mark)

**Methanol is more volatile because it has higher vapour pressure at the same temperature.**

***END***



**THE PERIODIC TABLE**

1	2																			3	4	5	6	7	8																
1 H 1.0																				1 H 1.0	2 He 4.0																				
3 Li 6.9	4 Be 9.0																			5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2																
11 Na 23.0	12 Mg 24.3																			13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.4	18 Ar 40.0																
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.7	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8																								
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc 98.9	44 Ru 101	45 Rh 103	46 Pd 106	47 Ag 108	48 Cd 112	49 In 115	50 Sn 119	51 Sb 122	52 Te 128	53 I 127	54 Xe 131																								
55 Cs 133	56 Ba 137	57 La 139	72 Hf 178	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 Tl 204	82 Pb 207	83 Bi 209	84 Po (209)	85 At (210)	86 Rn (222)																								
87 Fr (223)	88 Ra (226)	89 Ac (227)																	57 La 139	58 Ce 140	59 Pr 141	60 Nd 144	61 Pm (145)	62 Sm 152	63 Sm 150	64 Eu 152	65 Tb 159	66 Dy 162	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175								
																			89 Ac (227)	90 Th 232	91 Pa 231	92 U 238	93 Np 237	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf 251	99 Es (254)	100 Fm (257)	101 Md (256)	102 No (254)	103 Lw								

1.  $\frac{1}{H}$  - indicates Atomic number.

2.  $\frac{H}{1.0}$  - indicates relative Atomic number.

END.

**525/1**

## **S6 CHEMISTRY**

### **Exam 1**

### **PAPER 1**

**DURATION: 2 HOUR 45 MINUTES**

#### **Instructions**

- This paper consists of two sections A and B
- Section A is compulsory
- Attempt only six questions in section B
- Answers must be written in the spaces provided only.

Where necessary use the following:

Molar gas constant, R =  $8.31\text{JK}^{-1}\text{mol}^{-1}$

Molar volume of a gas at s.t.p = 22.4litres

Standard temperarue = 273K

Standard pressure =  $10125\text{Nm}^{-2}$

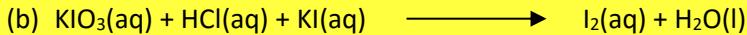
# Kampala Mathematics Club

For Examiner's Use Only

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

## SECTION A

1. Write a balanced overall ionic equation for the following reactions:



2. The osmotic pressure of an aqueous solution of a non-electrolyte containing 5.43 gdm<sup>-3</sup> of solution is  $7.093 \times 10^4 \text{ Nm}^{-2}$  at 25°C. Calculate the freezing point of solution. ( $K_f$  for water = 18.6°C per 100gmol<sup>-1</sup>)

Solution

First we find the formula mass of the solute

From  $PV = nRT$

$$7.093 \times 10^4 \times 1 \times 10^{-3} = \frac{5.43}{mr} \times 8.31 \times (273 + 25)$$

$$\text{Mr} = 190$$

# Kampala Mathematics Club

Then find freezing point depression

190g cause a freezing point depression of  $1.86^{\circ}$  per mole per 1000g of solvent

$$5.43\text{g of solute will cause } \frac{1.86 \times 5.43}{190} = 0.05^{\circ}$$

Freezing point of solution = freezing point of water – freezing point depression

$$= 0 - 0.05$$

$$= -0.05^{\circ}$$

3. (a) Define the term “disproportionation.”

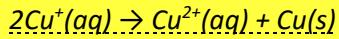
*Disproportionation, is a redox reaction in which one compound of intermediate oxidation state converts to two compounds, one of higher and one of lower oxidation states.*

- (b) Write the ionic equation for the disproportionation of the following species.

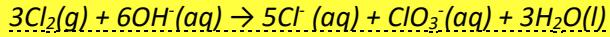
- (i)  $\text{MnO}_4^{2-}$  in acidic media.



- (ii) Copper (I) in aqueous solution.



- (iii) Chlorine in hot concentrated sodium hydroxide solution



4. The following data was obtained for the reaction between hydrogen peroxide and iodine ions and hydrogen ions

# Kampala Mathematics Club

Expt. No.	Concentration ( $\text{mol dm}^{-3}$ )			Rate of reaction ( $\text{mol dm}^{-3} \text{s}^{-1}$ )
	I-(aq) ion	$\text{H}_2\text{O}_2$ (aq)	$\text{H}^+$ (aq) ions	
1	0.010	0.010	0.010	$1.76 \times 10^{-6}$
2	0.010	0.030	0.010	$5.25 \times 10^{-6}$
3	0.020	0.030	0.010	$1.05 \times 10^{-5}$
4	0.020	0.030	0.020	$1.05 \times 10^{-5}$

(i) State the order of reaction with respect to



*It is first order because when the concentration of I- and H+ are kept constant while the concentration of  $\text{H}_2\text{O}_2$  is multiplied by 3 in experiments 1 and 2, the rate multiplies by 3.*



*Experiments 2 and 3 show that it is first order because when the concentration of  $\text{H}_2\text{O}_2$  and  $\text{H}^+$  are kept constant while the concentration of I- is multiplied by 2 the rate multiplies by 2.*



*Experiments 3 and 4 show that it is zero order because when the concentration of  $\text{H}_2\text{O}_2$  and I- are kept constant while the concentration of  $\text{H}^+$  is multiplied by 2 the rate remain unchanged; therefore the rate is independent of the concentration of  $\text{H}^+$ .*

(ii) Write the rate equation for the reaction:

$$\text{Rate} = K[\text{H}_2\text{O}_2][\text{I}^-]$$

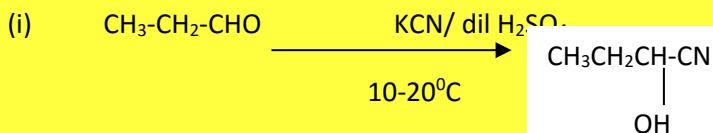
- (iii) Calculate the rate constant (K) for the reaction and indicate its units.

Substituting terms of experiment 1 in rate equation

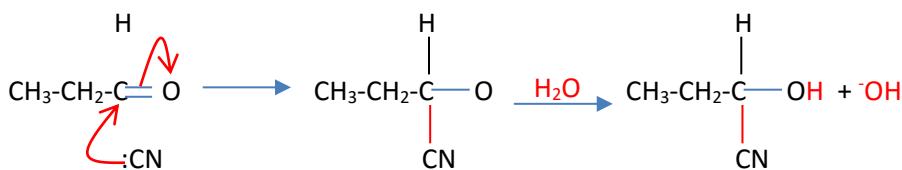
$$1.76 \times 10^{-6} = K \times 0.01 \times 0.01$$

$$K = 1.76 \times 10^{-2} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

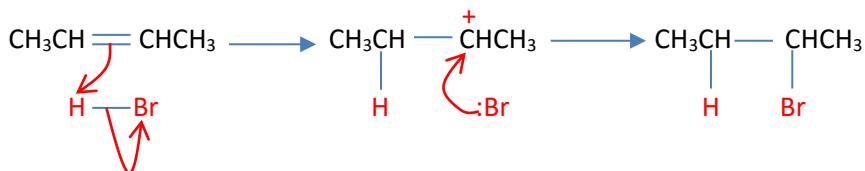
5. Complete each of the following equations and write the accepted mechanism.



Mechanism



Mechanism



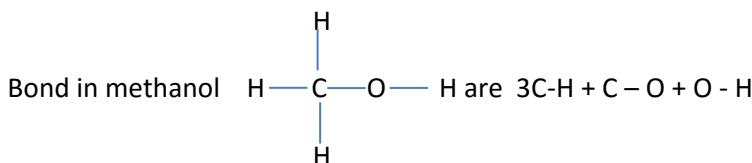
6. (a) Define the term “standard enthalpy of atomization”

Standard enthalpy of atomization is enthalpy change when 1 mole of gaseous atoms are formed from an element at 298K and 1 atmosphere.

(b) Bond energies for some bonds are given below.

Bond	Bond energy
C-O	358
C-H	413
O-H	464

Calculate the standard enthalpy of atomization of methanol



$$\text{Bond energies} = 3 \times 413 + 358 + 464 = 2061$$

(d) Explain why ammonium nitrate is readily soluble in water even though the standard enthalpy of solution has a positive value.

Because increase in entropy offsets the positive enthalpy of solution to make Gibb's free energy negative

7. Name the reagent that can be used to distinguish between  $\text{Co}^{2+}$  and  $\text{Mn}^{2+}$  ions. State what is observed when the aqueous solution of each ion is separately treated with the reagent.

Reagent: Sodium hydroxide

Observations:

$\text{Co}^{2+}$  (aq): forms a blue precipitate insoluble in excess which turns pink on standing

$\text{Mn}^{2+}$  (aq): form a white precipitate insoluble in excess which rapidly turns brown

(b) Cobalt forms a complex of formula  $\text{Co}(\text{NH}_3)_n^{3+}3\text{Cl}^-$ .

$5 \times 10^{-3}$  moles of a complex were heated in excess alkali and the ammonia liberated was absorbed in 50 cm<sup>3</sup> of dilute sulphuric acid of concentration 0.5M. The excess acid remaining after the absorption required 20.00cm<sup>3</sup> of 1M sodium hydroxide for complete neutralization. Calculate the value of n in the formula of the complex.

**Solution**

**Moles sodium hydroxide that reacted with excess sulphuric acid.**

1000cm<sup>3</sup> of sodium hydroxide solution contain 1 mole

20.0cm<sup>3</sup> of sodium hydroxide contain  $\frac{1 \times 20}{1000} = 0.02 \text{ moles}$

Moles of excess sulphuric acid =  $\frac{1}{2}$  the moles sodium hydroxide that reacted =  $\frac{1}{2} \times 0.02 = 0.01$  moles.

**Total moles of sulphuric acid**

1000cm<sup>3</sup> of sulphuric acid contain 0.5moles

50 cm<sup>3</sup> of the acid contains  $\frac{0.5 \times 50}{1000} = 0.025 \text{ moles}$

Moles of sulphuric acid that reacted with ammonia = total moles – excess moles of the acid

$$= 0.025 - 0.01$$

$$= 0.015$$

Moles of ammonia that reacted = twice the moles of sulphuric acid reacted =  $0.015 \times 2 = 0.03$  moles

$$n = \frac{\text{moles of ammonia}}{\text{moles of complex}} = \frac{0.03}{0.005} = 6$$

**8(a) Explain what is meant by the term “condensation polymerization?”**

A condensation polymerization is a form of step-growth polymerization in which monomers and/or oligomers react with each other to form larger structural units while releasing smaller molecules as a byproduct such as water or methanol.

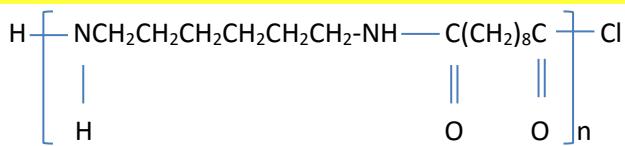
**(b) Nylon 6, 10 can be made by reacting 1, 6-diaminohexane with decanedioyl chloride  $\text{ClOC}(\text{CH}_2)_8\text{COCl}$ .**

Write the structural formula of:

(i) 1,6-diaminohexane



(ii) Nylon 6,10



(c) State one use of nylon 6, 10.

Packing material, clothes, water pipes

**9. Ammonium carbamate ( $\text{NH}_4\text{CONH}_2$ ) decomposes according to the following equation:**



(a) Write the expression for the equilibrium constant ( $K_p$ )

$$K_p = P_{\text{NH}_3}^2 \times P_{\text{CO}_2}$$

(b) At equilibrium, the total pressure of the system is 0.36 atm. at  $40^\circ\text{C}$ . Calculate the value of  $K_p$  for the reaction at  $40^\circ\text{C}$  (indicate units).

**Solution**

$$P_{NH_3} = \frac{2}{3} \times 0.36 = 0.24 \text{ atm}$$

$$P_{CO_2} = \frac{1}{3} \times 0.36 = 0.12 \text{ atm}$$

$$K_p = P_{NH_3}^2 \times P_{CO_2} = 0.24^2 \times 0.12 = 0.006912 \text{ atm}^3$$

(c) State what happens to the  $K_p$  calculated in (a)(i) if

(i) More solid ammonium carbamate is added to the equilibrium mixture.

The concentration of the carbamate has no effect on the value of  $K_p$

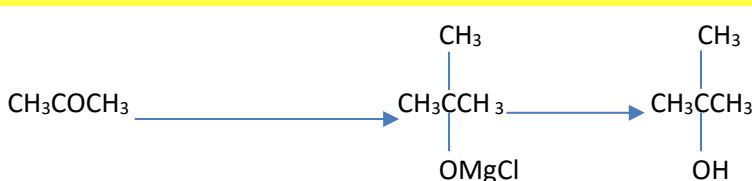
(ii) The temperature is increased to  $80^\circ\text{C}$ .

Increasing temperature increases the value of  $K_p$  because the reaction is endothermic.

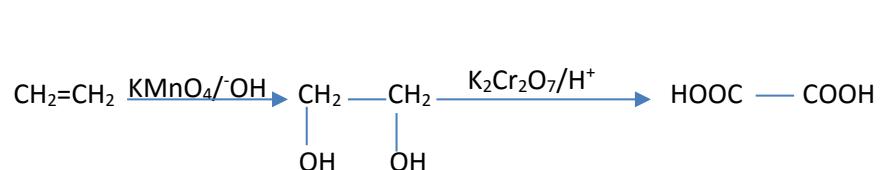
**SECTION B**

10 Show how the following organic conversions can be effected. (Indicate suitable reagents and conditions of reaction's n each). (3marks each)

(a)  $(CH_3)_3COH$  from  $CH_3COCH_3$



(b)  $H_2C_2O_4$  from  $CH_2=CH_2$



(c)  $\text{CH}_3\text{NH}_2$  from  $\text{CH}_3\text{COOH}$



11. Explain the following observations

(a) Silicon and phosphorus are both covalent substances, but the melting of silicon is much higher than that of phosphorus. (3marks)

*Silicon forms big molecules of 3 dimensional array of silicon atoms in which each silicon atom is bonded to 4 silicon atoms by strong covalent bonds whereas phosphorus molecules ( $P_4$ ) are bonded by weak Van der Waal forces.*

(b) Magnesium oxide ( $\text{MgO}$ ) has the same crystalline structure as sodium chloride ( $\text{NaCl}$ ) but the lattice energy of  $\text{MgO}$  is more exothermic than that of  $\text{NaCl}$ . (3marks)

*Magnesium ion have a valence of +2 while sodium ion has a valence of +1. The force of attraction between  $\text{Mg}^{2+}$  and  $\text{O}^{2-}$  are thus stronger than those between  $\text{Na}^+$  and  $\text{O}^{2-}$ .*

(c) A concentrated solution of calcium chloride forms a precipitate with sodium hydroxide but no precipitate form with aqueous ammonia. (3marks)

*Sodium hydroxide is a strong base while ammonia solution is a weak base. Therefore ammonia does not produce enough hydroxide ion to exceed  $K_{\text{sp}}$  of calcium hydroxide.*

12.(a) Phenylamine was mixed with concentrated hydrochloric acid and sodium nitrite at  $0-5^\circ\text{C}$ . The resultant solution Y was then treated with a mixture of phenol in aqueous sodium hydroxide. State what is observed and write the equation of reaction that takes place between:

(i) Phenylamine and a mixture of concentrated hydrochloric acid and sodium nitrite.

Observation

(½ mark)

No observable change

Equation:

(1½ marks)



(ii) Y and phenol in aqueous sodium hydroxide

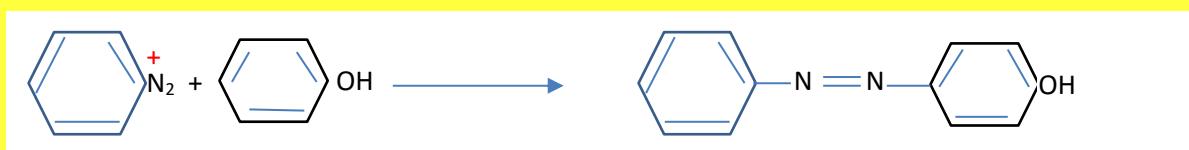
Observation

(½ mark)

Orange solution

Equation:

(1 ½ marks)



(b) 20 cm<sup>3</sup> of 0.05M aqueous phenylamine was mixed with 50cm<sup>3</sup> of 1M sodium bromide and electrolyzed at current of 0.2A. The first permanent bromine color was observed after 49.93 minutes; then electrolysis was stopped. (Faradays constant =96500Cmol<sup>-1</sup>).

(i) Calculate the moles of bromine that reacted with 1 mole of phenylamine

(3 ½ marks)

Solution

$$\text{Charge } Q = It = 0.2 \times 49.93 \times 60 = 599 \text{ C}$$

Mole of bromine

$96500C \times 2$  liberate 1mole od Br<sub>2</sub>

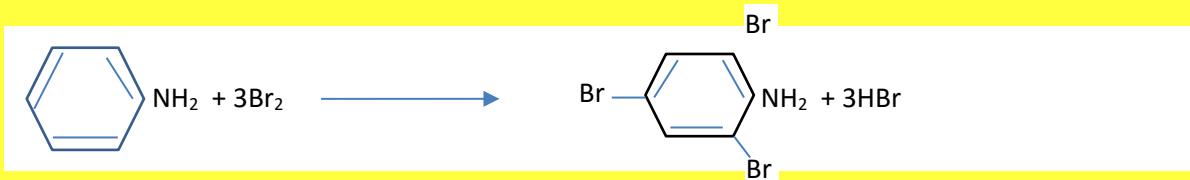
$$599C \text{ will liberate } \frac{1 \times 599}{2 \times 96500} = 0.003 \text{ moles}$$

$$\text{Moles of phenylamine} = \frac{20 \times 0.05}{1000} = 0.001 \text{ moles}$$

$$\text{Moles of bromine that react with 1 mole of phenylamine} = \frac{0.003}{0.001} = 3$$

(iii) Hence write equation of the reaction between bromine and phenylamine. Name the product

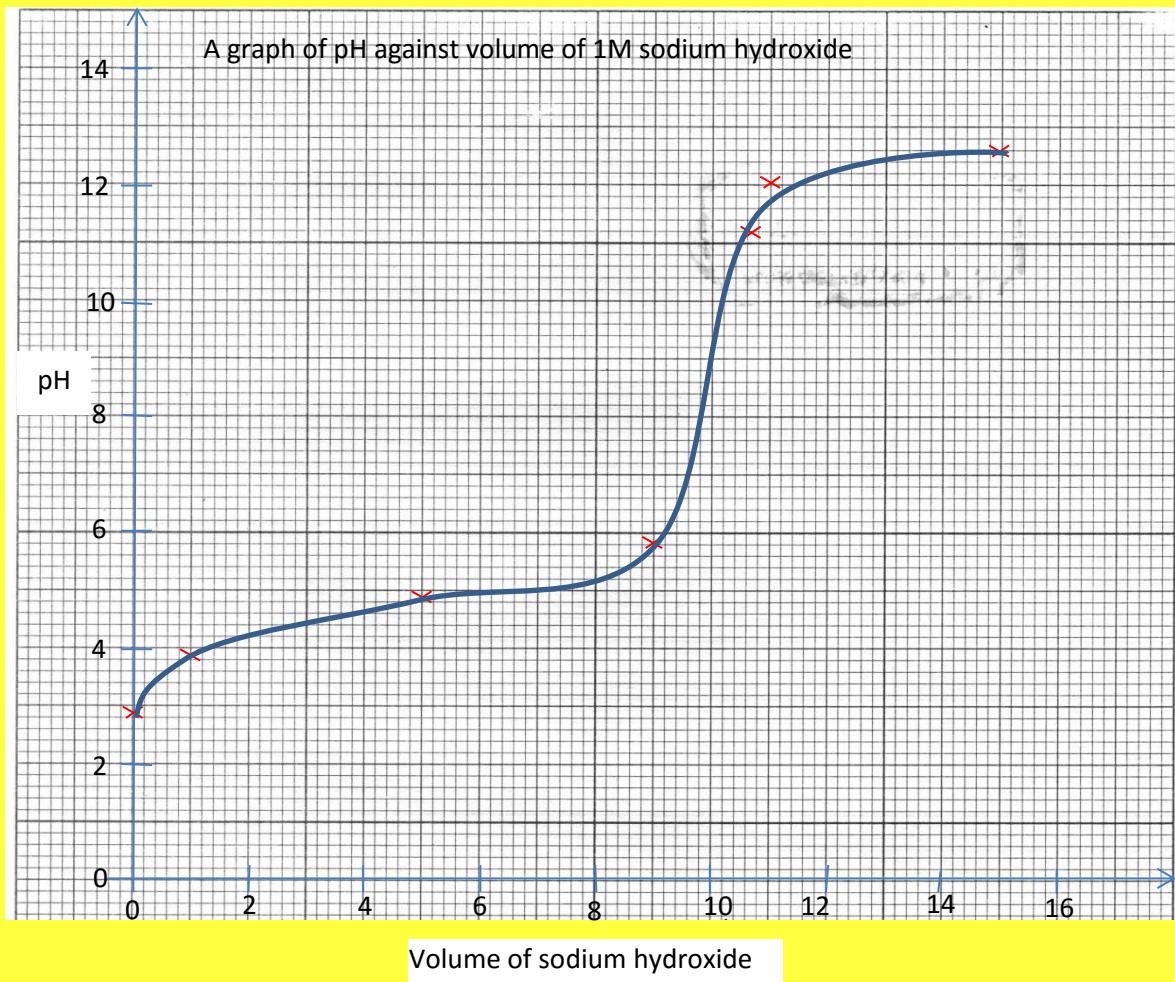
(1 ½ marks)



13. The table below gives data obtained when 100cm<sup>3</sup> of propanoic acid was titrated with 1.0M sodium hydroxide solution.

Volume of 1M NaOH added/ cm <sup>3</sup>	0.0	1.0	5.0	9.0	10.5	11.0	15.0
pH of solution	2.94	3.92	4.87	5.82	11.70	12.00	12.70

(a) (i) Plot a graph of pH against volume of 1M sodium hydroxide (3marks)



- (ii) Using the graph determine the pH and volume 1.0M sodium hydroxide used at equivalent point (1mark)

10cm<sup>3</sup>

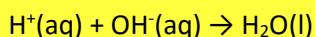
- (iii) Name the suitable indicator that can be used for the titration (½ mark)

Phenolphthalein with pH range 8-10

- (b) Explain the shape of the graph.

- Initially the pH is relatively high because propanoic acid is a weak acid that partially ionizes to liberate few hydrogen ions.

pH increase as the volume of sodium hydroxide added due to removal of hydrogen ions by hydroxyl ions.



- The end point occurs at PH above 7 due to hydrolysis of propanoate ions at a volume of sodium hydroxide = 10cm<sup>3</sup> to produce hydroxyl ions.



- After the end point pH increases due to excess hydroxyl ions.

14. The table below shows formulae of oxides of silicon, Aluminium and phosphorus. (Indicate the chemical nature, bonding type and the structure adopted by the oxide)

Oxide	Chemical nature	Bonding	Structure
SiO <sub>2</sub>	acidic	Covalent bond	3-dimension covalent solid
Al <sub>2</sub> O <sub>3</sub>	amphoteric	Ionic bond	Ionic solid
P <sub>4</sub> O <sub>10</sub>	acidic	covalent	molecular

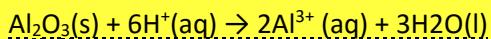
(c) Write equations of reaction to illustrate the chemical nature of

(i) P<sub>4</sub>O<sub>10</sub>

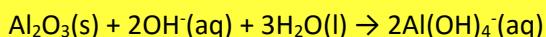
Equation



Equation



Or



15 (a) Define the term “Phase” (1mark)

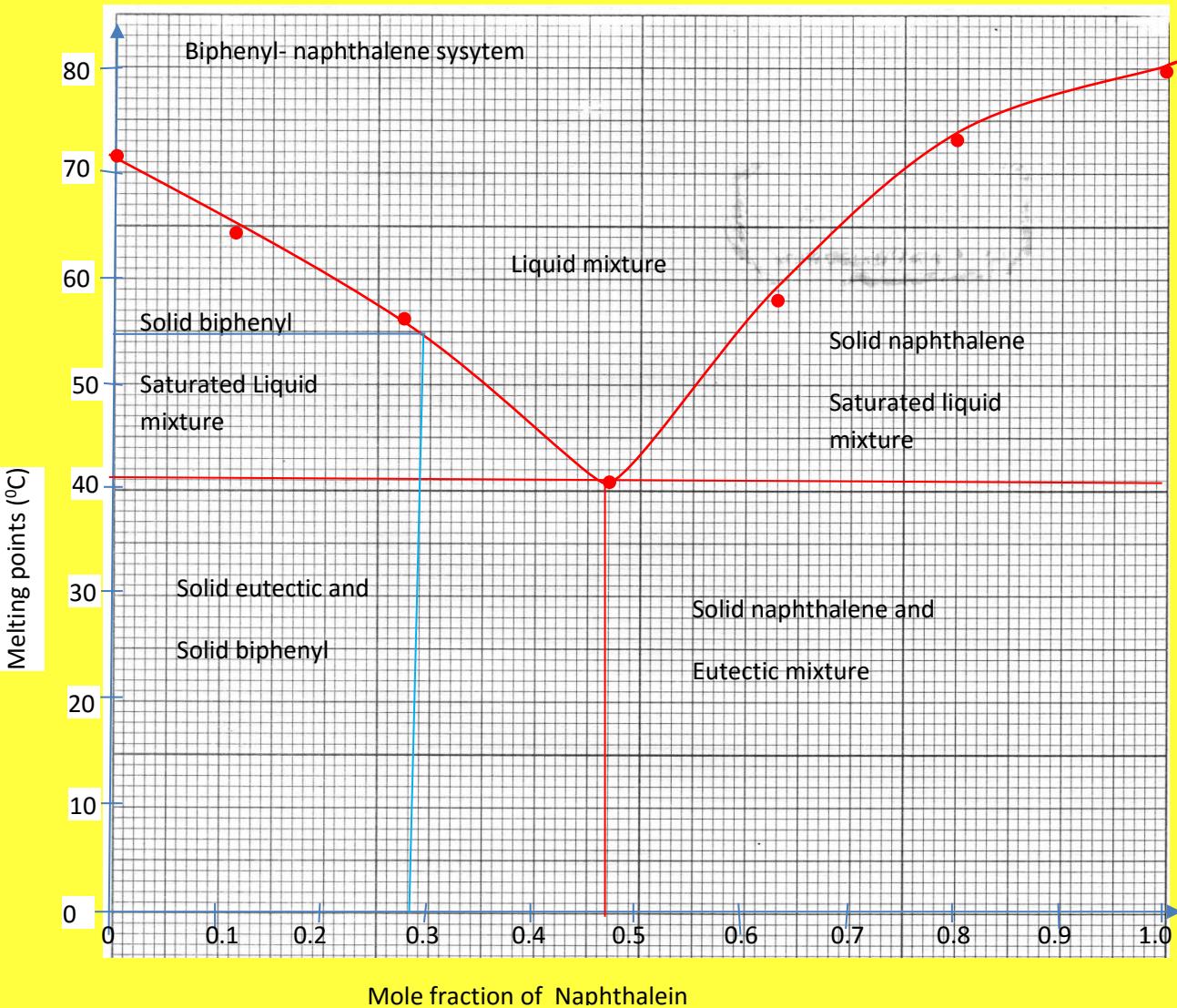
*A phase is a homogeneous state into which a substance can exist i.e. solid, liquid or gas.*

(b) The melting points of various composition of Naphthalene-biphenyl system are given below:

Mole fraction of Naphthalene	0.800	0.625	0.275	0.125
Melting points/ $^{\circ}\text{C}$	72.6	58.0	56.0	64.5

Naphthalene-biphenyl system form a eutectic mixture of composition of 0.47 mole fraction of naphthalene at temperature of  $41.0^{\circ}\text{C}$

(i) Plot a phase diagram for naphthalene-biphenyl system and label all regions. Melting point pure Naphthalene =  $80^{\circ}\text{C}$  and mpt. Of biphenyl =  $71^{\circ}\text{C}$  (5marks)



- (ii) Describe what happens when a mixture containing 0.70 mole fraction of biphenyl is cooled. (2marks)
- Solution freezes at 55 $^{\circ}\text{C}$ .
  - Solid biphenyl separates out
  - The concentration of biphenyl decreases to 0.59 mole fraction by 41 $^{\circ}$
  - At 41 $^{\circ}$ , temperature remains constant as both biphenyl and naphthalene freeze together to form a solid of constant composition.

- After all the liquid has solidified at 410, the temperature of the solid falls to that of room temperature.

(c) State one application of eutectic mixture (½ mark)

To make alloys.

16. 3.70g of an organic compound Q containing carbon, hydrogen and oxygen was exploded in excess oxygen, 4.50g of water and 6.48dm<sup>3</sup> of gaseous substance were passed through sodium hydroxide solution, 2.0dm<sup>3</sup> of oxygen was found unreacted. (All volumes of gaseous substances were measured at stp).

(a) (i) Determine the empirical formula of Q: (4marks)

Mass of hydrogen atoms in the compound

18g of water contain 2g of hydrogen

4.50g of water contain  $\frac{4.5 \times 2}{16} = 0.5\text{g of hydrogen}$

Volume of carbon dioxide =  $6.48 - 2 = 4.48\text{dm}^3$  at stp

Mass of carbon in the compound

22.4dm<sup>3</sup> of carbon dioxide contain 12g of carbon

4.48dm<sup>3</sup> of carbon dioxide contain  $\frac{12 \times 4.48}{22.4} = 2.4\text{g}$

Mass of oxygen =  $3.70 - 0.5 - 2.4 = 0.8$

Elements	hydrogen	Carbon	hysrogen
Symbols	H	C	O
Mass	0.5	2.4	0.8
Atomic mass	1	12	16
Mole	0.5	0.2	0.05
Mole ratio	10	4	1

Empirical formula:  $C_4H_{10}O$

- (iii) If the vapor density of Q is 37, determine the molecular formula of Q (1½ marks)

$$\text{Molecular formula} = 2 \times 37 = 74$$

$$[C_4H_{10}O]n = 74$$

$$[12 \times 4 + 1 \times 10 + 16]n = 74$$

$$n = 1$$

$$\text{molecular formula} = C_4H_{10}O$$

- (d) Q reacts with a mixture of sodium hydroxide and iodine solution to give a yellow precipitate

- (i) Identify Q (1mark)

Butan-2-ol

- (ii) Name the reagent(s) used to confirm the functional group in Q. (½ marks)

Sodium gives effervescence of hydrogen gas

17. (a) Explain what is meant by the term “salt hydrolysis” (1½ marks)

Hydrolysis is the reaction of a salt with water to give either alkaline or acidic solution

(b) Sodium sulphide undergoes hydrolysis. Write the

(i) Equation for hydrolysis of sodium sulphide



(iii) expression for hydrolysis constant ( $K_h$ ), for sodium sulphide.

$$K_h = \frac{[HS^-][OH^-]}{[S^{2-}]}$$

(c)(i) Calculate the pH of solution containing 3.9gdm<sup>-3</sup> of sodium sulphide (Hydrolysis constant at 25°C of sodium sulphide =  $1.25 \times 10^{-10}$  moldm<sup>-3</sup>) (4marks)

Formula mass of NaS = 23 + 32 = 55

$$\text{Molarity of sodium sulphide} = \frac{3.9}{55} \text{ 0.071 moldm}^3$$

Let the concentration of OH<sup>-</sup> be x

$$\frac{x^2}{0.071} = 1.25 \times 10^{-10} \Rightarrow x = 3 \times 10^{-6}$$

$$\text{Concentration of hydrogen ion} = \frac{10^{-14}}{[OH^-]} = \frac{10^{-14}}{3 \times 10^{-6}} 3.3 \times 10^{-9} \text{ moldm}^3$$

$$pH = -\log[H^+] = 8.47$$

(iv) State whether the resultant solution in (a)(i) is basic, neutral or acid (Give a reason for your answer) (1marks)

It is alkaline because it has pH above 7

525/1

## S6 CHEMISTRY

**Exam 7**

**PAPER 1**

**DURATION: 2 HOUR 45 MINUTES**

*Instructions:*

- This paper consists of two sections A and B
- Section A is compulsory.
- Attempt only six questions in section B
- Answers must be written in the spaces provided only

For Examiner's Use Only

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

SECTION A

Answer all questions from this section

1. The standard reduction electrode potentials ( $E^0$ ) for some half cells are given in the table below

Half cell	$E^0(V)$
$\text{Fe}^{3+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq})$	+ 0.77
$\text{S(s)} + \text{H}_2(\text{g}) \rightarrow \text{H}_2\text{S(g)}$	+0.14

(a) Write

(i) Cell notation (1mark)



(ii) Equation of reaction that takes place at the anode and cathode (2marks)



(iii) Equation for the overall cell reaction (1 ½ marks)



(b) State whether the reaction is feasible or not and give a reason for your answer. (1mark)

$$E_{\text{cell}} = E_{\text{LHE}} - E_{\text{RHE}}$$

$$= 0.77 - 0.14$$

$$= 0.63\text{V}$$

The reaction is feasible because emf is positive

2. State what is observed and write equation of reaction in each case when the following compounds are mixed.

(a) Methanoic acid and ammoniacal silver nitrate solution is heats

Observation

**Black precipitate or silver mirror**

Equation



(b) Benzoic acid and aqueous sodium bicarbonate solution

Observation

**Effervescence**

Equation

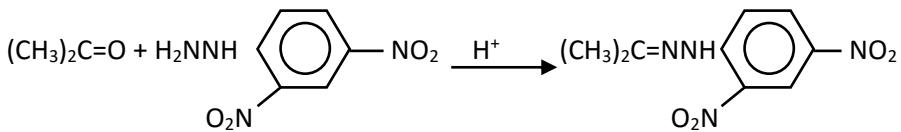


(c) Propanone and Brady's solution

Observation

**Yellow precipitate**

**Equation**



3. Calculate the boiling point of a solution formed by mixing 8g of glucose with 120g of water.  $\text{K}_b$  for water =  $5.2^\circ\text{C mol}^{-1}\text{kg}^{-1}$ )

**Solution**

Mass of glucose in 1000g of water

120g of water contain 8g of glucose

1000g of water contain  $\frac{8 \times 1000}{120} = 66.7\text{g}$

Formula mass of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6 = 180$

Boiling point elevation

180g of glucose cause an elevation of  $5.2^\circ\text{C}$

66.6g of glucose cause elevation of  $\frac{5.2 \times 66.7}{180} = 1.9^\circ\text{C}$

Boiling point of solution = boiling point of water + boiling point elevation

$$= 100 + 1.9 = 101.9^\circ\text{C}$$

4. (a) State three reasons for the difference in properties between fluorine and other group (VII) elements. (3marks)

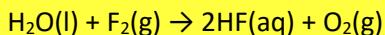
- High electronegativity
- Low F-F bond energy
- Small atomic radius

- (b) Write equation for the reaction that takes place between the following compounds

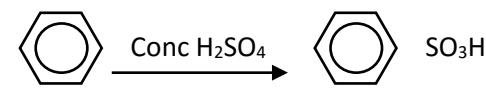
- (i) Silicon (IV) oxide and hydrofluoric acid (1 ½ )



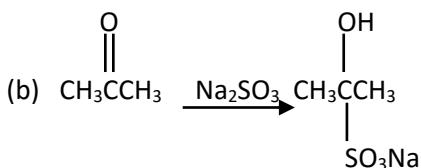
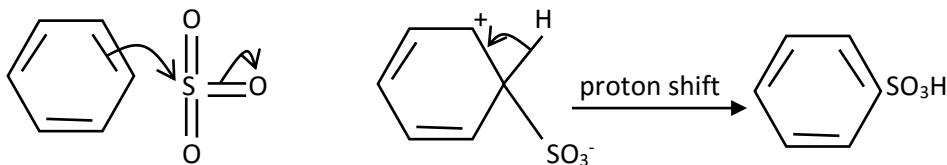
- (ii) Fluorine and water (1 ½ mk)



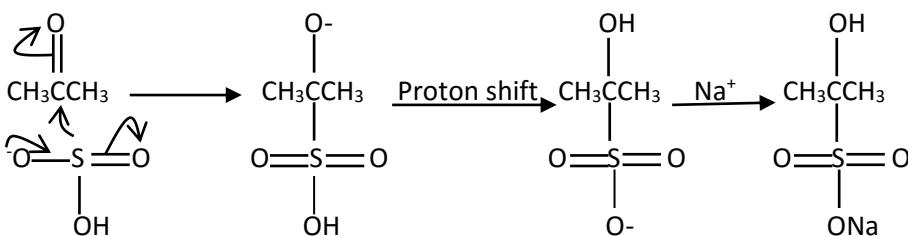
5. (a)



**Mechanism**



Mechanism



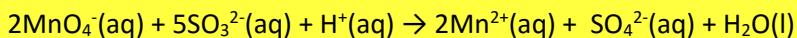
6. State what would be observed and write equation(s) for the reactions that would take place:

- (a) When aqueous sodium sulphite solution is added to acidified potassium manganite (VII) solution.

Observation

Potassium permanganate (VII) decolorized

Equation

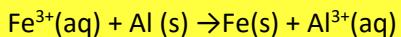


- (b) When aluminium powder is added to Iron (III) chloride

Observation

Yellow solution decolorize with formation of grey crystals

Equation



7. (a) write the electron configuration of

(i) Nitrogen:  $1s^2 2s^2 2p^3$

(ii) Phosphorous:  $1s^2 2s^2 2p^6 3s^2 3p^3$

- (b) Explain why nitrogen only forms ( $\text{NCl}_3$ ) whereas phosphorus forms the chlorides  $\text{PCl}_3$  and  $\text{PCl}_5$ .

**Nitrogen forms chloride of valence -3 only because it lacks a vacant d-orbital. Phosphorus, unlike nitrogen, can form chloride of valences 3 and 5; to form compounds of valence 5, one 3s electrons is promoted to a vacant 3d- orbital to give five unpaired electrons.**

- (c) Write equation(s) for the hydrolysis of phosphorus chlorides by water

(i) Phosphorus (V) chloride (3marks)



(ii) Phosphorus (III) chloride



8. (a) When 20 cm<sup>3</sup> of a hydrocarbon Z was exploded in 200cm<sup>3</sup> of oxygen (excess), it completely burnt with a sooty flame. The volume of residual gas after cool to room temperature was 160cm<sup>3</sup>. On addition of aqueous potassium hydroxide to residual gas, the final volume of the gas was 20cm<sup>3</sup>. Calculate the molecular formula of Z. (3marks)

**Combustion equation**

$$\text{Oxygen used} = 200 - 20 = 180\text{cm}^3$$

$$\text{Volume of carbon dioxide} = 160 - 20 = 140\text{cm}^3$$



Volume	20	180	140
--------	----	-----	-----

Volume ratio	1	9	7
--------------	---	---	---

$$x = 7$$

$$x + \frac{y}{4} = 9$$

$$y = 8$$

$$\text{Molecular formula} = \text{C}_7\text{H}_8$$

- (b) When Z was heated with alkaline potassium manganite (VII) solution forms a colorless solution which cooled in the presence of dilute sulphuric acid to form a crystalline solid P.

(i) Identify

Z- methylbenzene,  $\text{C}_6\text{H}_5\text{CH}_3$

P- benzoic acid



9. (a) Explain why diffusion in solution is very much slower than in gases

**Because particles in liquid move much slower than gas molecules**

- (b) 141.4cm<sup>3</sup> of gas X diffused through a porous plug in the same time as it took 50cm<sup>3</sup> of oxygen to diffuse through the same plug under identical condition.

Calculate the relative molecular mass of X.

$$\frac{\text{Rate of } X}{\text{Rate of } O_2} = \sqrt{\frac{\text{RFM of } O_2}{\text{RFM of } X}}$$

$$\frac{\frac{141.4}{t}}{\frac{50}{t}} = \frac{32}{\text{RFM of } X}$$

$$x = 4$$

Molecular mass of X = 4

## SECTION B

Attempt only six questions in this section

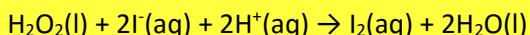
10. State what is observed and write equation for the reaction that takes place when

- (a) Potassium iodide is added to acidified hydrogen peroxide solution

Observation

Dark brown solution formed

Equation

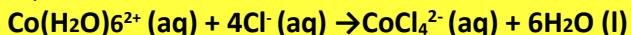


- (b) Concentrated hydrochloric acid is added drop wise until in excess to aqueous solution containing cobalt (II) ions

Observation

**Forms deep blue solution with concentrated hydrochloric acid.**

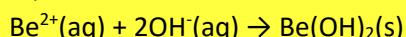
Equation



- (c) Aqueous sodium hydroxide is added drop wise to aqueous solution containing beryllium (II) ions

**White precipitate soluble in excess**

Equation



Then.



11. (a) A compound Y contains mass of 22.86% oxygen, 8.57% hydrogen and the rest is carbon  
 (i) Calculate the empirical formula of Y. ((2 ½ marks)

$$\text{Percentage of carbon} = 100 - (22.86 + 8.57) = 68.57$$

Element	C	H	O
percentage	68.57	8.57	22.86
RAM	12	1	16
moles	5.71	8.57	1.42
Mole ratio	4	6	1

Empirical formula:  $\text{C}_4\text{H}_6\text{O}$

- (ii) When 0.30g of Y is vaporized at  $80^\circ\text{C}$  and 700mmHg pressure, it occupied a volume of  $134.77\text{cm}^3$ . determine the molecular formula of Y. (3 ½ marks)

From  $\frac{PV}{T} = \text{constant}$ , volume V at stp

$$\frac{134.77 \times 700}{(273+80)} = \frac{760V}{273}$$

$$V = 97\text{cm}^3$$

Relative formula mass

$96\text{cm}^3$  weigh 0.3g

$$22400 \text{ cm}^3 \text{ weigh } \frac{22400 \times 0.3}{96} = 70$$

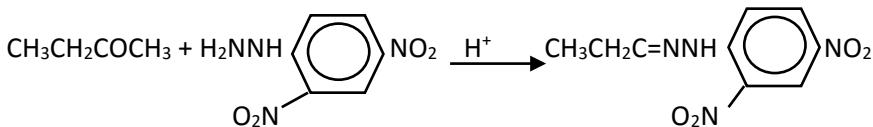
Therefore, molecular mass of Y = 70

$$[\text{C}_4\text{H}_6\text{O}]n = 70$$

$$n = 1$$

molecular formula of Y =  $\text{C}_4\text{H}_6\text{O}$

- (b) Y forms a yellow precipitate with 2,4-dinitrophenylhydrazine and does not react with Tollen's reagent. Identify Y (1mark)  
 $\text{CH}_3\text{CH}_2\text{COCH}_3$  butanone  
 (c) Write equation for the formation of yellow precipitate in (b)



12. (a) State three characteristics of chemical equilibrium (1 ½ mks)

- Occurs at constant temperature
- Occurs in closed system
- It is dynamic equilibrium

(b) Phosphorus (V) chloride when heated decomposed according to the following equation.



(i) Write the expression for the equilibrium constant  $K_c$ . (1mk)

$$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$$

(ii) When 1 mole of phosphorus (V) chloride was heated in a closed vessel at  $350^\circ\text{C}$ , the equilibrium mixture was found to contain 38.4% of chlorine. Calculate the equilibrium constant  $K_c$  at  $350^\circ\text{C}$ . (3 ½ mks)

$$\% \text{ of } \text{PCl}_3 = \% \text{ Cl}_2 = 38.4\%$$

$$\% \text{ of } \text{PCl}_5 = 23.2\%$$

$$K_c = \frac{0.384 \times 0.384}{0.232} = 0.64 \text{ mol dm}^{-3}$$

(iii) The equilibrium constant of  $250^\circ\text{C}$  is 1.54. State whether the reaction is exothermic or endothermic. Give a reason for your answer. (1 ½ mks)

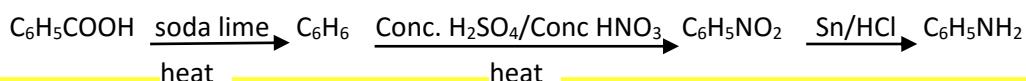
**The reaction is endothermic because  $K_c$  increases with temperature.**

(c) State what would happen to the concentration of chlorine if the pressure in the vessel was decreased while the temperature is maintained at  $350^\circ\text{C}$ . Give a reason for your answer. (1 ½ mks)

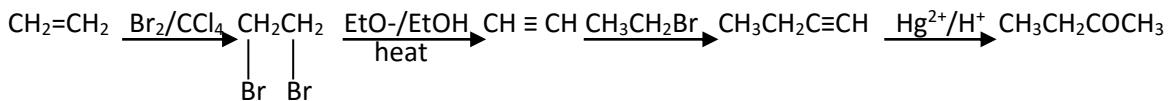
**Concentration of chlorine decreases because forward reaction proceeds with increase in number of moles of gases.**

13. Write equations to show the following conversions can be effected. (include conditions for reactions) (3marks each)

(a) Benzoic acid to phenylamine

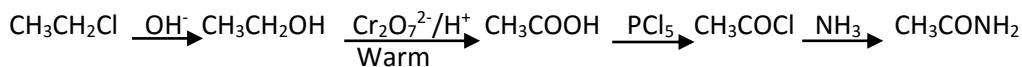


(b) Ethene to butan-2-ol



(c)

1-chloroethane to ethanamide



14. (a)(i) Explain what is meant by an acid-base indicator (1mk)

This is a substance in aqueous solution that changes color according to  $H^+$  concentration

- (ii) Explain why titration experiments only one or two drops are used (1mk)

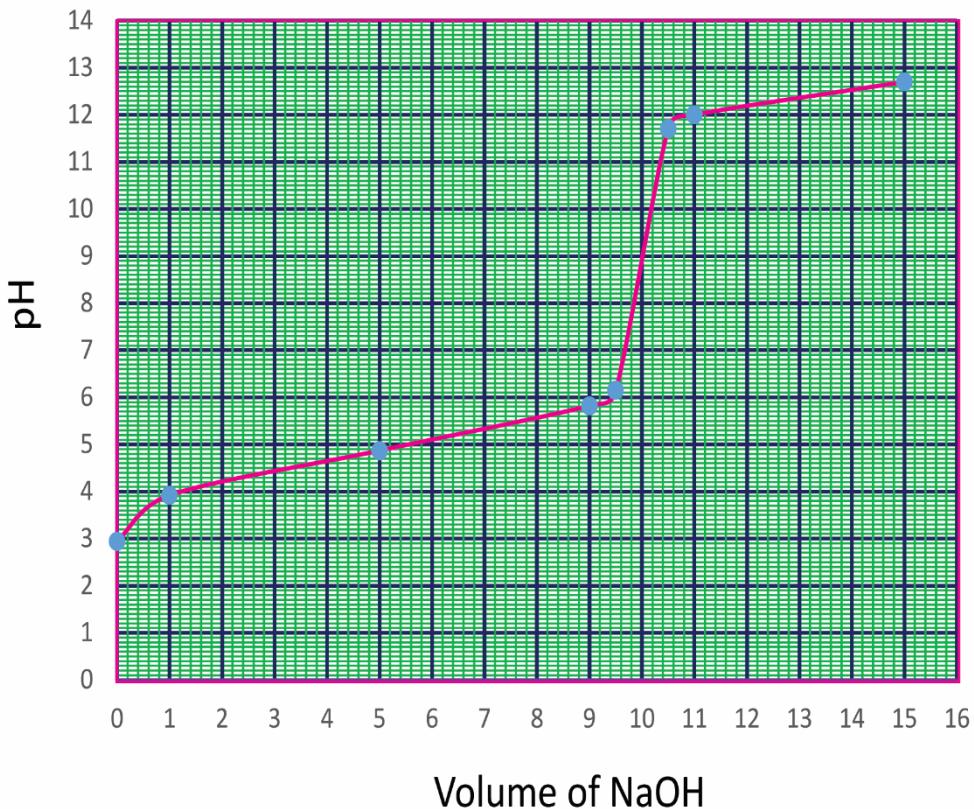
Because after the end point pH changes rapidly

- (b) The table give data obtained when 10cm<sup>3</sup> of propanoic acid was titrated with 1.0M sodium hydroxide solution

Volume of NaOH (1M) added (cm <sup>3</sup> )	0.0	1.0	5.0	9.0	9.5	10.5	11.0	15.0
pH of solution	2.94	3.92	4.87	5.82	6.15	11.70	12.0	12.7

- (i) Draw a graph of pH against the volume of sodium hydroxide (2 ½ marks)

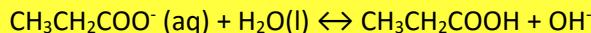
**pH of solution against volume of NaOH**



- (ii) Explain the shape of the graph in (b)(i) (2 ½ marks)

Initially the pH is 3 (relatively high) due to partial ionization of weak acid; the pH then increases due to the removal  $H^+$  up to the end point at pH = 9 when 10cm<sup>3</sup> of sodium hydroxide is added.

The end point occurs at pH above pH = 7 due to hydrolysis propanoate ions to produce OH<sup>-</sup> ions



After the end point pH increases due to excess OH<sup>-</sup>(aq)

- (iii) Determine the pH of the solution at equivalence point (1mark)

9

- (iv) Which of the following indicators would be suitable for titration? Give a reason for your answer.

indicator	Methyl red	Bromothymol blue	Phenol red
pH range	4.2 – 6.3	6.0 – 7.6	6.8 – 8.4

Indicator : **phenol red** (  $\frac{1}{2}$  mark)

Reason: **has pH range in alkaline solution of the end point of the titration (  $\frac{1}{2}$  mark)**

15. (a) Compare the following properties of group (II) and group (i) elements. In each case give a reason for your answer. (1  $\frac{1}{2}$  mark each)

- (i) First ionization energy

**The first ionization energy of group (II) element is higher than that of group (I) elements because group (II) element have higher electronegativity.**

- (ii) Melting points

**The melting points of group (II) elements are higher than those of group I elements because group (II) elements contribute two electrons to the formation of stronger metallic bonds whereas group (I) elements contribute one electron to the formation of weaker metallic bond.**

- (iii) Electropositivity

**Electropositivity of group (I) elements is higher than that of group (II) elements because group (I) elements have lower electronegativity.**

- (b) The decomposition temperatures of the carbonates of group (II) elements are given below

Carbonates	MgCO <sub>3</sub>	CaCO <sub>3</sub>	SrCO <sub>3</sub>	BaCO <sub>3</sub>
Decomposition temperature (°C)	404	826	1098	1370

- (i) State how the decomposition temperatures vary (1mark)

**The decomposition temperatures increase from MgCO<sub>3</sub><CaCO<sub>3</sub><SrCO<sub>3</sub><BaCO<sub>3</sub>**

- (ii) Explain your answer in (b)(i) (3  $\frac{1}{2}$  mark)

**The decomposition temperature increase with molecular mass and ionic character of the carbonates.**

16. Name a reagent that can be used to differentiate between the following pairs of compounds.  
State what would be observed if each compound is treated with the reagent you have named

(a)



and



Reagent: concentrated sulphuric and concentrated nitric acid  $< 50^{\circ}\text{C}$

Observation

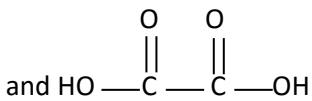
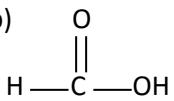


Yellow oily liquid



No observable change

(b)



Reagent: Tollen's reagent (ammoniacal silver nitrate)

Observation

$\text{HCOOH}$  – black precipitate or silver mirror

$\text{HOOCOOH}$  – no observable change

(c)



Reagent: sodium nitrite,  $\text{HCl} < 5^{\circ}\text{C}$

Observation



$\text{NH}_2$  no observable change



$\text{CH}_2\text{NH}_2$  effervescence

17. Ethanol can be produced by fermentation of molasses.

(a)(i) Name two other raw materials from which ethanol can be produced by fermentation

- banana juice
- cassava flour
- maize flour

(ii) Write equations to show how crude ethanol can be obtained from the materials named above



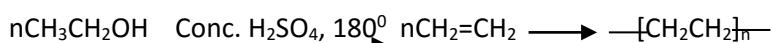
(b)(i) Describe how 100% (absolute) ethanol can be produced from crude ethanol in (a) (ii)

The crude mixture is fractional distilled to obtain rectified spirit.

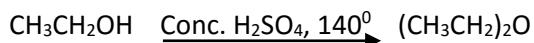
Calcium oxide is added to rectified spirit overnight to remove water and then pure ethanol is distilled off the following day.

(c) Write equation(s) to show each of the following compounds could be obtained from ethanol

(i) Polyethene (1 ½ marks)



(ii) Ethoxyethane (1 ½ marks)



Thank by Dr. Bbosa Science

525/1

## S6 CHEMISTRY

### Exam 8

#### PAPER 1

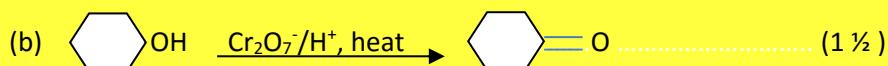
DURATION: 2 HOUR 45 MINUTES

Attempt all numbers

1. Complete the following organic reaction and name the major organic products.



Name: propan-1,2-diol



Name Cyclohexanone



Name: propane

## 2. (a) Explain what is meant by **Kampala Mathematics Club**

**This a technique of separating volatile, immiscible substance from nonvolatile substance using steam**

(b) A mixture of nitrobenzene and distilled water boiled at  $99^{\circ}\text{C}$  at one atmosphere. Calculate the percentage composition of the distillate. The saturate vapor pressure of water at  $99^{\circ}\text{C}$  is 723mmHg.

### Solution

Formula mass of nitrobenzene ( $\text{C}_6\text{H}_5\text{NO}_2$ ) =  $(12 \times 6 + 1 \times 5 + 14 + 16 \times 2) = 123$

Vapour pressure of nitrobenzene =  $760 - 723 = 37$

Let the % of nitrobenzene =  $x$

The % of water =  $(100 - x)$

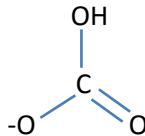
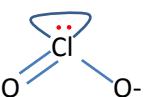
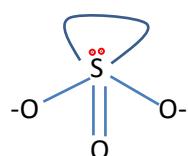
$$\frac{x}{100-x} = \frac{123 \times 37}{18 \times 723}$$

$$x = 25.9\%$$

Percentage of nitrobenzene = 25.9%

Percentage of water = 74.1%

## 3. Draw the structures and name the shapes of the following species.

	Structure	Name
(a) $\text{HCO}_3^-$		triangular planar
(b) $\text{ClO}_2^-$		V-shaped
(c) $\text{SO}_3^{2-}$		triangular pyramidal

## Kampala Mathematics Club

4. State what is observed and write equation that occur when

- (a) Dilute sulphuric acid is added to aqueous solution of potassium manganate (VI).

Observation: **green solution turns purple**

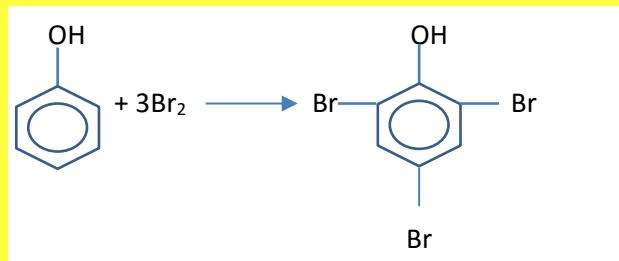
Equation



- (b) Bromine water is added to hydroxylbenzene

Observation: **bromine water decolorizes**

Equation



5. (a) State Raoult's law.

**Raoult's states that the partial pressure of a component in a mixture is proportional to its concentration**

- (b) At  $50^\circ\text{C}$  an aqueous solution of carbamide ( $\text{CH}_3\text{CONH}_2$ ) of concentration  $60.93\text{gdm}^{-3}$  has a vapor pressure of  $12100\text{Nm}^{-2}$ . Determine the vapor pressure of water at this temperature. (4marks)

Formula mass of carbamide,  $(\text{CH}_3\text{CONH}_2) = 12 + 3 + 12 + 16 + 14 + 2 = 59$

$$\text{Mole of carbamide} = \frac{60.93}{59} = 1.03$$

$$\text{Moles of water} = \frac{1000}{18} = 55.56$$

$$\text{Total mole} = 1.03 + 55.56 = 56.59$$

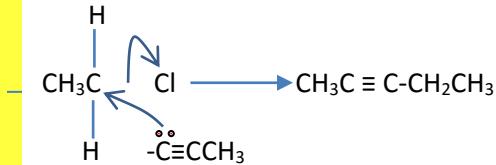
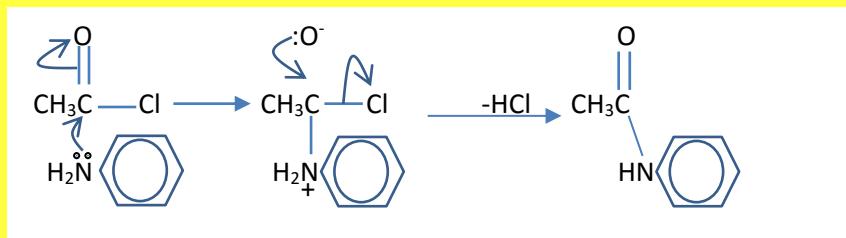
Let the vapour pressure of water be  $P$

$$\frac{55.56}{56.59}P = 12100$$

$$P = 12324\text{NM}^{-2}$$

6. Complete the following organic reactions and outline the accepted mechanism.





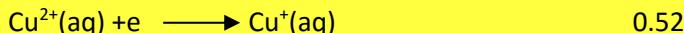
7. (a) Write electronic configuration of copper (I) and copper (II) ions

(i) Copper (I) ion:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^10$

(ii) Copper (II) ion:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$

(b) The electrode potentials for the following reactions are given below

$E^\circ/\text{V}$



Use the information given above to calculate the e.m.f value for the reaction given below



$$\text{Emf} = 0.52 + 0.52 = 1.04\text{V}$$

(c) What can you deduce from your answer?

**Copper (II) ions are more stable than Copper (I)**

8. Write equations for the reactions that occur between each of the following compounds with hot concentrated sodium hydroxide solution

(a) Chromium (III) oxide



(b) Fluorine





9. Define the term buffer solution

**A buffer is a solution that resist change in pH when small amount of acid or base is added to it**

(c) A 0.1M solution of sodium hydroxide was added to 50cm<sup>3</sup> of 0.1M ethanoic acid until when the acid is half way neutralized. Determine the pH of the resultant solution formed. (Ka for ethanoic acid is  $1.8 \times 10^{-5}$ )

At half neutralization

$$\text{Total volume} = 100\text{cm}^3$$

$$[\text{CH}_3\text{COOH}] = 0.05/100$$

$$[\text{CH}_3\text{COO}^-] = 0.05/100$$

$$\text{From } \text{Ka} = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$$

$$[\text{H}^+] = \frac{1.8 \times 10^{-5} \times \frac{0.05}{100}}{\frac{0.05}{100}} = 1.8 \times 10^{-5}$$

$$\text{pH} = -\log[\text{H}^+] = -\log 1.8 \times 10^{-5} = 4.44$$

(d) State one application of a buffer.

**Blood is buffered to enable enzymes work efficiently**

**Kampala Mathematics Club**

SECTION B (14 MARKS)

(Attempt six questions only)

10. (a) During manufacture of nitric acid, ammonia is catalytically oxidized with air in presence of a catalyst R.

(i) Name the catalyst R

*Platinized asbestos*

(ii) Write equation for the reaction in (a)(i) above



(b) State other conditions applied in the reaction above

High pressure

- (c) Write equation to show how nitric acid is formed from the product (s) in (a) above

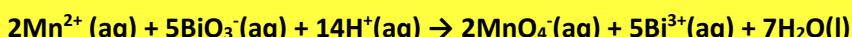


- (d) A few drops of concentrate nitric acid were added to aqueous solution of manganese (II) salt in presence of solid Q. A purple solution was formed.

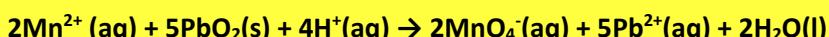
(i) Name solid Q

**Sodium bismuthate or lead (IV) oxide**

(ii) Write equation for the reaction



Or



11. Name the reagent(s) that can be used to distinguish between the following pairs of compounds. In each case state the observations made.

- (a) 1-Phenylethanol and 2-phenylethanol

Reagent: **anhydrous zinc chloride in concentrated hydrochloric acid****1-phenylethanol – two layers in 5-10 minutes****2-phenylethanol- no observable change**

- (b) 2- aminopropane and dimethylamine

Reagent: **sodium nitrite /HCl < 5°C**

Observation

**2- aminopropane – effervescence****Dimethylamine – yellow oily liquid**

- (c) Ethanol and methanol

Reagent: **iodine in sodium hydroxide solution**

Ethanol – **yellow ppt**

Methanol – **no observable change**

12. (a) Explain in what is meant by the term anomalous behavior

Anomalous is unusual/abnormal

- (b) State any two anomalous behavior of fluorine as compared to other group (VII) elements.

Use equations to illustrate your answer.

**Liberates oxygen from silicon dioxide**

Reacts with water to liberate oxygen

Displaces all halogens from their compounds

- (c) Give reasons(s) why fluorine exhibit the type of behaviors mentioned in (b) above.

Fluorine has

- Small atomic radius
- High electronegativity
- Has abnormally low F-F bond energy due to high electron repulsion of nonbonding electron pairs.

- (d) The acid strength of the following acids is in order:  $\text{HClO}_2 < \text{HClO}_3 < \text{HClO}_4$ . Explain this observation.

The higher the number of oxygen atoms attached to the chloride atom, the stronger they withdraw electron from H-O bond leading to the release of  $\text{H}^+$ .

13. (a) Explain what is meant by each of the following terms.

- (i) Order of the reaction

**Order of reaction is the sum of exponents to the concentration terms in a rate law**

- (ii) Molecularity of the reaction

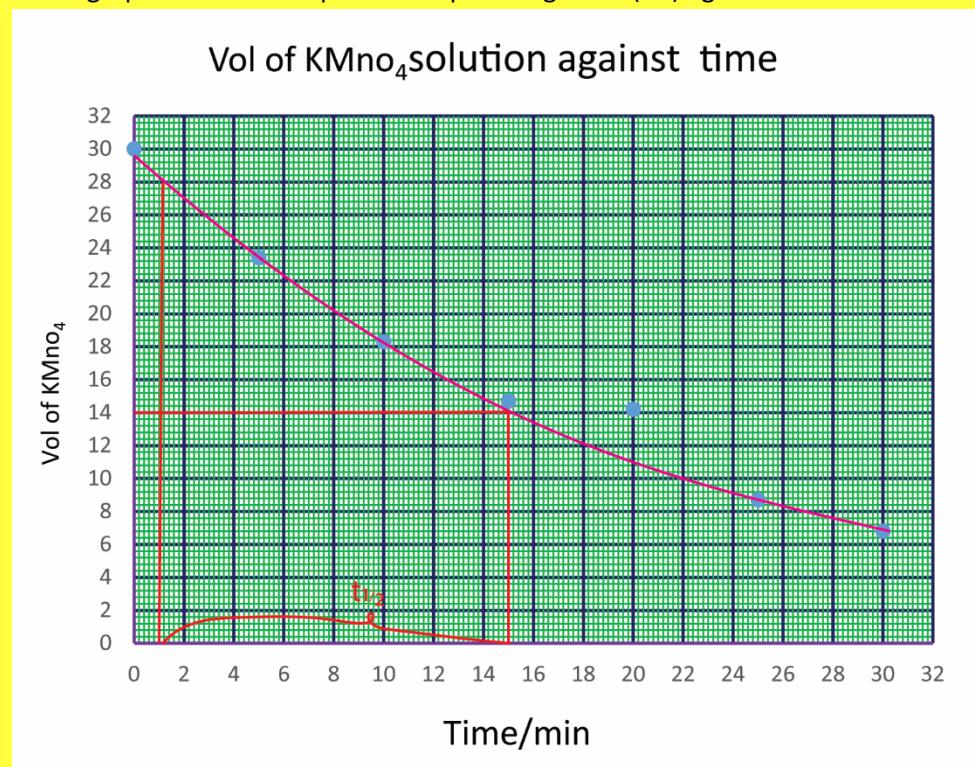
**Molecularity is the number of species that take part in the rate determining step of the reaction.**



The reaction is catalyzed by adding a known volume of iron (III) chloride. The order of this reaction can be determined by titrating the mixture with standard solutions of acidified potassium permanganate (VII). The following results were obtained during the experiment

Time/min	0	5	10	15	20	25	30
Vol of KMnO <sub>4</sub>	30	23.4	18.3	14.7	14.2	8.7	6.8

- (i) Plot a graph of volume of potassium permanganate (VII) against time



- (ii) Determine the order of reaction. Give reasons for your answer

**It is first order because the graph shows that the rate is proportional to concentration**

- (iii) Determine the rate constant for the reaction.

$$\text{Half life } t_{1/2} = 15 - 1 \text{ min} = 14$$

$$\text{Rate constant } K = \frac{\ln 2}{\frac{t_1}{2}} = \frac{\ln 2}{14} = 0.05 \text{ min}^{-1}$$

14. (a) State Grahams' law of gaseous diffusion.

**The rate of diffusion of gases is inversely proportional the root of their densities**

(b) Equimolar amounts of an amine, W and oxygen were allowed to diffuse through the same porous medium under the same conditions of pressure and temperature. The amine Oxygen diffuses 1.19 times as fast as the time taken by W.

(i) Determine the molecular mass of W.

$$\frac{\text{Rate of } O_2}{\text{Rate of } W} = \sqrt{\frac{\text{RFM of } W}{\text{RFM of } O_2}}$$

$$1.19 = \sqrt{\frac{\text{RFM of } W}{\text{RFM of } O_2}}$$

Formula mass of W = 45

(iii) Determine the molecular formula of W.

$$[C_nH_{2n+1}NH_2] = 45$$

$$n = 2$$

Molecular formula of W = C<sub>2</sub>H<sub>5</sub>NH<sub>2</sub>

(c)(i) Write equation for the reaction that occur when compound W is dissolved in water



(iii) Determine the pH of 0.1M aqueous solution of compound W. the base dissociation constant K<sub>b</sub> for compound W is 1.85x10<sup>-5</sup> and K<sub>w</sub> for water at 25°C is 1.0 x 10<sup>-14</sup>.



Initially	0.1	-	-
-----------	-----	---	---

At equlbm	0.1 - x	x	x
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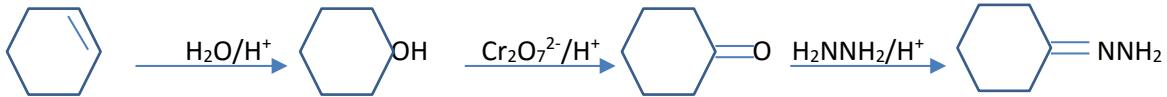
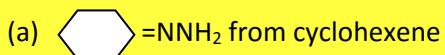
$$K_b = \frac{x^2}{0.1} = 1.85 \times 10^{-5}$$

$$x = 1.34 \times 10^{-3}$$

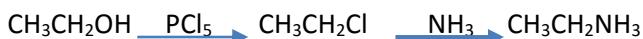
$$[H^+] = \frac{10^{-14}}{[OH^-]} = \frac{10^{-14}}{1.34 \times 10^{-3}} = 7.46 \times 10^{-12}$$

$$pH = -\log[H^+] = -\log 7.46 \times 10^{-12} = 11.1$$

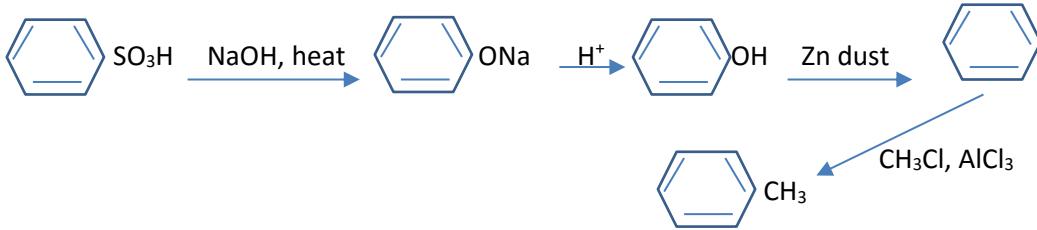
15. Write equations to show how the following synthesis can be carried out. In each case indicate the necessary reagents and conditions.



- (b) Ethylamine from ethanol



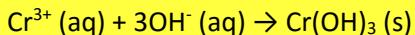
- (c) Methylbenzene from benzene sulphonic acid



16. State what will be observed and write equations for the reactions that occur when

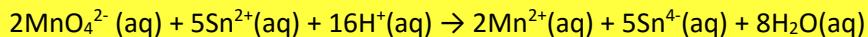
- (a) Sodium hydroxide solution is added drop wise until in excess to an aqueous solution of chromium (III) salt followed by hydrogen peroxide solution and the solution warmed
- (b) It forms a green precipitate with sodium hydroxide soluble in excess turns yellow with hydrogen peroxide solution and temporary blue when a few drops of concentrated sulphuric acid are added to the mixture..

Equations



- (c) Acidified potassium permanganate solution is added to aqueous solution of tin (II) chloride

Purple color decolorizes



17. (a) Boron and silicon show diagonal relationship

- (i) What is diagonal relationship

**Similarity in chemical properties between element of period II and period III that are diagonally related.**

- (ii) Briefly explain why silicon and boron show diagonal relationship

**Boron and silicon have similar electronegativity, i.e. increase in electronegativity one step across the period is cancelled by a decrease in electronegativity one step down the group**

- (d) Given any four ways in which both boron and silicon exhibit diagonal relationship

They are both non metals

They form acidic oxides

Form covalent chlorides

Form salts with metals e.g.  $\text{MgB}_2$  and  $\text{Mg}_2\text{Si}$

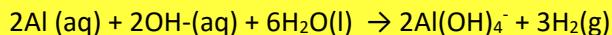
- (e) State two other pairs of elements in the periodic table that exhibit diagonal relationship.

Li and Mg

B and Al

- (f) Excess hot concentrated sodium hydroxide solution was added to 2.5g of a mixture of aluminium metal and magnesium metal. If the volume of the gas liberated at stp was  $22.4\text{cm}^3$ . Calculate the percentage of magnesium in the mixture.

Equation



Mass of aluminium reacted

$3 \times 22400\text{cm}^3$  of hydrogen are liberated by  $2 \times 27\text{g}$  of aluminium

$2.24\text{cm}^3$  of aluminium are liberated by  $\frac{2 \times 27 \times 22.4}{3 \times 22400} = 0.18\text{g}$

Mass of magnesium =  $2.5 - 0.18 = 2.32$

Percentage of magnesium =  $\frac{2.32 \times 100}{2.5} = 92.8\%$

525/1

**S6 CHEMISTRY****Exam 9****PAPER 1****DURATION: 2 HOUR 45 MINUTES**

Answer all question in part I and six questions in part II

All questions are to be answered in the spaces provided

Periodic table, with relative atomic masses, is supplied at the end of the paper.

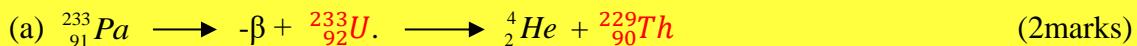
Simple calculator may be used

For Examiners use only

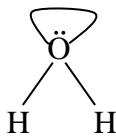
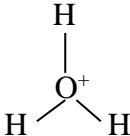
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total

**SECTION A**  
(Answer all questions)

1. Complete the following equation of radioactive decay



2. Draw the shapes and name the structure of each of the following species (2marks each)

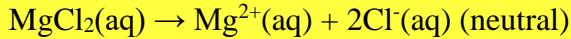
Species	Shape	name of the shape
i. $\text{H}_2\text{O}$		V-shaped
ii. $\text{CO}_2$	$\text{O} = \text{C} = \text{O}$	linear
iii. $\text{H}_3\text{O}^+$		triangular planar

3. Write an equation for dissolution of each of the following salt in water. State whether the resulting solution would be neutral, basic or acidic

(a) chromium (III) chloride (2marks)



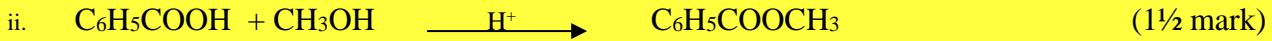
(b) Magnesium chloride (1mark)



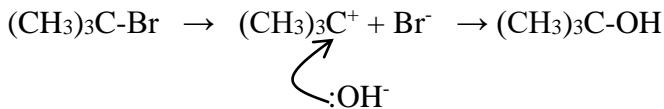
(c) ammonium methanoate (2marks)



4. (a) Complete the following equations



(b) State the name of the mechanism of the reaction in (a)(iv) (2marks)



5. 20.0cm<sup>3</sup> of 0.02M sodium hydroxide was added to 30 cm<sup>3</sup> of 0.025M sulphuric acid. Calculate

a. Molar concentration of the hydrogen ions in the initial sulphuric acid (1 ½ mark)

1 mole of H<sub>2</sub>SO<sub>4</sub> contains 2moles of H<sup>+</sup>.

0.025M H<sub>2</sub>SO<sub>4</sub> is 0.05M H<sup>+</sup>

b. Concentration of hydrogen ions in the resultant solution (3marks)

$$\text{Initial mole of hydrogen ions} = \frac{0.025 \times 2 \times 30}{1000} = 0.0015 \text{ moles}$$

$$\text{Mole of hydroxide ions} = \frac{20 \times 0.02}{1000} = 0.0004 \text{ moles}$$

$$\text{Moles of H}^+ \text{ neutralized} = 0.0004 \text{ moles}$$

$$\text{Moles of excess H}^+ = 0.0015 - 0.0004 = 0.0011 \text{ mole}$$

$$\text{Total volume} = 20 + 30 = 50 \text{ cm}^3$$

Molar hydrogen concentration

50cm<sup>3</sup> contain 0.0011mole

$$1000\text{cm}^3 \text{ contain} \frac{0.0011 \times 1000}{50} = 0.022 \text{M}$$

c. The pH of the resultant solution (1mark)

$$\text{pH} = -\log \text{H}^+ = -\log 0.022 = 1.6$$

6. (a) Write the electron configuration of an atom of aluminium (1mark)

$$1s^2 2s^2 sp^6 3s^1 3p^1$$

- (b) State the possible oxidation number of aluminium (½ mark)  
+3  
(c) Write an ionic equation for the reaction between aluminium and sodium hydroxide (1½ marks)



7. Name one reagent that can be used to distinguish between each of the following pairs of compound and state what would be observed in each case if the reagents reacted with the compounds.

- (a)  $\text{C}_6\text{H}_5\text{COCH}_2\text{CH}_3$  and  $\text{C}_6\text{H}_5\text{COCH}_3$  (3marks)

Reagent: **iodine in sodium hydroxide**

Observations

$\text{C}_6\text{H}_5\text{COCH}_2\text{CH}_3$  **no observable change**

$\text{C}_6\text{H}_5\text{COCH}_3$  **yellow precipitate**

- (b)  $\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$  and  $(\text{CH}_3)_3\text{COH}$  (3marks)

Reagent: **anhydrous zinc chloride and hydrochloric acid**

Observations

$\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$  – **no observable change**

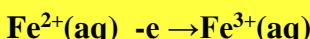
$(\text{CH}_3)_3\text{COH}$  – **cloudness solution immediate**

8. The convention of a cell is given below

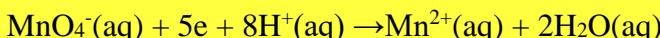


- (a) Write equation for the half cell reaction at

(i) anode (1marks)



(ii) cathode (1marks)



- (b) Write the overall equation for the cell reaction (1½ marks)

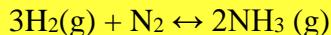


- (c) The electrode potential of system  $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$  and  $\text{MnO}_4^-(\text{aq})/\text{Mn}^{2+}(\text{aq})$  are +0.76 and 1.51 volts respectively. Deduce whether the reaction in (b) is feasible or not and give a reaction for your answer. (1mark)

$$\text{1.51} - 0.76 = 0.75\text{V}$$

9. Write an

(i) equation for the reaction between hydrogen and nitrogen. (1 marks)



(ii) Expression for equilibrium constant ( $K_p$ ) of the reaction in (a)(i) above. And state its units (2marks)

$$K_p = \frac{P_{\text{NH}_3}^2}{P_{\text{H}_2}^3 \cdot P_{\text{N}_2}}$$

(b) When hydrogen was reacted with nitrogen at 895K, the total pressure for the system at equilibrium was 30 atmospheres, and the partial pressure of nitrogen and hydrogen were 2 and 6 atmospheres respectively.

(i) Determine the partial pressure of ammonia in equilibrium mixture (1mark)

**Partial pressure of ammonia =  $30 - (2+6) = 22$  atmospheres**

(ii) Calculate equilibrium constant (1 ½ marks)

$$K_p = \frac{22^2}{6^3 \times 2} 1.12 \text{ atm}^{-2}$$

## SECTION B

Answer six questions from this section

10. (a) State the oxidation state of chromium in

(i) Potassium chromate = 6 (1mark)

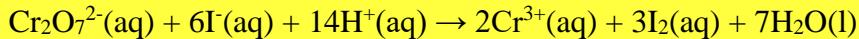
(i) Potassium dichromate = 6 (1mark)

(b) Acidified potassium dichromate was reacted with potassium iodide

(i) State what was observed (1mark)

**Orange solution turns brown**

(ii) Write half equations and overall equations for the reactions. (3marks)

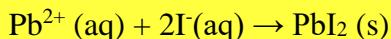


(c) Potassium chromate solution was added to aqueous Lead (II) nitrate

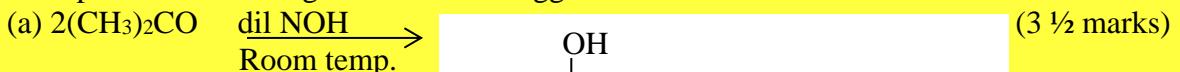
(i) State what was observed (1½ mark)

Yellow precipitate

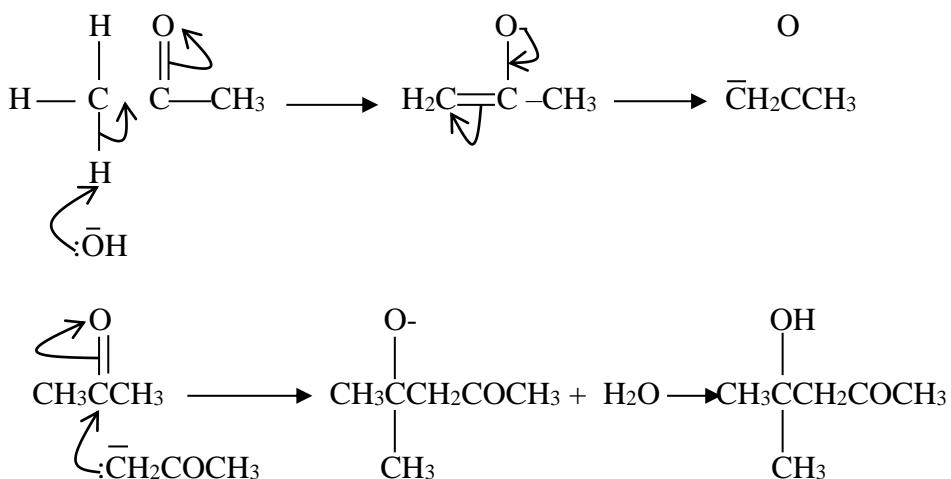
(ii) Write the ionic equation for the reaction (1½ mark)



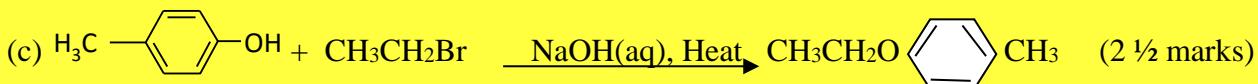
11. Complete the following reactions and suggest mechanisms for the reaction



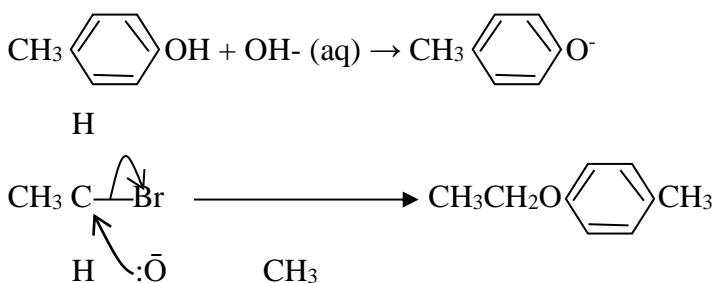
Mechanism



Mechanism



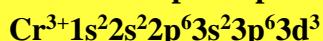
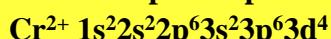
Mechanism



12 Explain the following:

- (a) Aqueous solutions of chromium (II) and chromium (III) are colored while that of copper (I) is not (3marks)

**Electron configuration**

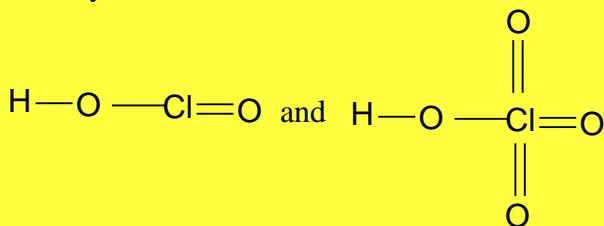


**Chromium II and chromium III ions are colored because they have partially filled d-orbital while Cu<sup>+</sup> compounds are white because it has full d-orbital.**

- (b) Manganese, iron, cobalt and nickel form ions in the <sup>+</sup>2 oxidation states. State which decrease in size from manganese to nickel. (2 marks)

**From the size decrease from manganese, iron, cobalt to nickel due to increase in electronegativity**

- (c) The oxy-acids, HClO<sub>2</sub> and HClO<sub>4</sub> have the following respective structures.

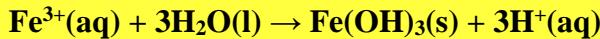


Explain why HClO<sub>4</sub> is stronger acid than HClO<sub>2</sub>

(Assume that oxygen is more electronegative than chlorine) (2 marks)

**The four oxygen atoms in HClO<sub>4</sub> strongly withdraw electron from H-O bond to release H<sup>+</sup> compared to 2 oxygen atoms in HClO<sub>2</sub>**

(d) Iron III sulphate solution changes litmus paper red (2 marks)

Iron (III) ions hydrolyses in solution to form H<sup>+</sup>

13 (a) State Kohlrausch's law of independent Conductivity of ions (1 mark)

**States that molar conductivity at infinite solution of a compound is the sum of molar conductivity at infinite dilution of its constituent ions.**

(b) Some ionic conductivity at infinite dilution at 25°C are shown below

Ion	Ionic conductivity ( $\Omega^{-1}\text{cm}^2$ )
OH <sup>-</sup>	198.6
Cl <sup>-</sup>	76.4
NH <sub>4</sub> <sup>+</sup>	73.6
Na <sup>+</sup>	50.1

Calculate the molar conductivity of ammonium hydroxide at infinite dilution (2marks)

$$\Lambda \text{NH}_4\text{OH} = \lambda\text{NH}_4^+ + \lambda\text{OH}^- = 73.6 + 198.6 = 272.2 \Omega^{-1}\text{cm}^2\text{mol}^{-1}$$

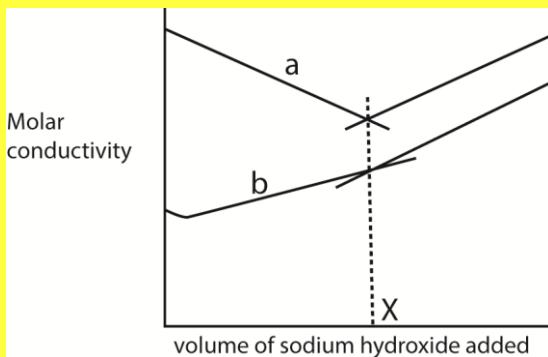
(c) The ionic radii and ionic conductivities at infinite dilution of some ions are shown in the table below:

Ion	Ionic radius/nm	Ionic conductivity/ $\Omega^{-1}\text{cm}^2$
Li <sup>+</sup>	0.060	38.7
Na <sup>+</sup>	0.095	50.1
K <sup>+</sup>	0.133	73.5

Explain the values in the table (3 marks)

**The molar conductivity of Li<sup>+</sup> is lower than expected because Li<sup>+</sup> has small ionic radius and big charge density; it attracts a big cloud of water of hydration. The effective size of hydrated Li<sup>+</sup> ions have a big effective size than that of Na<sup>+</sup> or K<sup>+</sup>, that it moves slower.**

- (d) The diagram below shows curves a and b obtained when aqueous sodium hydroxide was gradually added separately to equimolar solution of hydrochloric and ethanoic acid separately



Explain the shape of the curves

- (i) curve a

(1½ marks)

**Initially molar conductivity is high due to presence of H<sup>+</sup> from ionized HCl. It then decreases due to removal of hydrogen ions by OH<sup>-</sup> until the end point at X. After the end point conductivity increases due to excess OH<sup>-</sup>.**

- (ii) Curve b

(1½ marks)

**Initially conductivity is relatively high due to presence of H<sup>+</sup> from partially ionized acid, it initially decreases due to removal of H<sup>+</sup> and then increases to the end point due to addition of salt ions. After the end point conductivity increases more rapidly due to excess OH<sup>-</sup> ions**

14. Compound Y, C<sub>3</sub>H<sub>6</sub>O reacts with 2, 4-dinitrophenylhydrazine to give a yellow solid.

- (a) Write the structural formulae and IUPAC names of all isomers of Y. (2 marks)



- (b) When Y is heated with Fehling's solution, a red precipitate is formed, Identify Y (1 mark)

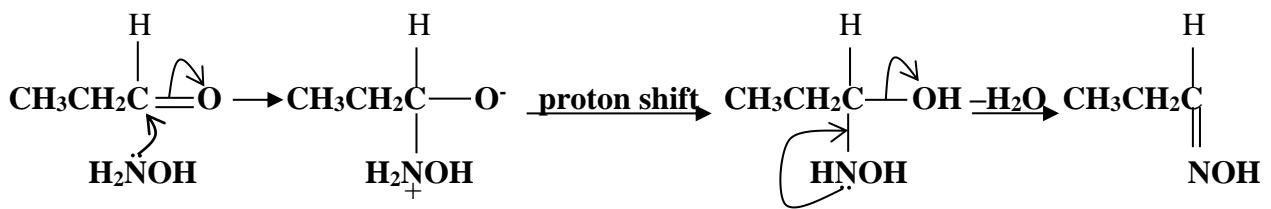


- (c) Write a mechanism for the reaction that would take place between Y and hydroxylamine, NH<sub>2</sub>OH.

(3 marks)



## Mechanism



(d) Write equations to show how Y can be converted to an alkene (3marks)



15. (a) An aqueous solution containing 7.2g of a non-cyclic substance Q in 250g of water freezes at  $-0.744^\circ\text{C}$ ; the freezing point constant, K, for water is  $1.86\text{mol}^{-1}\text{kg}^{-1}$ . (3marks)

Solution

$$\text{Freezing point depression} = 0 - (-0.744) = 0.744^\circ\text{C}$$

$$\text{Mass of Q in 1000g of water} = \frac{1000 \times 7.2}{250} = 28.8\text{g}$$

RFM of Q

$0.744^\circ\text{C}$  is caused by 28.8

$$1.86^\circ\text{C} \text{ is caused by } \frac{28.8 \times 1.86}{0.744} = 72$$

Therefore, molecular mass of Q = 72

(b) If Q contains carbon, 66.7%, hydrogen, 11.1% and oxygen 22.2%

(i) Calculate the simplest formula of Q (2 mark)

Element	C	H	O
Percentage	66.6	11.1	22.2
RFM	12	1	16
Moles	5.5	11.1	1.3785
Mole ratio	4	8	1

Empirical formula of Q = C<sub>4</sub>H<sub>8</sub>O

(ii) Determine the molecular formula of Q (1 mark)

$$(C_4H_8O)n = 72$$

$$n = 1$$



(iii) Write the structures of all possible isomers of Q (1½ mark)



(c) Q forms a yellow precipitate with phenyl hydrazine and iodine solution in presence of sodium hydroxide. Identify Q. (1½ mark)



16. The solubility product, K<sub>sp</sub>, of zinc hydroxide is  $4.5 \times 10^{-17}$  at 25°C

(i) Write an expression for solubility product of zinc hydroxide (1½ marks)

$$K_s = [Zn^{2+}][OH^-]^2$$

(b) Determine the concentration in moles per litre of zinc and hydroxide ions in a saturated solution of zinc hydroxide at 25°C (3marks)

Let the solubility of Zn(OH)<sub>2</sub> be x

$$[Zn^{2+}] = x$$

$$[OH^-] = 2x$$

$$x[2x]^2 = 4.5 \times 10^{-17}$$

$$x = 2.24 \times 10^{-6} \text{ mol dm}^{-3}$$

$$[Zn^{2+}] = 2.24 \times 10^{-6} \text{ mol dm}^{-3}$$

$$[OH^-] = 4.48 \times 10^{-6} \text{ mol dm}^{-3}$$

(c) State how solubility of zinc hydroxide would change if its saturated solution is treated separately with

(i) aqueous zinc sulphate (1 mark)

**decreases**

(ii) ammonia (1mark)

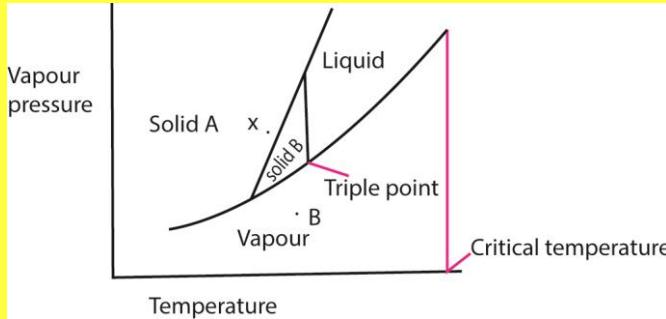
**increases**

(d) Briefly explain your answer in (c). (3marks)

Solubility of  $\text{Zn}(\text{OH})_2$  decreases in zinc sulphate solution due to common ion effect

Solubility of  $\text{Zn}(\text{OH})_2$  increases in ammonia solution because  $\text{Zn}^{2+}$  form soluble complex with ammonia shifting equilibrium to the right.

17. Figure 2 is a phase diagram for a certain substance



(a) Label the following on the diagram (4marks)

(i) the axes

(ii) the phases present

(iii) the critical temperature

(iv) the triple point

(b) Define the term

(i) Critical point (1½ marks)

**Critical point is temperature and pressure beyond which liquid and vapour are indistinguishable**

(ii) triple point (1½ mark)

**Triple point is temperature and pressure at which liquid, solid and vapour phases are at equilibrium**

(c) Explain what would happen when the substance at point X changes to point B (2marks)

**Pressure decreases, temperature increases; solid A changes to solid B and then to vapor.**

## Periodic Table

1	2													3	4	5	6	7	8
1.0 H 1														1.0 H 1	4.0 He 2				
6.9 Li 3	9.0 Be 4													10.8 B 5	12.0 C 6	14.0 N 7	16.0 O 8	19.0 F 9	20.2 Ne 10
23.0 Na 11	24.3 Mg 12													27.0 Al 13	28.1 Si 14	31.0 P 15	32.1 S 16	35.4 Cl 17	40.0 Ar 18
39.1 K 19	40.1 Ca 20	45.0 Sc 21	47.9 Ti 22	50.9 V 23	52.0 Cr 24	54.9 Mn 25	55.8 Fe 26	58.9 Co 27	58.7 Ni 28	63.5 Cu 29	65.7 Zn 30	69.7 Ga 31	72.6 Ge 32	74.9 As 33	79.0 Se 34	79.9 Br 35	83.8 Kr 36		
85.5 Rb 37	87.6 Sr 38	88.9 Y 39	91.2 Zr 40	92.9 Nb 41	95.9 Mo 42	98.9 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54		
133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	207 Ti 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86		
223 Fr 87	226 Ra 88	227 Ac 89																	
			139 La 57	140 Ce 58	141 Pr 59	144 Nd 60	147 Pm 61	150 Sm 62	152 Eu 63	157 Gd 64	159 Tb 65	162 Dy 66	165 Ho 67	167 Er 68	169 Tm 69	173 Yb 70	175 Lu 71		
			227 AC 89	232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pu 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	254 Es 99	257 Fm 100	256 Md 101	254 No 102	260 Lw 103		

End

**525/1**

## **S6 CHEMISTRY**

**Exam 10**

**PAPER 1**

**DURATION: 2 HOUR 45 MINUTES**

### Instructions

- This paper consists of two sections A and B
- Section A is compulsory
- Attempt only six questions in section B
- Answers must be written in the spaces provided only.

For Examiner's Use Only

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

**120**

**Approved: 0777 023 444**

**SECTION A**

Answer all questions from this section

- Oxygen diffused through a porous partition in 1.87 minutes. Under similar conditions the same volume of an alkene T diffused in 2.15 minutes  
 (a) Determine the formula of T (2 ½ marks)

$$\frac{\text{rate oxygen}}{\text{rate } T} = \sqrt{\frac{\text{RFM of } T}{\text{RFM of oxygen}}}$$

$$\frac{V}{1.87} \sqrt{\frac{V}{2.15}} = \sqrt{\frac{\text{RFM of } T}{32}}$$

$$\text{RFM of } T = 42$$

$$(C_nH_{2n})x = 42$$

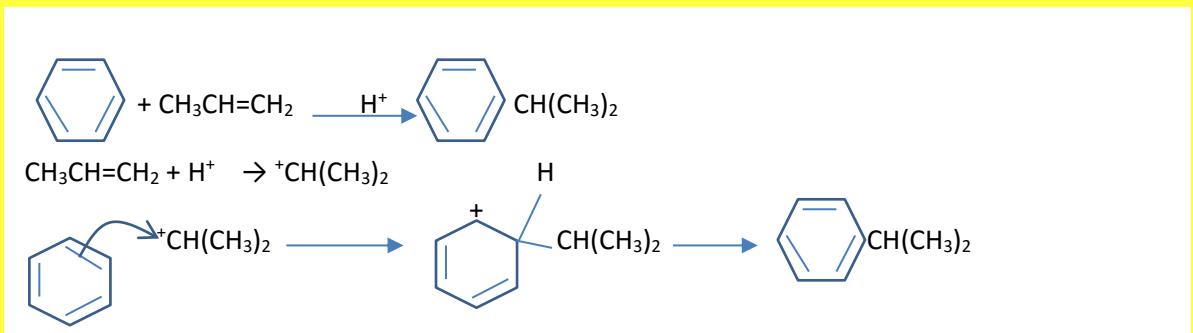
$$x = 3$$

Molecular formula of alkene = C<sub>3</sub>H<sub>6</sub> or CH<sub>3</sub>CH=CH<sub>2</sub>

- (b) Write equation and outline the mechanism for the reaction between T and benzene.

Indicate the condition (s) for the reaction

(3marks)

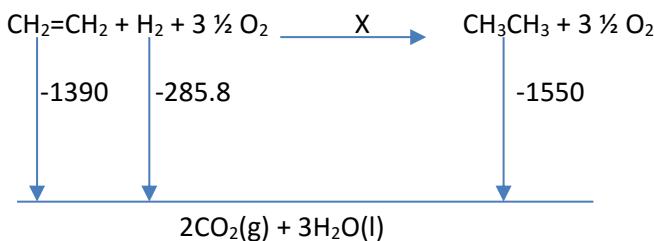


- (a) define the term heat of reaction (1mark)

**Enthalpy of reaction is enthalpy change when 1 mole of a compound is formed from its reactants**

**at 298K and 1 atmosphere**

(c) Calculate the standard enthalpy of hydrogenation of ethene from the data



$$-1390 + -285.8 = X - 1550$$

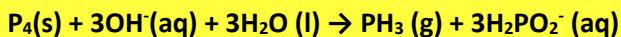
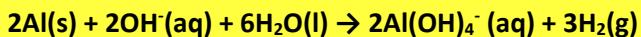
$$X = 125.2 \text{ kJ mol}^{-1}$$

3. (a) Aluminium and phosphorus both form compounds in which the oxidation state of the element is +3

(a) Briefly explain in terms of electron structure why aluminium conducts electricity but the common allotropes of phosphorus do not.

**The valence electrons of aluminium are delocalized and free to move in the metallic structure while the valence electron do not move**

(b) Write equation for the reaction of each of these elements with sodium hydroxide (3mark)



4. Name one reagent that can be used to distinguish between each of the following pairs of compounds and state what would be observed in each case if the reagent is reacted with the compounds;

(a)  $\text{CH}_3\text{CH}_2\text{NH}_2$  and  $(\text{CH}_3\text{CH}_2)_2\text{NH}$  (3marks)

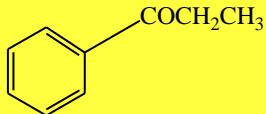
**Reagent: sodium nitrite and hydrochloric acid, <5°C**

**Observation:**

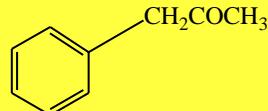
**CH<sub>3</sub>CH<sub>2</sub>NH<sub>2</sub> effervescence**

**(CH<sub>3</sub>CH<sub>2</sub>)<sub>2</sub>NH yellow oily solid**

(b)



and



**Reagent: iodine in sodium hydroxide solution**

**Observation:**



COCH<sub>2</sub>CH<sub>3</sub> no observable change



CH<sub>2</sub>COCH<sub>3</sub> yellow precipitate

5. (a) Explain the order of increasing basicity for the following compounds. (2marks)



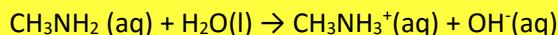
Methyl group on CH<sub>3</sub>NH<sub>2</sub> donate electrons to nitrogen atom; this increases the electron density of the lone pair of electron that attract hydrogen atom and releases OH<sup>-</sup> ions easily. This make methyl amine a stronger base than ammonia

The phenyl group withdraw electrons to nitrogen atom; this reduces the electron density of the lone pair of electron that make it difficult to attract hydrogen atom from water and make it difficult to releases OH<sup>-</sup> ions easily. This makes phenylamine a weaker base than ammonia.

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(b) When one mole of methylamine is dissolved in water, the hydrogen ion concentration is found to be  $2.5 \times 10^{-10}$  moldm<sup>-3</sup>.

(i) Write an equation for the reaction between water and methylamine (1 mark)

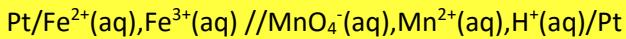


(ii) Calculate the base dissociation constant,  $K_b$ , for methylamine. (2 ½ marks)

$$[\text{OH}^-] = \frac{10^{-14}}{[\text{H}^+]} = \frac{10^{-14}}{[2.5 \times 10^{-10}]} = 4 \times 10^{-5}$$

$$K_b = \frac{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}{[\text{CH}_3\text{NH}_2]} = \frac{[4.5 \times 10^{-5}]^2}{1} = 1.9 \times 10^{-9} \text{ moldm}^{-3}$$

6. The convention of a cell is given below.



(a) Write equation for the half-cell reaction at:-

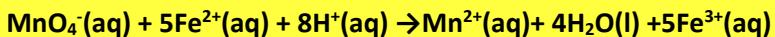
(i) Anode (1mark)



(ii) Cathode (1mark)



(b) Write the overall equation for the cell reaction. (1 ½ marks)



(c) The electrode potentials for the system  $\text{Fe}^{2+} \text{ (aq)}/\text{Fe}^{3+} \text{ (aq)}$  and  $\text{Mn}^{2+} \text{ (aq)}/\text{MnO}_4^- \text{ (aq)}$  are +0.76V and 1.51V respectively. Deduce whether the reaction in (b) is feasible or not and give a reason for your answer. (2marks)

$$E_{\text{cell}} = E_{\text{RHE}} - E_{\text{LHE}} = 1.51 - 0.76 = 0.75 \text{ V}$$

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7. (a) Define the term boiling point elevation constant of a substance. (1mark)

**This is the boiling point elevation caused by 1 mole of a substance in 1000g of solvent**

- (b) The boiling point of benzene under certain pressure condition is  $80.0^{\circ}\text{C}$ . Calculate the boiling point elevation constant of benzene, if a solution containing 5g of 2, 4 6-trinitrophenol, ( $\text{HOC}_6\text{H}_2(\text{NO}_2)_3$ ) in 100g of benzene, boils at  $80.568^{\circ}\text{C}$ . (4marks)

$$\text{Boiling point elevation } 80.568 - 80.0 = 0.568^{\circ}\text{C}$$

Mass of 2,4,6-trinitrophenol in 1000g of benzene

100g of benzene contain 5g

$$1000\text{g of benzene contain } \frac{1000 \times 5}{100} = 50\text{g}$$

Formula mass of 2,4,6-trinitrophenol ( $\text{HOC}_6\text{H}_2(\text{NO}_2)_3$ ) = 229

Boiling point constant,  $K_b$

50 g of 2,4,6-trinitrophenol cause  $0.568^{\circ}\text{C}$

229g of 2,4,6-trinitrophenol cause  $K_b$

$$K_b = \frac{229 \times .568}{50} = 2.7^{\circ}\text{C}$$

8. 2.00g of phosphorus pentachloride allowed to reach equilibrium at  $200^{\circ}\text{C}$  in a vessel of  $1\text{dm}^3$  capacity. If the equilibrium constant of the reaction  $\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)$  is  $0.008\text{mol dm}^{-3}$  at this temperature and in the conditions stated; calculate the percentage dissociation of phosphorus pentachloride at equilibrium. (4marks)

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Formula mass of  $\text{PCl}_5$  be  $31 + 35.5 \times 5 = 208$

$$\text{Mole of } \text{PCl}_5 = \frac{2}{208} = 0.1 \text{ moles}$$

Let the moles that dissociated be  $x$

Moles of  $\text{PCl}_3$  = moles of  $\text{Cl}_2$  =  $x$

Moles of  $\text{PCl}_5$  at equilibrium =  $1 - x$

$$K_c = \frac{x^2}{(0.1-x)} = 0.008$$

$$x = 0.025 \text{ mol dm}^{-3}$$

$$\text{Calculate \% dissociation} = \frac{0.025 \times 100}{0.1} = 25\%$$

9. The first ionization energies of some group II metals of the periodic table and the melting points of their chlorides are given below.

	Mg	Ca	Sr	Ba
First ionization energy / $\text{kJ mol}^{-1}$	738	590	549	505
Melting point of chlorides ( $^{\circ}\text{C}$ )	708	772	873	967

Explain

- (i) Why ionization energy decreases with increase in atomic number. (2marks)

**Ionization energy decrease due to decrease in effective nuclear charge. As atomic number increase, the atomic size increase, the distance between the nucleus and outer electrons increase reducing electronegativity.**

- (ii) Why the melting points of the chlorides of these metals increase with increase in atomic number of the metal. (2marks)

**This increases due to increase in the strength of ionic bonds**

**SECTION B (54 MARKS)**

(Attempt any six questions from this section)

10. (a) (i) Define the term “molar conductivity at infinite dilution,  $\Lambda_0$ . (1mark)

**This is the conductivity of 1 mole of electrolyte when the solution is very dilute that the ions experience no interaction from other ions.**

- (ii) State how you would expect the molar conductivity of sodium chloride solution to vary as the dilution of the solution is increased. Give a reason for your answer (2marks)

**Molar conductivity of sodium chloride increases linearly with dilution up to the maximum value of molar conductivity at infinity dilution since sodium chloride is a strong electrolyte**

- (c) The values of  $\Lambda_0$  at  $25^\circ\text{C}$  for some electrolytes are as follows

Electrolyte	$\Lambda_0/\text{Sm}^2\text{mol}^{-1}$
HCOONa	104.7
NaCl	126.5
HCl	426.2

- (i) Calculate  $\Lambda_0$  at  $25^\circ\text{C}$  for methanoic acid, HCOOH. (2marks)

$$\Lambda_0 \text{ HCOOH.} = \Lambda_0 \text{ HCOONa} + \Lambda_0 \text{ HC} - \Lambda_0 \text{ NaCl}$$

$$426.2 + 104.7 - 126.5 = 404.4$$

- (ii) If the value of molar conductivity,  $\Lambda$ , for 0.01M methanoic acid is  $50.5\text{Sm}^2\text{mol}^{-1}$  at  $25^\circ\text{C}$ .

Calculate the acid dissociation constant,  $K_a$ , for methanoic acid. (4marks)

$$\text{Degree of ionization, } \alpha = \frac{50.5}{404.4} = 0.125$$

$$K_a = c\alpha^2 = 0.125^2 \times 0.01 = 1.56 \times 10^{-4}\text{mol dm}^{-3}$$

11. (a) (i) Explain the term solubility product. (1mark)

Is a product of molar concentration of ions of a sparingly soluble salt raised to their stoichiometric ratios.

- (ii) Write an expression for the solubility product of silver chloride in water (1mark)

$$K_s = [\text{Ag}^+][\text{Cl}^-]$$

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- (b) Ionic conductivity of silver ions and chloride ions at infinite dilution are  $6.2 \times 10^{-2}$  and  $7.6 \times 10^{-2} \text{ Sm}^2\text{mol}^{-1}$  respectively at 298K. The electrolytic conductivity of silver chloride at 298K is  $1.22 \times 10^{-2} \text{ Sm}^2\text{mol}^{-1}$ .

- (i) Calculate the solubility in  $\text{mol dm}^{-3}$  of silver chloride at 298K (3 ½ marks)

$$\begin{aligned}\Lambda_0 \text{AgCl} &= \Lambda_0 \text{Ag}^+ (\text{aq}) + \Lambda_0 \text{Cl}^- \\ &= 6.2 \times 10^{-2} + 7.6 \times 10^{-2} \\ &= 0.138 \text{ Sm}^2\text{mol}^{-1}\end{aligned}$$

$$\begin{aligned}\Lambda_0 \text{AgCl} &= \frac{K}{S} \\ \text{Solubility} &= \frac{1.22 \times 10^{-2}}{0.138} = 0.0884 \text{ mol m}^{-3} = 0.0000884 \text{ mol dm}^{-3}\end{aligned}$$

- (ii) Calculate the solubility product,  $K_{\text{sp}}$ , of silver chloride at 298K (1 ½ marks)

$$K_s = [\text{Ag}^+][\text{Cl}^-] = 0.0000884^2 = 7.8 \times 10^{-9} \text{ mol}^2\text{dm}^{-6}$$

- (c) State the effect of the following actions on the solubility of silver chloride. Explain your answers.

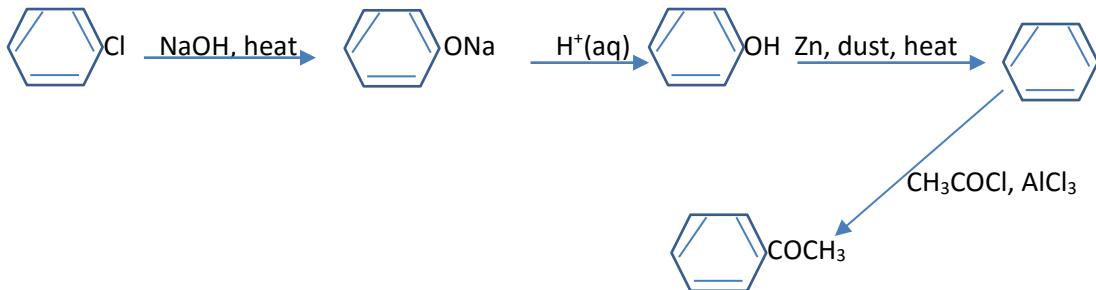
- (i) Addition of aqueous ammonia (1mark)

**Solubility increases because ammonia form a soluble complex with silver ions shifting solubility equilibrium to the right**

- (ii) Addition of potassium chromate (VI) solution. (1mark)

**Solubility of silver chloride increases because chromate ion form insoluble precipitate with silver ions shifting equilibrium to the right.**

12. Write equations to show how the following compounds can be synthesized.



(b)  $(\text{CH}_3)_3\text{COH}$  from  $(\text{CH}_3)_2\text{CHOH}$  (2½ marks)



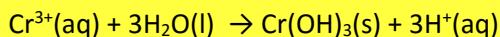
(c)  $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$  from ethyne (3marks)



13. (a) Explain each of the following observations:

- (i) Chromium (III) sulphate dissolves in water to form a solution whose pH is less than seven. (2 ½ marks)

Chromium (III) ions hydrolyze in water to form hydrogen ions



- (ii) Lead does not form lead (IV) bromide. (2marks)

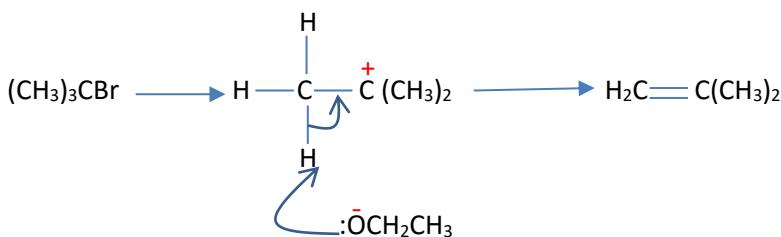
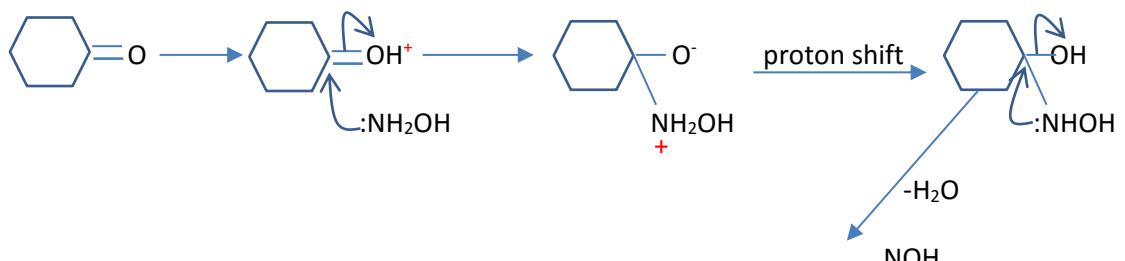
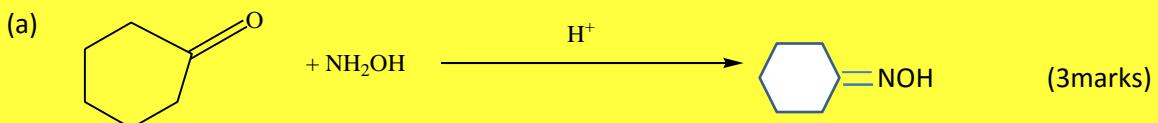
Probably bromine is not a strong oxidizing agent to oxidize lead (II) ions to lead (IV) ions

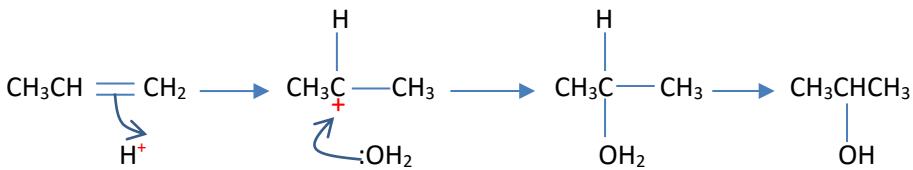
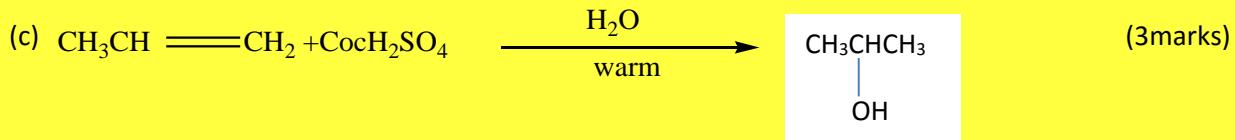
- (b) To a dilute solution of chromium (III) sulphate was added dilute sodium hydroxide drop wise until in excess followed by 3 drops of hydrogen peroxide and mixture warmed.  
State what was observed and use equations to explain the observations. (4 ½ marks)

**A green precipitate of chromium (III) oxide reacts with excess OH<sup>-</sup> ions to form a green solution of soluble complex which is oxidized to yellow solution of chromium (VI)**



14. Complete the following equations and in each case write a mechanism for the reaction.





15. Vegetable oils have great economic and social importance

(a)(i) Explain what is meant by the term vegetable oils (1mark)

**Oil obtained from plant seeds**

(ii) Name two main sources of vegetable oils. (1mark)

**Sun flower seeds**

**Cotton seed**

**Castor oil seed**

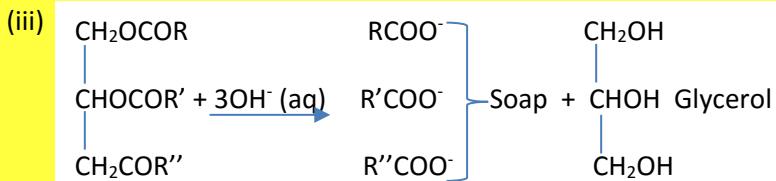
(iii) Describe briefly how vegetable oil can be obtained on a large scale from one of the sources you have named in (a)(i) above. (technical details are not required) (2marks)

**Seeds are crashed and oil obtained by solvent extraction.**

(b) (i) State the name given to the reaction leading to the formation of soap from oil. (1mark)

**Saponification**

(ii) Write a general equation for the formation of soap from oil. (1mark)



- (iv) Outline how soap is manufactured, (technical details not required). (3marks)

Vegetable oil is boiled with sodium hydroxide for some time, concentrated sodium chloride solution is added to precipitate soap. On cooling soap is skimmed off the mixture.

16. State what would be observed and write the equation for the reaction that would take place when:

- (a) Hydrogen sulphide gas is passed through an acidified solution of potassium dichromate (VI).

Observation (2 ½ mark)

**Orange solution turns green with formation of yellow solid**

Equation:

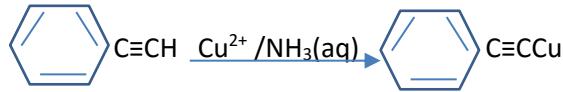


- (b) 2,3 drops of ammoniacal copper (I) chloride is added to phenylethyne. (2marks)

Observation

**Red precipitate**

Equation:

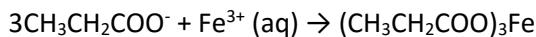


- (c) Neutral iron (III) chloride solution is added to 1 cm<sup>3</sup> of propanoic acid (2marks)

Observation

**Red solution**

Equation:



- (d) A spatula end ful of sodium hydrogen carbonate is added to iron (III) chloride solution

(2 ½ marks)

Observation

**Effervescence and brown precipitate**

Equation:



17. (a) Fluorine is the first member of the halogen group of elements in the periodic table and it shows anomalous behavior among the halogens.

- (i) State **three** major differences between fluorine and other halogens. (2½ marks)

Reacts with water to liberate oxygen

Reacts with concentrated sodium hydroxide solution to liberate oxygen

Reacts with carbon,  $\text{SiO}_2$

- (ii) Give **three** causes for the anomalous behavior of fluorine. (3mmarks)

**Has small atomic radius**

**Has high electronegativity**

**Has very low F-F bond energy**

**Forms strong bonds with other elements**

- (c) The acid dissociation constants  $K_a$  for the hydrides of elements of group (VII) elements are given in the table below:

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Hydride	HF	HCl	HBr	HI
Ka ( $\text{mol dm}^{-3}$ )	$5.6 \times 10^{-11}$	$1 \times 10^{-9}$	$1 \times 10^{-7}$	$1 \times 10^{-4}$

State and explain the trend in variation of acid strength of the hydrides (4marks)

Acid strength decrease from HI>HBr>HCl>HF due to increase in H-X bond strength HI<HBr<HCl<HF

# Kampala Mathematics Club

1	2											3	4	5	6	7	8
1.0 H 1												1.0 H 1		4.0 He 2			
6.9 Li 3	9.0 Be 4											10.8 B 5	12.0 C 6	14.0 N 7	16.0 O 8	19.0 F 9	20.2 Ne 10
23.0 Na 11	24.3 Mg 12											27.0 Al 13	28.1 Si 14	31.0 P 15	32.1 S 16	35.4 Cl 17	40.0 Ar 18
39.1 K 19	40.1 Ca 20	45.0 Sc 21	47.9 Ti 22	50.9 V	52.0 Cr	54.9 Mn	55.8 Fe	58.9 Co	58.7 Ni	63.5 Cu	65.7 Zn	69.7 Ga	72.6 Ge	74.9 As	79.0 Se	79.9 Br	83.8 Kr
85.5 Rb 37	87.6 Sr 38	88.9 Y 39	91.2 Zr 40	92.9 Nb 41	95.9 Mo 42	98.9 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	207 Ti 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
223 Fr 87	226 Ra 88	227 Ac 89															
			139 La 57	140 Ce 58	141 Pr 59	144 Nd 60	147 Pm 61	150 Sm 62	152 Eu 63	157 Gd 64	159 Tb 65	162 Dy 66	165 Ho 67	167 Er 68	169 Tm 69	173 Yb 70	175 Lu 71
			227 AC 89	232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pu 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	254 Es 99	257 Fm 100	256 Md 101	254 No 102	260 Lw 103

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## S6 CHEMISTRY

**Exam 1**

**PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

### INSTRUCTIONS TO CANDIDATES

Answer **five** questions, including **three** questions from section **A** and any **two** from section **B**

**Begin each question on a fresh page.**

**Graph papers are provided.**

**Non-programmable scientific calculators may be used**

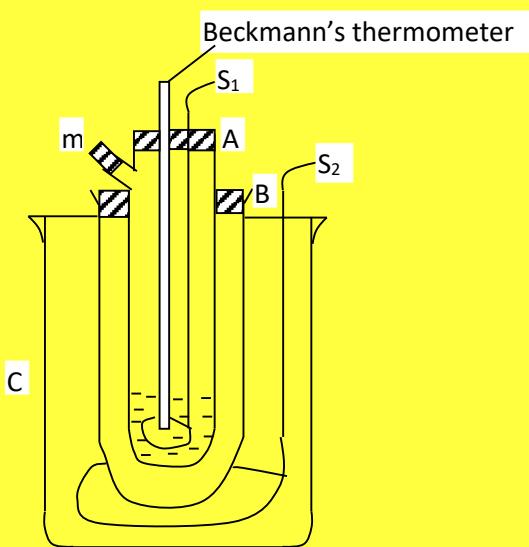
**SECTION A (do any 3 numbers)**

- 1.** (a) State what meant by the term boiling point constant of a liquid. (2marks)

Elevation of boiling point caused by 1 mole of a substance in 1000g of solute

- (b) Describe an experiment that can be used to determine the relative molecular mass of a compound using the method of elevation of the boiling point of a liquid. Draw a labeled diagram of the apparatus used. (9marks)
- (c) A given mass of the solvent ( $m_1$ ) is placed in glass tube A into which a thermometer is immersed. This tube is fitted with a wire stirrer,  $s_1$ , and a side arm, m, through which the solute can be introduced.

**Apparatus**



- the tube A is surrounded by a wider tube, B, which provides an air jacket to ensure uniform cooling
- The freezing agent is contained in vessel C consisting of a mixture of ice and salt and is kept stirred by stirrer  $S_2$ .
- The freezing point of the pure solvent  $T_1$ , is determined by stirring both freezing agent and the solvent and recording the constant temperature at which a liquid turns into a solid.
- After determining the freezing point of a solvent the solid is warmed to melt.
- A given mass of solute  $m_2$  is introduced into the solvent through side arm, m, and stirred until completely dissolved.
- Repeat procedure 4 and note the temperature ( $T_2$ ) at which pure solvent alone separate out from solution as solid.

**Treatment of results**

Mass of solvent	= M <sub>1</sub>
Mass of solute	= m <sub>2</sub>
Δt	= (T <sub>1</sub> -T <sub>2</sub> )
Molecular mass of solute	= Mr

$$\text{Mass of solute in 1000g of solvent} = \frac{1000m_2}{m_1}$$

Then,

$$K_f = \frac{(T_1 - T_2) \times Mr \times m_s}{1000m_2} \quad \text{where } K_f \text{ is the cryoscopic constant of a solvent.}$$

- (d) Explain why the method you have described in (b) is not suitable for determination of the relative molecular mass of polymers in aqueous solution. (03marks)

Boiling point elevations for dilute solutions of polymers are negligible

- (e) Calculate the freezing point of a solution containing 0.42g of ethane-1, 2-diol (molecular mass =62) in 30g of water. (K<sub>f</sub> of water =1.86°Cmol<sup>-1</sup>kg<sup>-1</sup>) (03marks)

Mass of ethene-1, 2-diol in 1000g of solvent

30g of water contain 0.42g of ethane-1,2-diol

$$1000\text{g of water contain } \frac{0.42 \times 1000}{30} = 14 \text{ g}$$

Freezing point depression

60g of ethane-1,2-diol cause a freezing point depression of 1.86°C

$$14\text{g of ethane-1,2-diol will cause a depression of } \frac{14 \times 1.86}{60} = 0.432^\circ\text{C}$$

$$\text{Freezing point of solution} = 0 - 0.432 = -0.432^\circ\text{C}$$

- (f) When a compound Y, was steam distilled at standard pressure, the temperature of distillation was 96°C, the vapour pressure of water at this temperature was 730mmHG and the distillate contained 74% of water. Calculate the molar mass of Y. (4marks)

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Vapour pressure of Y at 960°C = 760 - 730 = 30 mmHg

Percentage of Y in vapor = 100 - 74 = 26%

Formula mass of water, H<sub>2</sub>O = 2 + 16 = 18

Let the molecular mass of Y be M

$$\frac{26}{74} = \frac{M \times 30}{18 \times 730}$$

$$M = 154$$

Therefore molecular mass of Y = 154

2. (a) Write the formula and name of an ore of aluminium. (2marks)

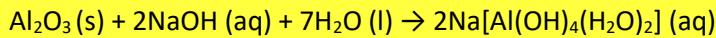
Bauxite (Al<sub>2</sub>O<sub>3.x</sub>H<sub>2</sub>O)

- (b) Describe the process of extraction of pure aluminium metal from its ore (7marks)

Extraction of aluminium involves removal of impurities (purification) and then reduction to metal by electrolysis.

Steps in extraction of Aluminium

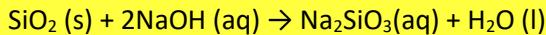
- (i) The ore is heated
  - to remove water and,
  - To convert iron salts to iron III oxide
- (ii) The powdered ore is heated with concentrated sodium hydroxide to dissolve aluminium oxide and silica such that the insoluble iron oxide is filtered off.  
Aluminium oxide forms aluminate



Or the ionic form

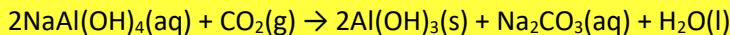


Silica also dissolves forming sodium silicate.

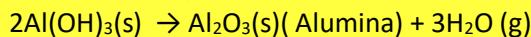


- (iii) To the filtrate a little aluminium hydroxide is added to precipitate Aluminium hydroxide (seeding).  
 $\text{NaAlO}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{NaOH}(\text{aq}) + \text{Al(OH)}_3(\text{s})$

Alternatively carbon dioxide bubbled through the filtrate to precipitate aluminium hydroxide as follows



- (iv) The precipitated aluminium hydroxide is filtered off, washed and ignited to give pure aluminium oxide (alumina).

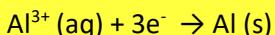


(v) Aluminum is obtained from aluminium oxide by electrolysis.

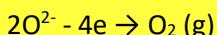
Cryolite,  $\text{Na}_3\text{AlF}_6$ , is added to

- lower the melting point of alumina from  $2050^{\circ}\text{C}$  to  $900^{\circ}\text{C}$
- and improve conductivity of aluminium oxide

At the cathode (carbon) aluminium is liberated

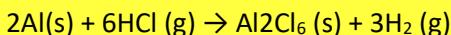


At the anode (carbon) oxygen is liberated



(c) State the conditions and write equations for the formation of aluminium chloride from the metal

(3marks)

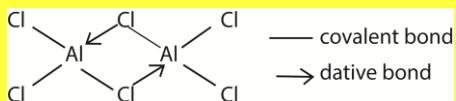


(d) The relative molecular mass of aluminium chloride in a vapour phase is 267.

(i) Write the molecular formula of aluminium chloride in a vapour phase. (1 ½ marks)



(ii) Write a structural formula to show the bonding in aluminium chloride vapour. (1marks)



(iii) Note the types of bonds involved in the structure you have drawn in (ii) above. (1 ½ marks)

Indicated on the structure in(d)(ii)

(e) With reference to aluminium oxide, explain the term amphoteric property. Write appropriate equations. (2marks)

Amphoteric compounds react with both acids and bases to form salts



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(f) Explain, giving the necessary equations, why.

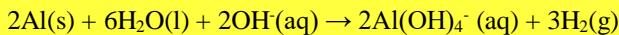
(i) solutions of simple Al<sup>3+</sup> salts are acidic. (1mark)

Aluminium ions hydrolyze in water to produce H<sup>+</sup>



(ii) aluminium utensils should not be washed in strong alkaline solution (1mark)

Alkaline solution dissolve aluminium



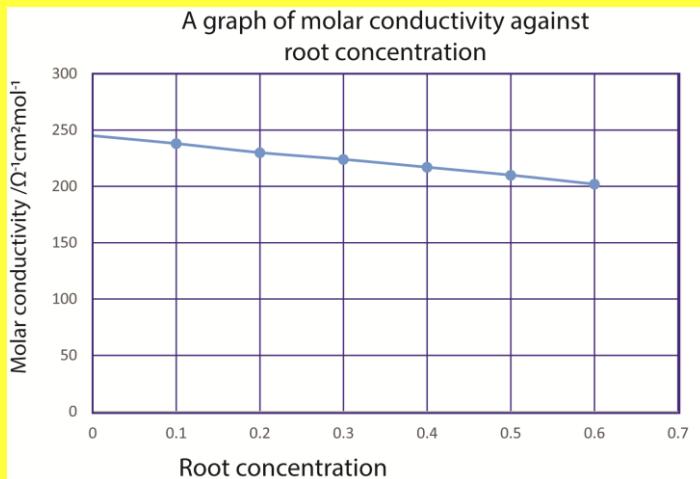
**3.** (a) What is molar conductivity? (1mark)

Molar conductivity is the conductivity of a solution containing 1 mole of an electrolyte

(b) The molar conductivity of sodium hydroxide solutions of different concentration are shown in the table below

Concentration/mol dm <sup>-3</sup>	0.01	0.04	0.09	0.16	0.25	0.36
Root concentration (mol <sup>1/2</sup> dm <sup>-3/2</sup> )	0.1	0.2	0.3	0.4	0.5	0.6
Molar conductivity Λ/Ω <sup>-1</sup> cm <sup>2</sup> mol <sup>-1</sup>	238	230	224	217	210	202

(i) Draw a graph of molar conductivity against the square root of concentration (04marks)



(ii) Explain the shape of the graph (04½ marks)

Molar conductivity increases as concentration decreases because as concentration decreases ionic interference decreases. This increases mobility of ions to respective electrodes.

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- (iii) Determine the value of molar conductivity at infinite dilution of sodium hydroxide and indicate its units. (02marks)

Molar conductivity at infinite dilution = Intercept =  $245 \Omega^{-1}cm^2mol^{-1}$

- (c) Using the same conductivity cell, the resistance of 0.1M potassium chloride solution and 0.1M bromoethanoic acid solution were found to be 24.96 and 66.50 ohms respectively at 25°C. [The conductivity of potassium chloride at 25°C is  $0.01164\Omega^{-1}cm^{-1}$  and molar conductivity of bromoethanoic acid at infinite dilution is  $389\Omega^{-1}cm^2mol^{-1}$ .]

- (i) Calculate the cell constant (02marks)

$$\text{Cell constant } (I/A) = R \times K = 24.96 \times 0.01164 = 0.29 \text{ cm}^{-1}$$

- (ii) Calculate the molar conductivity of 0.1M bromoethanoic acid (03marks)

$$K = \frac{1}{R} \times \text{cell constant} = \frac{1}{66.50} \times 0.29 = 0.00436 \Omega^{-1}cm^{-1}$$

$$\text{Molar conductivity } (\Lambda_c) = \frac{K}{C} = \frac{0.00436 \times 1000}{0.1} = 43.6 \Omega^{-1}cm^2mol^{-1}$$

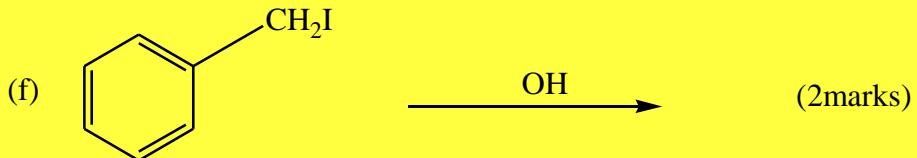
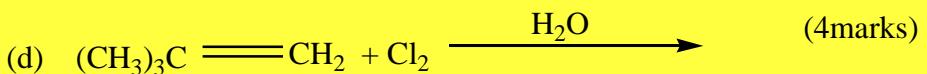
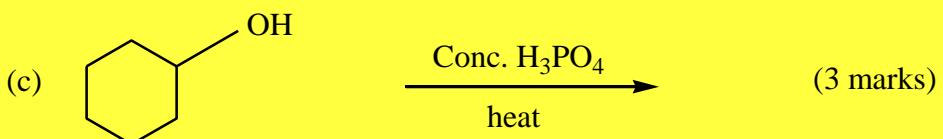
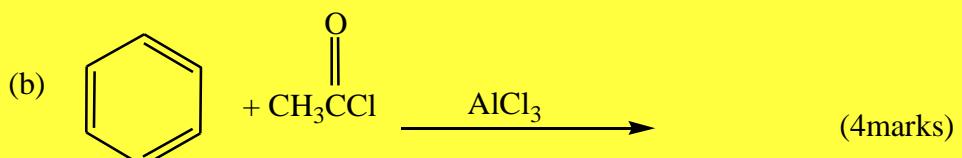
- (iv) Determine the pH of 0.1M bromoethanoic acid (4 ½ marks)

$$\text{Degree of ionization, } \alpha = \frac{\Lambda_c}{\Lambda_0} = \frac{43.6}{389} = 0.112$$

$$[H^+] = \alpha C = 0.112 \times 0.1 = 0.0112 \text{ mol dm}^{-3}$$

$$\text{pH} = -\log [H^+] = -\log 0.0112 = 1.95$$

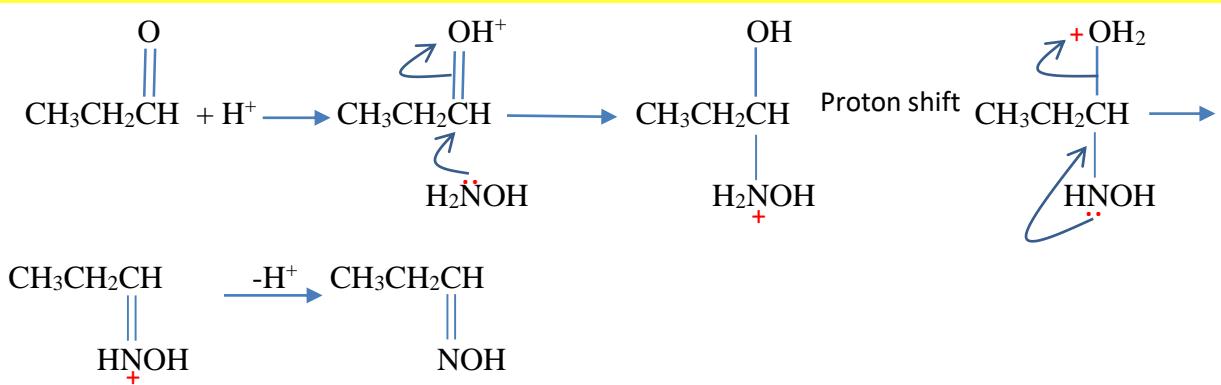
**4.** Complete the following equations and in each case write the mechanism for the reaction.



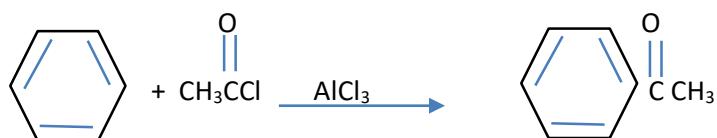
### Solution



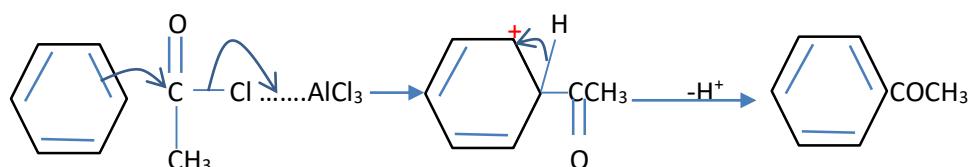
Mechanism



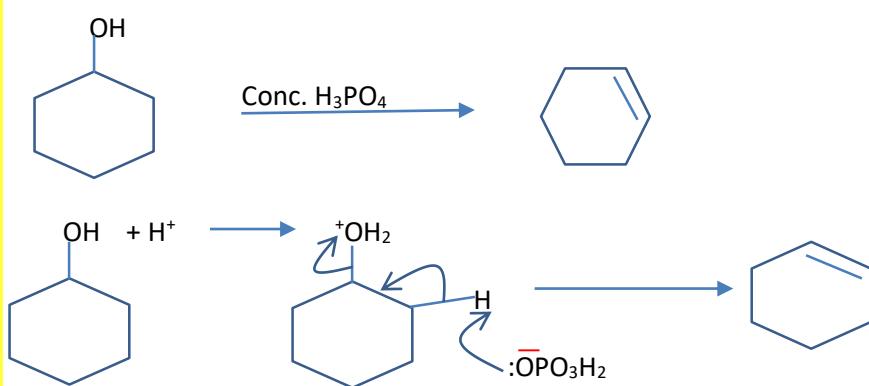
(b)



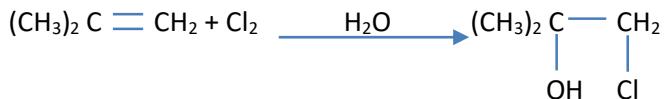
## Mechanism



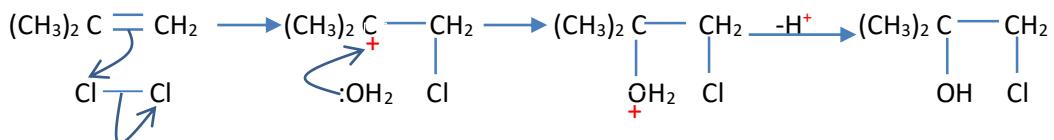
(c)



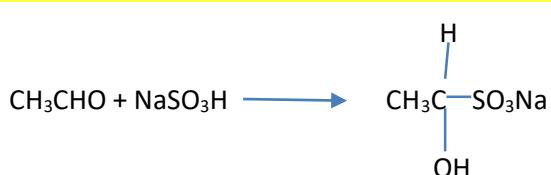
(d)

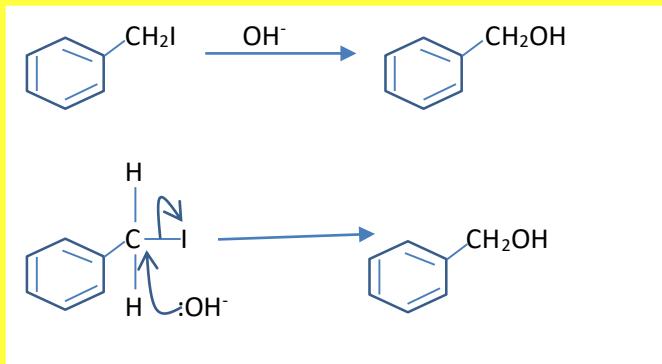
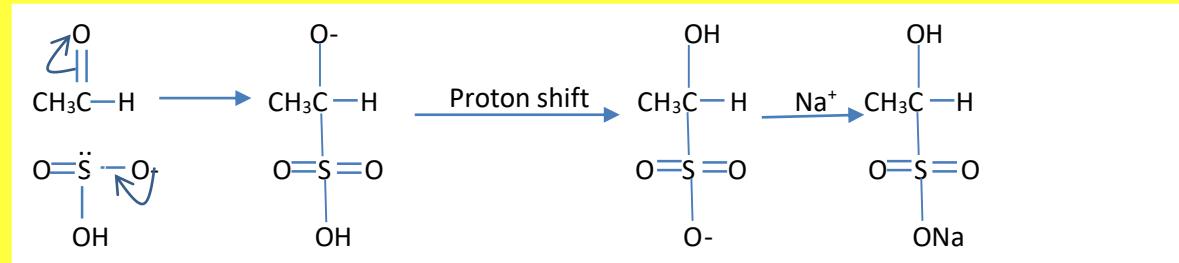


## Mechanism



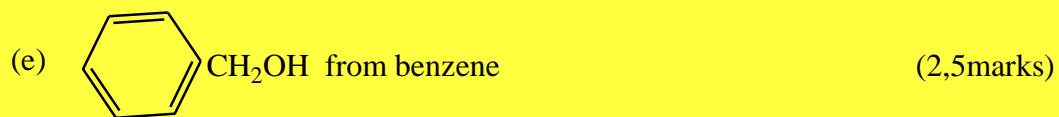
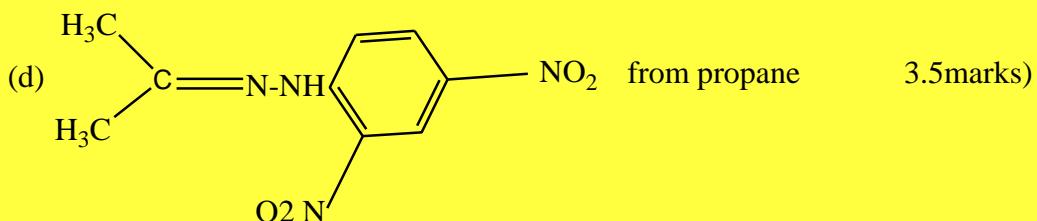
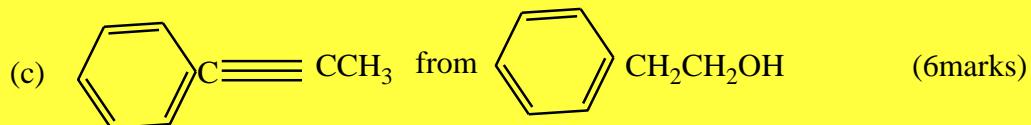
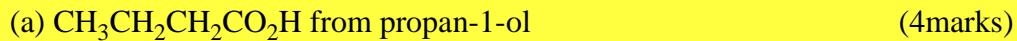
(e)





**SECTION B (Any two numbers)**

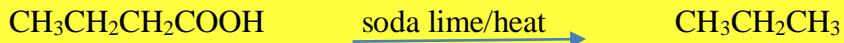
5. Write equations to show the following compounds can be synthesized.



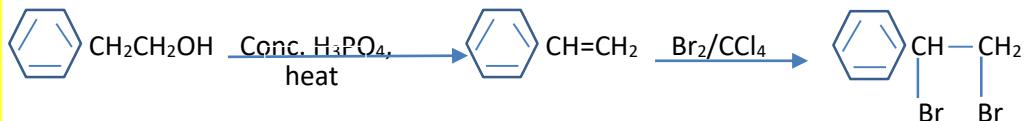
Solution



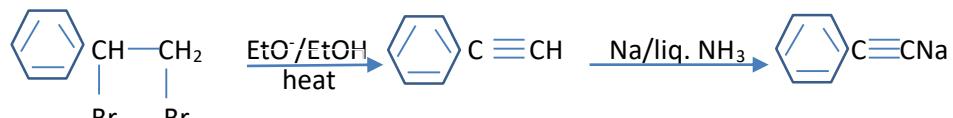
Then



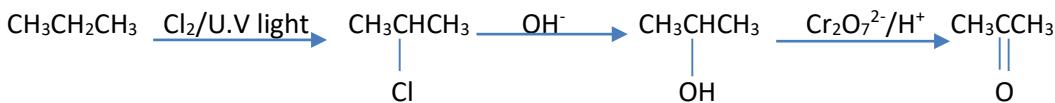
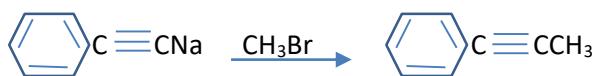
(c)



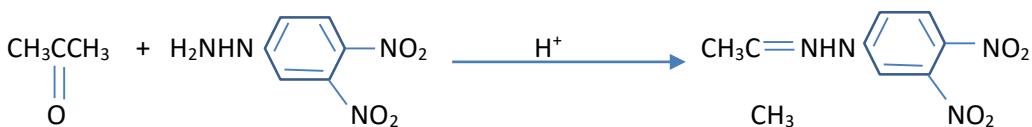
Then



Then



Then



(e)

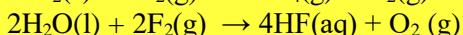
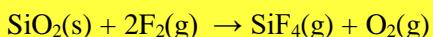


6. (a) (i) Explain why fluorine shows some differences in its properties from the rest of the group 7 elements (chlorine, bromine, and iodine) of the periodic table: (3marks)
- It has high electronegativity
  - It has small atomic radius
  - It has abnormally low bond energy
- (ii) State the different between the Chemistry of fluorine and the rest of the elements of group VII of PT. (8marks)

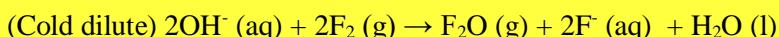
- Fluorine is the most electronegative element and displaces all other halogens from their ionic halides.



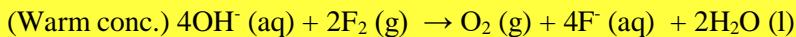
- Fluorine substitutes oxygen from silicon dioxide and water.



- Fluorine reacts with cold dilute solutions of alkalis to give oxygen difluoride;  $\text{F}_2\text{O}$ , and with warm concentrated alkalis to give oxygen.

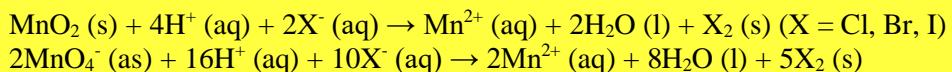


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- (b) Describe one general method for preparing the halogens (excluding fluorine) in the laboratory and write equations for the reactions. (4½ marks)

by reacting halides with acidified potassium permanganate (VII) or manganese dioxide



- (ii) How can you distinguish between sodium bromide and sodium iodide, given chlorine water and tetrachloromethane (2 ½ marks)

When chlorine is bubbled in a mixture of aqueous sodium bromide or sodium iodide with tetrachloromethane, bromine or iodine are liberated staining tetrachloromethane layers orange or black respectively.

- (iii) The acidity of halogens acids decrease in the order  $\text{HI} > \text{HBr} > \text{HCl}$  although their ionic characters increase in the reverse order. (3 marks)

the acidity decrease due to increase in the H-X bond strength  $\text{HI} < \text{HBr} < \text{HCl}$  whereas ionic strength increases due to increase in electronegativity of halogens from  $\text{I} < \text{Br} < \text{Cl}$ .

7. Carbon, silicon, tin and lead are elements in group IV of the periodic table.

- (a) State

- (i) the common oxidation state of group (IV) elements of the periodic table (01 marks)

+2 and +4

- (ii) how the stability of the oxidation states of group IV element vary down the group. (Illustrate your answer with the chloride of carbon and lead) (03 marks)

Stability of +2 increases down the group while that of +4 decreases down the group for example carbon form stable carbon (IV) chloride while lead form stable lead (II) chloride. Carbon does not form  $\text{CCl}_2$

- (b) Give a reason for your answer in (a)(ii) (01 marks)

Stability oxidation state +2 increases down the group due to inert pair effect

(c) Discuss the reaction of the chloride of each element with water (06marks)

$\text{CCl}_4$  does not hydrolyse in water

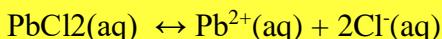
$\text{SiCl}_4$ ,  $\text{GeCl}_4$ ,  $\text{SnCl}_4$ ,  $\text{PbCl}_4$  hydrolyze in water forming dioxides and hydrochloric acid



$\text{SnCl}_2$  partially hydrolyze in water



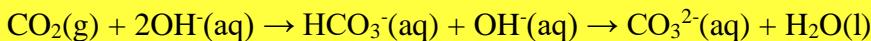
$\text{PbCl}_2$  ionizes in water



(d) Write equations for the reactions between

(i) the oxide of each element and sodium hydroxide (06marks)

Carbon dioxide reacts to give carbonate and hydrogen carbonates



$\text{SiO}_2$ ,  $\text{GeO}_2$ ,  $\text{SnO}_2$  and  $\text{PbO}_2$  react to give complexes

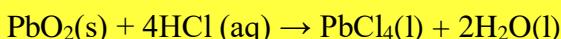


$\text{CO}$  does not react with sodium hydroxide

$\text{PbO}$  forms a complex



(ii) lead (IV) oxide and cold concentrated hydrochloric acid (1 ½ marks)



(iv) Lead (IV) oxide and warm concentrated hydrochloric acid (1 ½ marks)



8. Briefly explain each of the following observation:

(a) Sodium chloride melts at  $800^\circ\text{C}$  whereas aluminium chloride sublimes at  $180^\circ\text{C}$ . (03marks)

$\text{Al}^{3+}$  has a big charge and small radius leading to high charge density it strongly polarizes chloride ions forming a covalent compound with low sublimation temperature whereas  $\text{Na}^+$  has low charge density that  $\text{NaCl}$  is strongly ionic leading high melting point.

(b) Graphite and copper are both conductors of electricity. (04marks)

Graphite and copper have free delocalized electrons that are free to conduct electricity. The free Mo

For any

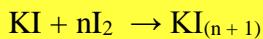
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electrons of graphite are the unbonded p-electron while for copper is the d- electrons

- (c) Iodine is much more soluble in potassium iodide than water. (03marks)

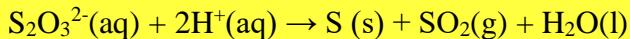
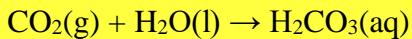
Iodine forms a soluble complex with potassium iodide



- (d) A solution of sodium thiosulphate become cloudy with the formation of

a yellow precipitate when left in air. (02marks)

carbon dioxide reacts with water to form acidic solution that decomposes sodium thiosulphate to insoluble yellow sulphur.



- (e) Phenylamine is a weaker base than ethylamine. (04marks)

The phenyl group withdraws electrons from nitrogen atom reducing the ability of its lone pair to pick a proton from water and form hydroxyl ions whereas the ethyl group donates electrons to nitrogen group and increases the ability its lone pair of electron to pick a proton and form hydroxyl ions

- (f) Phenol is a stronger acid than cyclohexanol. (04marks)

The phenyl group withdraws electrons from O-H bond and makes it easy for loss of a proton while the cyclohexyl group donates electrons and stabilizes the O-H bond which makes it difficult to release a proton.

END

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## S6 CHEMISTRY

### Exam 2

### **PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

#### ***Instructions to candidates:***

- Answer five questions, including three questions from section A and any two questions from section B
- Begin each question on a fresh page,
- Mathematical tables and graph papers are provided.
- Non programmable scientific electronic calculators may be used.
- Illustrate your answers with equations where application

C = 12, H = 1 , Na = 23, Pb= 207, I = 127

**SECTION A:**

Answer **three** questions in this section

1. (a) State

- (i) Raoult's law as applied to ideal solutions (1 mark)

The partial pressure of a component in a mixture is a product of its vapor pressure and its mole fraction.

- (ii) Distribution law. (2 marks)

The ratio of concentration of a solute in two immiscible solvents at equilibrium is constant at constant temperatures.

(b) State the two limitations of

- (i) Raoult's law (1 mark)

- formation of a mixture should not involve change in temperature

- formation of a mixture should not involve change in volume

- the forces of attraction between like and unlike molecules should be equal

- (ii) Distribution law (1 mark)

none of the solvent should be saturated

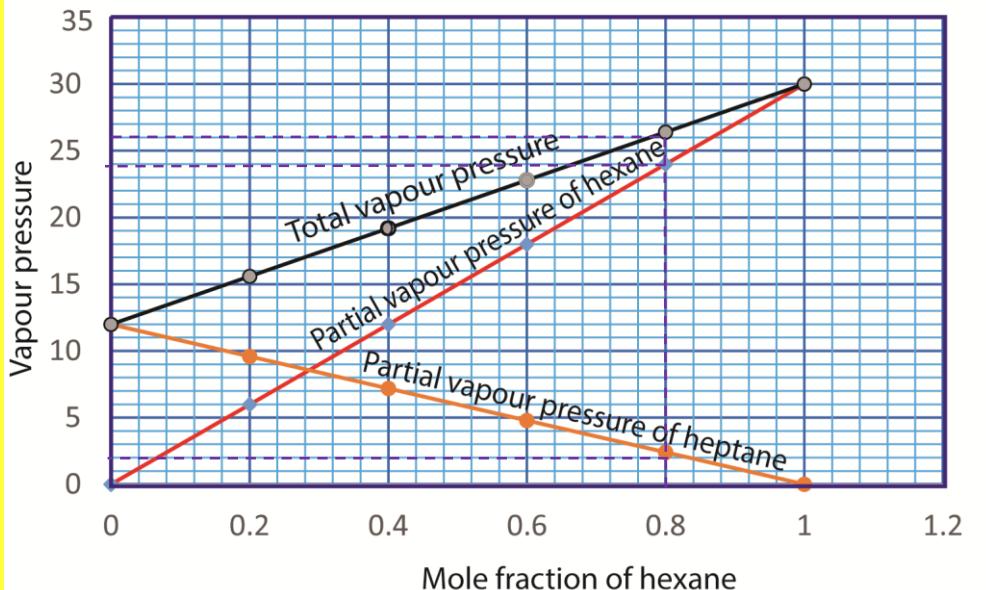
the solute should be in the same molecular state in both solvents.

(c) Hexane and heptane form an ideal solution. At 30°C, the saturated vapour pressures of pure hexane and pure heptane are  $30 \text{ kNm}^{-2}$  and  $12 \text{ KNm}^{-2}$  respectively.

The table below shows the variation of partial vapour pressures of hexane and heptane with composition.

Mole fraction of hexane	0.0	0.2	0.4	0.6	0.8	1.0
Partial vapour pressure of hexane	0	6	12	18	24	30
Partial vapour pressure of heptane	12	9.6	7.2	4.8	2.4	0.0
Total vapour pressure	12	15.6	19.2	22.8	26.4	30

(i) On the same axes, plot a graph of partial vapour pressures and total vapour pressure against composition for hexane and heptane. (4 marks)



Use the graph to determine

- (i) The mole fraction of hexane and heptane when the two liquids have the same partial vapour pressures. (2 marks)

$$\text{The mole fraction of hexane} = \text{mole fraction of heptane} = 0.24$$

- (ii) The masses of hexane and heptane the liquid mixture that produced a total vapour pressure of  $26\text{KNm}^{-2}$ . (4 marks)

$$\text{Partial pressure of heptane} = 24\text{kPa}$$

$$\text{Partial pressure of hexane} = 2\text{kPa}$$

$$\text{Formula mass of hexane} = 6 \times 12 + 14 = 86$$

$$\text{Formula mass of heptane} = 7 \times 12 + 16 = 100$$

$$\text{From } PV = nRT$$

$$\text{Let the mass of hexane be } x$$

$$\frac{24000 \times 1}{86} = \frac{x}{86} \times 8.31 \times (273 + 30)$$

$$x = 820\text{g}$$

$$\text{Let the mass of heptane be } y$$

$$2000 \times 1 = \frac{y}{100} \times 8.31 \times 303$$

$$y = 79\text{g}$$

- (d) An aqueous solution contains 10g of substance Y in 1 litre of solution. When  $100\text{cm}^3$  of this solution was shaken with  $20\text{cm}^3$  ethoxyethane; the ethoxyethane layer extracts 0.8g of Y. Calculate the volume of ethoxyethane that would be required to extract 80% of Y from  $500\text{cm}^3$  of the aqueous solution. (5 marks)

Solution

$$\text{Mass of Y in } 100\text{cm}^3 \text{ of aqueous solution} = \frac{10 \times 100}{1000} = 1\text{g}$$

$$K_D = \frac{[Y] \text{ in ethoxyethane}}{[Y] \text{ in water}} = \frac{0.8}{(1-0.8)} = \frac{0.8}{0.2} = 4$$

$$\text{Mass of Y in } 500\text{cm}^3 = \frac{500 \times 10}{1000} = 5\text{g}$$

$$80\% \text{ of } 5\text{g} = 4\text{g}$$

From

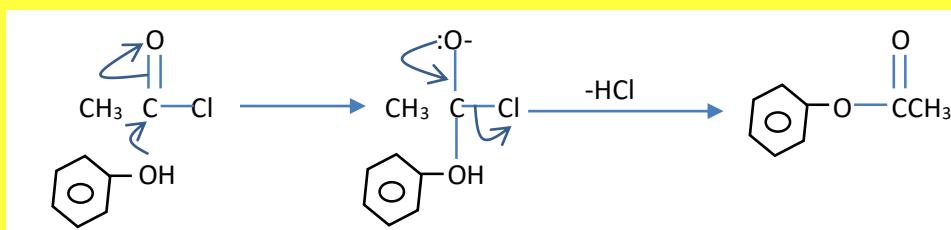
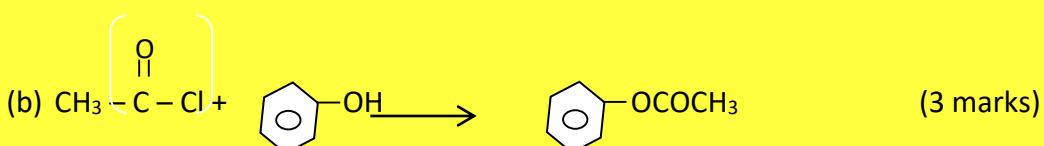
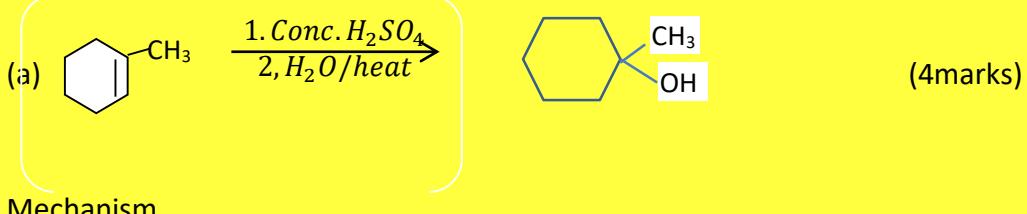
$$K_D = \frac{[Y] \text{ in ethoxyethane}}{[Y] \text{ in water}}$$

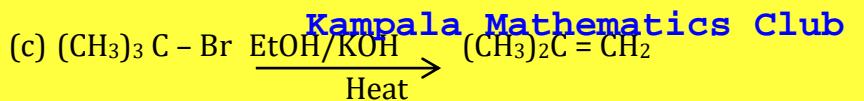
Let the volume be V

$$4 = \frac{4/V}{1/500}$$

$$V = 500\text{cm}^3$$

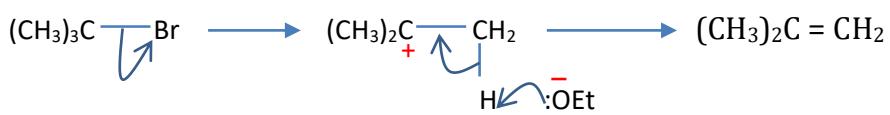
2. Complete the following equations and in each case suggest a mechanism for the reaction



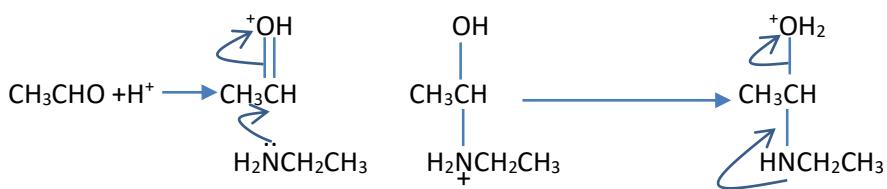


(3 marks)

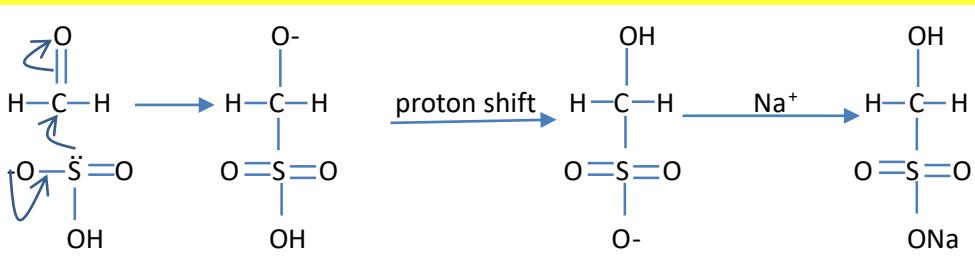
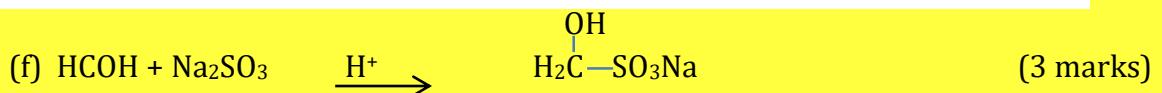
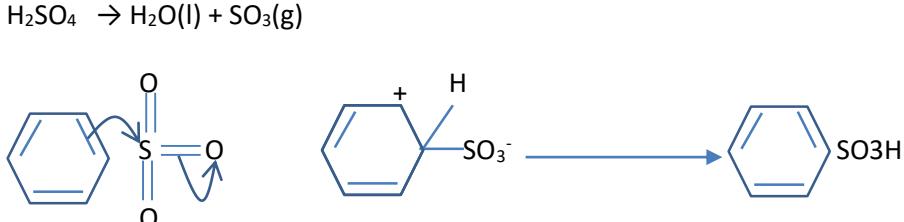
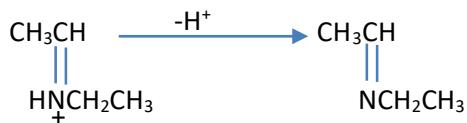
Mechanism



Mechanism



Then



3. Na, Mg, Al, Si, P, S and Cl are the members of period three of the periodic table

(a) State and explain how the following vary across the period

(i) Electro positivity (2 marks)

Electropositivity decrease from Na to Cl to increase in effective nuclear charge, i.e., increase in nuclear charge outweigh increase in screening effect.

(ii) Electro negativity (2 marks)

Increase across the period due to increase in effective nuclear charge, i.e., increase in nuclear charge outweigh increase in screening effect.

(b) (i) Write the formulae of the normal oxides of the elements. (3 ½ marks)

Na<sub>2</sub>O, MgO, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, SO<sub>2</sub>, Cl<sub>2</sub>O<sub>7</sub>

(ii) State the chemical nature of the oxides in b (i) (2 ½ marks)

Na<sub>2</sub>O and MgO are basic

Al<sub>2</sub>O<sub>3</sub> is amphoteric

SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, SO<sub>2</sub>, Cl<sub>2</sub>O<sub>7</sub> are acidic

(c) Discuss the reactions of the oxides of the elements in b (i) with

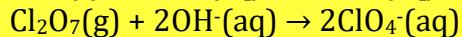
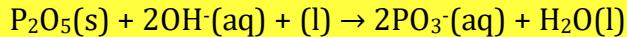
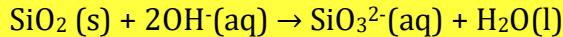
(i) Aqueous sodium hydroxide solution (6mark)

Na<sub>2</sub>O and MgO do not react because they are basic

Al<sub>2</sub>O<sub>3</sub> reacts to form a salt because it is amphoteric



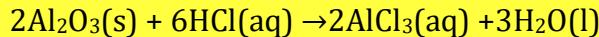
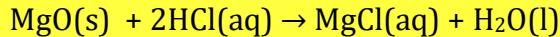
SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, SO<sub>2</sub>, Cl<sub>2</sub>O<sub>7</sub> react to form salts are acidic



(ii) Dilute hydrochloric acid (4mark)

(Your answer should include equations)

Na<sub>2</sub>O, MgO, Al<sub>2</sub>O<sub>3</sub> react because they are basic



4. (a) Explain what is meant by the following terms

(i) Solubility of a salt

Solubility is the mass of solute that saturate 100g of a solvent at a given temperature

(ii) Solubility product

Is the product of molar concentration of ions in a saturated solution of a sparingly soluble salt raised to their stoichiometric ratios in solubility equation at a given temperature.

(iii) Common ion effect (3 marks)

This is the reduction in the solubility of a salt in presence of another solute containing common ion(s).

- (b)(i) Describe an experiment which can be carried out to determine the solubility product of lead (II) iodide. (6 marks)

A given volume (v) of saturated solution is evaporated to dryness the mass (m) of dissolved PbI<sub>2</sub> is determined.

Calculation

$$\text{Concentration in gdm}^{-3} = \frac{1000m}{V}$$

$$\text{Formula mass of PbI}_2 = 207 + 2 \times 127 = 461$$

$$\text{Molarity of solution} = \frac{1000m}{461} \text{ mol dm}^{-3}$$

$$[I^-] = \frac{2000m}{461}$$

$$[Pb^{2+}] = \frac{1000m}{461}$$

$$K_{sp} = \left(\frac{2000m}{461}\right)^2 \left(\frac{1000m}{461}\right) \text{ mol}^2 \text{ dm}^{-6}$$

- (ii) The solubility of lead (II) iodide at 25°C is 0.2904g per litre of water. Calculate the mass of lead (II) iodide that can be precipitated out of solution when 50cm<sup>3</sup> of 0.2M calcium iodide solution was added to 950cm<sup>3</sup> of a saturated solution of lead (II) iodide at 25°C. (6marks)

$$\text{Molarity} = \frac{0.2904}{461} = 6.3 \times 10^{-4} \text{ mol dm}^{-3}$$

$$K_{sp} = (2 \times 6.3 \times 10^{-4})^2 (6.3 \times 10^{-4}) = 1.18 \times 10^{-15} \text{ mol}^2 \text{ dm}^{-6}$$

$$\text{Moles of iodide ions} = \frac{50 \times 0.2}{1000} = 0.01 \text{ moles}$$

$$\text{Let the solubility of lead iodide be } x \text{ mol dm}^{-3}$$

$$K_{sp} = 0.01^2 x = 1.18 \times 10^{-15}$$

$$x = 1.18 \times 10^{-11} \text{ mol dm}^{-3}$$

$$\text{Concentration of PbI}_2 = 1.18 \times 10^{-11} \times 461 = 5.4 \times 10^{-9} \text{ g mol}^{-3}$$

$$\begin{aligned} \text{Mass of PbI}_2 \text{ precipitated} &= 0.2904 \text{ g} - 5.4 \times 10^{-9} \text{ g} \\ &= 0.29039994 \text{ g} \end{aligned}$$

- (iii) State and explain how the solubility of lead (II) iodide can be affected when a small amount of iodine was added to a saturated solution of lead (II) iodide at 25°C. (3 marks)

No effect

- (c) State two applications of solubility product (2 mark)
- Purification of salts
  - gravimetric titration

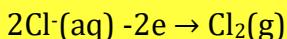
**Kampala Mathematics Club**  
SECTION B:

**Answer any two questions from this section**

5. (a) Describe how chlorine can be prepared in the laboratory. (Diagram not required)

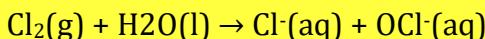
By electrolysis of brine using carbon anode and mercury cathode

Chlorine is liberated at the cathode



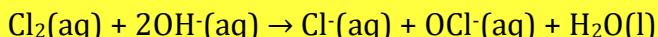
- (b) State how fluorine and chlorine can react with

(i) water

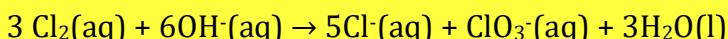


(ii) sodium hydroxide

Dilute sodium hydroxide



Concentrated sodium hydroxide



(Your answer should include equations)

(7 marks)

- (c) Explain the following observations,

(i) aluminium fluoride is ionic whereas aluminium chloride is covalent (3 marks)

Chloride ions are bigger than fluoride ions thus are easily polarized by aluminium ions to form a covalent compound while fluoride ion are not

(ii) hydrofluoric acid is a weak acid whereas hydrochloric acid is a strong acid

(3 marks)

The H-F bond is stronger than H-Cl making it difficult to release a proton

(iii) F – F bond is much weaker than Cl – Cl bond.

(3 marks)

Fluorine is a small atom that fluorine atoms in a molecule experience strong intermolecular repulsion from non-bonding electrons

6. Write equations to show how the following compounds can be synthesized.



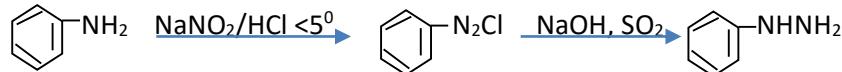
Solution



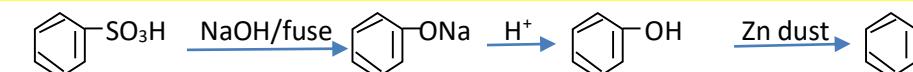
Then



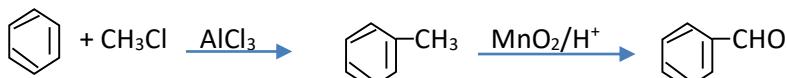
(b) -NNH<sub>2</sub> from -NH<sub>2</sub> (3 marks)

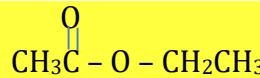


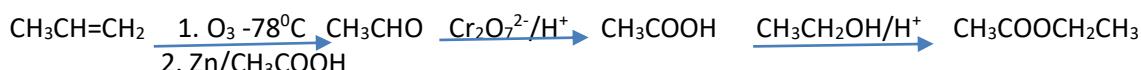
(c) -CHO from  (4 marks)

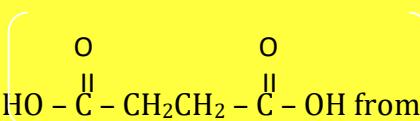


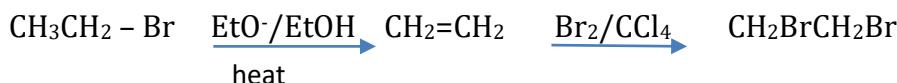
Then



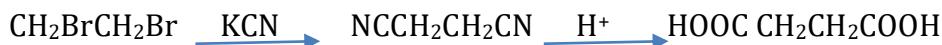
(d) CH<sub>3</sub>CH = CH<sub>2</sub> from  (5 marks)



(e)  from CH<sub>3</sub>CH<sub>2</sub>-Br (5 marks)



Then



7. Explain each of the following observations:

(a) When potassium iodide solution was added to a solution potassium permanganate. A purple solution turned brown. (3 marks)

Potassium permanganate is reduced to manganese (IV) oxide while iodide ions are oxidized to iodine



(b) The partial pressure constant ( $K_p$ ) and concentration equilibrium constant ( $K_c$ ) for the dissociation of hydrogen iodide are equal. (3 marks)

Because dissociation of hydrogen iodide gives equation moles of a gas

(c) An aqueous solution of phenol turns blue litmus paper pink while a solution of cyclohexanol in water is neutral to litmus. (4 marks)

The phenyl group withdraws electrons from O-H bond leading to release of a proton while the cyclohexyl group donates electrons and stabilizes the O-H bond

(d) The molar conductivities of  $\text{Li}^+$ ,  $\text{Na}^+$  and  $\text{K}^+$  are 38.7, 50.1 and  $73.5\Omega^{-1}\text{cm}^2\text{mol}^{-1}$  respectively. (3 marks)

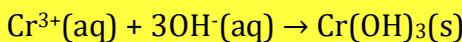
$\text{Li}^+$  has higher charge density than  $\text{Na}^+$  than  $\text{K}^+$ ;  $\text{Li}^+$  attracts a bigger cloud of water than  $\text{Na}^+$  than  $\text{K}^+$ ; this makes the effective size of  $\text{Li}^+$  to be bigger than that of  $\text{Na}^+$  than  $\text{K}^+$ ; the slow speed of  $\text{Li}^+$  lowers its conductivity than that of  $\text{Na}^+$  than  $\text{K}^+$ .

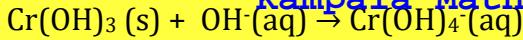
(e) Zinc chloride is a white solid whereas cobalt (II) chloride is a blue solid. (3 marks)

Zinc ions have full d-orbital while cobalt ions do not.

(f) When sodium hydroxide solution was added to chromium (III) sulphate drop wise until in excess and the resultant solution warmed with hydrogen peroxide solution, the violet solution formed green precipitate which dissolved to form a green solution and finally turned yellow on addition of hydrogen peroxide. (4 marks)

Chromium ions forms a green precipitate of chromium (III) hydroxide soluble in excess to form a complex that is oxidized by hydrogen peroxide to form yellow chromate (VI)



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8. 0.3 mole of hydrogen gas was mixed with 0.1 mole of nitrogen gas in a  $2\text{dm}^3$  sealed vessel. The vessel was heated to  $400^\circ\text{C}$  and allowed to stand until equilibrium was attained



- (a) (i) Define the term equilibrium (1 mark)

Equilibrium is said to occur when the rate of forward reaction is equal to the rate of backward reaction

- (ii) State any three characteristics of any chemical equilibrium (3 marks)

- Occurs at constant temperature
- Occurs in closed system
- It is dynamic equilibrium

- (b) Explain the effect of the following in the above equilibrium. (6 marks)

- (i) Increasing the temperature to  $500^\circ\text{C}$

Equilibrium shifts to the left to absorb heat and restore temperature.

- (ii) Adding water to the equilibrium mixture

Equilibrium shifts to right to restore ammonia that dissolves in water

- (c) The sealed tube in (a) above was rapidly cooled and broken under dilute sulphuric acid. The ammonia present was completely absorbed and neutralized by  $25\text{cm}^3$  of  $0.2\text{M}$ sulphuric acid. Calculate the value of the equilibrium constant  $K_c$  at  $400^\circ\text{C}$ . State its units. (6 marks)

$$\text{Moles of sulphuric acid} = \frac{25 \times 0.2}{1000} = 0.005 \text{ moles}$$

$$\text{Moles of ammonia} = 0.005 \times 2 = 0.01 \text{ moles}$$

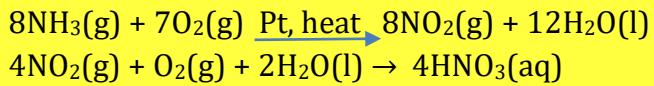
$3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \leftrightarrow 2\text{NH}_3(\text{g})$			
Initially	0.3	0.1	-
Reacted	0.015	0.005	
At Eqbm	0.285	0.095	0.01

$$\begin{aligned} \text{Concn. At Qbm} & 0.285/2 \quad 0.095/2 \quad 0.01/2 \\ & = 0.1425 \quad 0.0475 \quad 0.005 \end{aligned}$$

**Kampala Mathematics Club**

$$K_c = \frac{(0.005)^2}{(0.1425)^2(0.0475)} = 0.182 \text{ mol}^{-2} \text{ dm}^6$$

- (d) The ammonia formed can be used in the manufacture of nitric acid. Write equations to show how ammonia can be converted to nitric acid. (4 marks)



***END***

525/2

## S6 CHEMISTRY

**Exam 2**

**PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

### INSTRUCTIONS TO CANDIDATES:

Answer five questions, including three questions from Section A and any two from Section B.

Write the answers in the answer booklets provided.

Begin each question on a fresh page.

Mathematical tables and graph paper are provided. Non-programmable scientific electronic calculators may be used.

Use equations where necessary to illustrate your answers.

(Where necessary use H=1; C=12; N = 14; O=16).

**SECTION A: (60 MARKS)**

*Answer three questions from this section.*

1. (a) State:

(i) what is meant by the term **first ionization energy**. (01 mark)

First ionization energy is energy required to remove an electron from gaseous atom to form a gaseous ion with a single positive charge.

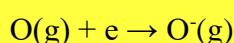
(ii) **two** factors that can determine the value of first ionization energy and explain how the factors affect the value of first ionization energy. (04 marks)

- atomic radius: the smaller the atom is the higher the first ionization energy because valence electrons experience strong nuclear attraction.
- Electronegativity: the higher the electronegativity of an atom I the higher the first ionization energy because electrons are strongly attracted to the nucleus.

(b) (i) Define the term **first electron affinity**. (01 mark)

First electron affinity is energy change when an electron is added to gaseous atom to form gaseous ion with single negative charge.

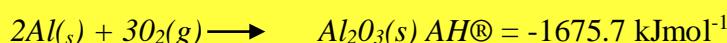
(ii) Write equation to show the first electron affinity of oxygen atom. (01 mark)



(iii) Explain why the first electron affinity of oxygen is an exothermic process while the second electron affinity is an endothermic process. (04 marks)

The first electron affinity of oxygen is exothermic because oxygen is highly electronegative; while the second is positive because the first added electron repels the second electron

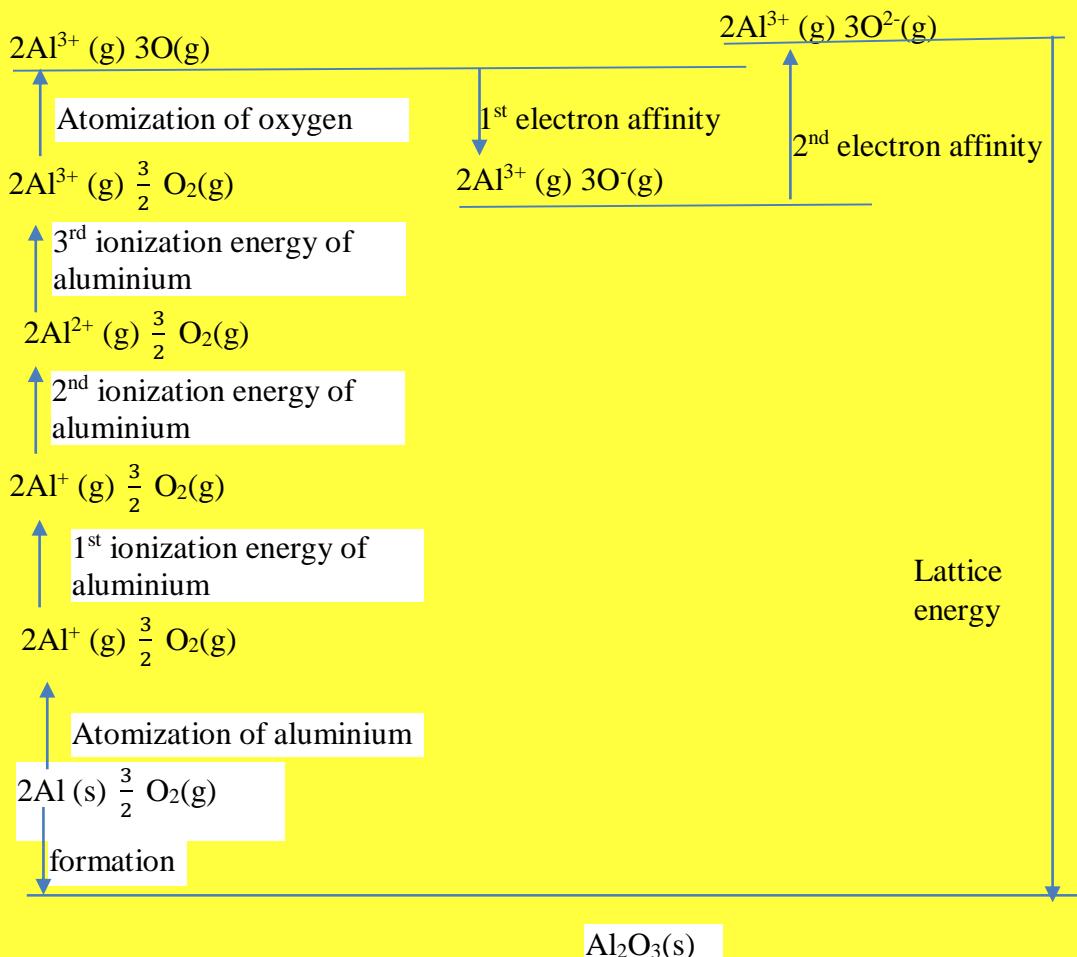
(c) Aluminium reacts with oxygen to form aluminium oxide according to the following equation.



Some thermo-chemical data of aluminium and oxygen are given below.

Heat of atomization of aluminium	= +324.3 kJ mol <sup>-1</sup>
First ionization energy of aluminium	= +578.0 kJ mol <sup>-1</sup>
Second ionization energy of aluminium	= +1817.0 kJ mol <sup>-1</sup>
Third ionization energy of aluminium	= +2745.0 kJ mol <sup>-1</sup>
Atomization energy of oxygen	= +249.2 kJ mol <sup>-1</sup>
First electron affinity of oxygen	= -141.4 kJ mol <sup>-1</sup>
Second electron affinity of oxygen	= +844.0 kJ mol <sup>-1</sup>

- (i) Draw an energy level diagram for the formation of aluminium(III) oxide. (05 marks)



- (ii) Calculate the lattice energy of aluminium(III) oxide. (04 marks)

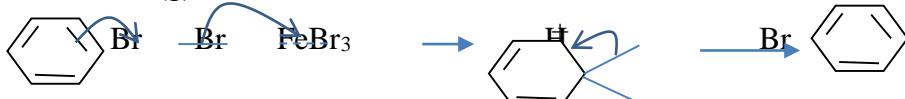
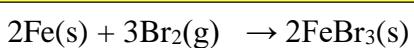
$$-1675.7 = 324.3 \times 2 + 578.0 \times 2 + 1817 \times 2 + 2745.0 \times 2 + 249.2 \times 3 - 141.4 \times 3 \\ + 844.0 \times 3 + \text{Lattice energy}$$

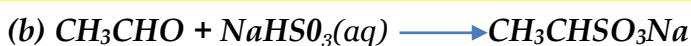
$$\text{Lattice energy} = -15459.7 \text{ kJ mol}^{-1}$$

- (iii) Comment on the value of lattice energy obtained in (c)(ii). (04 marks)

Lattice energy is highly exothermic showing that aluminium oxide is very stable

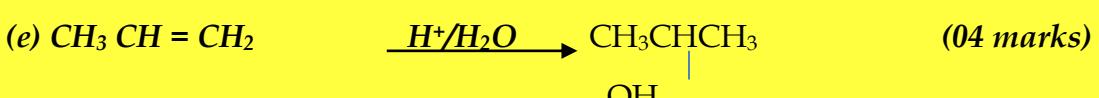
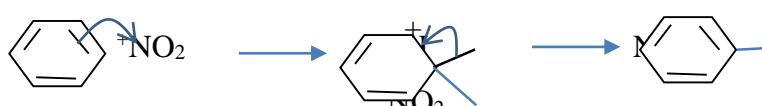
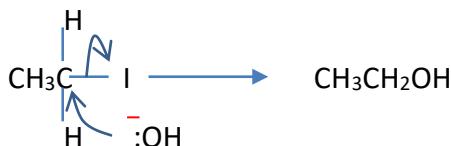
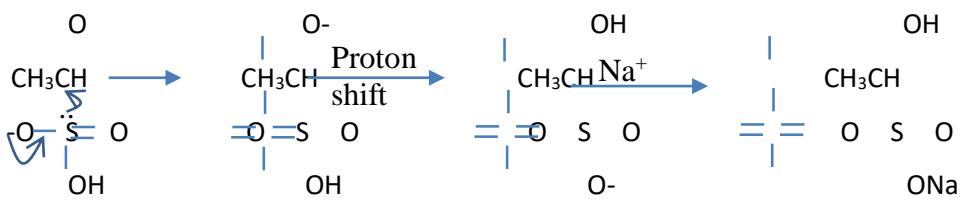
2. Complete the following equations and in each case outline a mechanism for the reaction.



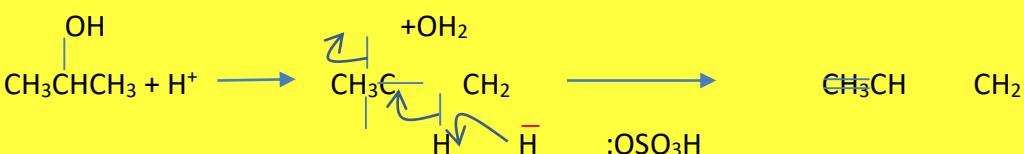
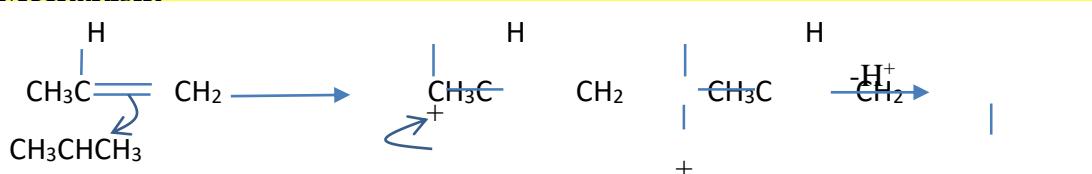


OH (2½ marks)

Mechanism



Mechanism



2. Beryllium, magnesium, calcium, strontium and barium are elements in group II of the Periodic Table.

(a) Describe the reaction of the elements with:

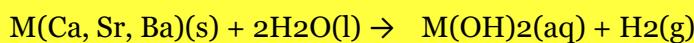
(i) water. (3½ marks)

Be does not react with water

Mg reacts slowly with water to form magnesium hydroxide and rapidly with steam to form magnesium oxide and hydrogen



Ca, Sr, and Ba react to form hydroxides with increasing vigor



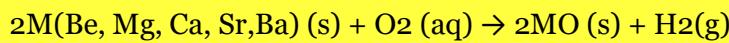
(ii) dilute hydrochloric acid. (3 ½ marks)

All group (II) elements react with dil. and conc. HCl to form chlorides



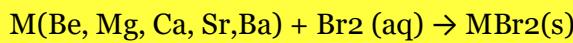
(iii) oxygen. (03 marks)

All group (II) elements react with oxygen to form oxides



(iv) bromine. (02 marks)

All group (II) elements react with bromine to form bromides



(b) State the reasons why beryllium differs from the rest of the group II members. (3½marks)

- Has small atomic radius
- Has high electronegativity
- Its ions have high polarizing power

(c) (i) Name the reagent that can be used to distinguish between calcium and barium ions. (01 mark)  
*potassium chromate followed by dilute ethanoic acid*

(ii) State what would be observed and write equation(s) for the reaction(s) that would take place if the reagent you have named in (c)(i) was treated separately with calcium and barium ions.

(3 ½ marks)

$\text{Ba}^{2+}\text{(aq)}$  – yellow ppt insoluble in dilute ethanoic acid

$\text{Ca}^{2+}\text{(aq)}$  – no observable change or yellow ppt soluble in dilute ethanoic acid

**Turn Over**

4. (a) State what is meant by the term;

(i) Radio-activity. (01mark)

Is spontaneous disintegration of unstable nuclides

(ii) Half-life. (01mark)

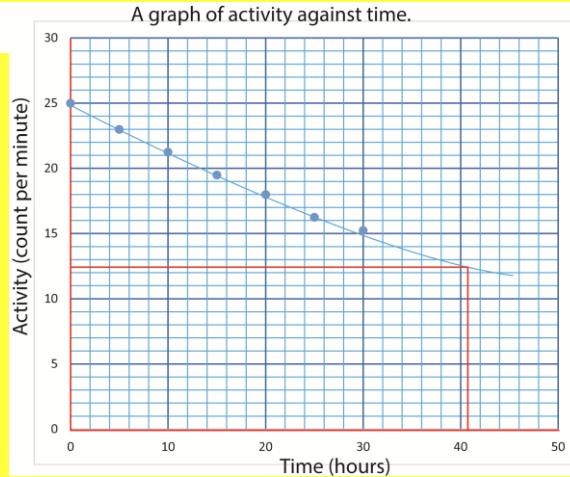
For any ass

This is the time taken by a radioactive substance to reduce to half its original value

- (b) The table below shows data for radio-active decay of an element Z.

Time (hours)	0.0	5.0	10.0	15.0	20.0	25.0	30.0
Activity (count per minute)	25.00	23.00	21.25	19.50	18.00	16.50	15.25

- (i) Plot a graph of activity against time. (03 marks)



- (ii) Determine the value of the half-life of element Z. (½ marks)

41 hour

- (iii) Determine the decay constant and state its unit. (02 marks)

Decay constant,  $K = \ln 2 / \text{half life} = 0.693 / 41 = 0.0169 \text{ hour}^{-1}$ .

- (c) The kinetic data for the reaction between substances X and Y are shown in the table below.

Experiment	Initial [X] (mol dm <sup>-3</sup> )	Initial [Y] (mol dm <sup>-3</sup> )	Initial rate (mol dm <sup>-3</sup> s <sup>-1</sup> )
I	$5.0 \times 10^{-3}$	$5.0 \times 10^{-3}$	$3.0 \times 10^{-3}$
II	$1.0 \times 10^{-3}$	$1.0 \times 10^{-2}$	$2.4 \times 10^{-2}$
III	$5.0 \times 10^{-3}$	$1.0 \times 10^{-2}$	$6.0 \times 10^{-3}$

Determine the

- (i) rate equation for the reaction. (02 marks)

$$\text{Rate} = K[X]^2[Y]$$

- (ii) value of the rate constant and state its units. (02 marks)

$$3 \times 10^{-3} = K(5.0 \times 10^{-3})^2(5 \times 10^{-3})$$

$$K = 24000 \text{ mol}^{-1} \text{ dm}^{-3} \text{ s}^{-1}$$

- (iii) initial rate of the reaction when the concentrations of X and Y are  $1.5 \times 10^{-3}$  and  $7.5 \times 10^{-3}$  mol dm<sup>-3</sup> respectively. (01 mark)

$$\text{Rate} = 24000(1.5 \times 10^{-3})(7.5 \times 10^{-3}) = 4.05 \times 10^{-4} (\text{mol dm}^{-3} \text{ s}^{-1})$$

Explain how the following factors affect the rate of a chemical reaction.

(i) Temperature. (3½ marks)

Increase in temperature increases the rate of reaction by increasing the kinetic energy of molecules and rate of collision. Secondly increase in temperature increase the proportions of molecules with energy higher than activation energy

(ii) Concentration. (1½ marks)

Increase in concentration increase the rate of reaction by increasing the rate of collision of molecules

(iii) Surface area (½ marks)

*Increase in surface area increases the rate of reaction by increasing the frequency of collision of molecules*

### **SECTION B: (40 MARKS)**

*Answer two questions from this section.*

5. (a) Ammonium chloride solution gives effervescence with magnesium ribbon, whereas sodium ethanoate solution gives a blue precipitate with aqueous copper (II) chloride solution. Explain the observation. (08 marks)

Ammonium chloride hydrolyze to form acidic solution that reacts with magnesium to liberate hydrogen



While sodium ethanoate hydrolyze to form alkaline solution that form a blue precipitate of copper (II) hydroxide



- (b) The hydrolysis constant of sodium methanoate is  $6.25 \times 10^{-11}$   $\text{mol dm}^{-3}$  at  $25^\circ\text{C}$ .

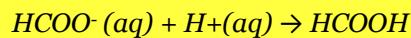
- (i) Calculate the pH of a 0.1M aqueous solution of sodium methanoate at  $25^\circ\text{C}$ . (*Ionic product of water is  $10^{-14}\text{mol dm}^{-3}$  at  $25^\circ\text{C}$* )

*(04 marks)*

*Let the concentration of  $\text{OH}^-$  be  $x$*

$$\begin{aligned} K_h &= \frac{[\text{CH}_3\text{COOH}][\text{OH}^-]}{[\text{CH}_3\text{COO}^-]} = \frac{x^2}{0.1} = 6.25 \times 10^{-11} \\ [\text{OH}^-] &= 2.5 \times 10^{-6} \text{ mol dm}^{-3} \\ [\text{H}^+] &= \frac{10^{-14}}{[\text{OH}^-]} = \frac{10^{-14}}{2.5 \times 10^{-6}} = 4 \times 10^{-9} \text{ mol dm}^{-3} \\ \text{pH} &= -\log \text{H}^+ = 8.3 \end{aligned}$$

- (ii) To 1 dm<sup>3</sup> of 0.1M sodium methanoate solution was added 10 cm of 1 M hydrochloric acid. Calculate the pH of the resultant solution. (*The acid ionization constant, K<sub>a</sub> of methanoic acid is 1.6 x 10<sup>-4</sup> mol dm<sup>-3</sup>.*) (04 marks)



$$\text{Moles of H}^+ = \frac{10 \times 1}{1000} = 0.01 \text{ moles}$$

Moles of  $\text{HCOO}^-$  that remained = 0.1 - 0.01 = 0.09  
 Moles of  $\text{HCOOH}$  formed = 0.01 moles

$$[\text{H}^+] = K_a \frac{[\text{HCOOH}]}{[\text{HCOO}^-]} = 1.6 \times 10^{-4} \frac{0.01}{0.09} = 1.78 \times 10^{-5} \text{ mol dm}^{-3}$$

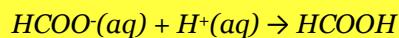
$$\text{pH} = -\log [\text{H}^+] = 4.75$$

- (c) Explain what would happen to the pH of a solution containing sodium methanoate and methanoic acid, if to it was added a small amount of

- (i) hydrochloric acid.

(02 marks)

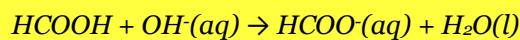
*pH would not change because the added  $\text{H}^+$  are neutralized by methanoate ion*



- (ii) sodium hydroxide.

(02 marks)

*pH would not change because the added  $\text{OH}^-$  are removed by methanoic acid*



6. Explain the following observations:

- (a) Diethylamine is a stronger base than aminobenzene.

(05 marks)

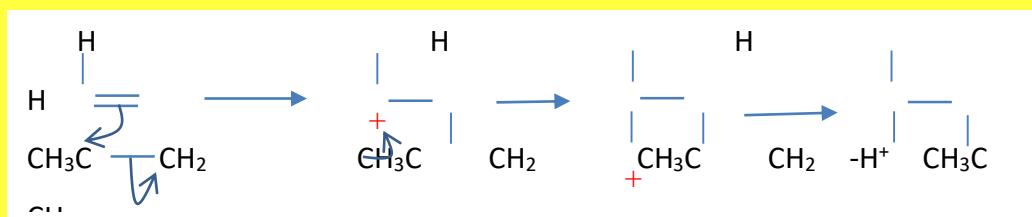
The ethyl

groups donate electrons to nitrogen atom. This increases the density of the lone pair of electron on nitrogen atom and its ability to pull a proton from water and form hydroxyl ions.

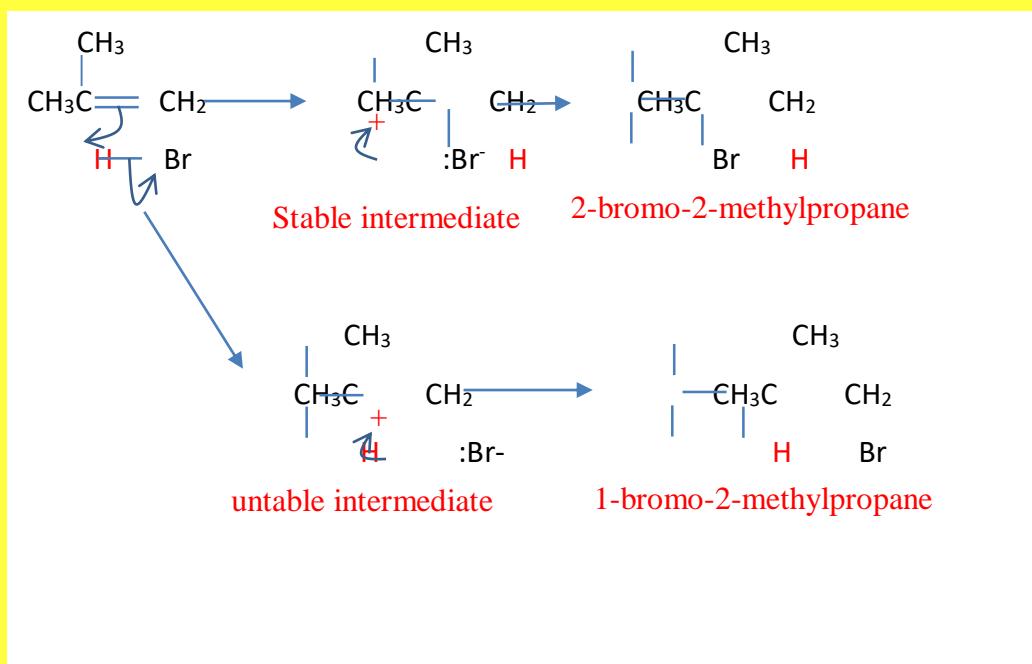
Whereas the phenyl group on amino benzene withdraws electrons from a nitrogen atom. This reduces the density of lone pair of electron and its ability to pull a proton from water and form hydroxyl ions.

- (b) Bromine water reacts with propene to form 1-bromopropan-2-ol as the major product rather than 1, 2-dibromopropane. (5½ marks)

Bromine reacts with propene to a 1-bromo-2-propyl carbonium ion, water being in excess competes with bromide ions and reacts with this ion to form 1-bromopropan-2-ol



- (c) Ethanoic acid is a weaker acid than dichloroethanoic acid. (4½ marks)
- The methyl group in ethanoic acid donates electrons and stabilizes the O-H bond while the electronegative chlorine atoms withdraw electron from O-H bond leading to loss of a proton
- (d) When 2-methylpropene is reacted with hydrogen bromide, the major product is 2-bromo -2- methylpropane rather than 1-bromo -2- methylpropane. (05 marks)
- 2-bromo-2- methylpropane is formed through a stable tertiary carbonium ion (intermediate) while 1-bromo-2-methylprane is formed through unstable intermediate of primary carbonium ion*



**7. Explain the following observations:**

- (a) Lithium carbonate is decomposed by heat, whereas sodium carbonate is not. (3 ½ marks)

*L<sup>+</sup> has a big charge density, it polarizes the carbonate ion to form a covalent compound that decomposes at low temperature while sodium has low charge density, it forms an ionic compound with carbonate ions of a higher decomposition temperature than that produced in the laboratory.*

- (b) Lead(IV) chloride exists but lead(IV) bromide does not. (2 ½ marks)

*Chlorine is a strong oxidizing agent, it oxidizes Pb<sup>2+</sup> to Pb<sup>4+</sup> whereas bromine a weaker oxidizing agent does not*

- (c) Nitrogen is a gas at room temperature whereas phosphorous is a solid at the same temperature, yet both of them belong to the same group in the Periodic Table. (08 marks)

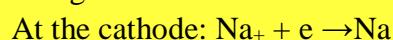
*Phosphorus exist as P<sub>4</sub> molecules while nitrogen exist as N<sub>2</sub>. The heavy P<sub>4</sub> molecules are held by stronger van der Waal forces than the lighter N<sub>2</sub> molecules.*

- (d) Iron(II) ions are readily oxidized to iron(III) ions, whereas manganese(II) ions are not oxidized to manganese(III) ions. (Atomic number of iron and manganese are 26 and 25 respectively.) (06 marks)

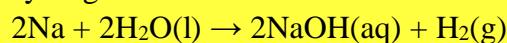
$Fe^{2+} ([Ar]3d^6)$  ions has unstable electron configuration and is easily oxidized to  $Fe^{3+} ([Ar]3d^5)$  with stable electron configuration while  $Mn^{2+} ([Ar]3d^5)$  has a stable electron configuration thus cannot be oxidized to  $Mn^{3+} ([Ar]3d^4)$  with unstable electron configuration

8. (a) *Describe how sodium hydroxide can be prepared on industrial scale.  
(Your answer should include equations for the relevant reactions.)* (06 marks)

By electrolysis of brine using carbon anode and mercury cathode. Chlorine is liberated at the anode while sodium is liberated at the cathode forming sodium amalgam



The sodium amalgam is dissolved in water to produce sodium hydroxide and hydrogen



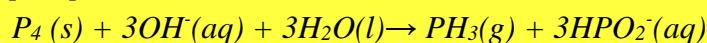
Sodium hydroxide solution is concentrated to form pellets

- (b) *Write equations and state the conditions under which sodium hydroxide can react with*

- (i) aluminium. (2marks)

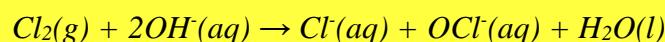


- (ii) phosphorous. (2marks)



- (iii) chlorine. (05 marks)

with dil  $NaOH$



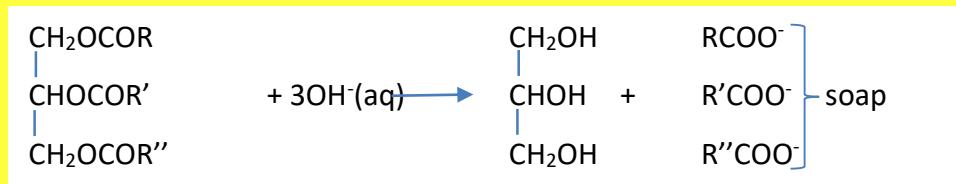
With Conc.  $NaOH$



- (c) (i) *Describe how soap is manufactured from sodium hydroxide and oil or fat.* (03 marks)

Vegetable oil or fat is boiled with concentrated sodium hydroxide then a saturated solution sodium chloride is added to precipitate soap and soap is skimmed off.

- (ii) *Write equation for the reaction leading to the formation of soap. (01 mark)*



**525/2**

**S6 CHEMISTRY**

**Exam 4**

***PAPER 2***

**DURATION: 2 HOUR 30 MINUTES**

**INSTRUCTIONS**

Answer any five questions including three questions from section A and any two from section B.

Write the answer I the answer booklets provided.

Begin each question from a fresh page

Mathematical tables and graph papers are provided

Non programmable scientific electronic calculators may be use

Use equations where necessary to illustrate your answers.

(C=12, O=16, H=1)

**SECTION A**

1. (a) A compound X, vapor density 58, contains carbon 62.07%, hydrogen 10.34% and the rest being oxygen. X does not burn with a sooty flame.

i. Calculate the empirical formula of X

(3 marks)

$$\text{Percentage of oxygen} = (100 - (62.07 + 10.34)) = 27.59$$

Element	C	H	O
percentages	62.07	10.34	27.59
RAM	12	1	16
Moles	5.1725	10.34	1.72
Mole ratio	3	6	1

Empirical formula:  $\text{C}_3\text{H}_6\text{O}$

ii. Determine the molecular formula

(2 marks)

$$\text{Molecular mass} = 2 \times 58 = 116$$

$$(\text{C}_3\text{H}_6\text{O}) n = 116$$

$$n = 2$$

$$\text{molecular formula} = \text{C}_6\text{H}_{12}\text{O}_2$$

- b. Hydrolysis of X yielded compounds, Y,  $\text{C}_4\text{H}_{10}\text{O}$  and Z,  $\text{C}_2\text{H}_4\text{O}_2$ . Both Y and Z react with metallic sodium. Z reacted with sodium carbonate but Y did not.

(i) Identify Z.

(1 mark)

$\text{CH}_3\text{COOH}$ , ethanoic acid

(ii) Write names and the structural formulae of all the possible isomers of Y.

(4 marks)



- (iii) Name a reagent that can be used to distinguish between the isomers in (b) (ii) and state what would be observed if the reagent you have named is reacted separately with each of the isomers.

(4 marks)

Reagent: anhydrous zinc chloride and concentrated hydrochloric acid

Observations

Butan-1-ol and 2-methylpropan-1-ol show no observation

Butan-2-ol show cloudiness in 5- 10 minutes

2-methylpropan-2-ol show immediate cloudines

c. When Y was warmed with acidified potassium dichromate solution, there was no observable change.

i. Identify Y. (1mark)

2-methylpropan-2-ol

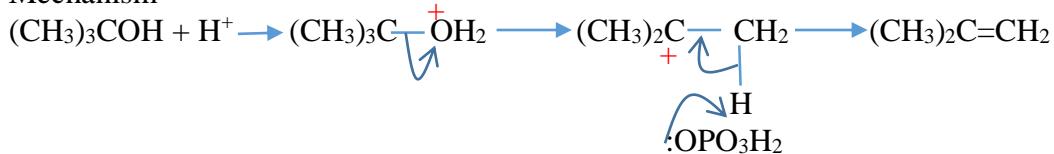
ii. write the structural formulae of Y (2mark)

$(\text{CH}_3)_3\text{COH}$

d. (i) write equation and outline a mechanism for the reaction between Y and concentrated phosphoric acid (3½ marks)



Mechanism



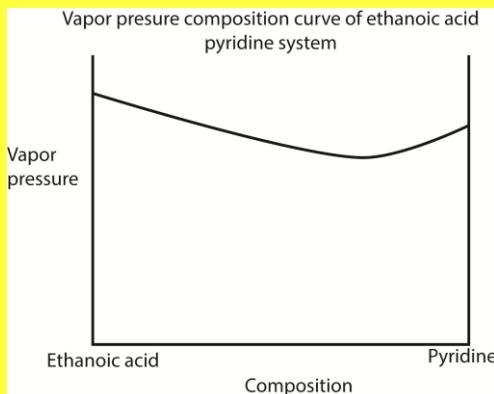
(ii) Write the IUPAC name of the product in d(i). (½ mark)

3-methylpropene

2. (a) state **Raoult's Law**. (3 marks)

(b) A mixture of ethanoic acid (B.P 118°C) and pyridine (b.pt. 123°C) show negative deviation from Raoult's law.

(i) Draw the vapor pressure/composition curve for the mixture of ethanoic acid and pyridine and indicate the line of Ideal behavior. (4 marks)



(ii) Explain the shape of the curve in relation to Raoult's Law. (6 marks)

The force of attraction between ethanoic acid and pyridine molecules are stronger than the cohesive forces.

This reduces the rate of evaporation lowering the vapor pressure of the mixture.

The stronger intermolecular forces are due to hydrogen bonds between ethanoic acid and pyridine molecules

(c) (i) Explain what is meant by '**steam distillation**' (3 marks)

It a technique of separating a volatile immiscible substance from nonvolatile substance by heating with steam

(ii) When a compound Y, was steam distilled at standard atmospheric temperature and pressure, the temperature of distillation was  $96^{\circ}\text{C}$ . The vapor pressure of water at this temperature was 730mm Hg and the distillate contained 74% of water.

Calculate the relative molar mass of Y (4 marks)

$$\text{Vapor pressure of Y} = 760 - 730 = 30\text{mmHg}$$

$$\text{Percentage of Y} = 100 - 74 = 26$$

Let the molecular mass of Y be M

$$\frac{26}{74} = \frac{30 \times M}{18 \times 730}$$

$$M = 154$$

3. (a) The first ionization energies of an element B are shown below

Ionization Energy/kJMol <sup>-1</sup>							
1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>
786	1580	3230	4360	16000	20000	23600	29100

(i) Explain what is meant by the term *First ionization energy*?

Energy required to remove an electron from a gaseous atom to form a positively charged ion with a single positive charge.

(ii) State the factors that determine the value of first ionization energy

- atomic radii
- electronegativity
- nuclear charge

(ii) To which group of the periodic table does element B belong

Give reason for your answer

Group IV ; the big difference between the 4<sup>th</sup> and 5<sup>th</sup> ionization energies indicates the 5<sup>th</sup> electron resides in the inner electron shells while the first four electrons reside in outer most shell

(b) Explain the term *electronegativity*.

Electronegativity is the relative tendency of an atom to attract bonding electrons in a covalent bond of dissimilar atoms

State the factors that determine the value of electronegativity of an element.

- (i) Atomic radius
- (ii) Nuclear charge
- (iii) The screening effect of the inner electrons

(c) Explain how the following factors affect the value of electronegativity of an element

- (i) Atomic radius

Small atom have high electronegativity because its valence electrons are strongly attracted to the nucleus

- (ii) Nuclear charge

The higher the nuclear charge the higher the electronegativity because its valence electrons are strongly attracted to the nucleus

- (iii) The screening effect of the inner electrons

When the screening effect is high, electronegativity is low because valence electrons are repelled from the nucleus

(d) Explain the difference between electronegativity and electron affinity.

Electronegativity is the relative tendency of an atom to attract bonding electron in a covalent bond while electron affinity is energy change when an electron is added to gaseous atom or a negatively charged gaseous ion

4. (a) Define the term *eutectic mixture*.

(3 marks)

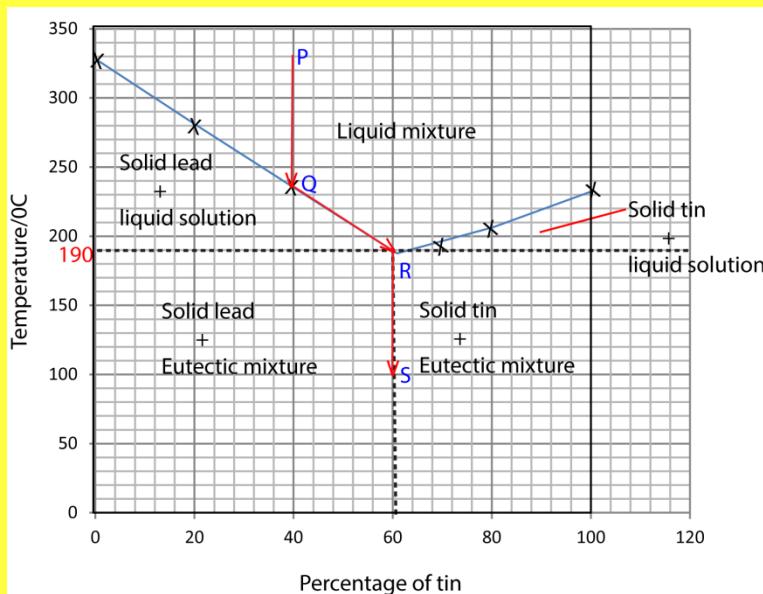
This is a liquid mixture that solidify at constant temperature to give a solid of the same composition

(b) The table below shows the melting points f various mixtures of lead and tin.

% tin	0	20	40	70	80	100
Melting point/ <sup>0</sup> C	327	280	234	193	206	232

(i) Draw a fully labeled diagram for the tin-lead system.

(5 marks)



- (ii) Determine the eutectic temperature and the composition of the eutectic mixture (3 marks)

Eutectic composition 60% tin,  
Eutectic temperature  $190^0\text{C}$

- (c) Describe the changes that would take place when a liquid mixture of the above system containing 40% tin is cooled from  $400^0\text{C}$  to  $100^0\text{C}$ .

The temperature of the liquid falls from  $400^0\text{C}$  to about  $235^0\text{C}$  along PQ (shown on the graph); at Q solid lead crystallizes out and the freezing point of the remaining solution drops along QR as more lead solidifies. At R ( $190^0\text{C}$ ) the composition of tin will be 60%, temperature remains constant until all the liquid has turned into a solid before the temperature drops further to  $100^0\text{C}$  along RS.

- (d) (i) State one application of the lead-tin eutectic mixture (1 mark)  
Welding  
(ii) Name one other pair of metals which can give a similar phase diagram as in (b) (i). (1 mark)  
Zn and Cd, Cu and Zn, Ca and Mg, Pb +Ag  
(iii) State one similarity between a eutectic mixture and pure metal (1 mark)  
both have a sharp melting point  
Have same cooling curve  
Have the same composition in solid as in liquid

**SECTION B**

5. (a) Describe the spectrum of a hydrogen atom.

Use diagrams to illustrate your answer

(7 marks)

Hydrogen produces both absorption and emission spectrum

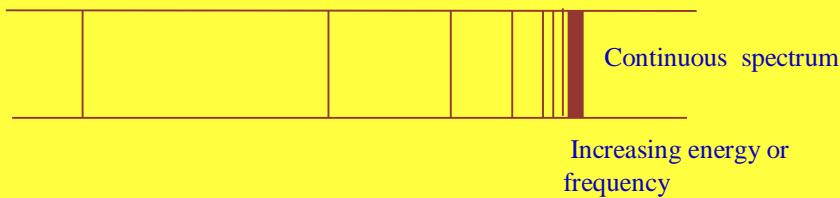
- (i) Absorption spectra

It is observed as dark lines on a black background when white light is passed through gaseous hydrogen. This is caused by hydrogen atoms absorbing energy corresponding to certain wavelengths from the light.

- (ii) Emission

It is observed as a pink glow when an electric discharge is passed through hydrogen at low pressure. Analyzed through a spectrometer, the emission is seen to be a number of separate sets of lines or series of lines.

In each series, the intervals between the frequencies of the lines become smaller and smaller towards the high frequency end of the spectrum until the lines run together or converge to form a continuum of light or continuum.



- (b) Explain how the spectrum of a hydrogen atom

- (i) is formed

(4 marks)

When a hydrogen atom in ground state is struck by light, its electron absorbs energy of certain wavelength/frequency. The absorbed frequency appears as a dark line in absorption spectrum

After absorbing energy, an electron jumps to a higher energy level. Energy absorbed is equal to the energy difference between two the energy levels. When the excited electron drops to the orbits of a lower energy level, it emits this energy in form of radiation giving, an emission spectrum corresponding to the frequency of radiation emitted.

- (ii) Provides evidence for the existence of energy levels in an atom

(7 marks)

- The fact that the hydrogen spectrum is a line spectrum, suggests that only specific amounts of energy absorptions and emissions are possible suggesting existence of energy levels within an atom and that an electron occupies certain energy levels

around the nucleus. The various lines in each series are suggestive that the main energy levels are subdivided into lower energy levels.

- The spacing between adjacent lines in each series of the spectrum decreases with in the direction of decreasing wavelength showing that the series lines are produced from radiations of differing wavelengths that are emitted as a result of electron transitions from different energy levels.

- (c) The frequency of hydrogen at the point of ionization id  $32.8 \times 10^{14}$ Hz

Calculate the ionization energy of hydrogen. (Planks constant =  $6.6 \times 10^{-34}$ JS (2 marks)

$$\text{Energy} = hf \quad (h \text{ is Plank's constant, } f = \text{frequency})$$

$$= 6.6 \times 10^{-34} \times 32.8 \times 10^{14}$$

$$= 2.165 \times 10^{-18}\text{J or } 2.165 \times 10^{-21}\text{ kJ}$$

But 1 mole contains 6.023 particles, according to Avogadro

$$E = 2.165 \times 10^{-21} \times 6.023 \times 10^{23} = 1304 \text{ kJ}$$

6. (a) (i) Define “Standard Electrode potential” (2marks)

is the electrode potential value of an electrode measure with respect to a standard hydrogen electrode of 0 volts. When an electrode is immersed or dipped into a solution of 1M concentration of its ions at a standard temperature of 298K and pressure of 1 atmospheres.

- (ii) Why is it not possible to measure standard electrode potential absolutely?(2marks)

it requires a second electrode to be introduced since it's a difference in potential; the second electrode also produces its own electrode potential making such a difference relative rather than absolute

- (iii) Discuss the factors which affect the value of standard electrode potential(5½marks)

$$\begin{aligned}\text{Electrode potential} &= \text{sublimation energy} \\ &+ \text{ionization energy} \\ &+ \text{Hydration energy}\end{aligned}$$

- Sublimation energy: the higher the sublimation energy the more positive the electrode potential. This is because it becomes difficult to convert a solid into gaseous atoms (i.e. sublimation is endothermic)
- Ionization energy: if ionization energy is high; electrode potential becomes more positive because ionization energy is endothermic.
- Hydration energy: a high hydration energy give a more negative electrode potential since hydration is exothermic reaction.

(b) Describe a standard hydrogen half cell (2marks)

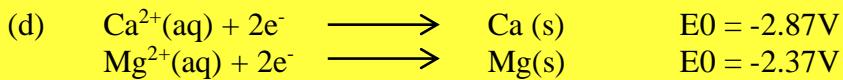
It consists of a molar solution of H<sup>+</sup> ions having platinized titanium or platinum coated with finely divided titanium, around which pure hydrogen gas at 1 atmosphere and 298K (25°) is bubbled.

(c) How would you measure standard electrode potential of a metal in solution of its ions? (3marks)

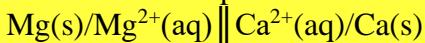
The metal is placed in one molar solution of its ions and connected to the standard hydrogen electrode by a salt bridge

A voltmeter connected in parallel will show the emf of the cell

The standard electrode potential of the metal is equal to the emf shown by the voltmeter, measured relative to the electrode potential of hydrogen electrode considered to be zero



A cell was set up as below



(i) Calculate the e.m.f of the cell (2marks)

$$\begin{aligned} E^0_{\text{cell}} &= E^0_{\text{Reduction}} - E^0_{\text{oxidation}} \\ &= -2.87 - (-2.37) \\ &= -0.5\text{V} \end{aligned}$$

(ii) What conclusion can you draw from your e.m.f value in (d)(i) above (3marks)

The cell as set up is non spontaneous because emf is negative. It is spontaneous in the opposite direction.

- 7.(a) Write the name and formula of one ore from which aluminium can be extracted and describe how aluminium is extracted from the ore (08marks)

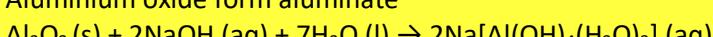
Ore: bauxite  $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$

Extraction of aluminium involves removal of impurities (purification) and then reduction to metal by electrolysis.

Steps in extraction of Aluminium

- (i) The ore is heated
  - to remove water and,
  - To convert iron salts to iron III oxide
- (ii) The powdered ore is heated with concentrated sodium hydroxide to dissolve aluminium oxide and silica such that the insoluble iron oxide is filtered off.

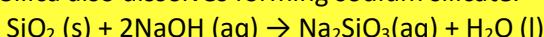
Aluminium oxide form aluminate



Or the ionic form



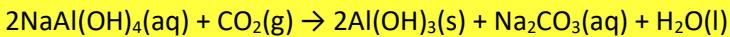
Silica also dissolves forming sodium silicate.



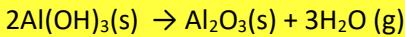
- (iii) To the filtrate a little aluminium hydroxide is added to precipitate Aluminium hydroxide,(seeding).



Alternatively carbon dioxide bubbled through the filtrate to precipitate aluminium hydroxide as follows



- (iv) The precipitated aluminium hydroxide is filtered off, washed and ignited to give pure aluminium oxide (alumina).



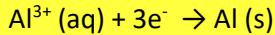
Alumina

- (v) Aluminum is obtained from aluminium oxide by electrolysis.

Cryolite,  $\text{Na}_3\text{AlF}_6$ , is added to

- lower the melting point of alumina from  $2050^\circ\text{C}$  to  $900^\circ\text{C}$
- and improve conductivity of aluminium oxide

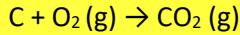
At the cathode (carbon) aluminium is liberated



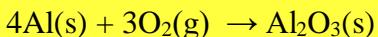
At the anode (carbon) oxygen is liberated



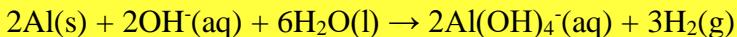
The anode is eaten up by oxygen



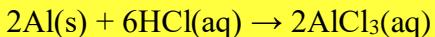
- (b) Write equations and state conditions under which aluminium reacts with  
 (i) Air



- (ii) Sodium hydroxide

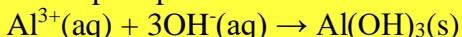


- (iii) hydrochloric acid

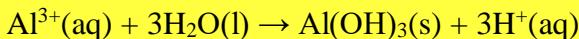


- (c) State what is observed and write equation for the reaction which take place when aqueous ammonia is added drop-wise to a solution containing aluminium ions      (2½ marks)

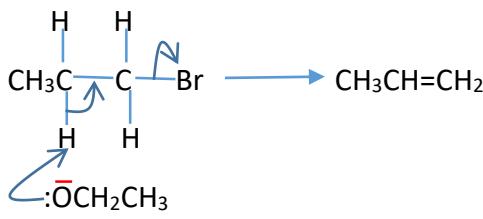
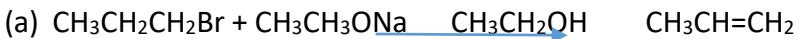
White precipitate insoluble in excess



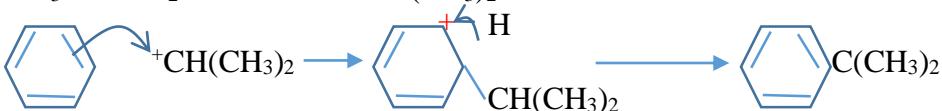
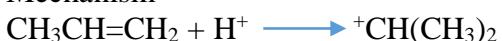
- (d) Write equation for the reaction that take place when aluminium chloride is dissolved in water      (1½ marks)



8. Complete the following equations and in each case outline a mechanism of the reaction

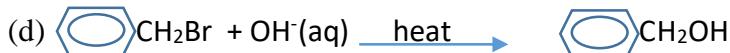
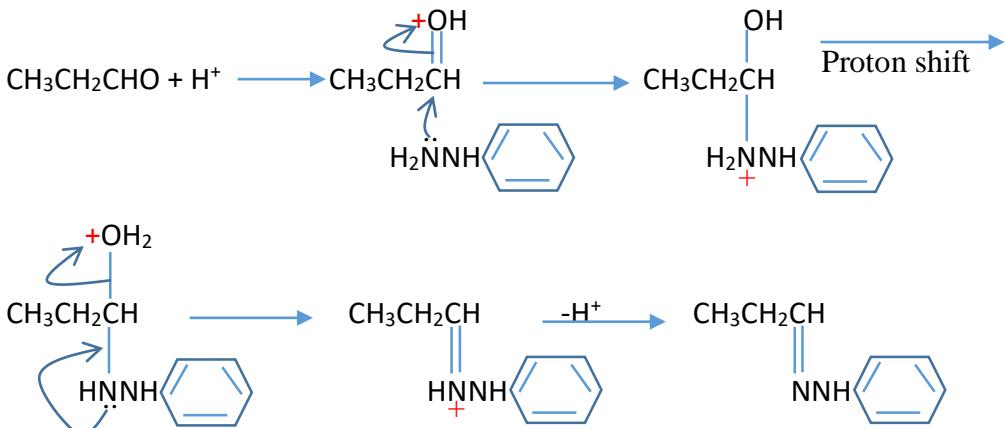


Mechanism

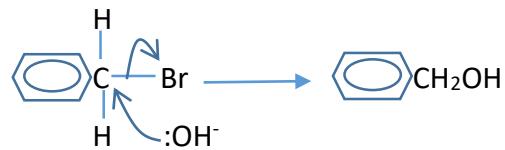




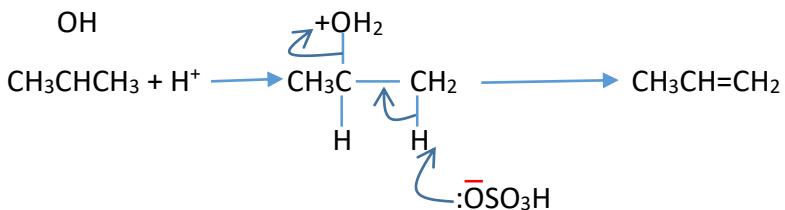
Mechanism

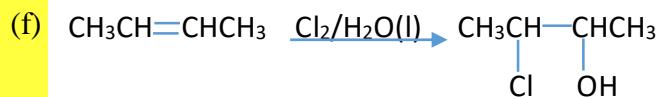


Mechanism

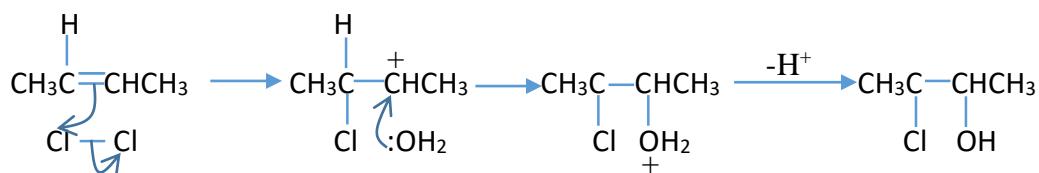


OH





Mechanism



525/2

## **S6 CHEMISTRY**

### **Exam 5**

### **PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

#### **Section A**

Answer any three question

1. The elements Be, mg, Ca, Sr, Ba are in group II of the periodic tabel

- (a) Explain how the following factors vary in the group

(i) Atomic radii (3marks)

Atomic radii increase down the group due to to increase in the number of electron shells and screening effect

(ii) Ionization energy (3marks)

Ionization energy decreases down the group because increase in creening effect outweighs increase in nuclear charge leading to decrease in effective nucelar charge.

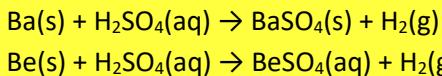
(iii) Electropositivity (3marks)

## Kampala Mathematics Club

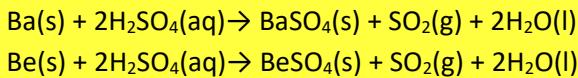
Electropositivity increases down the group because down the group both nuclear charge and screening effect increase but increase in the screening effect outweighs increase in nuclear charge.

- (b) State what would be observed and write an equation for the reaction which takes place when:
- (i) Magnesium is reacted with steam (3marks)  
Violent reaction and formation of white powder  
 $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$
- (ii) Barium is reacted with water (3marks)  
Effervescent giving a colorless solution  
 $Ba(s) + 2H_2O(l) \rightarrow Ba(OH)_2(aq) + H_2(g)$
- (c) Compare the reaction of beryllium and barium with sulphuric acid under various conditions (5marks)

Both beryllium and barium react with dilute sulphuric acid to liberate hydrogen gas but barium reacts for a short time because it forms an insoluble sulphate.



Both beryllium and barium react with hot concentrated sulphuric acid to form sulphur dioxide and water. The reaction of barium is temporary due to the formation of insoluble barium sulphate



2. (a) Differentiate between order and molecularity of reaction (5marks)  
Order of a reaction is the sum of exponents to the concentration terms in a rate equation while molecularity is the number of species that take part in the rate determining step.

- (b) The table below shows some data for the reaction



Expt.	Initial concentration of Moldm <sup>-3</sup> of		Initial rate of reaction Moldm <sup>-3</sup> s <sup>-1</sup>
	A	B	
I	$1.00 \times 10^{-2}$	$2.80 \times 10^{-3}$	2.2
II	$5.00 \times 10^{-3}$	$2.80 \times 10^{-3}$	1.1
III	$1.00 \times 10^{-2}$	$5.60 \times 10^{-3}$	4.4

- (i) Determine the order of reaction with respect to A and B (3marks)  
Order of reaction with respect to A = 1 because halving the concentration of A in experiments I and II halves the rate

# Kampala Mathematics Club

The order of reaction with respect to B = 1 because doubling the concentrations in experiments I and III multiplies the rate by 4 or  $2^2$ .

- (ii) Write the rate equation for the reaction. (1mark)

$$\text{Rate} = K[A][B]$$

- (iii) Calculate the rate constant for the reaction and give its units (2marks)

Using experiment I

$$2.2 = K \times 1.00 \times 10^{-2} \times 2.80 \times 10^{-3}$$

$$K = 78,571 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

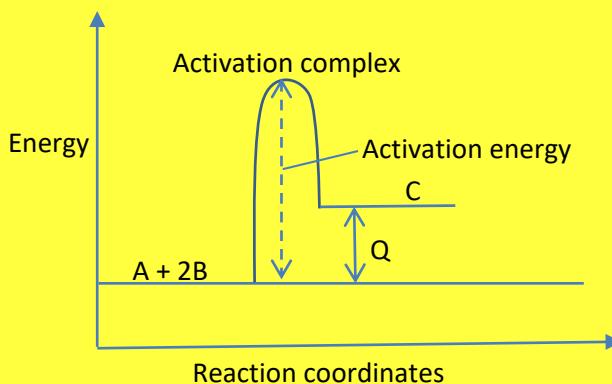
- (iv) Calculate the rate of the reaction when the concentration of A and B are  $8.0 \times 10^{-3}$  mol dm<sup>-3</sup> and  $3.83 \times 10^{-3}$  mol dm<sup>-3</sup> respectively. (2marks)

$$\text{Rate} = 78571 \times 8.0 \times 10^{-3} \times 3.83 \times 10^{-3} = 2.4 \text{ mol dm}^{-3} \text{ s}^{-1}$$

- (v) State What would happen to the order of reaction in (b) if B was present in larger excess. Explain your answer. (3marks)

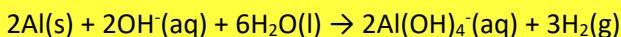
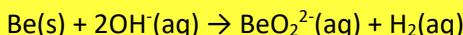
It becomes pseudoorder 1 because when there is negligible change in concentration of B in the reaction

- (vi) Draw a fully labelled energy diagram for the reaction in (b) (4marks)



3. (a) Beryllium, like aluminium can react with sodium hydroxide solution. Other group II elements do not.

- (i) Write ionic equation for the reaction of beryllium and aluminium with sodium hydroxide solution (3marks)



- (ii) List three other properties in which beryllium show similarity to aluminium (4 ½ marks)  
- They both do not react with nitric acid  
- They form covalent polymeric chloride

- They react with sodium hydroxide to liberate hydrogen
- (iii) Explain why beryllium behaves differently from other group II elements. (3marks)
- Beryllium has
- Small atomic radius
  - Its ions has high charge density
  - It iona has high polarizing power
  -
- (iv) Name two other elements which have similar relation ship like beryllium and aluminium. (1marks)
- Lithium and magnesium  
Boron and silicon

(b) The table below shows the ionic radii of sodium, magnesium, and aluminium and the melting points of the chlorides formed by the three cations.

	$\text{Na}^+$	$\text{Mg}^{2+}$	$\text{Al}^{3+}$
Ionic radius (nm)	0.095	0.065	0.050
Mpt. /°C of chlorides	801	712	180(sublimes)

- (i) Calculate the charge/radius ration for each cation (1 ½ marks)

$$\text{Na} = \frac{1}{0.095} = 10.5$$

$$\text{Mg}^{2+} = \frac{2}{0.065} = 15.4$$

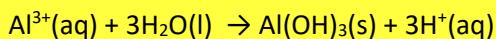
$$\text{Al}^{3+} = \frac{3}{0.05} = 60$$

- (ii) State and explain the trend in the melting points of chlorides for the three elements (5marks)

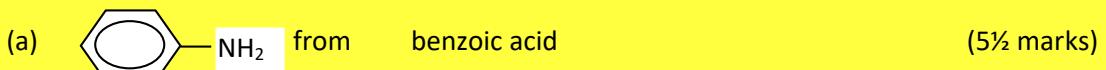
The melting points decrease from  $\text{NaCl} > \text{MgCl}_2 > \text{AlCl}_3$  because polarizing power of the cations increase from  $\text{Na}^+ < \text{Mg}^{2+} < \text{Al}^{3+}$ ; thus the ionic character of the chloride decrease in order  $\text{NaCl} > \text{MgCl}_2 > \text{AlCl}_3$  loweing the melting points

- (iii) Use equations only to explain why aluminium chloride solution has a pH less than 7 (2marks)

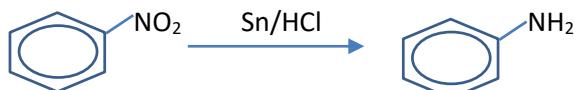
Aluminium ions hydrolyse to form hydrogen ions



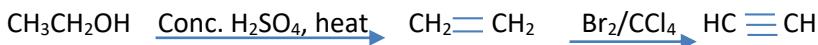
4. Write equation to show how each of the following compounds can be synthesized. In each case, indicate the reagents and conditions for the reaction.



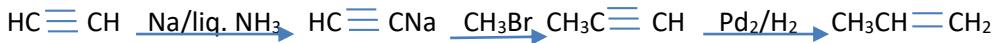
Then



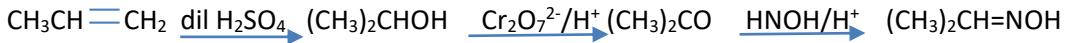
Then



Then



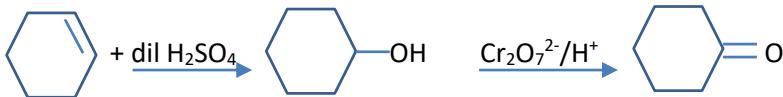
Then



(d)

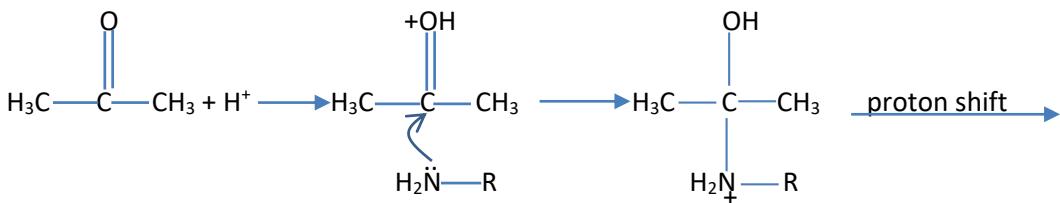
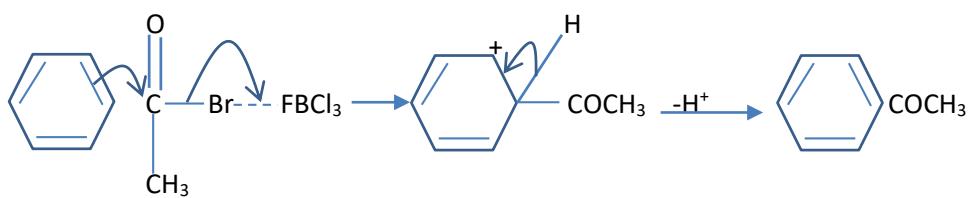


(4marks)

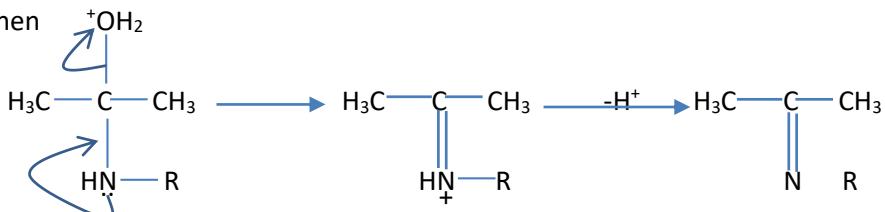


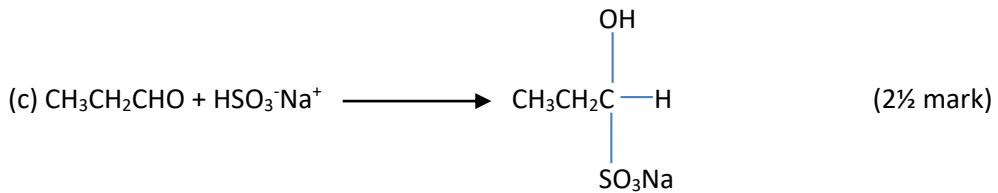
### SECTION B

5. Complete the following equations and in each case outline a mechanism for the reaction

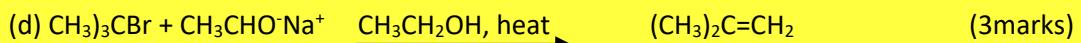
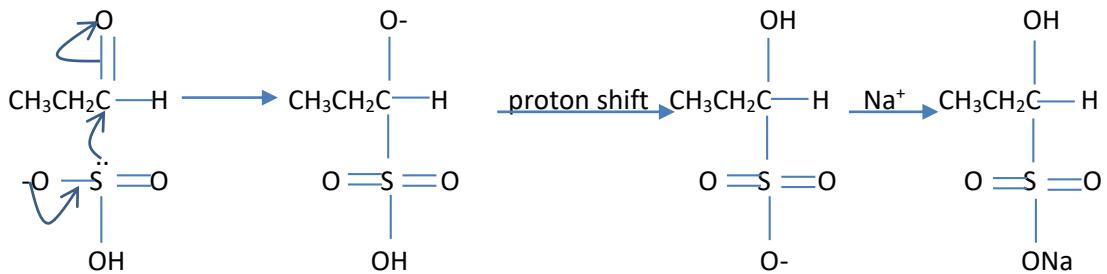


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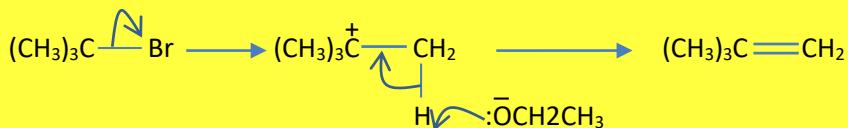




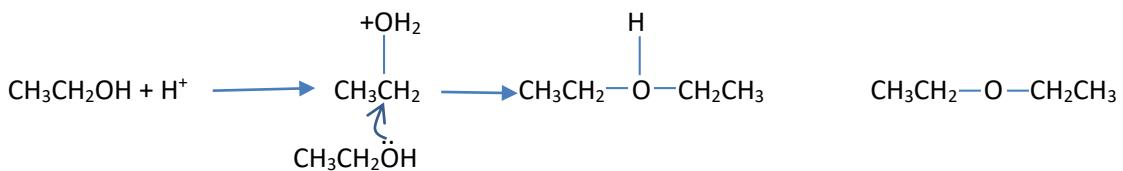
Mechanism



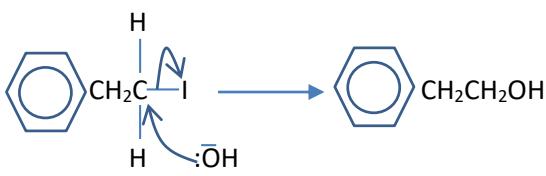
mechanism



Mechanism



**Mechanism**



6. (a) Define the following terms

(i) Colligative property (2marks)

Colligative property is a property of dilute solutions that depend on the number of dissolved particles in solution rather than their chemical nature.

(ii) Eutectic point (2marks)

Is the temperature and composition of eutectic mixture.

(iii) Eutectic mixture (2marks)

It is a liquid mixture that solidifies at constant temperature to give a solid of the same composition.

- (b) A solution contain 1.80g of naphthalene in 0.3g of camphor

(i) Calculate the melting point of the solution. (4marks)

[The relative molecular mass of naphthalene = 128; melting point of pure camphor = 177°C

The freezing point constant,  $K_f$ , for camphor =  $4^{\circ}\text{Cmol}^{-1}$  per 100g]

**Solution**

$$\text{Mass of naphthalene in a 100g of camphor} = \frac{1.80 \times 100}{0.3} = 600\text{g}$$

**Freezing point depression**

128g of naphthalene cause a depression of  $4^{\circ}\text{C}$

$$600\text{g of naphthalene cause a depression of } \frac{600 \times 4}{128} = 18.75^{\circ}\text{C}$$

$$\text{Freezing point of solution} = 177 - 18.75 = 158.25^{\circ}\text{C}$$

- (ii) State whether your answer would be significantly affected if the pressure of the system was lowered. Give a reason for your answer (2marks)

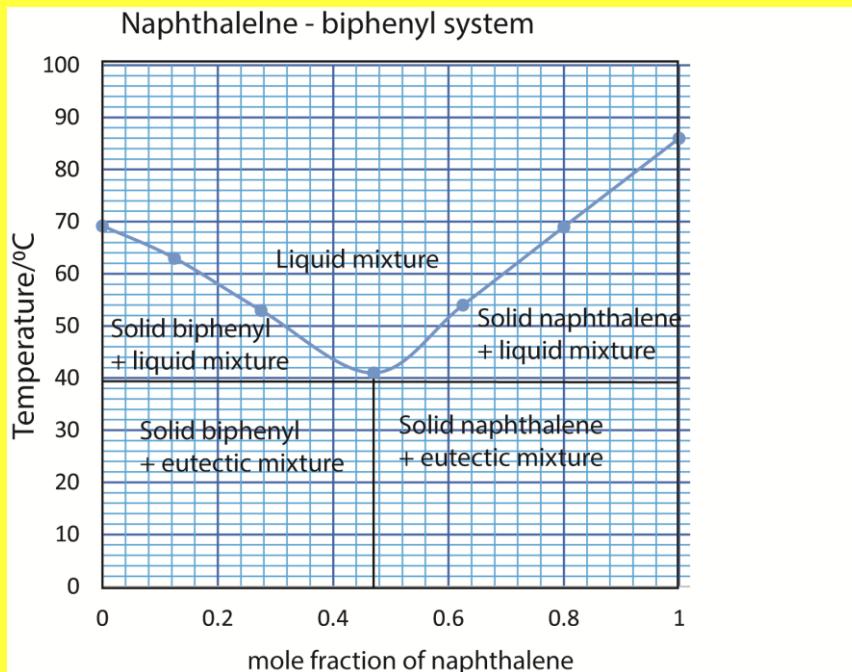
Yes because lowering pressure lower melting point

- (d) Naphthalene-biphenyl system forms a eutectic mixture at  $41^{\circ}\text{C}$ . the eutectic mixture contains 0.47mole fraction of naphthalene. The melting points of various composition of naphthalene-biphenyl system are given in the table below:

Mole fraction of naphthalene	0.125	0.275	0.625	0.800
Melting point ( $^{\circ}\text{C}$ )	63.0	53.0	54.0	69.0

- (i) Draw an accurate phase diagram for naphthalene-biphenyl system and label all the regions of the diagram. [Melting point of naphthalene and biphenyl are  $86^{\circ}\text{C}$  and  $69.2^{\circ}\text{C}$  respectively.

04marks)



- (ii) Explain what would happen if a liquid mixture containing 80% naphthalene at  $70^{\circ}\text{C}$  was gradually cooled (2marks)
- The mixture freezes  $69^{\circ}\text{C}$  forming solid naphthalene.

- The concentration of naphthalene in the mixture falls to mole fraction of 0.47 by 41°C
  - At 41°C temperature remains constant when both naphthalene and biphenyl freeze together to form a solid of the same composition as liquid mixture.
  - Then the temperature of the solid falls.
  -
- (e) State one similarity and one difference between a eutectic mixture and pure substance (2marks)
- Similarities: both freeze at a constant temperature giving a solid of the same composition as a liquid mixture.
- Differences
- their composition varies with pressure
  - can be separated by other physical methods as distillation and evaporation to dryness
  - X-ray analysis shows that eutectic mixtures are not pure compound
  - Microscopic analysis shows that eutectic mixtures are heterogeneous, made of a mixture crystals of separate substances
  - Chemical properties of eutectic mixtures are those of individual components making up the mixture for example when solder is reacted with dilute hydrochloric acid, tin reacts whereas lead does not.
7. (a) 25cm<sup>3</sup> of a solution containing sodium carbonate and sodium hydrogen carbonate required 15.0cm<sup>3</sup> of a 0.5M hydrochloric acid for complete reaction using phenolphthalein indicator. Another 25cm<sup>3</sup> of the same solution required 34.5cm<sup>3</sup> of the acid using methyl orange indicator. Calculate the molar concentration of the solution with respect to
- (i) Sodium carbonate  
(ii) Sodium hydrogen carbonate (9marks)

Solution

Volume of 0.5M HCl that reacted with sodium carbonate =  $15 \times 2 = 30\text{cm}^3$

$$\text{Moles of HCl that reacted with sodium carbonate} = \frac{30 \times 0.5}{1000} = 0.015 \text{ moles}$$

$$\text{Mole of sodium carbonate} = \frac{0.015}{2} = 0.0075 \text{ moles}$$

$$\text{Concentration of sodium carbonate} = \frac{0.0075 \times 1000}{25} = 0.3 \text{ mol dm}^{-3}$$

## Kampala Mathematics Club

Volume of 0.5M HCl that reacted sodium hydrogen carbonate =  $34.5 - 30 = 4.5\text{cm}^3$

$$\text{Moles of HCl that reacted with sodium hydrogen carbonate} = \frac{4.5 \times 0.5}{1000} \text{ 0.00225moles}$$

Moles of sodium hydrogen carbonate = 0.00225moles

$$\text{Concentration of sodium hydrogen carbonate} = \frac{0.00225 \times 1000}{25} = 0.09\text{M}$$

(b) Carbon, silicon, tin and lead are elements of group IV of the periodic table

State

- (i) The common oxidation state shown by elements in group IV (1mark)  
+2, +4
- (ii) How the stability of the oxidation states of the elements vary down the group?  
(illustrate your answer with the chlorides of carbon and lead) (3marks)  
+2 becomes more stable down the group while +4 becomes less stable down the group for example carbon forms stable  $\text{CCl}_4$  while lead forms stable  $\text{PbCl}_2$ .
- (iii) Give a reason for your answer in (b)(ii). (1mark)  
+2 oxidation state becomes more stable down the group due to inert pair effect.

(c) With reference to transition metals explain what is meant by the following

- (i) complex ion (2marks)  
A complex ion is an ion composed of central metal ion bonded to small molecules called ligands by dative bonds, e.g.  $[\text{Cu}(\text{NH}_3)_4]^{2+}$
- (ii) catalyst (2marks)  
A catalyst is a substance that speeds up a chemical reaction without taking part in the reaction, e.g. iron catalyzes formation of ammonia from nitrogen and hydrogen
- (iii) Variable oxidation state (2marks)  
Transition elements exhibit different oxidation states in different compounds  
e.g.  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$

8. Explain the following observation

- (a) The basic strength of amino benzene, ammonia and dimethylamine are in order:

Amino benzene < ammonia < dimethylamine. (4marks)

The phenyl group on amino benzene withdraws electrons from the nitrogen atom; this reduces the electron density of a lone pair of electrons and reduces its ability to attract a proton from water to produce hydroxyl ion than ammonia.

The methyl groups on dimethylamine donate electrons to the nitrogen atom; this increases the electron density of a lone pair of electrons and increase its ability to attract a proton from water to produce hydroxyl ion than ammonia.

- (b) The tendency of group 2 elements to form complex ions is in order.

Be > Mg > Ca > Ba (4marks)

It is because the charge density of the ions of these elements decrease in order  $\text{Be}^{2+} > \text{Mg}^{2+} > \text{Ca}^{2+} > \text{Ba}^{2+}$  which reduces the ability of the cation to attract ligands

- (c) The bond angle in a water molecule is  $104^{\circ}\text{C}$  whereas that in a molecule of ammonia is  $107^{\circ}$

(4marks)

Oxygen is more electronegative than nitrogen; the bonding electrons are thus closer to oxygen in water than nitrogen in ammonia. This causes greater repulsion between bonding pairs of electrons in water leading to bigger bond angles.

- (d) The acid dissociation constant,  $K_a$ , of bromoethanoic acid is greater than that of ethanoic acid at the same temperature. (4marks)

The electronegative bromine atom in bromoethanoic acid withdraws electrons and destabilizes the O-H bond leading to loss of a proton while the methyl group in ethanoic acid donates electrons and stabilizes the O-H bond

## Kampala Mathematics Club

- (e) Ammonia boils at  $-33^{\circ}\text{C}$  whereas phosphine,  $\text{PH}_3$ , boils at  $-88^{\circ}\text{C}$  (4mark)

Nitrogen atom is more electronegative than phosphorus; thus N-H is more polar than P-H bond. Consequently, ammonia form stronger hydrogen bonds that require a higher temperature to break.

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**525/2**

**S6 CHEMISTRY**

**Exam 6**

**PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

**INSTRUCTIONS TO CANDIDATES:**

Attempt five questions, including three questions from section A and any two from section B. Begin each question on a fresh page.

Mathematical tables and graph papers are provided.

Non-programmable scientific electronic calculators may be used.

Illustrate your answers with equations where applicable.

You may where necessary use the following values C = 12, H = 1 O = 16 Na = 23

**SECTION A:**

Answer **three** questions from this section

1. Some elements of group (II) of the periodic table are Be, Mg, Ca and Ba

(a) Write a general outermost electron configuration for the elements

(1m)

$ns^2$

(b) Explain how the following factors vary within these elements (4m)

(i) first ionisation energy

first ionization energy decreases down the group due to the decrease in effective nuclear charge.

(ii) melting point

melting points generally decrease down the group probably due to decrease in electronegativity. The melting point of magnesium is abnormally low with unclear explanation

(c) Beryllium behaves differently from the other elements

Explain why

(i) (i) beryllium behaves differently from the other elements

(4m)

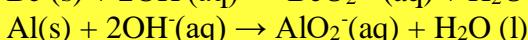
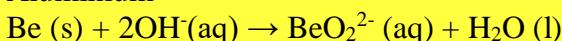
- Has small atom with high electronegativity

- Its ions has high charge density
- (ii) the tendency of these elements to form complexes decreases down the group (3 m)

this is due to decrease in charge density that reduces the ability of the ions to attract ligands

- (d) Name one other element with which Beryllium has similar properties and write ionic equations for the reactions of Beryllium and the element you have named with sodium hydroxide (4m)

Aluminium



- (e) Explain why Beryllium carbonate decomposes at 25°C whereas calcium carbonate decomposes at 900°C. (4m)

Beryllium ions have high charge density that they polarize carbonate ions to form covalent compound that decomposes at low temperature while calcium ions have low charge density form ionic bonds with carbonate ions with high decomposition temperature.

2. Show how the following conversions could be carried out. In each case indicate the reagents and conditions for the reaction.

- (a) Propanoic acid from ethene



- (b) Methylmethanoate from ethene



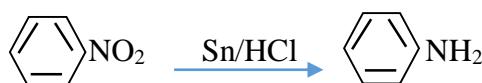
Then,



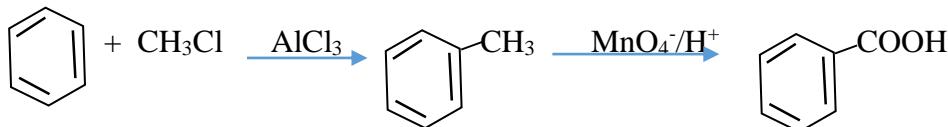
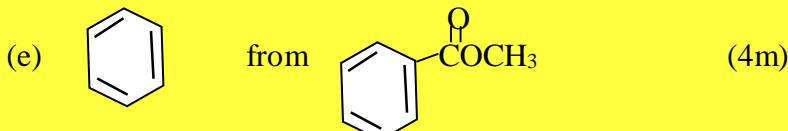
- (c) Aminobenzene from benzoic acid



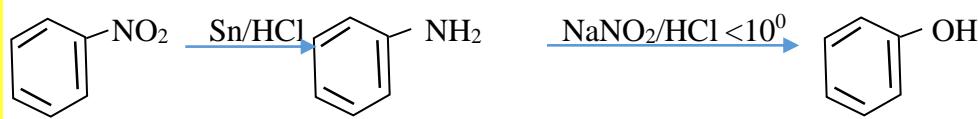
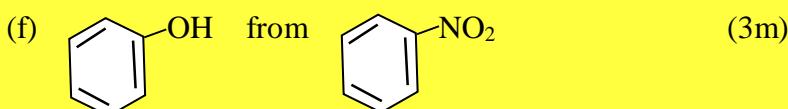
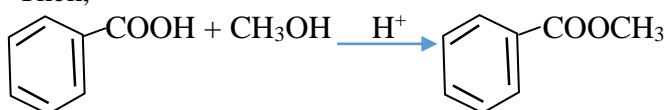
then,



(d) Ethoxyethane from ethanal



Then,



3. (a) Ethanoic acid is a weak acid

(i) Explain what is meant by a “weak acid”

A weak acid is a substance that partially ionizes in water to produce  $\text{H}^+$  as the only positive ion

(ii) Calculate the pH of a 0.05M ethanoic acid solution ( $K_a$  of ethanoic acid =  $1.8 \times 10^{-5}$  – mol dm<sup>-3</sup>)

$$[\text{H}^+] = \sqrt{K_a [\text{CH}_3\text{COOH}]} = \sqrt{1.8 \times 10^{-5} \times 0.05} = 9.5 \times 10^{-4} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log \text{H}^+ = 3$$

(b) (i) Explain what is meant by a “buffer solution” (4m)

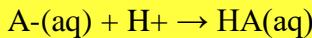
A buffer is solution that resist change in pH when small acid or base is added

(ii) Discuss the action of a buffer solution (5m)

A buffer is made of a solution of a weak acid and its salt with strong base or a weak base and its salt with strong acid.

Consider a buffer made of a weak acid ( $\text{HA}$ ) and its salt ( $\text{A}^-$ ), solution the salt is fully ionized suppressing ionization of the acid.

When small acid is added, the added  $\text{H}^+$  are removed by reacting with the salt ions



When small base is added, the added  $\text{OH}^-$  are neutralized by reacting with the acid

$$\text{HA}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{A}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$$

In either case, the change in concentration of  $\text{H}^+(\text{aq})$  or  $\text{OH}^-(\text{aq})$  is minimized and pH does not change

(c) A solution was made by dissolving 7.2g of ethanoic and 12.0g of sodium ethanoate to make 1 litre solution. To the solution was added 0.8 cm<sup>3</sup> of 1M hydrochloric acid. Calculate the pH of the solution. State any assumptions you make (4m)

formula mass of ethanoic acid,  $\text{CH}_3\text{COOH} = 15 + 12 + 32 + 1 = 60$

mole of ethanoic acid =  $\frac{7.2}{60} = 0.12$  moles

Formula mass of sodium ethanoate,  $\text{CH}_3\text{COONa} = 15 + 12 + 32 + 23 = 82$

Moles of sodium ethanoate =  $\frac{12}{82} = 0.146$  moles

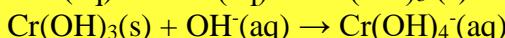
$$[\text{H}^+] = K_a \frac{[\text{acid}]}{[\text{salt}]} = (1.8 \times 10^{-5} \times 0.12)/0.146 = 1.5 \times 10^{-5}$$

$$\text{pH} = -\log \text{H}^+ = 4.8$$

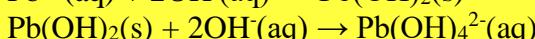
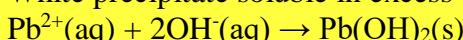
4. (a) State what would be observed and write equation for the reactions which take place when dilute sodium hydroxide solution is added drop wise until excess to



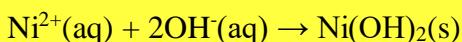
A green precipitate soluble in excess



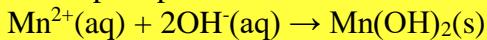
White precipitate soluble in excess



A green precipitate insoluble in excess



White precipitate insoluble in excess

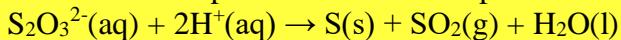


- (b) A solution of sodium thiosulphate is left exposed in air. State what is observed after some time and explain your answer. (4m)

Yellow precipitate

Carbon dioxide react with water to form an acid

The acid decomposes sodium thiosulphate to sulphur



- (c) 25.00cm<sup>3</sup> of a mixture of sodium-carbonate and sodium hydrogen carbonate was titrated with 0.1M hydrochloric acid and 10.00 cm<sup>3</sup> of the solution was required with phenolphthalein indicator. A further 35.00 cm<sup>3</sup> of the same acid was required when methyl orange indicator was added and the titration continued to the end point. Calculate the percentage of sodium carbonate in the mixture. (8m)

$$\text{Volume of 0.1M HCl that neutralized sodium carbonate} = 10 \times 2 = 20\text{cm}^3$$

$$\text{Moles of HCl that reacted with sodium carbonate} = \frac{20 \times 0.1}{1000} = 0.002\text{moles}$$

$$\text{Moles of sodium carbonate} = \frac{0.002}{2} = 0.001\text{moles}$$

$$\begin{aligned}\text{Concentration of sodium carbonate} &= \frac{0.001 \times 1000}{25} = 0.04\text{M} \\ &= 0.04 \times 106 \\ &= 4.24\text{g dm}^{-3}\end{aligned}$$

$$\begin{aligned}\text{Volume of the acid that reacted with sodium hydrogen carbonate} &= 35 - 10 \times 2 \\ &= 15\text{cm}^3\end{aligned}$$

$$\begin{aligned}\text{Moles of acid that reacted with sodium hydrogen carbonate} &= \frac{15 \times 0.1}{1000} \\ &= 0.0015\text{moles}\end{aligned}$$

$$\text{Moles of sodium hydrogen carbonate} = 0.0015\text{mole}$$

$$\text{Molar concentration of sodium hydrogen carbonate} = \frac{0.0015 \times 1000}{25} = 0.06\text{M}$$

$$\begin{aligned}\text{Concentration of sodium hydrogen carbonate in g/l} &= 0.06 \times 84 \\ &= 2.88\end{aligned}$$

$$\text{Percentage of sodium carbonate} = \frac{4.24 \times 100}{(4.24+2.88)} 59.55\%$$

## **SECTION B:**

Answer two questions from this section.

5. (a) (i) Explain what is meant by the term ideal solution

Ideal solution is a solution that obeys Raoult's law and its formation does not involve change in temperature and volume

(ii) Calculate the vapour pressure of a solution containing 50g heptane and 38g of octane at 20°C. The vapour pressure of heptane at 20°C = 473.2 Pa and that of octane at 20°C = 139.8 Pa.

**Solution**

$$\begin{aligned}\text{Molar mass of heptane. } C_7H_{16} &= 12 \times 7 + 16 \times 1 \\ &= 100\end{aligned}$$

$$\text{Moles of heptane} = \frac{50}{100} = 0.5$$

$$\text{Molar mass of octane, } C_8H_{18} = 12 \times 8 + 18 \times 1 = 114$$

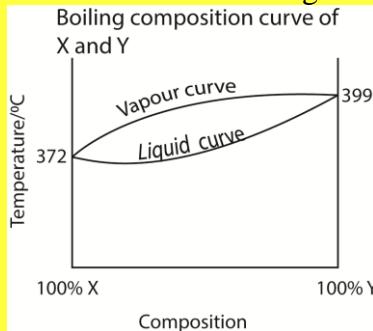
$$\text{Moles of octane} = \frac{38}{114} = 0.3$$

$$\text{Total moles} = 0.5 + 0.3 = 0.8$$

$$\text{Vapour pressure of solution} = \frac{0.5}{0.8} \times 473.2 + \frac{0.3 \times 139.8}{0.8} = 348.2 \text{ Pa}$$

- (b) Compound X (b.p. 372°C) and compound Y (b.p. 399°C) form an ideal solution.

- (i) sketch a labelled boiling/composition diagram for the mixture

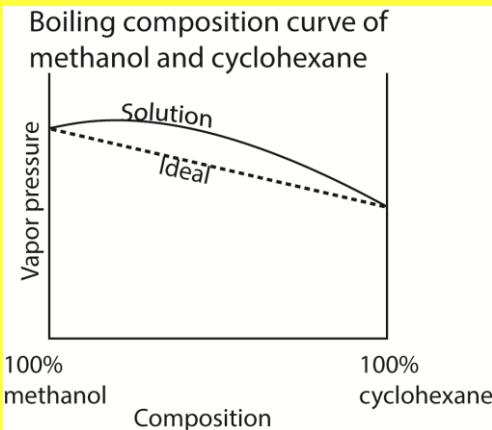


- (ii) Using the diagram describe and explain how pure Y can be obtained from a mixture containing 70% Y.

When fractional distilled, a solution that contains 70% Y gives a residue that is richer in Y. Continuous distillation of the residue gives the final residue as pure Y.

- (c) Draw the vapour pressure/composition curve for mixtures of methanol and cyclohexane and explain the shape of the curve with reference to Raoult's law

(8m)

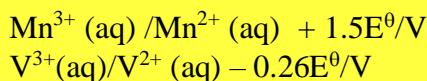


The forces of attraction between methanol and cyclohexane molecules are weaker than those between similar molecules facilitating evaporation of molecules causing the vapour pressure of solution being higher than expected.

6. (a) (i) Define the term standard Electrode potential (2m)

This is the electrode potential of a metal dipped in a solution containing one mole of metal ions in a dm<sup>3</sup>/litre of solution at 298K and 1 atmosphere.

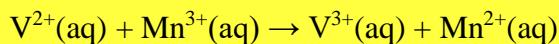
- (ii) The standard electrode potentials for some systems are given below:



- (iii) Write the convention for the cell formed by combining the two systems (1m)



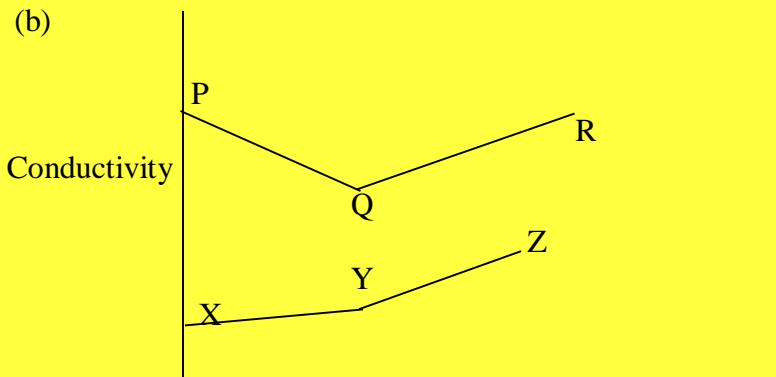
- (iv) Write the overall equation for the reaction (2m)



- (v) Calculate the e.m.f of the cell. State whether the reaction is possible or not and give a reason for your answer. (2m)

$$1.5 - (-0.27) = +1.77\text{V}$$

(b)



Volume of sodium hydroxide

Graphs PQR and XYZ show variations of the conductivities of solutions formed when equal volumes of 0.1M hydrochloric acid and 0.1M ethanoic acid respectively were titrated with 1M sodium hydroxide solution. Explain the shapes of the graphs (8 marks)

**Solution**

**Graph PQR**

- At P the conductivity is high due to presence of hydrogen ions from ionization of HCl.
- Along PQ conductivity decrease due to removal of hydrogen ions by OH<sup>-</sup> ions.
- After the end point at Q, conductivity increase due to excess OH<sup>-</sup> ions.

**Graph XYZ**

- At X conductivity is low due to presence of few hydrogen ions from partial ionization of ethanoic acid.
- Along XY conductivity increases due to addition of salt ions and further ionization of the acid on dilution
- After the end point at Y conductivity increases due to excess hydroxyl ions from sodium hydroxide

7. Write notes on the following (your answer should include suitable examples and mechanisms for reactions in each case) (20m)

(a) Elimination reaction

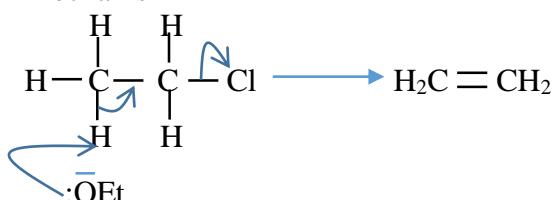
It is a reaction where an atom or group of atoms are removed from an organic compound to form unsaturated compound.

Example removal of HX from alkyl halides.

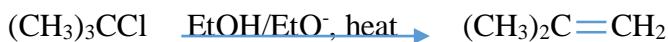
(i) Primary alkyl halide



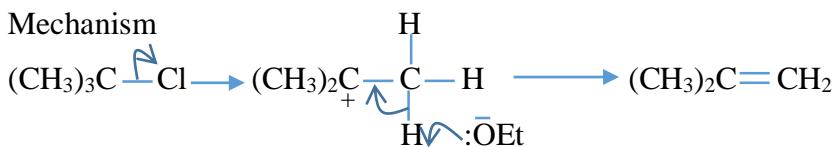
Mechanism



Tertiary alkylhalide



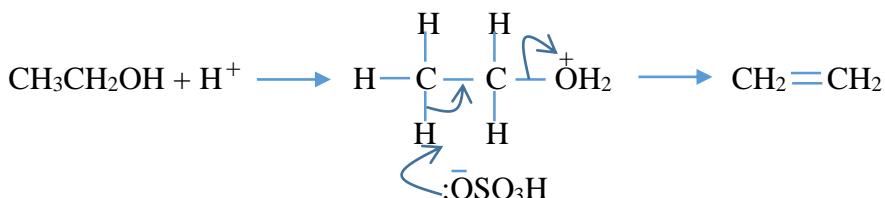
Mechanism



Alternatively we can use examples for dehydration of alcohols



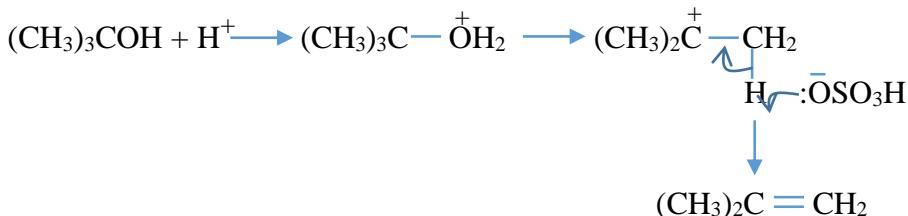
Mechanism



Tertiary alcohol



Mechanism

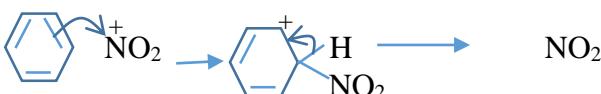


(b) Electrophilic substitution reaction

It is a reaction where electron deficient group replace an atom or a group of atoms on a benzene ring.



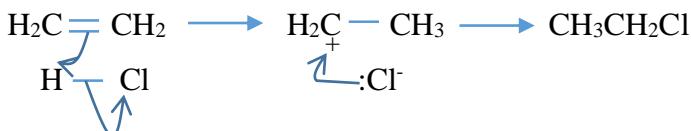
Mechanism



(c) Electrophilic addition

It is addition of electron deficient groups to unsaturated compound to form saturated compounds

Example

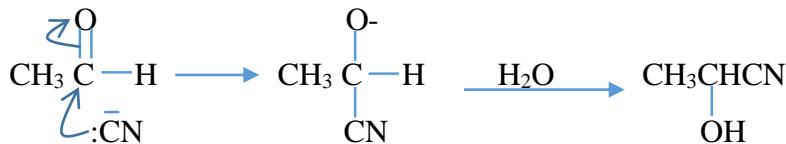


(d) Nucleophilic substitution

It is a reaction where electron rich species adds to unsaturated compound to form a saturated compound



Mechanism



8. Explain each of the following observations

- (a) Calcium forms compounds containing  $\text{Ca}^{2+}$  ions but none containing  $\text{Ca}^+$  ions even though the second ionisation energy of calcium is greater than its first ionisation energy

$\text{Ca}^{2+}$  ( $1s^2 2s^2 2p^6 3s^2 3p^6$ ) has a stable electron configuration whereas  $\text{Ca}^+$  ( $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$ ) does not

- (b) The basic strength of aminobenzene ammonia and dimethylamine are in the order



(6m)

- The phenyl group on aminobenzene withdraws electrons from the nitrogen atom; this reduces the density of the lone pair of electrons; this makes lone pair of electron unavailable to attract a proton from water to form hydroxyl ions than ammonia.
- The methyl groups on dimethylamine to a nitrogen atom; this increases the electron density of a lone pair of electron; this increase the availability alone pair of electrons to attract a proton from water to form hydroxyl ions than ammonia

- (c) The ionic conductivities of Lithium ion is much less than that of caesium although lithium and caesium ions have ionic radii of 0.06 and 0.01 (mm)  
(2m)

$\text{Li}^+$  has a big charge density, attracts a big cloud of water molecules making its effective size to be bigger than that caesium ion. Thus lithium ions move slower than caesium ions in solution

- (e) A mixture of water (b.p  $100^\circ\text{C}$ ) and benzene (b.p  $80^\circ\text{C}$ ) boils at  $70^\circ\text{ C}$  1 atmosphere

Water molecules are polar and form strong hydrogen bonds that require high temperature to break while benzene molecules are held by weak van der Waal forces.

- (f) Methanoic acid reacts with ammoniac silver nitrate solution whereas ethanoic acid does not  
(3 m)

Methanoic acid reduces silver ions to silver while ethanoic acid does not.

**END**

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**S6 CHEMISTRY**

**Exam 7**

***PAPER 2***

**DURATION: 2 HOUR 30 MINUTES**

Instructions

Answer five questions including **three** from section A and any **two** from section B

Begin each question on a fresh page.

**210**

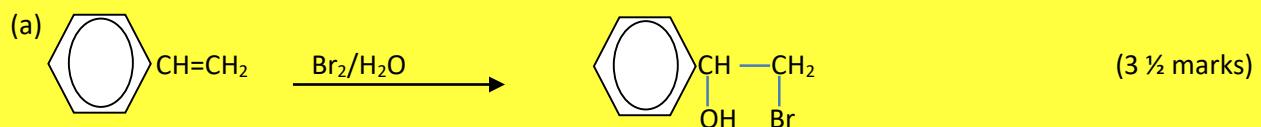
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# Kampala Mathematics Club

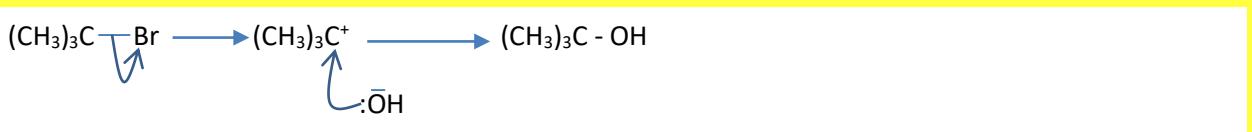
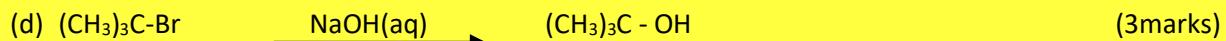
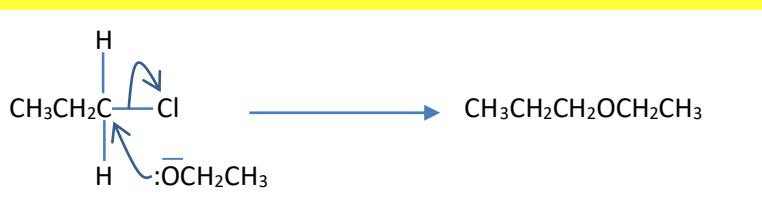
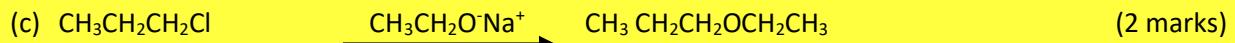
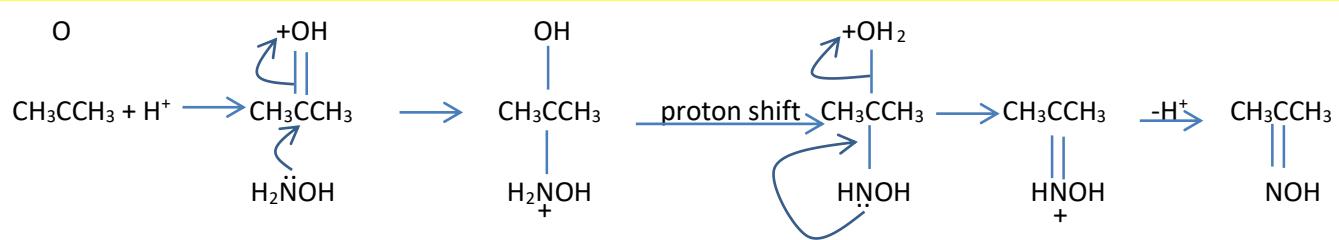
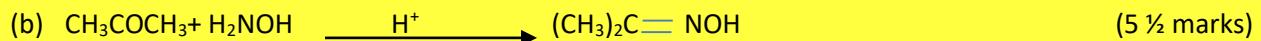
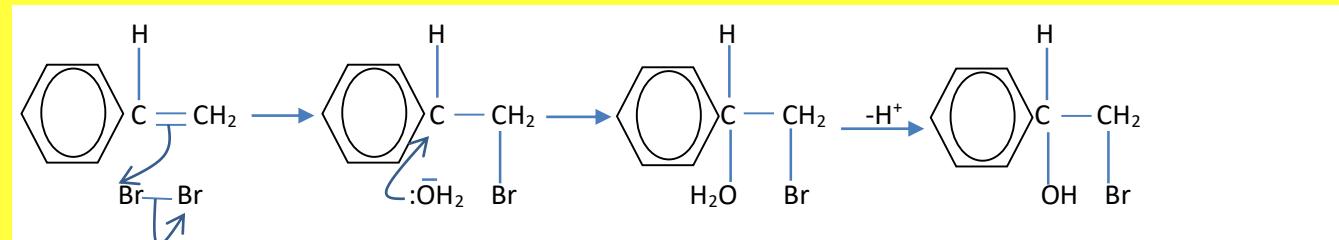
SECTION A

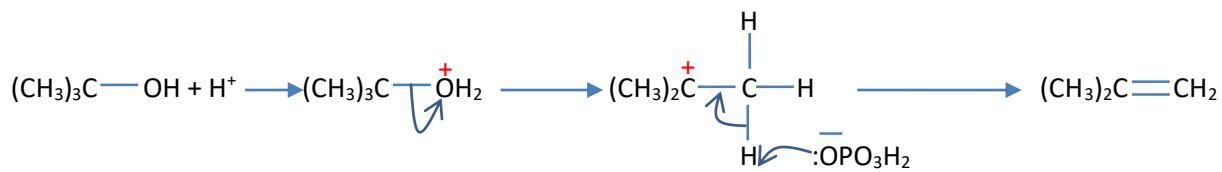
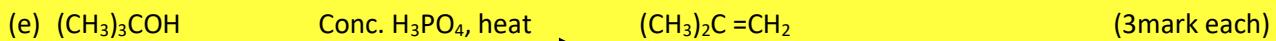
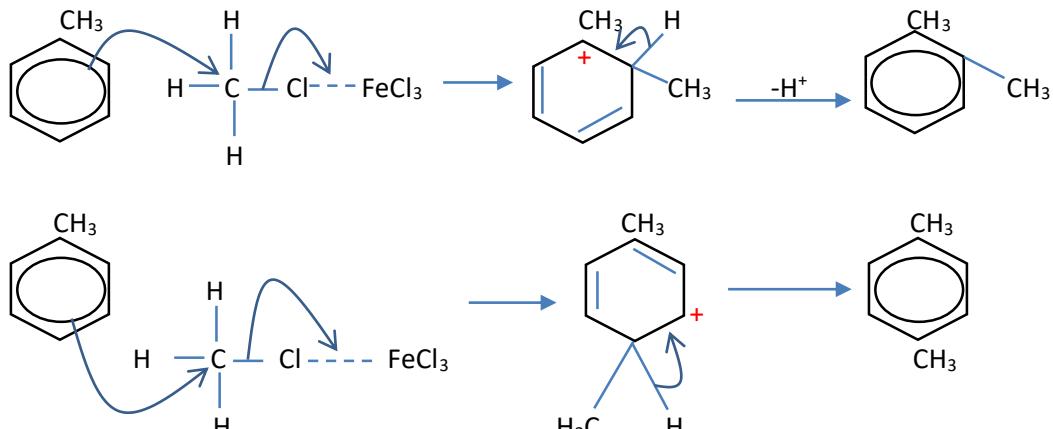
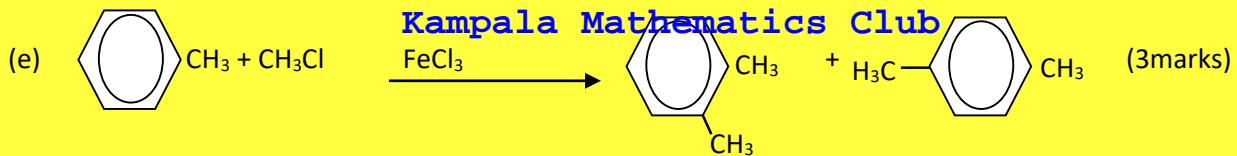
Answer any **three** questions from this section

1. Complete the following equations and in each case suggest an acceptable mechanism.



Mechanism





2. (a) Explain what is meant by terms (3marks each)
- (i) Activation energy  
It is the minimum amount of energy required by the reactants to react
  - (ii) Order of reaction  
It is the sum exponents to the concentration terms in a rate law
  - (iii) Half life of a reaction  
Is the time taken by a reactant to reduce to half its initial concentration
  - (iv) Rate determining step  
Is the slowest step in a reaction

(b) The rate of reaction;

### Kampala Mathematics Club



May be calculated by measuring the time for the first appearance of  $\text{I}_2$  in solution i.e. the time required for the concentration of iodine to reach  $10^{-5}$  moldm $^{-3}$ .

- (i) For a particular experiment in which initially

$$[\text{H}_2\text{O}_2] = 0.01\text{M}$$

$$[\text{I}^-] = 0.010\text{M}$$

$$[\text{H}^+] = 0.10\text{M}$$

Calculate the reaction rate if  $\text{I}_2$  first appears after 6 seconds

(2marks)

$$\text{Rate} = \frac{[\text{I}_2]}{\text{time}} = \frac{10^{-5}}{6} = 1.7 \times 10^{-6} \text{ moldm}^{-3}\text{s}^{-1}$$

- (ii) For a particular experiment in which initially

$$[\text{H}_2\text{O}_2] = 0.005\text{M}$$

$$[\text{I}^-] = 0.010\text{M}$$

$$[\text{H}^+] = 0.10\text{M}$$

Calculate the reaction rate if  $\text{I}_2$  first appears after 12 seconds

(2marks)

$$\text{Rate} = \frac{[\text{I}_2]}{\text{time}} = \frac{10^{-5}}{12} = 8.3 \times 10^{-7} \text{ moldm}^{-3}\text{s}^{-1}$$

- (iii) From the calculations b(i) and b(ii) determine the order of reaction with respect to  $\text{H}_2\text{O}_2$ . (2marks)

It is first order because halving concentration halves the rate

- (iv) Given that the rate law is; rate =  $K[\text{H}_2\text{O}_2][\text{H}^+][\text{I}^-]$ , calculate the rate constant, K, giving it units. (2marks)

Using conditions in (i)

$$1.7 \times 10^{-6} = K(0.01)(0.01)(0.1)$$

$$K = 0.17 \text{ mol}^{-2}\text{dm}^6\text{s}^{-1}$$

- (v) Predict the rate of reaction when  $[\text{H}_2\text{O}_2] = 0.05\text{M}$ ,  $[\text{H}^+] = 0.10\text{M}$ , and  $[\text{I}^-] = 0.02\text{M}$  (2marks)

$$\text{Rate} = 0.17 \times 0.05 \times 0.1 \times 0.02 = 1.7 \times 10^{-5} \text{ moldm}^{-3}\text{s}^{-1}$$

3. Halogens, fluorine, chlorine, bromine and iodine show close group similarities

- (a) Explain how the variation of the following physical quantities among the elements

(3marks each)

- (i) Atomic radii

Atomic radii increase down the group due to increase in the number of electron shells and screening effect on outer electrons.

- (ii) First ionization energy

First ionization energy decreases down the group due to increase in atomic sizes and reduction in effective nuclear charge on valence electrons.

- (iii) First electron affinity

Decreases down the group due to decrease in electronegativity.

- (iv) Melting points

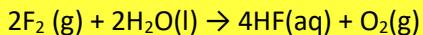
Increase down the group due to increase molecular mass and strength of molecular forces

(b) Write equations to show how fluorine and chlorine react with

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(i) Water

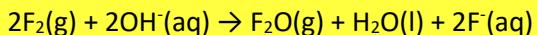
(3marks)



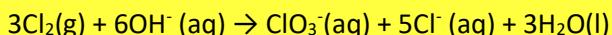
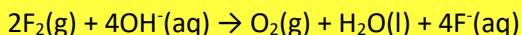
(ii) Sodium hydroxide

(5marks)

Dilute



Concentrated



4.

(a) What is meant by the term 'colligative properties?'

(2marks)

Colligative property is a property of dilute solution that depends on the number of dissolved particles rather than their chemical composition

(b) Write an experiment that can be used to determine the molecular mass of a substance using freezing point depression method.

(6marks)

The freezing point ( $t$ ) a solution that contain  $X$ g of solute of molecular mass  $M$  in  $y$  g of a solvent is determine. Suppose the freezing point of the solvent is  $t^0$  and freezing point depression constant =  $K_f$ . Then,

$$\text{Mass of a solute in } 1000\text{g of a solvent} = \frac{1000X}{y} \text{ g}$$

$$\text{Freezing point depression} = (t - t^0)$$

It implies that

$$(t - t^0) \text{ is caused by } \frac{1000X}{y} \text{ g}$$

$K_f$  is caused by  $M$

$$\text{The molecular mass, } M = \frac{1000X \times K_f}{y(t - t^0)}$$

(c) State four limitations of the method used in (b)

(4marks)

- Solution is dilute
- Solute does not react with solvent
- Solute does associate
- Solute is nonvolatile
- Solute does not dissociate

(d) Give one reason why method in (b) is not suitable to determine the molecular mass of polyethene.

(2marks)

Dilute solutions of polyethene give negligible freezing point depression since it is a polymer

(e) Calculate the freezing point of solution containing 1.5g of ethanoic acid in 250g of camphor. The freezing point depression and freezing point of camphor are  $40^\circ\text{mol}^{-1}$  per 1000g and  $193^\circ\text{C}$  respectively.

(4marks)

# Mass of ethanoic acid in 1000g of camphor

250g of camphor contain 1.5g of ethanoic acid

$$1000\text{g of camphor contain} = \frac{1.5 \times 1000}{250} = 6\text{g}$$

Formula mass of ethanoic acid  $\text{CH}_3\text{COOH} = 15 + 12 + 32 + 1 = 60$

Freezing point depression

60g cause  $40^\circ\text{C}$

$$6\text{g cause} \frac{40 \times 6}{60} = 4\text{g}$$

Freezing point of solution =  $193 - 4 = 189^\circ\text{C}$

- (f) Name two other colligative properties (2marks)

- Elevation of boiling point
- Lowering of vapor pressure
- Osmotic pressure

## SECTION B

(Answer any **two** question)

5. Elements beryllium, magnesium, calcium and barium belong to group II of the periodic table.

- (a) Describe the reaction of the elements with

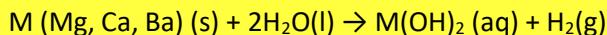
- (i) Water (7marks)

Beryllium does not react with water

Magnesium reacts steam to form magnesium oxide and hydrogen



Magnesium, calcium, barium react with water with increasing vigour to form hydroxides



- (ii) Sulphuric acid (5marks)

Beryllium, magnesium, calcium and barium react with dilute sulphuric acid liberating hydrogen



Beryllium, magnesium, calcium and barium react with hot concentrated sulphuric acid liberating sulphur dioxide and water



Barium reacts shortly with dilute and concentrated sulphuric acid due to the formation of insoluble sulphates.

- (b) Explain the trend in

- (i) Solubility of their hydroxides (3marks)

Solubility decreases increases down the group because lattice energy decreases more rapidly than the decrease in hydration energy.

- (ii) Thermostability of carbonates (3marks)

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Thermostability of carbonates increases down the group due to increase in ionic character and lattice energy of the carbonates. Beryllium ion with high charge density strongly polarizes carbonate ions to form covalent bond.

(c) Write the equation for the reaction between:

(i) Beryllium and sodium hydroxide

(1mark)



(ii) Beryllium carbide with water

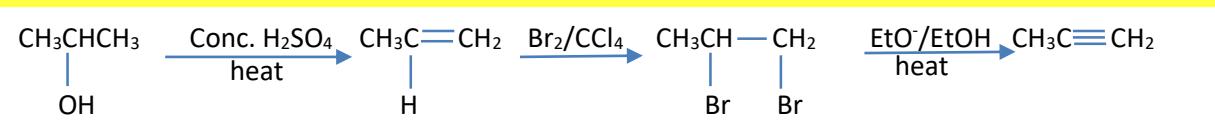
(1mark)



6. Write equations to show how the following compounds can be synthesized

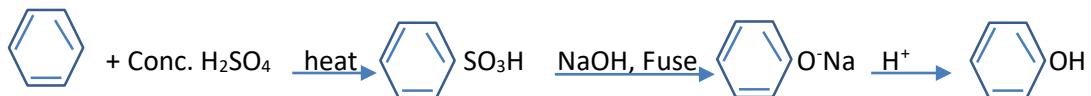
(a) Propyne from propan-2-ol

(4 ½ marks)



(b) Phenol from benzene

(3 ½ marks)



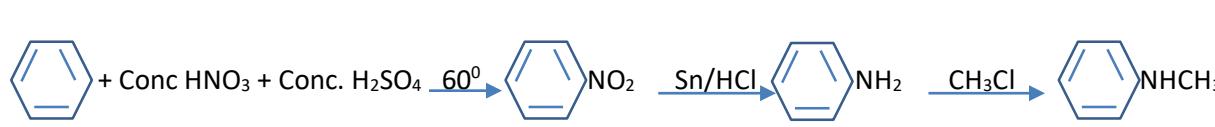
(c) Ethanoylchloride from ethane

(4marks)



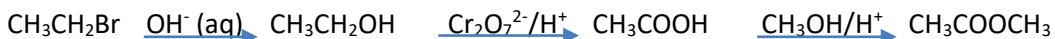
(d) Methylphenylamine from benzene

(4marks)



(e) Methylethanoate from bromoethane

(4marks)



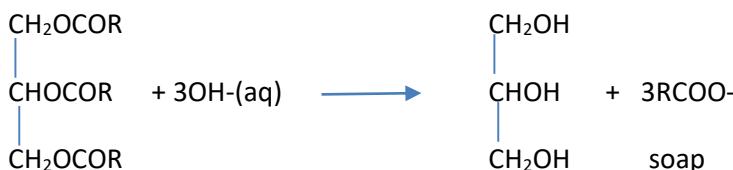
7. (a) (i) Briefly describe how a sample of soap can be prepared

(4marks)]

Sodium hydroxide is boiled with vegetable oil, a concentrated solution of sodium chloride is added to precipitate soap. On cooling soap is skimmed off.

(iii) Write equation(s) for the reaction leading to the formation of soap

(01mark)



(b) Explain why soap cannot be used effectively in:

(i) Hard water

Soap fails to lather due to formation of insoluble salts with magnesium and calcium ions in hard water

(ii) Strongly acidic solution

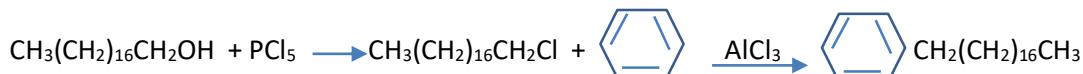
(05marks)

Soap form insoluble fatty acid that are weak surfactants

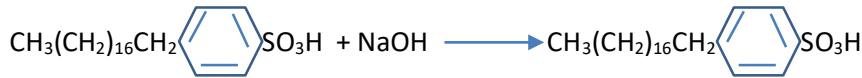
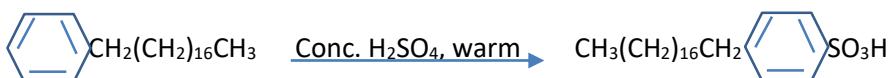
(c) Write equations to show how alkylbenzenesulphonate can be prepared from octadecan-1-ol,

$\text{CH}_3(\text{CH}_2)_{16}\text{CH}_2\text{OH}$ .

(06marks)



then



(d) Explain why the following compound are added to soapless detergents:

(i) Polyphosphates

(02marks)

Complex and prevent calcium ions from forming scum with soap

(ii) Disodium sulphate

(02marks)

(8) Explain the following observations

(a) Lithium is in group (I) but its properties resemble those of magnesium in group (II) of the periodic table. (4marks)

Both lithium and magnesium have the same electronegativity and their ions have the same polarizing power because increase in electronegativity across the periodic table one step right is cancelled by a decrease in electronegativity one step down the group.

(b) Aluminium trifluoride is ionic, while aluminium trichloride is covalent

(05marks)

Chloride ion is bigger than fluoride ions, thus is more easily polarized to form a covalent bond with aluminium ions.

(c) Boron trichloride  $\text{BCl}_3$  is non polar molecule while nitrogen trichloride,  $\text{NCl}_3$  is polar

(4marks)

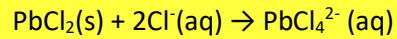
Boron trichloride is a symmetrical molecule leading to cancellation of the dipole moments in its molecules while nitrogen trichloride is asymmetric molecule and the dipole moments do not cancel.

(d) The elements of group (II) of the Periodic Table are harder and have higher melting points and boiling points than those of group (I) elements (02marks)

Group (II) elements are bonded by stronger metallic bonds than group (I) elements because group (II) elements use two electrons per atom to form metallic bonds while group (I) elements use one electron

(e) Lead (II) chloride is more soluble in concentrated hydrochloric acid than in dilute hydrochloric acid (5marks)

Lead (II) chloride is soluble in concentrated hydrochloric acid due to formation of soluble complex



End

**Our country, our future**

**525/2**

**S6 CHEMISTRY**

**Exam 8**

**PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

**INSTRUCTIONS TO CANDIDATES**

Answer five questions, including **three** questions from section A and any **two** from section B

Begin each question on a fresh page.

Graph papers are provided.

Non-programmable scientific calculators may be used

# Kampala Mathematics Club

## SECTION A (do any 3 numbers)

1. (a) State Raoult's law and mention its limitation. (2marks)

Raoult's law states that the partial pressure of a component in an ideal mixture is a product of its vapour pressure and mole fraction at the same temperature.

Limitations

- the forces of attraction between like and unlike molecules are equal.
- its formation should not involve change in volume nor temperature

- (b) (i) Explain what is meant by an ideal solution. (2marks)

Is a solution that obeys Raoult's law; it has uniform forces of attraction between like and unlike molecules; its formation does not involve change in volume or temperature.

- (ii) Explain why some liquid mixtures do not obey Raoult's law. (4marks)

Some liquids deviate from Raoult's law because the forces of attraction between like and unlike molecules are either greater or less than those between like molecules; lowering or elevating the vapour pressure.

- (c) The vapour pressure of a solution containing 1mole of A and 4moles of B is 0.75atm, at 25°C.

At the same temperature the vapour pressures of pure A and B are 0.674 and 0.453 atm. respectively.

- (i) Calculate the vapour pressure of the liquid mixture assuming it was ideal. (3marks)

$$\text{Total moles} = 1 + 4 = 5$$

$$\text{Vapour pressure of mixture} = \frac{1}{5} \times 0.674 + \frac{4}{5} \times 0.453 = 0.4972 \text{ atm.}$$

- (ii) State how the mixture deviates from Raoult's law. Explain your answer. (2marks)

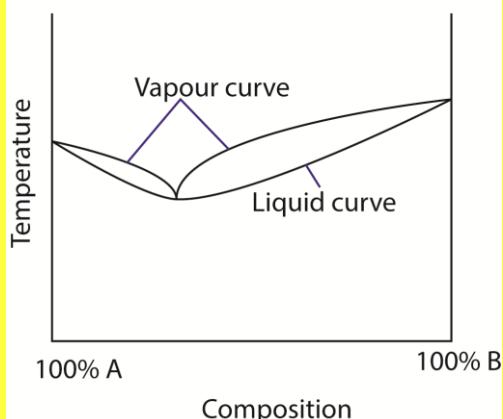
It deviates positively because the vapour pressure of the mixture is higher than that of ideal solution

- (iii) Calculate the composition of the vapour assuming above the liquid mixture assuming it is ideal. (2marks)

$$\text{Percentage of A in vapour} = \frac{0.2 \times 0.674}{0.4972} \times 100 = 27.1\%$$

(d) Sketch a labeled temperature-composition diagram for the mixture of A and B. (3marks)

Boiling-composition curve of A and B

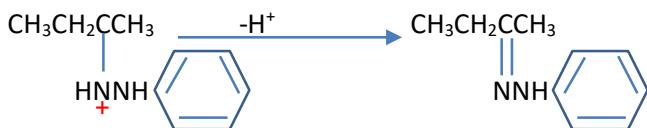
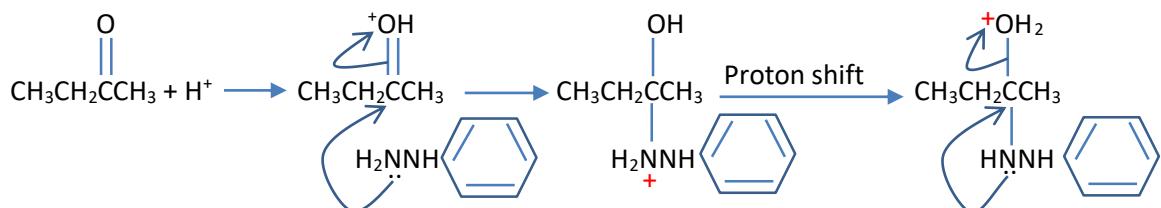
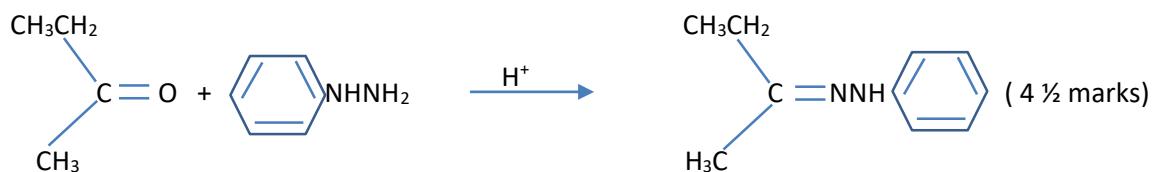


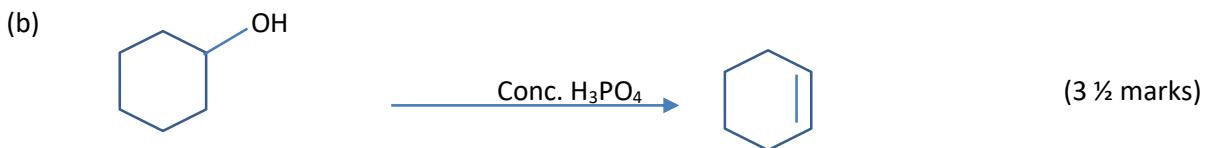
(e) State one similarity and one difference between an azeotropic mixture and a compound

(2mark)

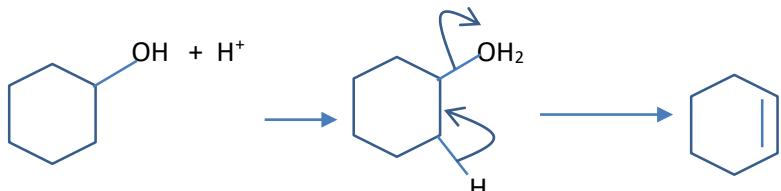
- Both boil at constant temperature
- Both have the same composition in liquid and solid

2. Complete the following equations and outline the mechanisms

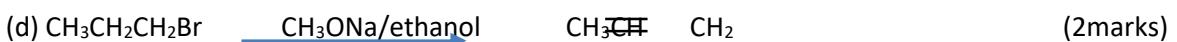
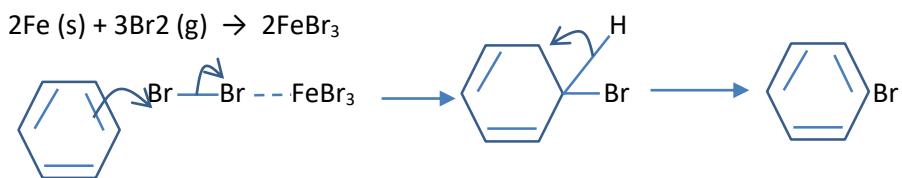




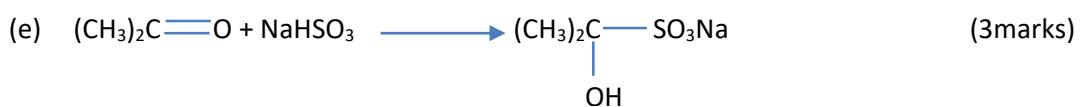
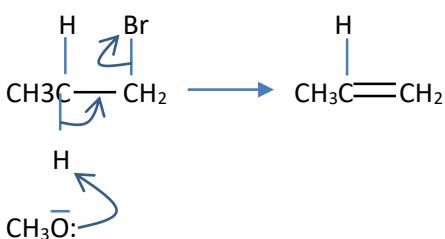
Mechanism

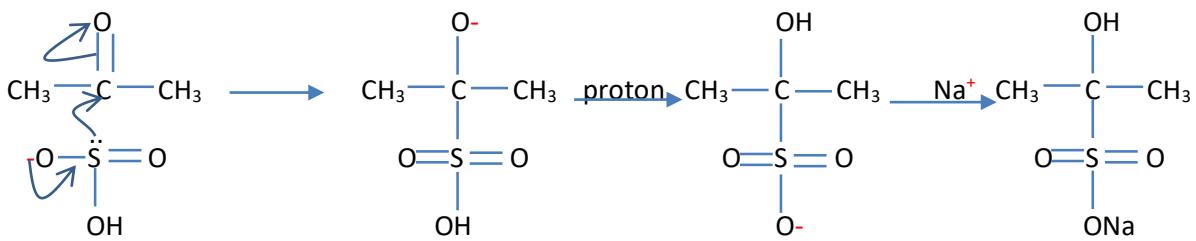


Mechanism

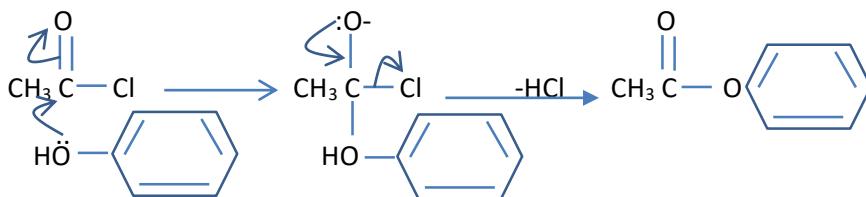


Mechanism





Mechanism



3. (a) (i) Write the outermost electronic configuration of group (IV) elements (½ mark)

$$\text{ns}^2\text{np}^2$$

(ii) State the oxidation states of these elements. (1marks)

+2 and +4

(iii) Explain the trend in stability of oxidation state (2 ½ marks)

The stability of +2 oxidation state increases down the group while that of +4 oxidation states decreases down the group due to inert pair effect.

(b) (i) State the type of bonding in the chlorides of lead (1mark)

$\text{PbCl}_2$  is ionic

$\text{PbCl}_4$  is covalent

(ii) State two properties of each chloride which suggest the type of bonding that you have stated in (b)(i) above (2marks)

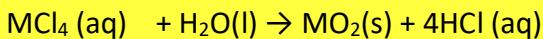
$\text{PbCl}_2$  conducts electricity in molten and solution form. It also has high melting point

$\text{PbCl}_4$  has low melting point and is soluble in organic solvent

## Kampala Mathematics Club

(iii) Describe the reactions of the chlorides of group (IV) with water (5marks)

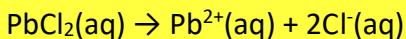
- Carbon tetrachloride does not hydrolyze
- Silicon, germanium, tin and lead tetrachlorides hydrolyze to form dioxides and hydrogen chlorides



- Tin (II) chloride partially hydrolyze in water



- Lead (II) chloride ionizes in water

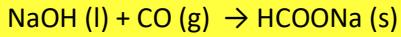


(c) Describe the reactions of the oxides of group (IV) elements with sodium hydroxide (5marks)

- Carbon dioxide reacts with limited sodium hydroxide to form sodium hydrogen carbonate and with excess sodium hydroxide to form sodium carbonate



- Carbon monoxide reacts with concentrated sodium hydroxide to form sodium methanoate



- Dioxides react with sodium hydroxide to form complexes



- Lead (II) oxide react to form complex



(d) Write the equation(s) for the reaction of lead (IV) Oxide with hydrochloric acid. State the condition(s) for the reaction (s) (3marks)

Lead (IV) oxide reacts with cold concentrated hydrochloric acid to form lead (IV) chloride

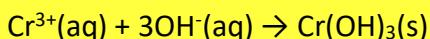


Lead (IV) oxide oxidizes hot concentrated hydrochloric acid to chlorine



- 4.** Explain the following observations. Write equations where necessary.
- (a) When sodium hydroxide solution is added to aqueous solution of chromium (III) sulphate a green precipitate is formed which dissolves in excess alkali to form a green solution. The solution changes to yellow when heated with hydrogen peroxide solution (6marks)

A green precipitate of chromium (III) hydroxide dissolve to form a complex that is oxidized by hydrogen peroxide to chromate (VI)



- (b) Aqueous solution of 0.01M sodium chloride and 0.02M solution of urea have the same freezing points. (3marks)

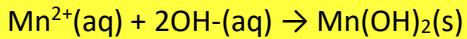
1 mole of sodium chloride ionizes to produce two moles of particles thus 0.01M sodium chloride contains the same number of particles as 0.02M solution of urea given that freezing point depression is a colligative property that depends on the number of dissolved particles.

- (c) Hydrogen fluoride is a liquid at 20°C whereas hydrogen chloride is a gas. (4marks)

Fluorine is more electronegative than chlorine; hydrogen fluoride is more polar than hydrogen chloride and forms stronger hydrogen bonds that require high temperature to break during boiling. In other words hydrogen fluoride being a liquid show that it has a higher boiling point than hydrogen chloride that is a gas.

- (d) When a sodium hydroxide is added to a solution of manganese (II) chloride a white precipitate is formed which quickly changes to brown. The precipitate is insoluble in excess sodium hydroxide. (4marks)

Manganese (II) ions react with sodium hydroxide to form insoluble manganese (II) hydroxide which is oxidized by air to form brown manganese (III) or (IV) oxide



- (e) When a solution of manganese (II) chloride is heated with lead (IV) oxide and concentrated nitric acid, the solution changes to purple. (3marks)

Manganese (II) ions are oxidized to purple manganese (VII) ions



**SECTION B (answer 2 questions only)**

5. (a) Describe the reaction of group (II) with

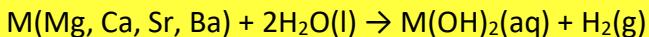
- (i) Water

Be does not react with water

Magnesium reacts with steam to form magnesium oxide and hydrogen



Magnesium, calcium, strontium and barium react with cold water to form hydroxide with increasing vigor.



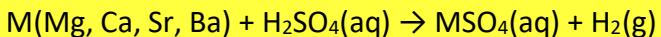
The reaction of magnesium is short lived due to the formation of insoluble hydroxide.

- (ii) Sulphuric acid

Write equations for the reactions that took place

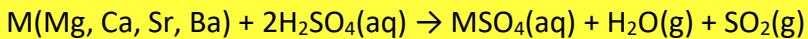
(6marks)

Be, Mg, Ca, Sr and Ba react with dilute sulphuric acid to form sulphates and hydrogen



The reaction of Ca, Sr and Ba is short lived due to the formation of insoluble sulphates

Be, Mg, Ca, Sr and Ba react with concentrated sulphuric acid to form sulphates and water and sulphur dioxide.



The reaction of barium is short lived due to formation of insoluble sulphate

Calcium reacts with excess concentrated sulphuric acid to form soluble calcium hydrogen sulphate.

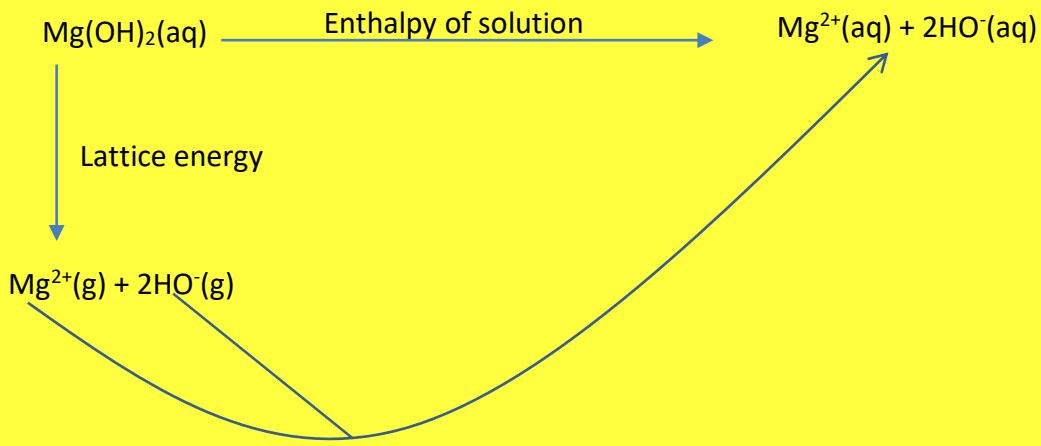


- (b) Describe the reaction of beryllium with sodium hydroxide. State what you will observe and write equation for the reaction that took place (3marks)

Beryllium reacts with hot concentrated sodium hydroxide to form colorless solution with evolution of hydrogen.



(c) Draw a Born Haber cycle for the solubility of group (II) metal hydroxide. (2marks)



(d) Explain the trend in the solubility of group (II) metal

(i) hydroxide

Solubility of group (II) hydroxides increase down the group due to decrease in lattice energy, lattice energy decreases more rapidly than the decrease in hydration energy.

(ii) sulphate

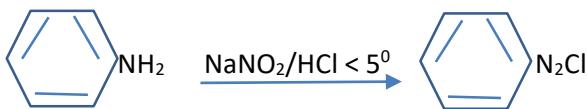
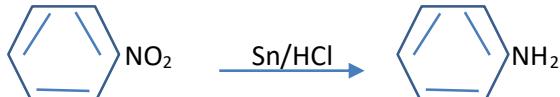
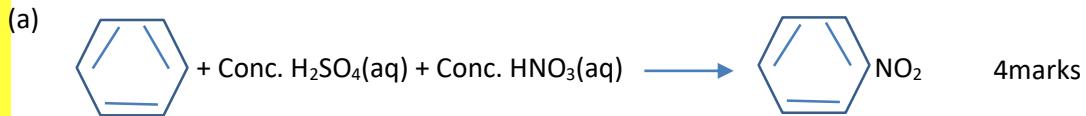
(6 marks)

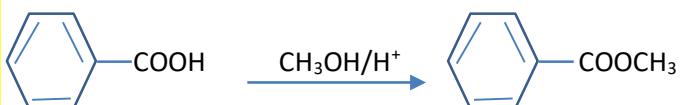
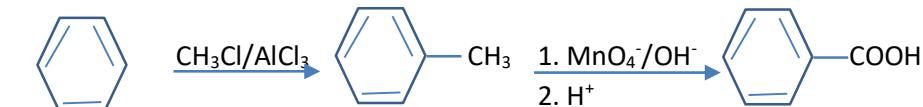
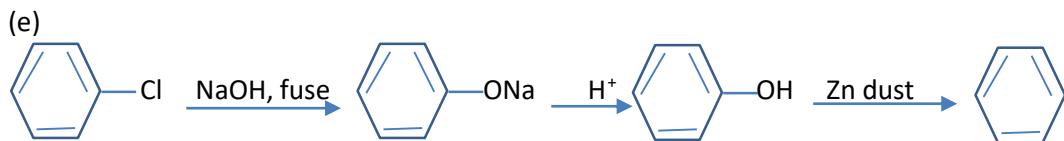
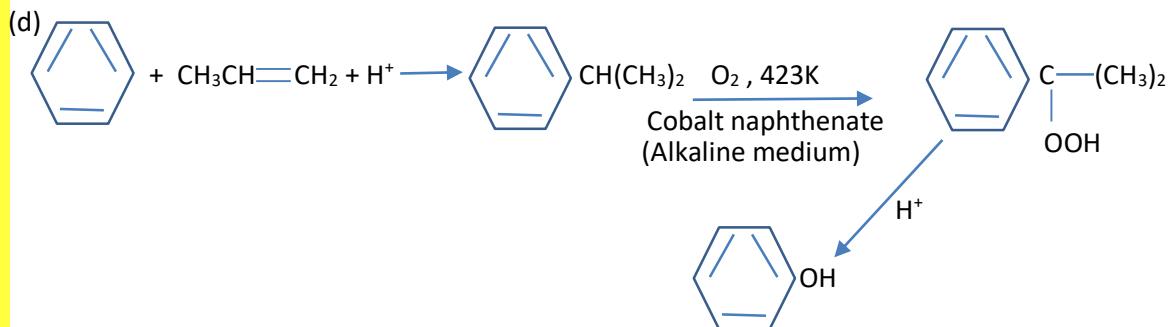
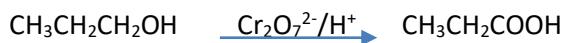
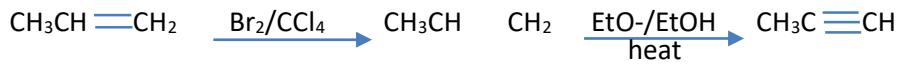
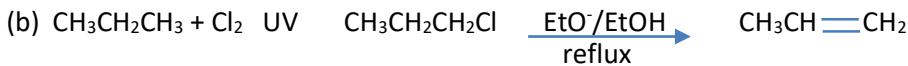
Solubility of group (II) sulphate decrease down the group due to increase in lattice energy.

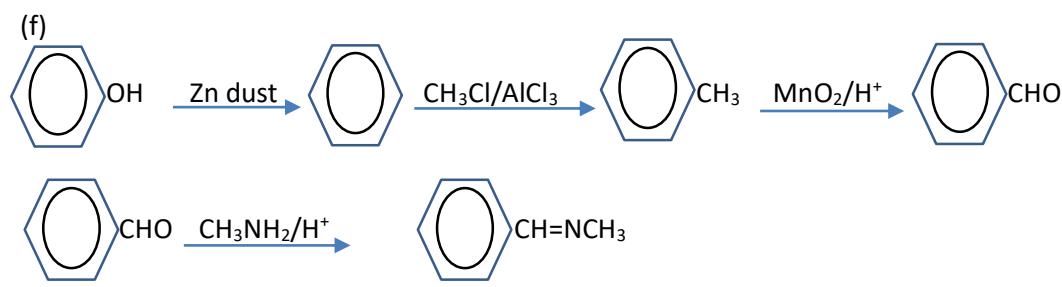
(e) Explain why the tendency to form complexes decrease down the group (II) metals (3marks)

The tendency to form complexes decrease due to decrease in charge density.

6. Write equations to show how the following conversions can be carried out. Indicate the reagents and the conditions







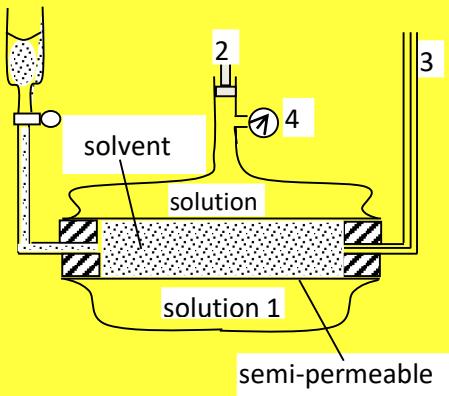
7. (a) Distinguish osmosis from osmotic pressure. (2marks)

Osmosis is the movement of solvent molecules from a region of their high concentration to a region of their low concentration through a semi permeable membrane while osmotic pressure is the minimum pressure that stops osmosis.

- (b) Describe an experiment that could be carried out to determine the relative molecular mass of a compound using the osmotic pressure method. Draw a diagram to illustrate your answer. (6marks)

Method of determination of Relative formula mass of a substance by osmotic pressure method

Working Diagram

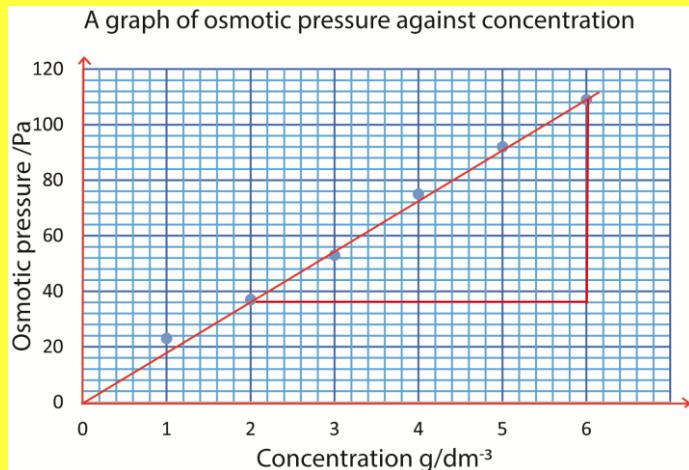


1. cylindrical tube between the solvent and solution is porous/semi-permeable
2. Pressure is applied to the solution and adjusted until there no flow of solvent into solution.
3. Capillary tube indicates movement of solvent into the solution.
4. Osmotic pressure obtained from the pressure gauge.

(c) The osmotic pressure of solutions of a solute Y in benzene at 25°C are given below

Concentration g/dm <sup>-3</sup>	1.0	2.0	3.0	4.0	5.0	6.0
Osmotic pressure /Pa	23	37	53	75	92	109

(i) Plot a graph of osmotic pressure against concentration (3marks)



(ii) Use the graph to determine the molecular mass of Y. (3marks)

$$\text{From } PV = nRT = \frac{m}{Mr}RT$$

$$P = \frac{m}{V} \times \frac{1000RT}{Mr}$$

$$\text{Slope} = \frac{1000RT}{Mr} = \frac{109 - 37}{6 - 2} = \frac{72}{4} = 18 \text{ Pa/gdm}^{-3}$$

$$Mr = \frac{1000RT}{18} = \frac{1000 \times 8.31 \times 298}{18} = 137,577$$

(d) (i) Define the freezing point constant. (1mark)

Freezing point constant is the depression of freezing point caused by 1 mole of a solute in 1000g of a solvent.

(ii) Calculate the freezing point of a solution containing 4.2gdm<sup>-3</sup> of Y in (c) above. (Kf of benzene = 5.50Cmol<sup>-1</sup>K<sup>-1</sup>; freezing point of benzene = 5.5°C) (3marks)

137,577 g of Y cause 5.5

$$4.2 \text{ g of Y cause } \frac{5.5 \times 4.2}{137,577} = 0.00017$$

$$\text{Freezing point of solution} = 5.5 - 0.00017 = 4.49983^\circ\text{C}$$

- (iii) Y is a polymer formed from phenylethene. Calculate the number of monomer unit in Y  
(1mark)

RFM ethene  $C_2H_4 = 12 \times 2 + 4 = 28$

$$\text{Number of monomers} = \frac{137577}{28} = 4913$$

- (iv) Write the equation for the formation of Y.  
(1mark)



8. (a) Write the formula and name of one ore of copper  
(1mark)

- (b) Describe how:

- (i) the ore is concentrated.  
(4marks)

The finely pulverized ore is mixed with water, containing 'frothing' agent (s).

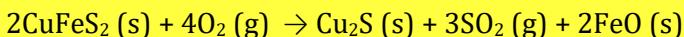
Air is blown into the mixture, froth is produced and the earthly material is "wetted" and sinks.

The sulphide ore particles, rise to the surface in the froth and are skimmed off the surface.

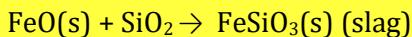
Anti-frothing agent is added to break up the froth, the concentrated ore is filtered and dried.

- (ii) pure copper is obtained from the concentrated ore.  
(6marks)

- The ore is then roasted in a limited supply of air to convert the iron into iron (II) oxide.



- Silica,  $SiO_2$ , is added to the mixture and heated in the absence of air to convert the iron (II) oxide into a slag of iron (II) silicate,  $FeSiO_3$ , which is poured away.



- The copper (I) sulphide is reduced to copper by heating in a controlled amount of air.



- **Purification of copper by electrolysis**

Anode: Impure copper:  $Cu(s) - 2e \rightarrow Cu^{2+}(aq)$

Cathode; pure copper strip:  $Cu^{2+}(aq) + 2e \rightarrow Cu(s)$

Electrolyte: Copper sulphate

(c) Describe the reaction of copper with sulphuric acid (3marks)

Copper does not react with dilute sulphuric acid

Copper is oxidized to copper sulphate by hot concentrated sulphuric acid

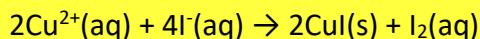


(d) Briefly describe how you would determine the percentage of copper in impure sample (6marks)

- A given mass of m of ore is reacted with concentrated sulphuric acid to oxidize copper



- Excess potassium iodide is added to liberate iodine and the mix titrated against standard sodium thiosulphate solution.



The mass of copper and percentage determined

END

525/2

## **S6 CHEMISTRY**

**Exam 9**

***PAPER 2***

**DURATION: 2 HOUR 30 MINUTES**

### **INSTRUCTIONS**

**Do ALL number in section A and any TWO numbers in section B**

- Time 2hr 30minutes

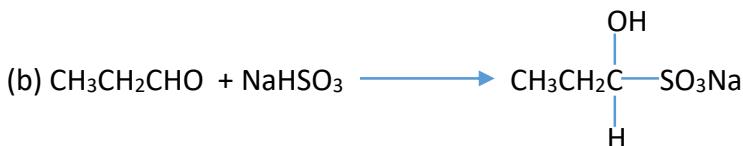
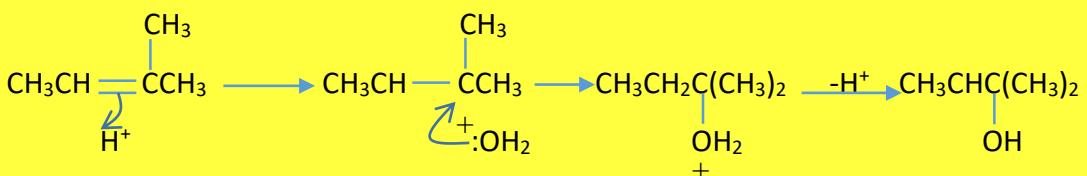
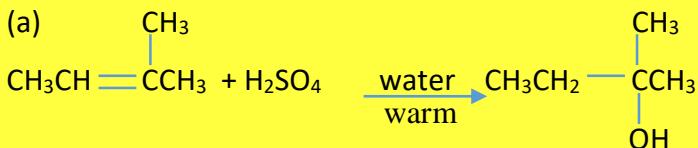
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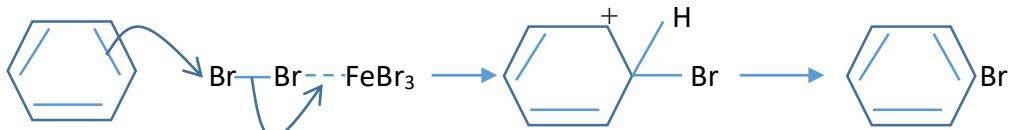
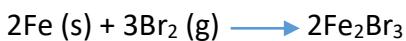
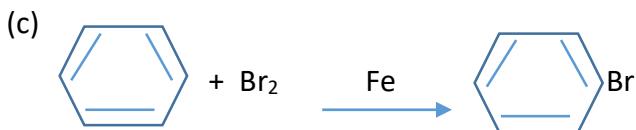
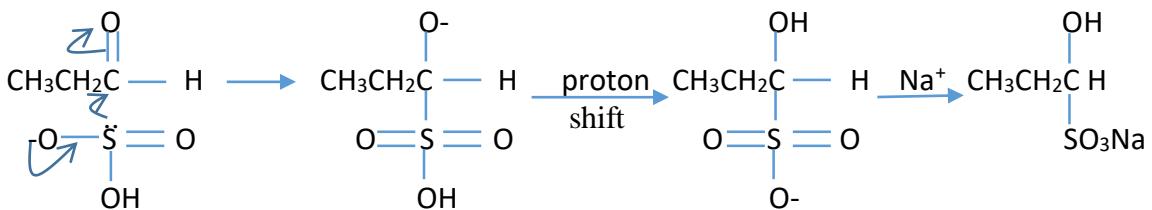
**Section A**

(Do all number 60 marks, 1 ½ hours)

1. Complete the following reactions and give the mechanisms involved (3marks each)



Mechanism



2. Write down equations and indicate the conditions for each of the following

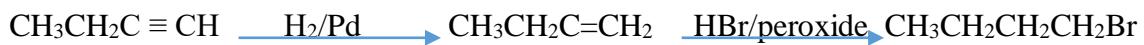
(i)  $\text{CH}_3\text{CH}_2\text{Cl}$  to  $\text{CH}_3\text{COOH}$  (3marks)



(ii)  $\text{CH}_2 = \text{CH}_2$  to  $\text{CH}_3\text{CH}_2\text{OH}$  (2 marks)



(iii)  $\text{CH}_3\text{CH}_2\text{C} \equiv \text{CH}$  to  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$  (2½ marks)



(iv)  to  (2½ marks)



3. Name one reagent you would use to distinguish between each member of the following pairs of compounds. State what would be observed if the reagent is reacted with each member of the pair.

(a)  $\text{CH}_3\text{C} \equiv \text{CCH}_3$  and  $\text{CH}_3\text{CH}_2\text{C} \equiv \text{CH}$  (3marks)

Reagent: ammoniacal silver nitrate

Observation

$\text{CH}_3\text{C} \equiv \text{CCH}_3$  no observable change

$\text{CH}_3\text{CH}_2\text{C} \equiv \text{CH}$  white precipitate

(b)  $\text{CH}_3\text{CH}_2\text{NHCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$  (3marks)

Reagent: sodium nitrite/HCl < 5°

Observation

$\text{CH}_3\text{CH}_2\text{NHCH}_3$  yellow oily liquid

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$  effervescence

- (c)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  (3marks)

Reagent: sodium hydrogen carbonate solution

Observation

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$  no observable change

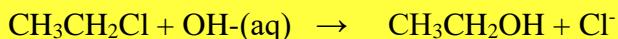
$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  effervescence

4. Explain the following term giving examples where possible (3 marks each)

- (i) Functional groups      (ii)  $\text{SN}^2$       (iii) elimination reaction      (iv) free radical

(i) A functional group is the reactive part of an organic compounds e.g. a double bond in alkenes

(ii)  $\text{SN}^2$  in full is substitution nucleophilic bimolecular: it is a reaction whereby an electron rich species replaces a group on an organic compound  
Example reaction of reaction of chloroethane with sodium hydroxide to form alcohol.



(iii) Elimination reaction is the removal of an atom or a group of atoms from a molecule to form unsaturated compound.

For example dehydration of alcohol with hot concentrated sulphuric acid.



(iv) A free radical is an atom or a group of atoms with unpaired electron

5. State the regents that can be used to confirm the presence of the following ions in solution; in each case state what would be observed when the reagent is reacted with the solution of ion. (3marks each)

(i)  $\text{Pb}^{2+}$ : Potassium iodide give a yellow precipitate

(ii)  $\text{Ni}^{2+}$  a few drops of ammonia followed by dimethylglyoxime gives pink precipitates

(iii)  $\text{Cl}^-$  acidified silver nitrate gives a white precipitate soluble in excess ammonia solution

(iv)  $\text{Cr}^{3+}$  form a green precipitate soluble in excess sodium hydroxide solution that turns yellow with hydrogen peroxide and temporary blue with sulphuric acid

6. (a) what is an atom (3marks)

An atom is the smallest indivisible electrically neutral particle that can take part in chemical reaction

- (b) Name and state the charges of components of an atom (3marks)

Proton      +1

Electron      -1

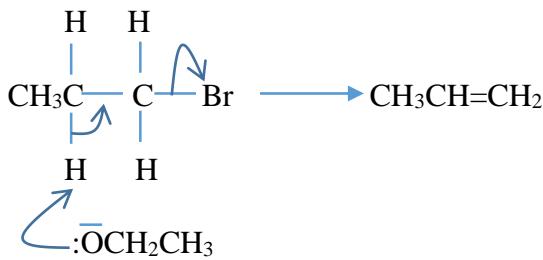
Neutron      no charge

- (c) Calculate the wavelength and frequency of the first line in Layman's series (RH = 109678cm<sup>-1</sup>) (3marks)

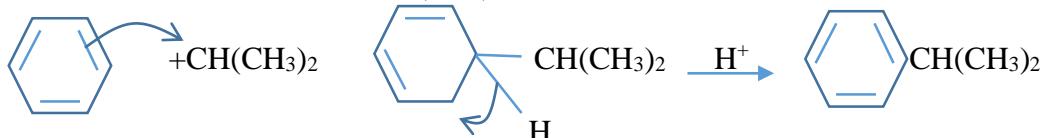
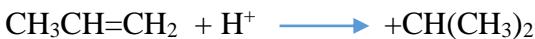
$$\text{Wave number} = \text{RH} \left[ \frac{1}{n^2} - \frac{1}{m^2} \right] = 109678 \left[ \frac{1}{1^2} - \frac{1}{2^2} \right] = 82258\text{cm}^{-1}$$

**SECTION B**  
**(Any TWO questions, 1hour)**

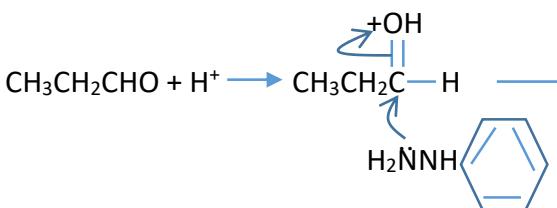
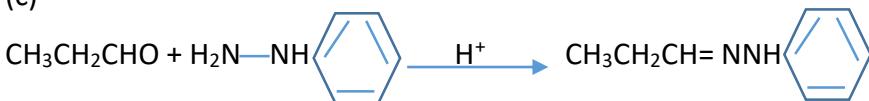
7. Complete the following equations and in each case outline a mechanism of the reaction



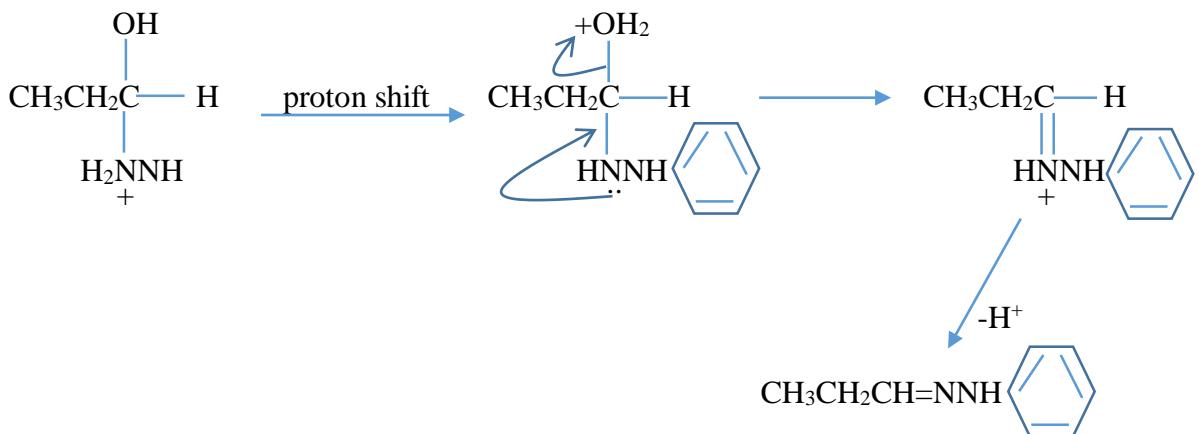
(b)



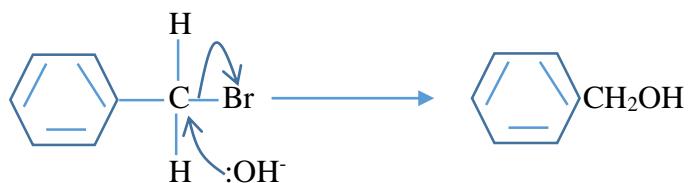
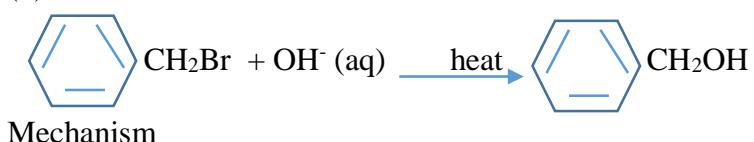
(c)



Then



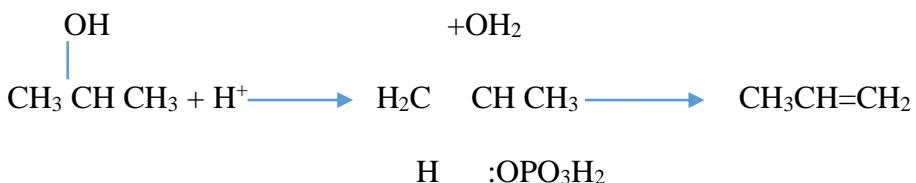
(d)



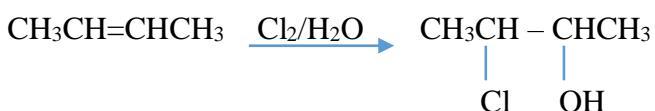
(e)



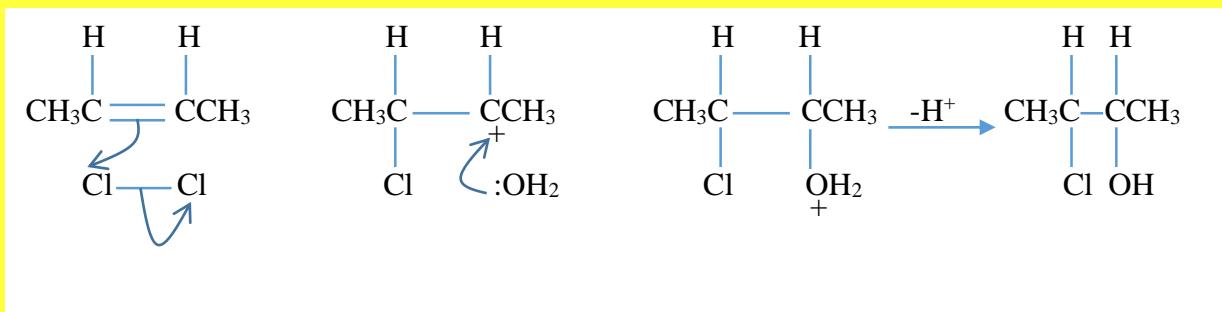
Mechanism



(f)



### Mechanism



8. (a) Describe the spectrum of a hydrogen atom.

Use diagrams to illustrate your answer

(7 marks)

Hydrogen spectrum is of two types:

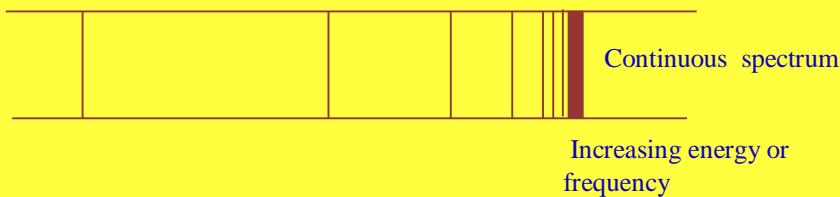
- (i) Absorption spectra

It is observed as dark lines on a black background when white light is passed through gaseous hydrogen. This is caused by hydrogen atoms absorbing energy corresponding to certain wavelengths from the light.

- (ii) Emission

It is observed as a pink glow when an electric discharge is passed through hydrogen at low pressure. Analyzed through a spectrometer, the emission is seen to be a number of separate sets of lines or series of lines.

In each series, the intervals between the frequencies of the lines become smaller and smaller towards the high frequency end of the spectrum until the lines run together or converge to form a continuum of light or continuum.



- (b) Explain how the spectrum of a hydrogen atom

- (i) is formed

( 4 marks)

When a hydrogen atom in ground state is struck by light, its electron absorbs energy of certain wavelength/frequency. The absorbed frequency appears as a dark line in absorption spectrum

After absorbing energy, an electron jumps to a higher energy level. Energy absorbed is equal to the energy difference between two the energy levels. When the excited electron drops to the orbits of a lower energy level, it emits this energy in form of radiation giving, an emission spectrum corresponding to the frequency of radiation emitted.

(ii) Provides evidence for the existence of energy levels in an atom (7 marks)

The fact that the hydrogen spectrum is a line spectrum, suggests that only specific amounts of energy absorptions and emissions are possible suggesting existence of energy levels within an atom and that an electron occupies certain energy levels around the nucleus. The various lines in each series are suggestive that the main energy levels are subdivided into lower energy levels.

(c) The frequency of hydrogen at the point of ionization id  $32.8 \times 10^{14}$ Hz

Calculate the ionization energy of hydrogen. (Planks constant =  $6.6 \times 10^{-34}$ Js (2 marks)

Energy = hf (h is Plank's constant, f = frequency)

$$= 6.6 \times 10^{-34} \times 32.8 \times 10^{14}$$

$$= 2.165 \times 10^{-18} \text{J or } 2.165 \times 10^{-21} \text{ kJ}$$

But 1 mole contains 6.023 particles, according to Avogadro

$$E = 2.165 \times 10^{-21} \times 6.023 \times 10^{23} = 1304 \text{ kJ}$$

9. (a) The reaction equation for formation of ammonia is represented as follows

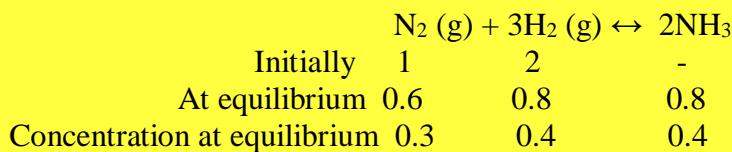


a) Write expression for equilibrium constants K<sub>c</sub> and K<sub>p</sub> for production of ammonia and indicate their units (4 marks)

$$K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} \text{ mol}^{-2}\text{dm}^6$$

$$K_p = \frac{P_{\text{NH}_3}^2}{P_{\text{N}_2}P_{\text{H}_2}^3} \text{ atm}^{-2}$$

- b) Discuss the effects of the following on the constants in (a)
- (i) Pressure (3marks)  
Pressure has no effect on the values of constants above
- (ii) Temperature (5marks)  
Increasing temperature shift equilibrium from right to left lowering the values of Kc and Kp. Alternatively lowering temperature shifts equilibrium to the right increasing the concentration of ammonia increasing the values of Kc and Kp.
- (c) At a certain temperature, 1 mole of nitrogen gas was reacted with 2 moles of hydrogen gas in a 2 dm<sup>3</sup> vessel; at equilibrium, 0.4 moles of nitrogen gas had reacted and the total pressure of the system at equilibrium was 2 atmospheres. Calculate:
- (i) Kc (3marks)  
(ii) Kp (3marks)



(i)  $K_c = \frac{0.4^2}{0.3 \times 0.4^3} 8.3 \text{ mol}^{-2} \text{ dm}^6$

Total moles at equilibrium  $0.6 + 0.8 + 0.8 = 2.2$

Partial pressure of nitrogen =  $\frac{0.6}{2.2} \times 2 = 0.54$

Partial pressure of nitrogen = partial pressure of hydrogen =  $\frac{0.8}{2.2} \times 2 = 0.73$

$K_p = \frac{0.54^2}{0.73 \times 0.73^3} = 1.03 \text{ atm}^{-2}$

END

## S6 CHEMISTRY

**Exam 10**

**PAPER 2**

**DURATION: 2 HOUR 30 MINUTES**

### **INSTRUCTIONS**

- Answer any five questions
- Time 2hr 30minutes

1. (a) A compound X, vapour density 58, contains carbon 62.07%, hydrogen 10.34% and the rest being oxygen. X does not burn with a sooty flame.

- i. Calculate the empirical formula of X (C=12, O=16, H=1) (3 marks)

Solution

$$\text{Percentage of } = 100 - (62.07 + 10.34) = 27.59$$

Elements	C	H	O
Percentage	62.07	10.34	27.59
RAM	12	1	16
Moles	5.173	10.34	1.724
Mole ratio	3	6	1

Empirical formula  $\text{C}_3\text{H}_6\text{O}$

- ii. Determine the molecular formula (2 marks)

$$\text{Molecular mass} = 58 \times 2 = 116$$

$$(\text{C}_3\text{H}_6\text{O})_n = 116$$

$$n = 2$$

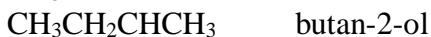
$$\text{molecular formula} = \text{C}_6\text{H}_{12}\text{O}_2$$

b. Hydrolysis of X yielded compounds, Y,  $C_4H_{10}O$  and Z,  $C_2H_4O_2$ . Both Y and Z react with metallic sodium. Z reacted with sodium carbonate but Y did not.

(i) Identify Z. (1 mark)

Ethanoic acid,  $CH_3COOH$

(ii) Write names and the structural formulae of all the possible isomers of Y. (4 marks)



(iii) Name a reagent that can be used to distinguish between the isomers in (b) (ii) and state what would be observed if the reagent you have named is reacted separately with each of the isomers. (4 marks)

Reagent: anhydrous zinc chloride/conc. HCl

Butan-1-ol and 2-methylpropan-1-ol - no observable change

Butan-2-ol - two layers in 5 -10minutes

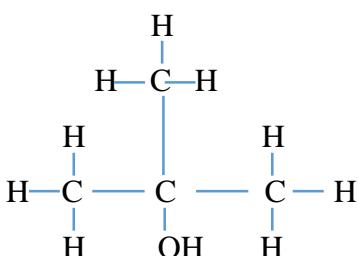
2-methylpropan-2-ol - immediate cloudiness

c. When Y was warmed with acidified potassium dichromate solution, there was no observable change.

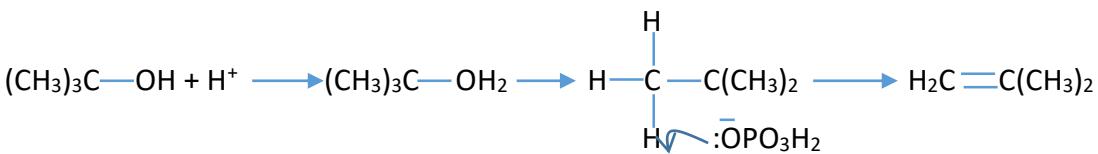
i. Identify Y.

2-methylpropan-2-ol

ii. write the structural formulae of Y



d. (i) write equation and outline a mechanism for the reaction between Y and concentrated phosphoric acid (3½ marks)



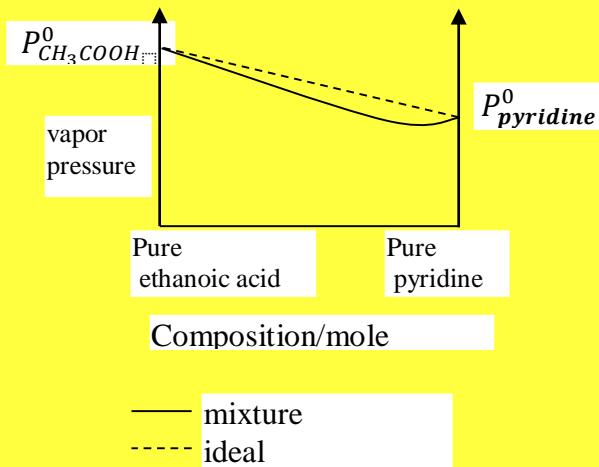
(ii) Write the IUPAC name of the product in d(i). (½ mark)

2-methylpropene

2. (a) state **Raoult's Law**. (3 marks)

(b) A mixture of ethanoic acid (B.P 118°C) and pyridine (b.p. 123°C) show negative deviation from Raoult's law.

(i) Draw the vapour pressure/composition curve for the mixture of ethanoic acid and pyridine and indicate the line of Ideal behavior. (4 marks)



Note that

- ethanoic acid with lower boiling point thus has higher vapor pressure
- The minimum boiling point occurs to the composition containing more pyridine (the less volatile) than ethanoic acid.

(ii) Explain the shape of the curve in relation to Raoult's Law. (6 marks)

- the curve for the mixture lies below the line for ideal behavior
- this is because the attraction between the molecules of ethanoic acid and those of pyridine are greater (stronger) than those between ethanoic acid-ethanoic acid or pyridine – pyridine
- pyridine molecules are held by weak van der Waal forces
- ethanoic acid molecules are associated with hydrogen bonds
- when ethanoic acid and pyridine are mixed , intermolecular hydrogen bonds are formed between ethanoic acid and pyridine molecules which are stronger than the bonds in pure or equal to those in pure ethanoic acid

- consequently, the escaping tendency of individual molecules of each component is reduced, leading to reduced vapor of solution of the mixture

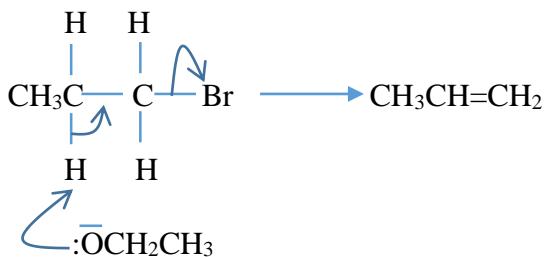
(c) (i) Explain what is meant by ‘steam distillation’ (3 marks)

It is a technique of separating a volatile liquid/substance that is immiscible with water from nonvolatile component at temperature below its boiling point by bubbling steam through the mixture

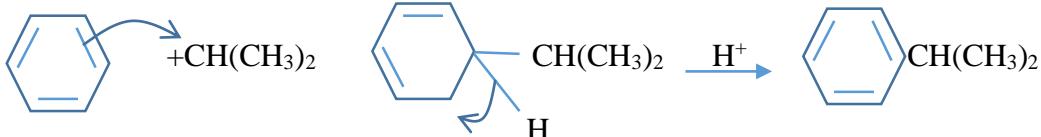
(ii) When a compound Y, was steam distilled at standard atmospheric temperature and pressure, the temperature of distillation was  $96^{\circ}\text{C}$ . The vapour pressure of water at this temperature was 730mm Hg and the distillate contained 74% of water.

Calculate the relative molar mass of Y (4 marks)

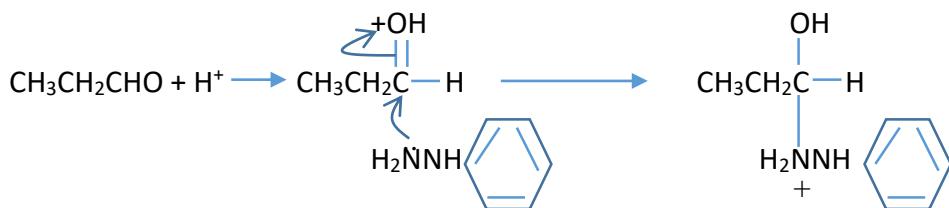
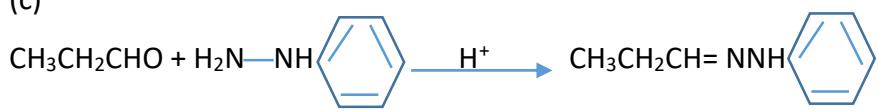
3. Complete the following equations and in each case outline a mechanism of the reaction



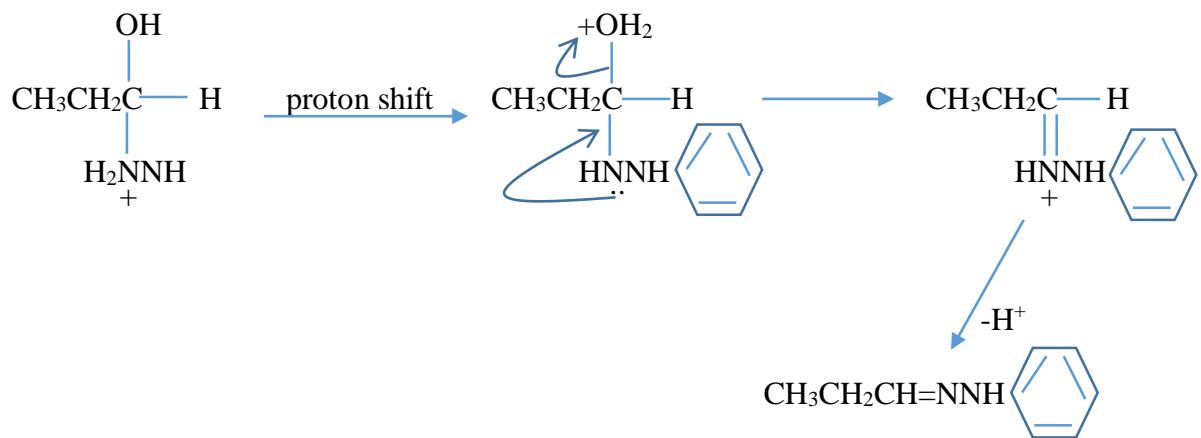
(b)



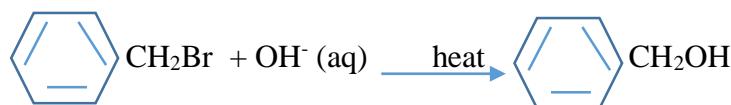
(c)



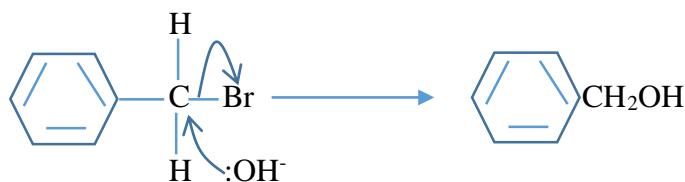
Then



(d)



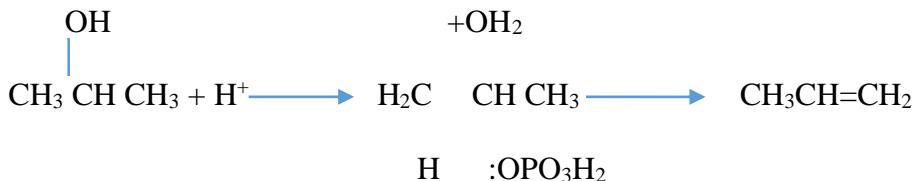
Mechanism



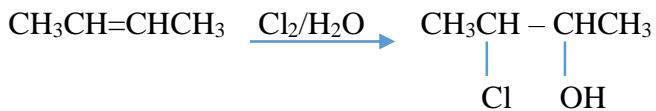
(e)  $\begin{array}{c} \text{OH} \\ | \\ \text{CH}_3\text{CHCH}_3 \end{array}$



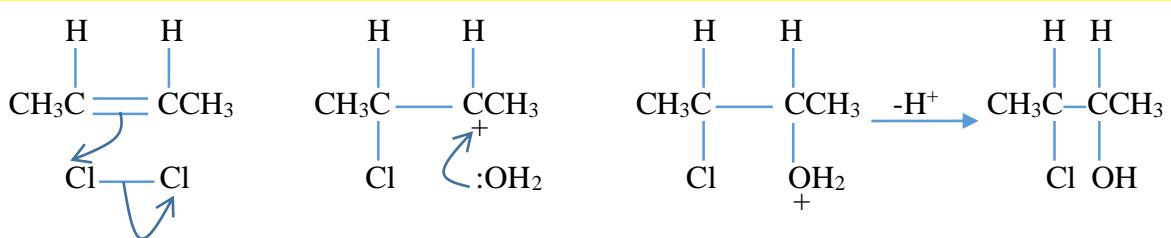
Mechanism



(f)



Mechanism



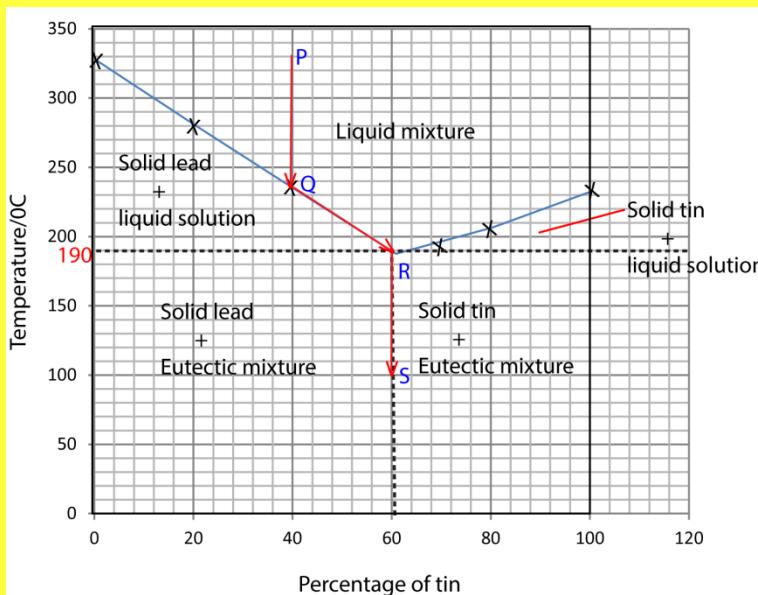
4. (a) Define the term *eutectic mixture*. (3 marks)

These are mixtures which at constant pressure freeze at constant temperature to give a solid of the same composition.

- (b) The table below shows the melting points of various mixtures of lead and tin.

% tin	0	20	40	70	80	100
Melting point/ $^{\circ}\text{C}$	327	280	234	193	206	232

- (i) Draw a fully labeled diagram for the tin-lead system. (5 marks)



- (ii) Determine the eutectic temperature and the composition of the eutectic mixture (3 marks)

Eutectic composition 60% tin,  
Eutectic temperature  $190^{\circ}\text{C}$

- (c) Describe the changes that would take place when a liquid mixture of the above system containing 40% tin is cooled from  $400^{\circ}\text{C}$  to  $100^{\circ}\text{C}$ .

The temperature of the liquid falls from  $400^{\circ}\text{C}$  to about  $235^{\circ}\text{C}$  along PQ (shown on the graph); at Q solid lead crystallizes out and the freezing point of the remaining solution drops along QR as more lead solidifies. At R ( $190^{\circ}\text{C}$ ) the composition of tin will be 60%, temperature remains constant until all the liquid has turned into a solid before the temperature drops further to  $100^{\circ}\text{C}$  along RS.

- (d) (i) State one application of the lead-tin eutectic mixture (1 mark)  
welding

- (ii) Name one other pair of metals which can give a similar phase diagram as in (b) (i). (1 mark)

(ii) Zn and Cd; Cu and Zn; Ca and Mg; Pb +Ag

- (iii) State one similarity between a eutectic mixture and pure metal (1 mark)  
Have same cooling curve  
Have the same composition in solid as in liquid

5. (a) Describe the spectrum of a hydrogen atom.

Use diagrams to illustrate your answer

(7 marks)

Hydrogen spectrum is of two types:

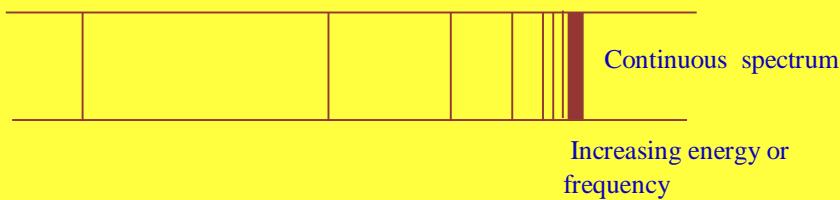
(i) Absorption spectra

It is observed as dark lines on a black background when white light is passed through gaseous hydrogen. This is caused by hydrogen atoms absorbing energy corresponding to certain wavelengths from the light.

(ii) Emission

It is observed as a pink glow when an electric discharge is passed through hydrogen at low pressure. Analyzed through a spectrometer, the emission is seen to be a number of separate sets of lines or series of lines.

In each series, the intervals between the frequencies of the lines become smaller and smaller towards the high frequency end of the spectrum until the lines run together or converge to form a continuum of light or continuum.



(b) Explain how the spectrum of a hydrogen atom

(i) is formed

( 4 marks)

When a hydrogen atom in ground state is struck by light, its electron absorbs energy of certain wavelength/frequency. The absorbed frequency appears as a dark line in absorption spectrum

After absorbing energy, an electron jumps to a higher energy level. Energy absorbed is equal to the energy difference between two the energy levels. When the excited electron drops to the orbits of a lower energy level, it emits this energy in form of radiation giving, an emission spectrum corresponding to the frequency of radiation emitted.

- (ii) Provides evidence for the existence of energy levels in an atom (7 marks)

The fact that the hydrogen spectrum is a line spectrum, suggests that only specific amounts of energy absorptions and emissions are possible suggesting existence of energy levels within an atom and that an electron occupies certain energy levels around the nucleus. The various lines in each series are suggestive that the main energy levels are subdivided into lower energy levels.

- (c) The frequency of hydrogen at the point of ionization is  $32.8 \times 10^{14}$ Hz

Calculate the ionization energy of hydrogen. (Plank's constant =  $6.6 \times 10^{-34}$ JS (2 marks)

$$\text{Energy} = hf \quad (h \text{ is Plank's constant, } f = \text{frequency})$$

$$= 6.6 \times 10^{-34} \times 32.8 \times 10^{14}$$

$$= 2.165 \times 10^{-18}\text{J or } 2.165 \times 10^{-21}\text{ kJ}$$

But 1 mole contains 6.023 particles, according to Avogadro

$$E = 2.165 \times 10^{-21} \times 6.023 \times 10^{23} = 1304 \text{ kJ}$$

6. (a) The first ionization energies of an element B are shown below

Ionization Energy/kJmol <sup>-1</sup>							
1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>
786	1580	3230	4360	16000	20000	23600	29100

(I) Explain what is meant by the term *First ionization energy*?

Is the energy required to remove one mole of electrons from 1 mole gaseous atoms to form gaseous ions with single positive charge

(ii) State the factors that determine the value of first ionization energy

- (i) Atomic radius
- (ii) Nuclear charge
- (iii) The screening effect of the inner electrons

(ii) To which group of the periodic table does element B belong

Give reason for your answer

Group 4; the big difference of ionization energy between the 4<sup>th</sup> and 5<sup>th</sup> indicates that the 5<sup>th</sup> electron resides in a stable full electron shell and that the outermost shell contains 4 electrons.

(b) Explain the term *electronegativity*.

State the factors that determine the value of electronegativity of an element.

- (i) Atomic radius
  - (ii) Nuclear charge
  - (iii) The screening effect of the inner electrons
- (c) Explain how the following factors affect the value of electronegativity of an element
- (i) Atomic radius

The bigger the atomic radius the farther from the nucleus the outer electrons and thus experience less nuclear charge lowering the values of electronegativity

- (ii) Nuclear charge

When the nuclear charge is high electronegativity is high because the outer electrons are strongly attracted to the nucleus

- (iii) The screening effect of the inner electrons

When screening effect is high; electronegativity is low because the outer electrons are less attracted to the nucleus.

- (d) Explain the difference between electronegativity and electron affinity.

Electronegativity is the relative tendency of an atom to attract bonding electrons in a covalent bond while electron affinity is energy change when an electron is added to gaseous atom or an anion

7. (a) (i) Define “ Standard Electrode potential” (2marks)

It is the electrode potential value of an electrode measure with respect to a standard hydrogen electrode of 0 volts. When an electrode is immersed or dipped into a solution of 1M concentration of its ions at a standard temperature of 298K and pressure of 1 atmospheres.

- (ii) Why is it not possible to measure standard electrode potential absolutely?  
(2marks)

It requires a second electrode to be introduced since it's a difference in potential, however, the second electrode also produces its own electrode potential making such a difference relative rather than absolute

- (iii) Discuss the factors which affect the value of standard electrode potential (5½marks)

$$\text{Electrode potential} = \text{sublimation energy} + \text{ionization} + \text{Hydration energy}$$

- Sublimation energy: the higher the sublimation energy the more positive the electrode potential. This is because it becomes difficult to convert a solid into gaseous atoms (i.e. sublimation is endothermic)

- Ionization energy: if ionization energy is high; electrode potential becomes more positive because ionization energy is endothermic.
- Hydration energy: a high hydration energy give a more negative electrode potential since hydration is exothermic reaction.

(b) Describe a standard hydrogen half cell (2marks)

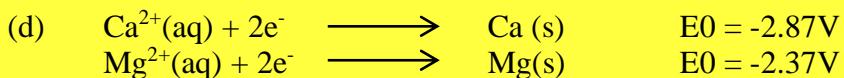
It consists of a molar solution of H<sup>+</sup> ions having platinized titanium or platinum coated with finely divided titanium, around which pure hydrogen gas at 1 atmosphere and 298K (25°) is bubbled.

(c) How would you measure standard electrode potential of a metal in solution of its ions? (3marks)

The metal is placed in one molar solution of its ions and connected to the standard hydrogen electrode by a salt bridge

A voltmeter connected in parallel will show the emf of the cell

The standard electrode potential of the metal is equal to the emf shown by the voltmeter, measured relative to the electrode potential of hydrogen electrode considered to be zero



A cell was set up as below



(i) Calculate the e.m.f of the cell (2marks)

$$\begin{aligned} E^{\circ}_{\text{cell}} &= E^{\circ}_{\text{Reduction}} - E^{\circ}_{\text{oxidation}} \\ &= -2.87 - (-2.37) \\ &= -0.5\text{V} \end{aligned}$$

(ii) What conclusion can you draw from your e.m.f value in (d)(i) above (3marks)

The cell as set up is non spontaneous because emf is negative. It is spontaneous in the opposite direction.

8.(a) Write the name and formula a of one ore from which aluminium can be extracted and describe how aluminium is extracted from the ore (08marks)

Extraction of Aluminium  
Ore: Bauxite ( $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ )

Major impurities are

- ✓ Silica or  $\text{SiO}_2$
- ✓ Iron salts

#### Principles in extraction

Extraction of aluminium involves removal of impurities (purification) and then reduction to metal by electrolysis.

#### Steps in extraction of Aluminium

- (i) The ore is heated
  - to remove water and,
  - To convert iron salts to iron III oxide
- (ii) 2. The powdered ore is heated with concentrated sodium hydroxide to dissolve aluminium oxide and silica such that the insoluble iron oxide is filtered off.  
Aluminium oxide form aluminate  

$$\text{Al}_2\text{O}_3(\text{s}) + 2\text{NaOH}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{Na}[\text{Al}(\text{OH})_4(\text{H}_2\text{O})_2](\text{aq})$$

Or the ionic form



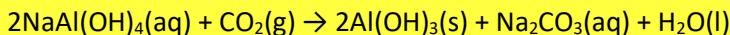
Silica also dissolves forming sodium silicate.



- (iii) 3. To the filtrate a little aluminium hydroxide is added to precipitate Aluminium hydroxide,(seeding).  

$$\text{NaAlO}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{NaOH}(\text{aq}) + \text{Al}(\text{OH})_3(\text{s})$$

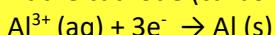
Alternatively carbon dioxide bubbled through the filtrate to precipitate aluminium hydroxide as follows



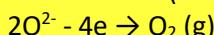
- (iv) 4. The precipitated aluminium hydroxide is filtered off, washed and ignited to give pure aluminium oxide (alumina).  

$$2\text{Al}(\text{OH})_3(\text{s}) \rightarrow \text{Al}_2\text{O}_3(\text{s}) + 3\text{H}_2\text{O}(\text{g})$$
  
 Alumina
- (v) 5. Aluminum is obtained from aluminium oxide by electrolysis.  
 Cryolite,  $\text{Na}_3\text{AlF}_6$ , is added to
  - lower the melting point of alumina from  $2050^\circ\text{C}$  to  $900^\circ\text{C}$
  - and improve conductivity of aluminium oxide

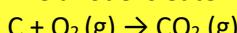
At the cathode (carbon) aluminium is liberated



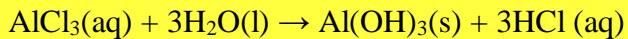
At the anode (carbon) oxygen is liberated



The anode is eaten up by oxygen



- (b) Write equations and state conditions under which aluminium reacts with
- (i) Air  
Hot aluminium reacts with air to form aluminium oxide  
$$4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3$$
  - (ii) Sodium hydroxide  
Aluminium reacts with hot concentrated sodium hydroxide solution to form sodium aluminate  
$$2\text{Al(s)} + 2\text{OH}^-(\text{aq}) + 6\text{H}_2\text{O(l)} \rightarrow 2\text{Al(OH)}_4^-(\text{aq}) + 3\text{H}_2\text{(g)}$$
  - (iv) hydrochloric acid  
Aluminium reacts with dilute hydrochloric acid to liberate hydrogen  
$$2\text{Al(s)} + 6\text{HCl(aq)} \rightarrow 2\text{AlCl}_3(\text{aq}) + 3\text{H}_2\text{(g)}$$
- (c) State what is observed and write equation for the reaction which take place when aqueous ammonia is added drop-wise to a solution containing aluminium ions (2½ marks)  
White precipitate insoluble in excess  
$$\text{Al}^{3+}(\text{aq}) + 3\text{OH}^-(\text{aq}) \rightarrow \text{Al(OH)}_3(\text{s})$$
- (d) Write equation for the reaction that take place when aluminium chloride is dissolved in water (1½ marks)



END

