

~~PROPOSED~~ PROPOSED GUIDE
Candidate's Name: SEMAKULA MUZAPHAR 0781711895

Signature: 

Random No.					Personal No.		

(Do not write your School/Centre Name or Number anywhere on this booklet.)

P525/1
CHEMISTRY
Paper 1
(Theory)
Nov./Dec. 2023
2 $\frac{3}{4}$ hours



UGANDA NATIONAL EXAMINATIONS BOARD

Uganda Advanced Certificate of Education

CHEMISTRY

Paper 1
(Theory)

2 hours 45 minutes

INSTRUCTIONS TO CANDIDATES:

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

All questions must be answered in the spaces provided.

The Periodic Table, with relative atomic masses, is attached at the end of the paper.

Mathematical tables (3-figure tables) are adequate or non-programmable scientific electronic calculators may be used.

Illustrate your answers with equation(s) where applicable.

Where necessary, use the following:

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

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

Standard temperature = 273 K.

Standard pressure = 101325 Nm^{-2} .

For Examiners' Use Only

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

SECTION A (46 MARKS)

Answer all questions in this section.

1. (a) Kinetic data for the decomposition of nitrogen(V) oxide is shown in table 1.

Table 1

$[N_2O_5]$ (mol dm $^{-3}$)	Initial Rate (mol dm $^{-3} s^{-1}$)
0.0016	0.12
0.0024	0.18
0.0032	x

Calculate the;

- (i) order of the reaction.

(1½ marks)

Let the order of reaction be f $f = 1$

$$\text{Rate} = k [N_2O_5]^f$$

Taking expts 1 and 2 ~~1, 2~~

$$0.12 = k(0.0016)^f \quad \text{X} \quad \text{ii}$$

$$0.18 = k(0.0024)^f \quad \text{X} \quad \text{iii}$$

Eqn. ii, iii \div Eqn. i, ii

$$\frac{k(0.0024)^f}{k(0.0016)^f} = \frac{0.18}{0.12}$$

$$1.5^f = 1.5 \quad \text{X}$$

\therefore The order of reaction

is 1.



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

- (ii) rate constant for the reaction.

(1½ marks)

$$\text{From expt 1 : } 0.12 = k(0.0016) \quad \text{X}$$

$$k = \frac{0.12}{0.0016} \quad \text{X}$$

$$= 75 s^{-1} \quad \text{X}$$

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

- (iii) value of x.

(01 mark)

$$\text{Rate} = 75 [N_2O_5] \quad \text{X}$$

$$x = 75 \times 0.0032 \quad \text{X}$$

01

$$= 0.24 \text{ mol dm}^{-3} s^{-1} \quad \text{X}$$

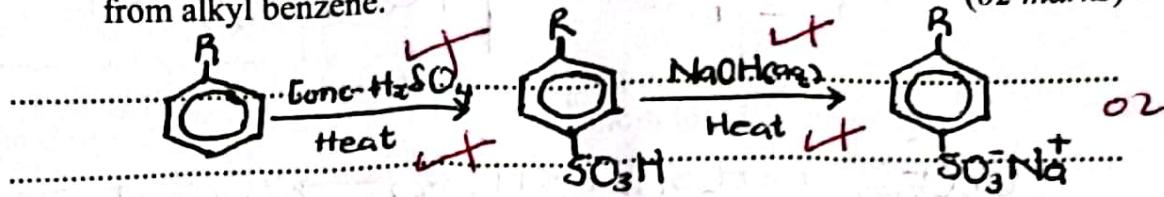
- (b) Name two methods that can be used to determine orders of reactions.

- Initial rate method X 01 (01 mark)

- Graphical method X Any two given

- Half life method

2. (a) Write an equation to show how soapless detergent can be prepared from alkyl benzene. (02 marks)



- (b) State;

- (i) one advantage of soapless detergent over soapy detergent.

Soapless detergent does not form scum with hard water since the salts it forms with calcium ions and magnesium ions are soluble in water. 01

- (ii) one disadvantage of soapless detergent over soapy detergent.

Soapless detergent pollutes the environment because it is non-biodegradable and contains phosphates for algal growth. 01

3. (a) A compound Q consists of 94.11% sulphur, the rest being hydrogen. Calculate the empirical formula of Q. (02 marks)

$$\begin{array}{l}
 \text{Elements : H : S} \\
 \text{\% of hydrogen} = 100 - 94.11 \\
 = 5.89 \quad \checkmark
 \end{array}$$

$$\text{\% composition : } 5.89 : 94.11$$

$$\text{Number of moles : } \frac{5.89}{1} : \frac{94.11}{32} \quad \checkmark$$

$$\text{Mole ratio : } \frac{5.89}{2.9409375} : \frac{2.9409375}{2.9409375} \quad \checkmark \quad 02$$

$$\text{Simplest ratio : } 2 : 1$$

The empirical formula of Q is H_2S ✓

- (b) When 0.15 g of Q was vapourised at 293 K, the vapour produced occupied 106 cm^3 at 101325 Nm^{-2} . Determine the molecular formula of Q. (02 marks)

$$\begin{aligned}
 \text{Mr} &= \frac{m \cdot R \cdot T}{P \cdot V} = \frac{0.15 \times 8.31 \times 293}{101325 \times 106 \times 10^{-6}} \quad \checkmark \\
 &= 34.00458 \approx 34
 \end{aligned}$$

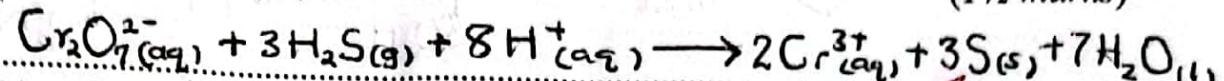
$$(H_2S)_n = 34$$

$$n[2x1 + 32x1] = 34$$

$$n = 1 \quad \checkmark$$

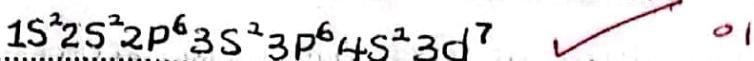
∴ The molecular formula of Q is H_2S \checkmark (02)

- (c) Write an equation for the reaction of Q with acidified potassium dichromate(VI) solution. (1½ marks)



4. (a) The atomic number of cobalt is 27.

- (i) Write the electronic configuration of cobalt. (01 mark)

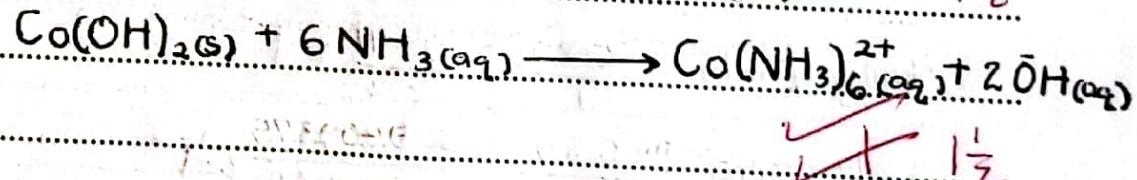
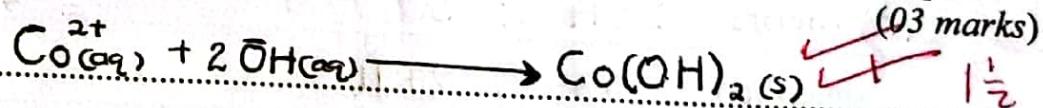


- (ii) State how cobalt is able to form ions with oxidation state of +2 and +3. (02 marks)

Cobalt forms ions in the +2 oxidation state by losing the two electrons in the 4s subshell.

It forms ions in the +3 oxidation state by losing two electrons in the 4s subshell and one electron in 3d subshell.

- (b) When concentrated ammonia solution was added to cobalt(II) chloride solution, a blue precipitate was formed which dissolved giving a red-brown solution. Write equation(s) for the reaction(s) that took place. (03 marks)



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

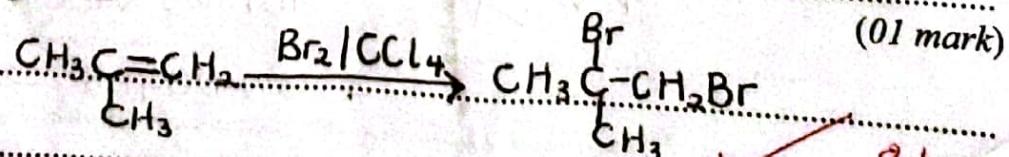
- (a) $CH_3C=CH_2$ and bromine in tetrachloromethane.

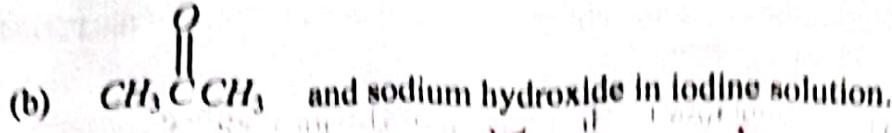
Observation

~~Preddish-brown solution~~ \checkmark (01 mark)

furns colourless \checkmark (01)

Equation





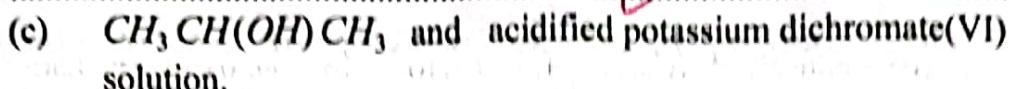
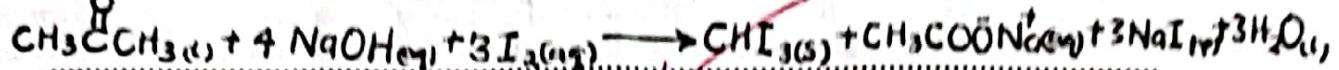
Observation

A yellow precipitate is formed

Equation

(1/2 mark)

(01 mark)



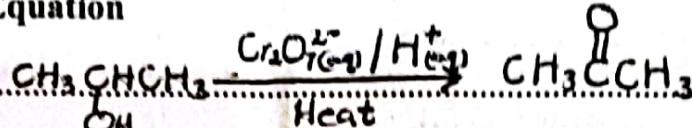
Observation

The colour of the solution turns from orange to green.

Equation

(01 mark)

(01 mark)



6. (a) Define the term standard enthalpy of formation.

Is the enthalpy change which occurs when one mole of a compound is formed from its elements in their normal states at 298K and 1 atmosphere.

- (b) The bond energies of some bonds are shown in table 2.

Table 2

Bond	Bond enthalpy (kJ mol ⁻¹)
C—H	+413
C—C	+347
C=C	+612

Calculate the enthalpy of formation of but-1-ene. (03 marks)

(The Standard enthalpies of atomisation of carbon and hydrogen are

In C_4H_8 molecule are +717 and +218 kJmol⁻¹ respectively.)

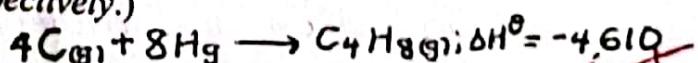
Two C=C bonds of standard enthalpy = 2(+347)

one C=C bond of standard enthalpy = +694 kJmol⁻¹

eight C—H bonds of standard enthalpy = 8(+413)

= +3,304 kJmol⁻¹

Total standard enthalpy of bonds = +4,610 kJmol⁻¹



$$\Delta H^\theta = \Delta H_F^\theta (\text{product}) - \Delta H_F^\theta (\text{reactants})$$

$$-4,610 = \Delta H_F^\theta (\text{product}) - [4(+717) + 8(+218)]$$

$$\Delta H_F^\theta (\text{product}) = +2 \text{ kJmol}^{-1}$$

03

∴ The enthalpy of formation of but-1-ene is +2 kJmol⁻¹.

7. The boiling points of some chlorides of period 3 elements of the Periodic Table are shown in table 3.

Table 3

Formula of chlorides	$NaCl$	$MgCl_2$	Al_2Cl_6	$SiCl_4$
Boiling points (°C)	1465	1418	423	57

- (a) State the trend in the boiling points of the chlorides. (01 mark)

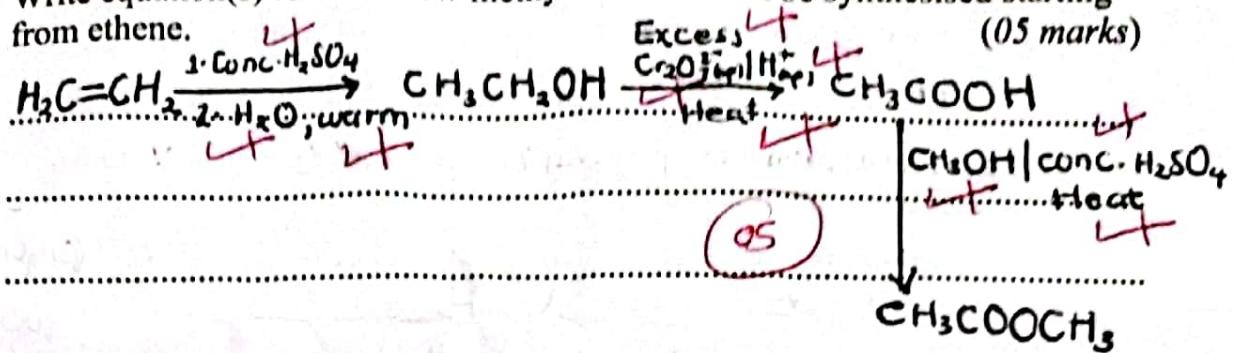
The boiling points decrease from sodium chloride to magnesium chloride to aluminium chloride to silicon(IV) chloride. a/

- (b) Explain your answer in (a). (05 marks)

Sodium chloride and magnesium chlorides have giant ionic structures held by strong ionic bonds which require a high amount of energy to break. The decrease in boiling point from sodium chloride to magnesium chloride is because magnesium ion has a smaller ionic radius, higher polarising power than sodium ion making magnesium chloride less ionic than sodium chloride.

Aluminium chloride has a lower boiling point than magnesium chloride because among the cations, the aluminium ion has the smallest ionic radius which gives it the highest polarising power. Aluminium chloride therefore is predominantly covalent. Silicon(IV) chloride has a simple molecular structure in which the molecules are held by weak Van der Waal's forces of attraction which require a low amount of energy to break hence the lowest melting point.

8. Write equation(s) to show how methylethanoate can be synthesised starting from ethene. (05 marks)



9. (a) State Kohlrausch's law. (01 mark)

It states that the molar conductivity at infinite dilution of an electrolyte is equal to the sum of the molar conductivities of infinite dilution of the ions produced by the electrolyte.

- (b) The molar conductivities at infinite dilution for some electrolytes at 18 °C are shown below.

$$\text{BaCl}_2, \quad \Lambda_{\infty} = 240.6 \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$$

$$\text{NH}_4\text{Cl}, \quad \Lambda_{\infty} = 129.6 \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$$

$$\text{Ba(OH)}_2, \quad \Lambda_{\infty} = 457.6 \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$$

Determine the molar conductivity of NH_4OH at 18 °C. (03 marks)

$$2\Lambda_{\infty} \text{ NH}_4\text{OH} = 2\Lambda_{\infty} \text{ NH}_4\text{Cl} + \Lambda_{\infty} \text{ Ba(OH)}_2 - \Lambda_{\infty} \text{ BaCl}_2$$

$$\Lambda_{\infty} \text{ NH}_4\text{OH} = \frac{1}{2} [2 \times 129.6 + 457.6 - 240.6]$$

$$= 238.1 \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$$

- (c) State one application of conductivity measurements. (01 mark)

- Determination of solubility of sparingly soluble salt

- Determination of ionic product of water. Any one

- Conductometric titrations.

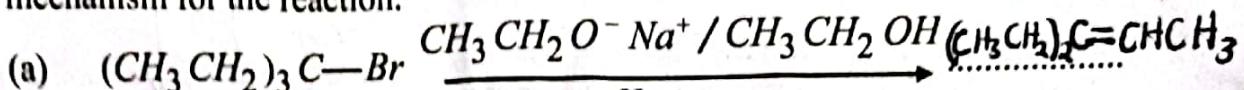
- Determination of dissociation constants of weak acids and weak bases.

SECTION B (54 MARKS)

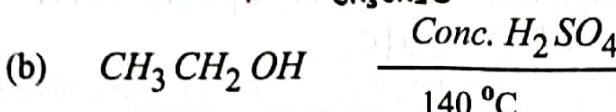
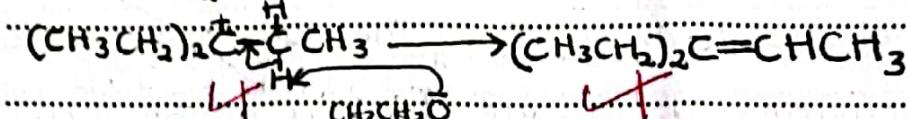
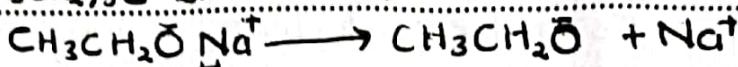
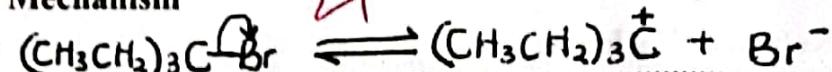
Answer any six questions from this section.

Any additional question(s) answered will not be marked.

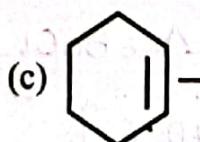
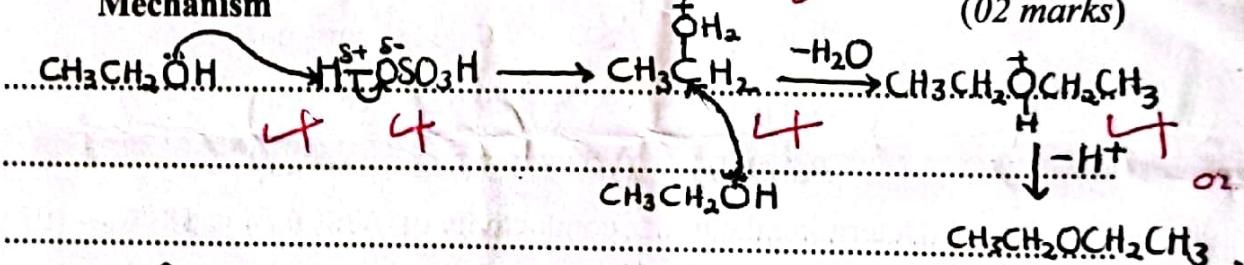
10. Complete each of the following equations and in each case outline a mechanism for the reaction. 01



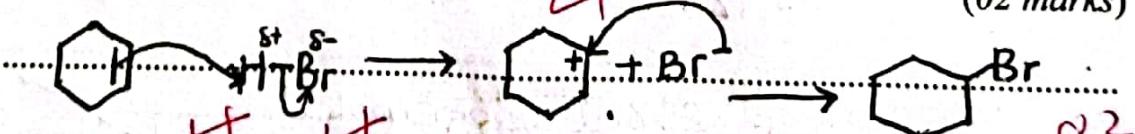
Mechanism



Mechanism



Mechanism:



11. Beryllium and magnesium are elements in group (II) of the Periodic Table.

- (a) Explain the following:

- (i) The first ionisation energy of beryllium is higher than that of magnesium. 02

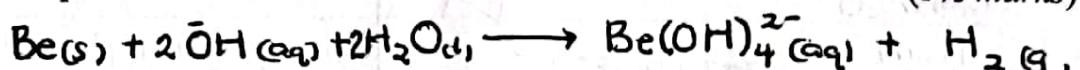
$$\text{Be} - 1s^2 2s^2, \text{Mg} - 1s^2 2s^2 2p^6 3s^2$$

For beryllium, the first electron is removed from 2s subshell which is closer to the nucleus thus experiencing stronger attraction from the nucleus. As a result more energy is need to remove it. For magnesium, the first electron is removed from 3s subshell which is far from the nucleus compared to the electron from 2s, hence experiences less attraction from the nucleus hence lower energy is required to remove it. 02

- (ii) The polarising power of magnesium ions is lower than that of beryllium ions. + (01 mark)

Magnesium ion has a bigger ionic radius than beryllium ion. Since polarising power is inversely proportional to the ionic radius, magnesium ion will have lower polarising power. 01

- (b) Beryllium reacts with aqueous sodium hydroxide solution. Write an equation for the reaction. (1½ marks)



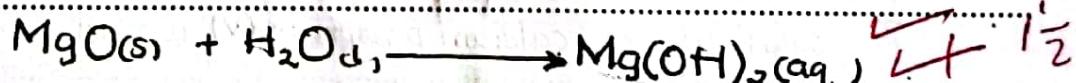
+ 1½

- (c) State the conditions under which beryllium oxide and magnesium oxide react with the following substances and where applicable, write equation(s) for the reaction(s):

- (i) Water. (02 marks)

Beryllium oxide does not react with water.

Magnesium oxide reacts with water on heating forming magnesium hydroxide 02

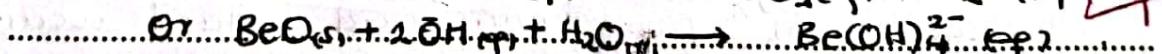
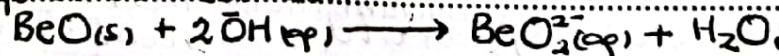


+ 1½

- (ii) Sodium hydroxide. (2½ marks)

Magnesium oxide is basic therefore does not react with sodium hydroxide.

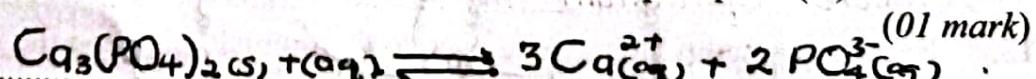
Beryllium oxide being amphoteric reacts with hot concentrated sodium hydroxide solution. 2½



12. (a) Calcium phosphate(V), $\text{Ca}_3(\text{PO}_4)_2$, is sparingly soluble in water.

Write the;

- (i) equation for the solubility of calcium phosphate(V) in water.



+ 01

- (ii) expression for the solubility product, K_{sp} , of calcium phosphate(V). (01 mark)

$$K_{sp} = [\text{Ca}^{2+}]^3[\text{PO}_4^{3-}]^2$$

01

- (b) The solubility product of calcium phosphate(V) is $2.0 \times 10^{-29} \text{ mol}^5 \text{ dm}^{-15}$ at 25°C . Calculate the solubility of calcium phosphate(V) in g dm^{-3} at 25°C . (03 marks)

Let $[\text{Ca}_3(\text{PO}_4)_2] = x$

$$[\text{Ca}^{2+}] = 3x$$

$$[\text{PO}_4^{3-}] = 2x$$

From

$$K_{sp} = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2$$

$$2.0 \times 10^{-29} = (3x)^3 (2x)^2$$

$$x = 7.1371 \times 10^{-7} \text{ mol dm}^{-3}$$

Molar mass of $\text{Ca}_3(\text{PO}_4)_2$

$$= (40 \times 3) + (3 \times 2) + (8 \times 16)$$

$$= 310 \text{ g}$$

1 mole of calcium phosphate(V) weighs 310g

7.1371×10^{-7} mol of calcium phosphate(V) weighs

$$(3/0.002212501 \times 7.1371 \times 10^{-7}) \text{ g}$$

$$= 0.0002212501 \text{ g dm}^{-3}$$

The solubility of calcium phosphate(V) is $0.0002212501 \text{ g dm}^{-3}$.

- (c) Explain how the solubility of calcium phosphate(V), would be affected if to its saturated solution a few drops of;

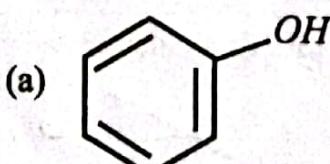
- (i) aqueous sodium phosphate(V) were added. (02 marks)

The solubility of calcium phosphate(V) would decrease because sodium phosphate(V) contains phosphate(V) ions. These are common to ions in calcium phosphate(V). Thus the excess phosphate(V) ions added would combine with calcium ions in solution precipitating calcium phosphate(V) hence reducing solubility.

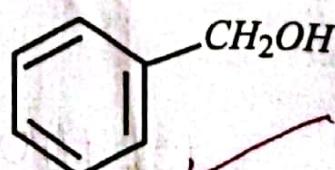
- (ii) dilute nitric acid were added. (02 marks)

The solubility of calcium phosphate(V) would increase. This is because the hydrogen ions from nitric acid added would react with phosphate(V) ions to form phosphoric(V) acid. This reduces the concentration of phosphate(V) ions in solution hence more calcium phosphate(V) dissolves to restore equilibrium hence increasing solubility.

13. Name a reagent which can be used to distinguish between the following pairs of compounds and in each case state what would be observed if each member is separately treated with the reagent: (02)



and

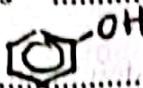


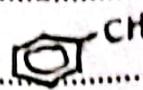
(03 marks)

Reagent

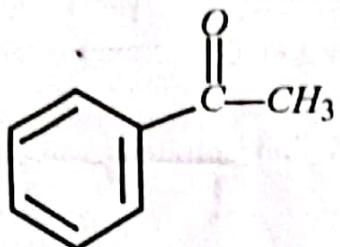
Neutral Iron(III) chloride solution.

Observations

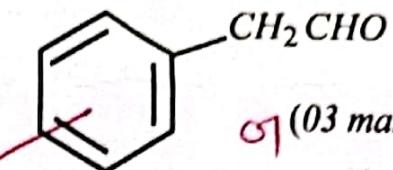
With  - A violet / Purple colouration. ✓ 01

With  - No observable change. ✓ 01

(b)



and



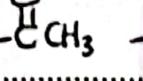
01 (03 marks)

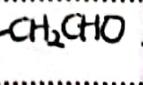
Reagent

Iodine solution and sodium hydroxide solution.

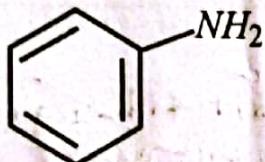
Or Ammoniacal silver nitrate solution Or Fehlings solution.

Observations

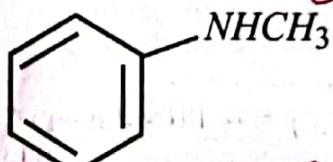
With  - A yellow precipitate ✓ 01

With  - No observable change. ✓ 01

(c)



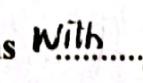
and

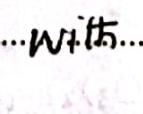


01 (03 marks)

Reagent

Sodium nitrite, and concentrated hydrochloric acid at 0°C

Observations With  - A colourless solution. ✓ 01

With  - A yellow oil. ✓ 01

14. (a) Some elements in group (IV) of the Periodic Table are given in table 4. Complete the table by;

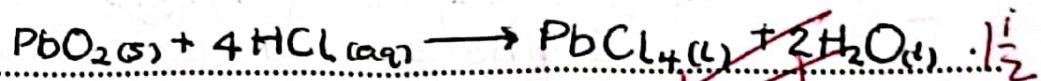
(i) writing the formula of the oxide in which each element is in the +4 oxidation state. (1½ marks)

(ii) stating the class of each oxide. (1½ marks)

Table 4

Element	Formula of oxide	Class of oxide.
Tin	SnO_2 ✓	Amphoteric ✓
Silicon	SiO_2 ✓	Acidic ✓
Lead	PbO_2 ✓ $\frac{1}{2}$	Amphoteric ✓ $\frac{1}{2}$

- (b) Write an equation for the reaction between;
- tin(IV) oxide and concentrated sodium hydroxide. (1½ marks)
- ~~SnO₂(s) + 2OH⁻(aq) → SnO₃²⁻(aq) + H₂O(l),~~ ✓ 1½
- Or SnO₂(s) + 2OH⁻(aq) + 2H₂O(l) → Sn(OH)₆²⁻(aq)
- lead(IV) oxide and cold concentrated hydrochloric acid. (1½ marks)



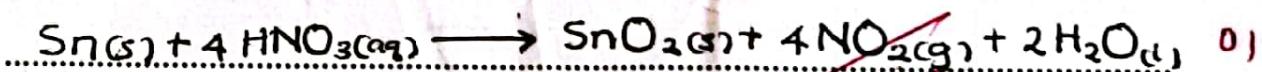
- (c) State the condition and write an equation for the reaction between concentrated nitric acid and;

- (i) tin.

Condition ✓ ½ (½ mark)

Heating .

Equation (01 mark)

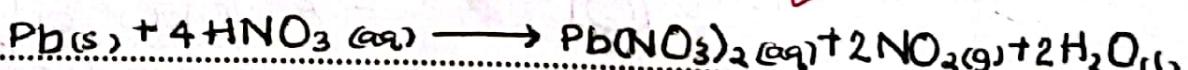


- (ii) lead.

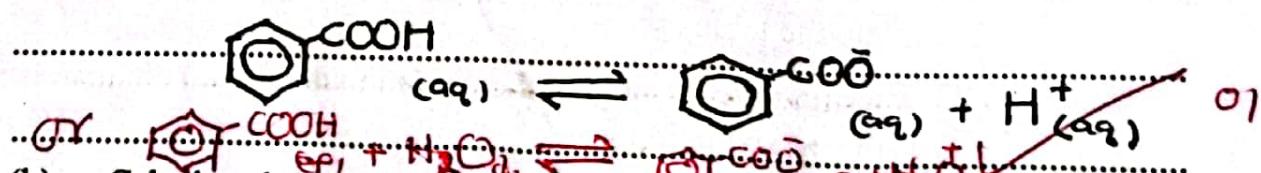
Condition ✓ ½ (½ mark)

Heating .

Equation ✓ 01 (01 mark)



15. (a) Write an equation for the ionisation of benzoic acid in water. (01 mark)



- (b) Calculate the pH of a solution containing 2.06 g of benzoic acid per dm³.

(04 marks)

(The acid dissociation constant, K_a , for benzoic acid = 6.3×10^{-5} mol dm⁻³.)

$$K_a = \frac{[\text{C}_6\text{H}_5\text{COO}^-][\text{H}^+]}{[\text{C}_6\text{H}_5\text{COOH}]}$$

Molar mass of C₆H₅CO₂H

$$= (7 \times 12) + (6 \times 1) + (2 \times 16)$$

$$= 122 \text{ g}$$

At equilibrium

$$[H^+] = [C_6H_5COO^-] \quad \text{X}$$

$$K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$$

$$[C_6H_5COOH] = \frac{2.06}{122} = 0.016885M$$

$$6.3 \times 10^{-5} = [H^+]^2 \quad \text{X}$$

$$0.016885$$

$$[H^+] = 0.00103M \quad \text{X}$$

- (c) 4.32 g of sodium benzoate was dissolved in one dm³ of benzoic acid in (b). Calculate the pH of the resultant solution. (04 marks)

Molar mass of C₆H₅COONa

$$= (7 \times 12) + (5 \times 1) + (2 \times 16) + (1 \times 23) \quad \text{pH} = -\log[H^+]$$

$$= 144g \quad \text{X}$$

$$[C_6H_5COONa] = \frac{4.32}{144} = 0.03M \quad \text{X}$$

$$K_a = \frac{[C_6H_5COO^-][H^+]}{[C_6H_5COOH]} \quad \text{X}$$

At equilibrium

$$[C_6H_5COO^-] = [C_6H_5COONa] = [\text{salt}] \quad \text{X}$$

$$[C_6H_5COOH] = [\text{Acid}]$$

$$K_a = \frac{[\text{salt}][H^+]}{[\text{Acid}]}$$

$$6.3 \times 10^{-5} = \frac{0.03}{0.016885} \times [H^+] \quad \text{X}$$

$$[H^+] = 0.000354585M$$

16. (a) During the extraction of aluminium from bauxite, Al₂O₃ · 2H₂O, the ore is first purified.

- (i) Name two major impurities in the ore. (01 mark)

- Silicon(IV) oxide SiO_2 - Titanium(IV) oxide

- Iron(III) oxide Fe_2O_3 Any two

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

$$= -\log(0.00103)$$

$$= 2.98716$$

04

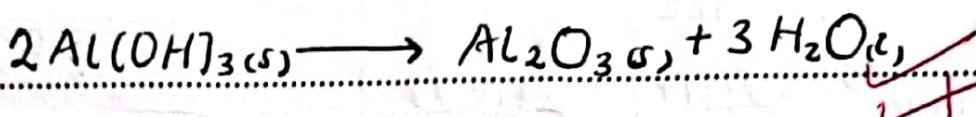
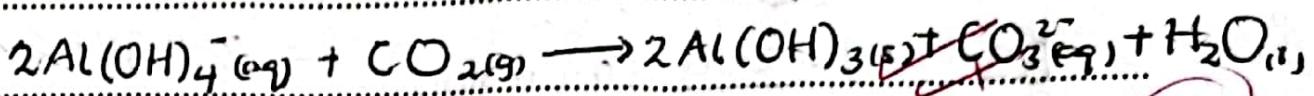
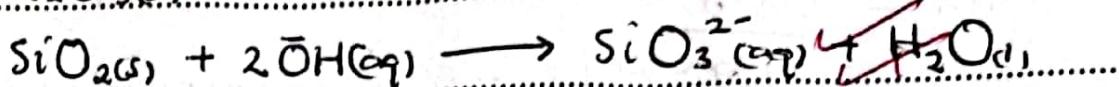
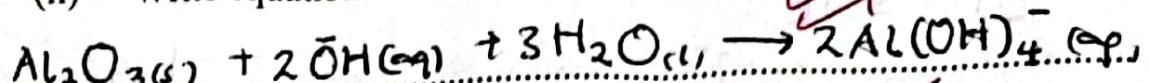
$$\text{pH} = -\log[H^+]$$

$$= -\log(0.0000354585) \quad \text{X}$$

$$= 4.45028 \quad \text{X}$$

04

- (ii) Write equations to show how the ore is purified. (06 marks)



06

- (b) Describe how aluminium is obtained from the pure ore.

(Equations are not required.)

(02 marks)

Aluminium oxide is dissolved in molten cryolite maintained at 950°C and electrolysed at temperatures between $800 - 1000^\circ\text{C}$ using graphite electrodes and a current of high density and low voltage. Aluminium is produced at the cathode.

17. (a) State what is meant by the term partition coefficient. (01 mark)

Is the constant ratio of concentration of a solute in a solvent to the concentration of the same solute in another solvent where the two solvents are immiscible and in contact at a given temperature at equilibrium.

- (b) 4.5 g of an impure sample of zinc sulphide was dissolved in excess concentrated solution of ammonia and the solution diluted to 500 cm^3 . The resultant solution was shaken with 25 cm^3 of carbon tetrachloride and allowed to settle.

12.5 cm^3 of aqueous layer required 20.0 cm^3 of a 0.25 M hydrochloric acid for complete reaction, while 25.0 cm^3 of the carbon tetrachloride layer required 12.5 cm^3 of a 0.025 M hydrochloric acid for complete reaction.

Calculate the number of moles of;

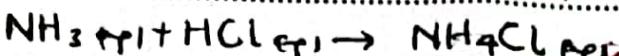
- (i) free ammonia in aqueous layer.

(The partition coefficient, K_D , for ammonia between carbon tetrachloride and water is 0.04)

(2½ marks)

Moles of the acid that reacted with ammonia in organic layer

$$= \frac{12.5 \times 0.025}{1000} = 0.000312 \text{ moles}$$



1 mole of acid reacts with 1 mole of ammonia

0.000312 moles of acid react with 0.000312 moles of ammonia

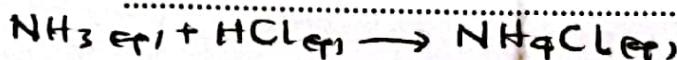
25 cm³ of organic layer contain 0.000312 moles of NH₄⁺

1000 cm³ of organic layer contain $\frac{0.000312 \times 1000}{25.0} = 12.5$ moles of NH₄⁺

(ii) complexed ammonia.

Moles of HCl (aq) that reacted with NH₃ in aqueous layer

$$= \frac{20.0 \times 0.25}{1000} = 0.005 \text{ moles}$$



mole ratio of HCl : NH₃ = 1 : 1

Moles of ammonia in aqueous layer

$$= 0.005$$

12.5 cm³ of aqueous layer contain 0.005 moles of ammonia

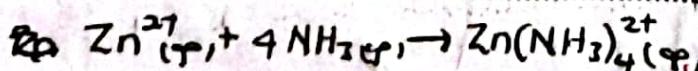
1000 cm³ of aqueous layer contain $\frac{0.005 \times 1000}{12.5} = 40$ moles of NH₃

(c) Determine the percentage by mass of zinc in the impure zinc sulphide.

1000 cm³ contain 0.0875 moles of NH₃ that complexed with Zn²⁺

500 cm³ will contain $\frac{0.0875 \times 500}{1000} = 0.04375$ moles of NH₃

$$= 0.04375 \text{ moles of NH}_3$$



4 moles of ammonia complex with 1 mole of Zn²⁺

0.04375 moles of ammonia complex ($\frac{1}{4} \times 0.04375$)

of Zn²⁺ ions

$$= 0.0125 \text{ M}$$

$$[\text{NH}_3]_{\text{CCl}_4} = 0.0125 \text{ M}$$

$$[\text{NH}_3]_{\text{free}} = \frac{[\text{NH}_3]_{\text{aq}}}{K_D}$$

$$= \frac{0.0125}{0.04} = 0.3125 \text{ M}$$

$$= 0.3125 \text{ M}$$

(2½ marks)

$$= 0.4 \text{ M}$$

$$[\text{NH}_3]_{\text{complexed}} = [\text{NH}_3]_{\text{aq}} - [\text{NH}_3]_{\text{free}}$$

$$= 0.4 - 0.3125$$

$$= 0.0875 \text{ M}$$

2½

(03 marks)

$$= 0.0109 \text{ moles of Zn}^{2+} \text{ ions}$$

$$\text{Mass of Zn}^{2+} = (0.0109 \times 65.7)$$

$$= 0.71613 \text{ g}$$

$$\% \text{ of Zn} = \frac{0.71613}{100} \times 100 \%$$

$$= 4.5 \quad 0.3$$

$$= 15.914 \%$$