Our country, our future

525/1

S6 CHEMISTRY

Exam 21

PAPER 1

DURATION: 2 HOUR 45 MINUTES

Instructions

Answer all questions in section A and six questions in section B.

All questions must be answered in the spaces provided.

Illustrate your answers with equations where applicable.

The periodic table is provided.

SECTION. A(46 MARKS)

Answer all questions from this section

1. (a) i) State the conditions for steam distillation. (1½ marks)

- The substance to be separated should be volatile, immiscible with water, and mixed with nonvolatile substances

ii) State one advantage of steam distillation over fractional distillation. (1 mark)

Substances are separated at low temperature which protects them from decomposition.

b) Substance A distills with steam at 98.3^{O}C under pressure of 753mmHg. Calculate the percentage by mass of A in the distillate. (The vapour pressure of water at 98.3^{O}C is 715mmHg; A =128) (03 marks)

Solution

Vapor pressure of substance A = 753 – 715 = 38mmHg

Let the percentage of A = x

The percentage of water = 100 – x

$\frac{x}{100-x} = \frac{38\ x\ 123}{18\ x\ 715}$

x = 26.6%

∴ percentage of A= 26.6

2. (a) Write the electronic configuration of copper. (01 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$

b) State two properties of copper as a transition element. (04 marks)

- Forms colored compounds e.g. Cu^{2+} is blue
- Has variable oxidation state, i.e, +1 and +2
- Forms complexes e.g. $Cu(NH_3)_4^{2+}$

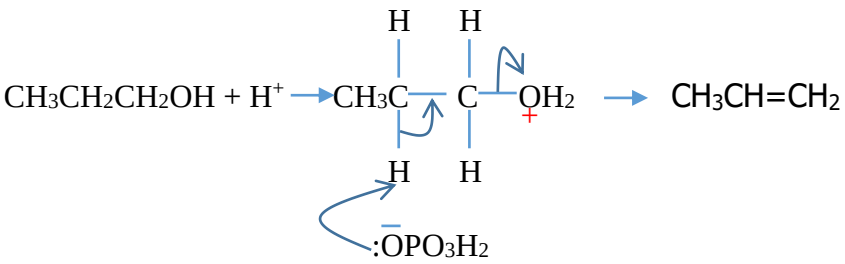
c) Hydrated copper (ii) sulphate was dissolved in water. Write equation (s) for the reaction (s) that took place. (03 marks)

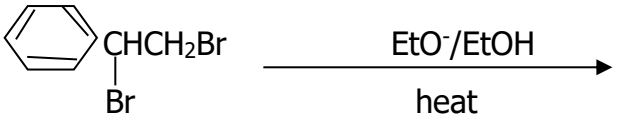
$CuSO_4.5H_2O + aq \rightarrow CU^{2+}(aq) + SO_4^{2-}(aq)$

3. Complete the following equations and in each case write a mechanism for the reaction.

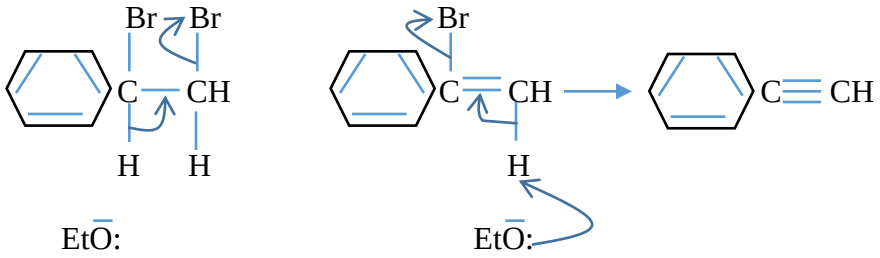
a) $CH_3CH_2CH_2OH \xrightarrow[180^0C]{\text{Conc } H_3PO_4} CH_3CH=CH_2$ (03 marks)

$H_3PO_4(aq) \rightarrow H^+(aq) + -OPO_3H_2$



b) 

(02 marks)



4.a) Define the term "partial pressure" (1 mark)

The pressure that would be exerted by one of the gases in a mixture if it occupied the same volume on its own.

b) The vapour pressures of pure chloroform and carbon tetrachloride are 199.1 and 114.5mmHg respectively at 25^OC.

(Assume that a mixture of the two liquids behave as an ideal gas and that it contains 0.96 mole of each pure liquid).

i) The partial pressure of each component in the mixture. (2 ½ marks)

Mole fraction of each = $\frac{0.96}{0.96+0.96}$ = 0.5

Partial pressure of chloroform = $X_{CHCl_3} x\ P^0_{CHCl_3}$ = 0.5 x 199.1 = 99.55mmHg

Partial pressure of tetrachloromethane =$X_{CCl_4} x\ P^0_{CCl_4}$ = 0.5 x 114.5 = 57.25mmHg

ii) The total pressure. (1 mark)

99.5 +57.25 = 156.8mmHg

(c) Calculate the percentage of carbon tetrachloride in the vapour in equilibrium with the liquid mixture. (1 mark)

Percentage of tetrachloromethane = $\frac{57.25\ x\ 100}{156.8}$ = 36.5%

5. Lithium is in group 1 and magnesium is in group II of the periodic table but the two elements show some common chemical properties.

a) State the name given to this type of relationship. (1 mark)

diagonal relationship

b) Give four examples of the properties in which the two elements show similarities. (4 marks)

- both react with nitrogen to form nitrides
- both react with oxygen to form normal oxide
- They combine with carbon to form carbide

  $Mg(s) + 2C(s) \rightarrow Mg^{2+}(C\equiv C)^{2-}(s)$

  $2Li(s) + 2C(s) \rightarrow Li_2C_2(s)$
- Their carbonates decompose to form carbon dioxide

c) Name two other pairs of elements that show similar type of relation as lithium and magnesium. (1 mark)

- Beryllium and aluminium
- Boron and silicon

6. Complete the following equations and write the IUPAC name of the main organic production each case.

a) $CH_3CH_2CO_2H$ $\xrightarrow{+ PCl_5 \text{ heat}}$ CH_3CH_2COCl propanoylchloride (1 ½ marks)

b) $HC \equiv CH$ $\xrightarrow{Ag(NH_3)_2^+ (aq)}$ $HC \equiv CAg$ silver ethyne (1 ½ marks)

7. The ionic radii of Na^+, Mg^{2+} and Al^{3+} are 0.095, 0.065 and 0.050 respectively.

a) Calculate the charge/ radius ratio per

i) Na^+ (01 mark)

$\frac{1}{0.095} = 10.5$

ii) Mg^{2+} (01 mark)

$\frac{2}{0.065} = 30.8$

iii) Al^{3+} (01 mark)

$\frac{3}{0.05} = 60$

b) Which of the ions has

i) The least polarizing power? (½ marks)

Na^+

iii) The greatest polarizing power. (½ marks)

Al^{3+}

c) Give reasons for your answers in c) i) and ii) above. (02 marks)

Na^+ has the least charge density while Al^{3+} has the highest charge density

8. (a) State Graham's law. (01 mark)

The rate of effusion of a gas is inversely proportional to the square root of either the density or the molar mass of the gas.

b) A certain volume of oxygen diffused through a porous membrane in 120s. Under the same conditions the same volume of a gas. X diffuses in 112s. Calculate the relative molecular mass of X. (3½ marks)

$\frac{\frac{V}{120}}{\frac{V}{112}} = \sqrt{\frac{RFM\ of\ X}{32}} = 27.8$

9. The empirical formula of a fluoride of sulphur, Y 1 is SF_4. 0.1g of Y occupied 22.10cm^3 when vaporized at 20^0C and 766mmHg.

a) Determine the molecular formula of Y. (3 ½ marks)

let the volume at stp be V

$\frac{766\ x\ 22.1}{293} = \frac{760V}{273}$; V = 20.754$cm^3$

Formula mass

20.754 cm^3 weigh 0.1g

22400cm^3 weigh RFM

RFM = $\frac{22400\ x\ 0.1}{20.754}$ = 108

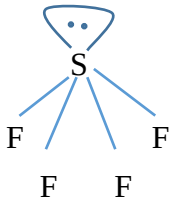
$(SF_4)n$ = 108

(32 + 19 x 4)n =108

n = 1

molecular formula = SF_4

b) Draw the structure of Y and name the shape (1 ½ marks)



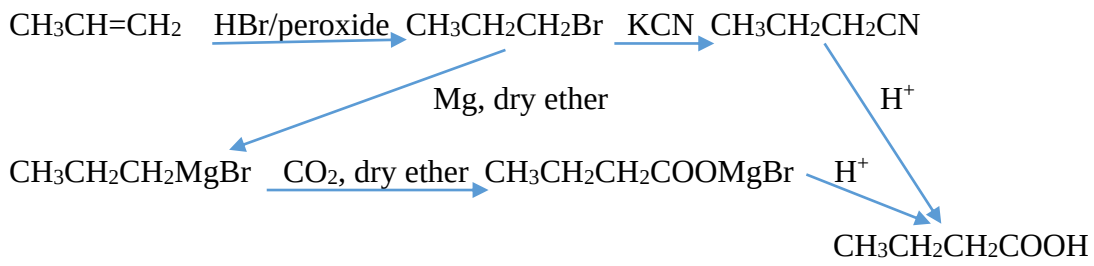
shape trigonal bipyramidal

SECTION. B (54 MARKS)

Attempt six questions from this section

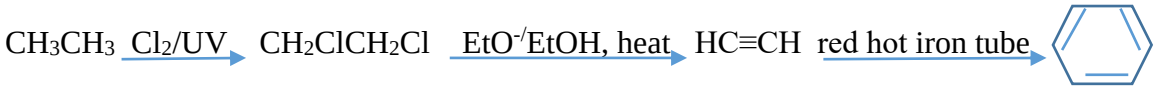
10. Write equations to show how the following compounds can be synthesized.

a) $CH_3CH_2CH_2COOH$ from $CH_3CH{=}CH_2$. (3 marks)

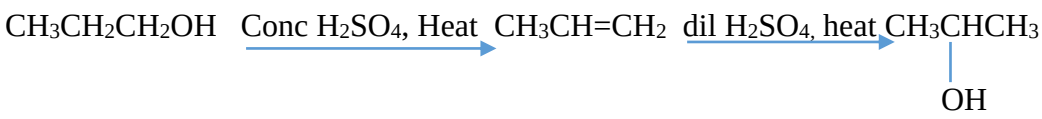


b) C_6H_6 from CH_3CH_3. (3 marks)

Benzene is prepared from ethyne by the process of cyclic polymerization. In this process, Ethyne is passed through a red hot iron tube at 873 K. The ethyne molecule then undergoes cyclic polymerization to form **benzene**.



c) $CH_3CH_2CH_2OH$ to $CH_3\underset{\displaystyle OH}{\underset{|}{C}}HCH_3$ (3 marks)



11. State what would be observed and write equation for the reaction that would take place when

a) Copper is added to a solution of concentrated nitric acid. (2½ marks)

Equation

$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2\,(aq) + 2NO_2(g) + 2H_2O(l)$

Observation

Brown fumes and green solution

b) Potassium iodide is added to acidified solution of hydrogen peroxide. (02 marks)

Equation.

$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$

Observation

Brown solution

c) Sodium sulphite is added to a solution of acidified potassium dichromate (VI) (2 ½ marks)

Equation

$Cr_2O_7^{2-}(aq) + 3SO_2(g) + 2H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + H_2O(l)$

Observation

Orange solution turns green

d) Aqueous iron (ii) sulphate is added to acidified potassium manganate (VII) solution.

(2 marks)

Equation

$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$

Observation

Purple color turns colorless

12. A compound P contains 52.2% of carbon, 13% of hydrogen the rest being oxygen

a) Determine the empirical formula of P (2 marks)

Percentage of oxygen = 100 – (52.2 + 13) =34.8

Elements	C	H	O
Percentages	52.2	13	34.8
RAM	12	1	16
Moles	4.35	13	2.175
Moles	2	6	1

Empirical formula = C_2H_6O

b) When vaporized 0.1g of P occupied 78.8cm^3 at 150^{0}C and a pressure of 740mmHg

i) Calculate the formula mass of P (2½ marks)

Let the volume at stp be V

$\frac{78.8\ x\ 740}{423} = \frac{760V}{273}$

V = 49.5cm^3

Formula mass

49.5cm^3 weigh 0.1g

22400cm^3 weigh $\frac{0.1\ 22400}{49.5}$ =45

ii) Determine the molecular formula of P. (1 ½ marks)

$(C_2H_6O)n = 45$

$n = 1$

molecular formula = C_2H_6O

iii) Write the structural formula of all the possible isomers of P. (1 mark)

CH_3CH_2OH ethanol

CH_3OCH_3 diethylether

c) P does not react with sodium metal. Identify P. (0 ½ marks)

ethanol

d) Write an equation to show how P can be prepared from methanol. (1 ½ marks)

$CH_3OH \xrightarrow{PCl_5} CH_3Cl \xrightarrow{Mg,\ dry\ ether} CH_3MgCl \xrightarrow{HCHO,\ dry\ ether} CH_3CH_2OMgCl \xrightarrow{H^+} CH_3CH_2OH$

13. Name the reagent (s) that can be used to distinguish between the following pairs of compounds and state what is observed in each case.

a) CH_3CH_2OH and $CH_3\overset{OH}{\overset{|}{C}}HCH_3$ (3 marks)

Reagent: anhydrous zinc chloride and concentrated hydrochloric acid

Observation

CH_3CH_2OH no observable change

$CH_3CH(OH)GH_3$ cloudiness in 5- 10minutes

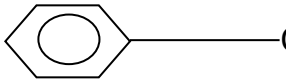
b) $CH \equiv CCH_3$ and $CH_3C \equiv CCH_3$ (3 marks)

Reagent: ammoniacal silver nitrate

Observation

$CH \equiv CCH_3$ white ppt

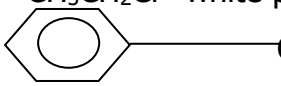
$CH_3C \equiv CCH_3$ no observable change

c) CH_3CH_2Cl and  Cl (3 marks)

Reagent: hot sodium hydroxide followed acidified silver nitrate

Observation

CH_3CH_2Cl –white precipitate

 Cl - No observable change

14. (a) State what is meant by the term order of a reaction. (2 marks)

It is the sum of exponents to concentration terms in a rate law

(b) Methyl ethanoate is hydrolyzed by water in the presence of an acid according to the following equation;

$CH_3CO_2CH_3 + H_2O \xrightarrow{H^+} CH_3CO_2H + CH_3OH$

i) State the molecularity of the reaction. (1 mark)

3

ii) Determine the order of the reaction. (Assume that the acid takes part in the reaction.

(01 mark)

3

iv) State the conditions under which the reaction can be overall first order. (02 marks)

Acid is working as a catalyst and water is in excess

(c) The table below shows some kinetic data for the following reaction: $3A + B \longrightarrow 2P$.

Experiment	Initial conc'n of A ($Moldm^{-3}$)	Initial conc'n of B ($Moldm^{-3}$)	Initial rate ($moldm^{-3}s^{-1}$)
1	0.20	0.20	1.2×10^{-8}
2	0.20	0.60	1.2×10^{-8}
3	0.40	0.60	4.8×10^{-8}

i) Write the overall rate equation. (1½ marks)

Rate = $K[A]^2$

ii) Calculate the rate constant and give its units. (1½ marks)

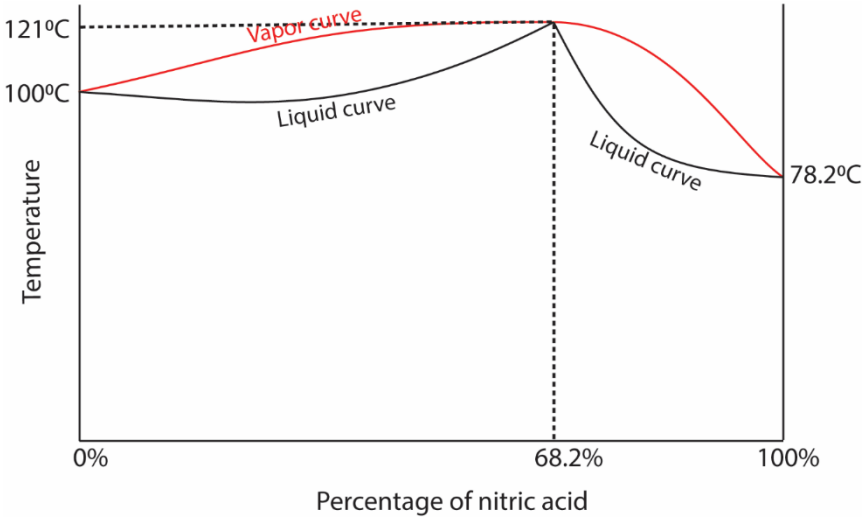
$1.2 \times 10^{-8} = K(0.2]^2$

$K = 3 \times 10^{-7} mol^{-1}dm^3s^{-1}$

15. (a) State Raoult's law (2 marks)

The partial pressure of a component in a mixture is equal to the product of its mole fraction and its vapour pressure at a given temperature.

b) The boiling point composition diagram of a mixture of water and substance nitric acid which is miscible with water is given below.



i) State how the mixture deviates from Raoult's law. (1 mark)

It deviates negatively

ii) Explain how pure nitric acid can be obtained from a mixture containing 80% of water. (4 marks)

When fraction distilled the distillate is water; the residue is an azeotrope that contains 68.2% nitric acid. When concentrated sulphuric acid is added to azeotrope and the mixture is distilled, the distillate is pure nitric acid

iii) What name is given to the mixture containing 68% of X? (1 mark)

Azeotrope

iv) Name one substance that would behave in a different way from nitric acid. (1 mark)

Ethanol

16. 0.9875g of an impure potassium manganate (vii) was dissolved in water to make 250cm^3 of solution. When 20.0cm^3 of this solution was acidified with dilute sulphuric acid, warmed and titrated against sodium ethane dioate (oxalate) solution, made by dissolving 1.675g of anhydrous sodium ethane dioate to make 250cm^3 of solution, 24.40cm^3 of the sodium ethane dioate solution was used.

($Na_2C_2O_4$ = 134 and $KMnO_4$ = 158)

a) Write an ionic equation for the reaction between sodium ethane dioate and potassium manganate (vii) (2 marks)

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$

b) Determine the molar concentration of manganate (vii) ions. (3 ½ marks)

Moles sodium oxalate in 250cm^3 =0.0125mole

Moles of sodium oxalate that reacted = 0.00122moles

Moles MnO_4^- that reacted = $\frac{0.00122\ x\ 2}{5}$ = 0.000488 moles

Moles of MnO_4^- in 1000cm^3 of solution = $\frac{0.000488\ x\ 1000}{20}$ = 0.0244M

c) Calculate the percentage purity of potassium manganate (vii) (2½ marks)

Mole MnO_4^- in 250cm^3 = $\frac{0.000488\ x\ 250}{20}$ =0.0061

Mass of potassium manganite (VII) = 0.0061 x 158 = 0.9638g

Percentage purity = $\frac{0.9638\ x\ 100}{0.9875}$ = 97.6%

d) Name one compound which is a common impurity in potassium manganate. (1 mark)

MnO_2

17. (a) State Hess's law of constant heat summation (2 marks)

Hess's law states that energy change in a reaction is independent of route taken from the reactants to the products.

b) i) Use the data below to calculate the enthalpy change for the reaction

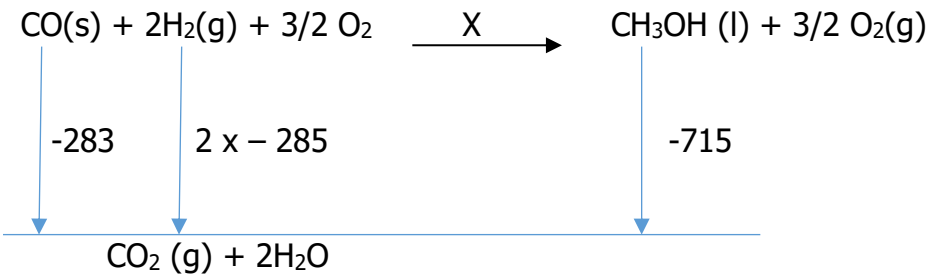
$CO(g) + 2H_2(g) \longrightarrow CH_3OH(l)$ at 298K

Data;

$CO(g) + ½\ O_2(g) \longrightarrow CO_2(g)$ $\quad DH = -283KJmol^{-1}$

$H_2(g) + ½\ O_2(g) \longrightarrow H_2O(g)$ $\quad DH = -285.8KJmol^{-1}$

$CH_3OH(l) + 3/2\ O_2(g) \longrightarrow CO_2(g) + 2H_2O$ $\quad DH = -715\ KJ\ Mol^{-1}$



$-283 - 2 \times -285 = X - 715$

$X = -138\ kJmol^{-1}$

i) Name the type of reaction in b) i) above. (1 mark)

Oxidation

END