THE KENYA NATIONAL EXAMINATIONS COUNCIL
Kenya Certificate of Secondary Education

233/2

Paper 2

CHEMISTRY – (Theory)

Dec. 2022 – 2 hours

M. S.

Name MANA S.N. Index Number 0860

Candidate's Signature ..... Date .....

Instructions to candidates

(a) Write your name and index number in the spaces provided above.
(b) Sign and write the date of examination in the spaces provided above.
(c) Answer **all** the questions in the spaces provided in the question paper.
(d) **Non-programmable** silent electronic calculators and KNEC mathematical tables may be used.
(e) All working **must** be clearly shown where necessary.
(f) **This paper consists of 16 printed pages.**
(g) **Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.**
(h) **Candidates should answer the questions in English.**

For Examiner's Use Only

Question	Maximum Score	Candidate's Score
1	11	
2	13	
3	12	
4	13	
5	11	
6	10	
7	10	
Total Score	80	

1. (a) Aluminium and phosphorus form oxides with general formula M_2O_3. Complete Table 1 by writing the properties of the oxides.

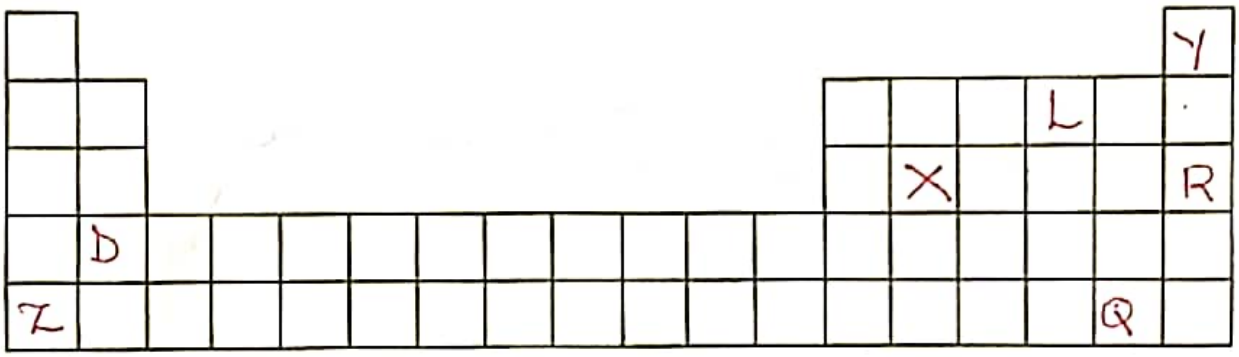
Table 1

Property	Al_2O_3	P_2O_3
Structure	Giant ionic ✓½	Simple Molecular / Molecular ✓½
Bonding	Ionic ✓½	Covalent ✓½
Acid/base character	Amphoteric ✓½	Acidic ✓½

(½ M each)

(3 marks)

(b) The grid in **Figure 1** shows part of the Periodic Table. Use it to answer the questions that follow.



(1mk each)

Figure 1

(i) Give the total number of elements that can be placed in:

I. period I (½ mark)

2 elements ✓½

.....

II. period 5 (½ mark)

18 elements ✓½

.....

(ii) Place each of the following elements in the grid:

I. Element X, whose atomic number is 14 (1 mark)

II. Element Y, with the highest first ionisation energy (1 mark)

III. Element Z, with the lowest first ionisation energy (1 mark)

IV. Element L, whose ion L^{2-} has electron arrangement 2.8 (1 mark)

V. Element D, whose ion D^{2+} has electron arrangement 2.8.8 (1 mark)

VI. Element Q, a halogen with the highest atomic radius (1 mark)

VII. Element R, a period 3 element that exists as a monoatomic gas (1 mark)

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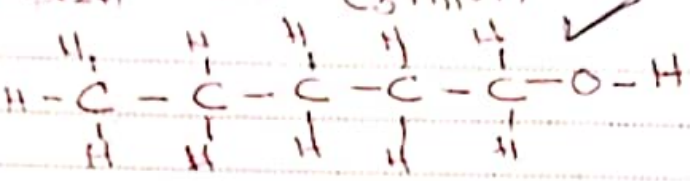
2. The general formula of alkanols is $C_nH_{2n+1}OH$.

(a) Draw the structure and give the name of the alkanol with n = 5. (2 marks)

Structure $C_5H_{2(5)+1}OH \rightarrow C_5H_{11}OH$ ✓1



Accept bracketed isomer followed by correct name

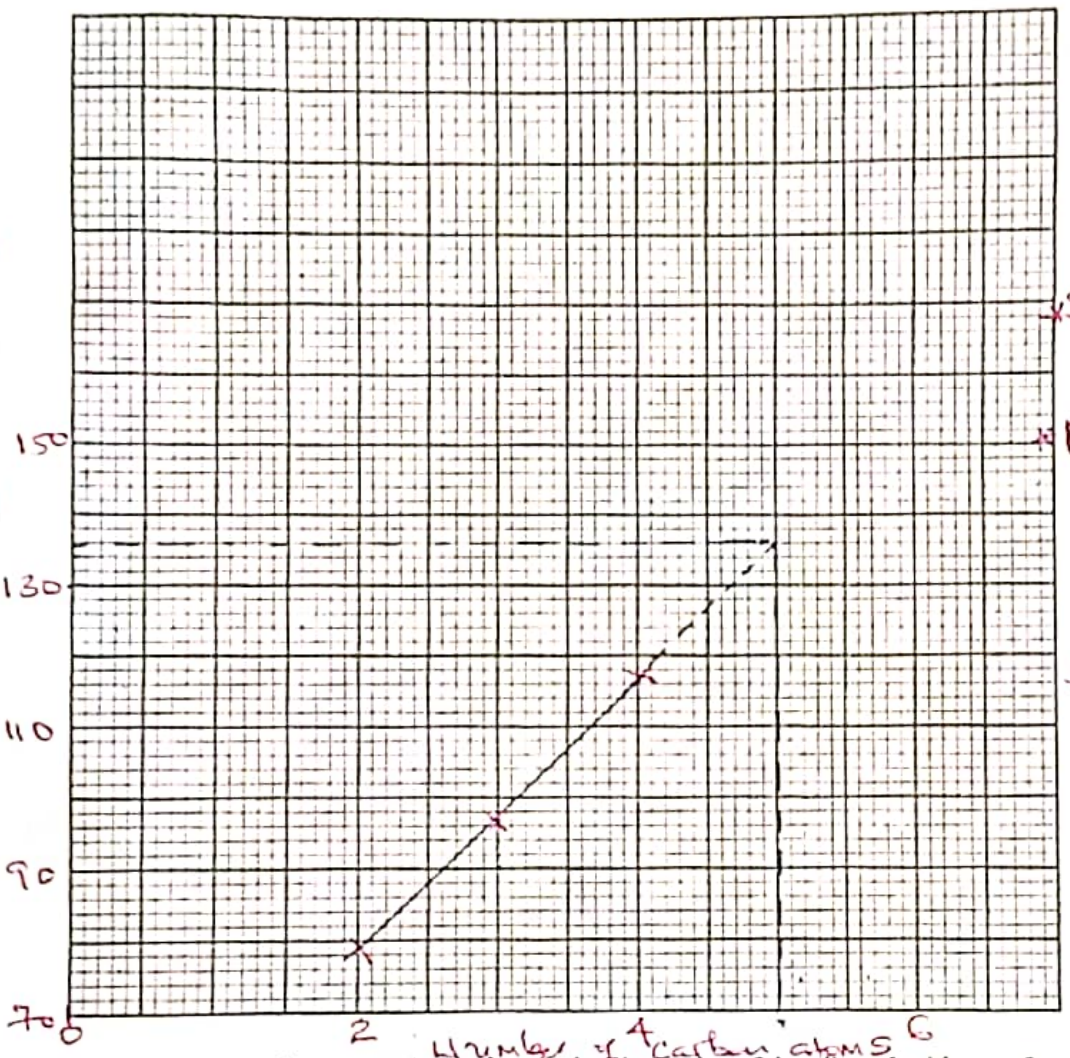
Name Pentan-1-ol ✓1/1 Pentanol

(b) **Table 2** gives the boiling points of some alkanols.

Table 2

n	Boiling point/°C
2	78.5
3	97.2
4	117.0

(i) On the grid provided, draw the graph of boiling point against number of carbon atoms, n. (3 marks)



Scale: y axis ½
x axis ½
Plotting 3 points 1MK
2 points ½M
1 point 0M
Straight line = 1MK if line of best fit

(ii) From the graph, determine the boiling point of the alkanol with n = 5. (1 mark)

136°C ✓ (Value correctly read from graph)

(iii) The boiling point of the alkanol with n = 2 is much higher than that of butane. Explain (C = 12.0; H = 1.0; O = 16.0). (2 marks)

Ethanol has hydrogen bonds ✓ between its molecules while butane the weak van der Waals forces between its molecules ✓

(c) Alkanols are used as fuel.

(i) Give another use of alkanols. (1 mark)

- Manufacture of: - synthetic fibres
  - alcoholic drinks
- As solvents in manufacture of drugs

Any 1 ✓

(ii) Write an equation for the combustion of the alkanol with n = 2. (1 mark)

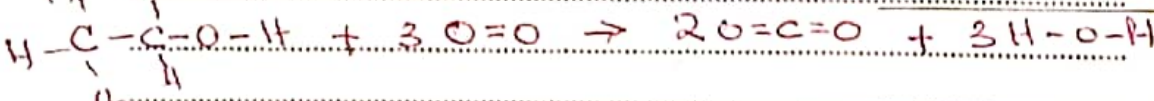
$CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ ✓

Physical state not required

(iii) Use the bond energies in Table 3 to calculate the enthalpy change of combustion of the alkanol with n = 2. (3 marks)

Table 3

Bond	Energy kJ/mol
C – C	348
C – H	412
C – O	360
O – H	463
O = O	496
C = O	743



Bonds broken

$(5 \times 412) + 348 + 360 + 463 + (3 \times 496)$ ✓½

$2060 + 708 + 463 + 1488$

$= +4719$ kJ ✓½

Bonds formed

$(4 \times 743) + 6(463)$ ✓½

$= -5750$ kJ ✓½

ΔH_c Ethanol $= +4719 + -5750$ ✓½

$= -1031$ kJ/mol ✓½

Penalise ½ mk for wrong units

3. (a) Use the following cell notation to answer the questions that follow:

$Al(s)/Al^{3+}(aq)\ //\ Pb^{2+}(aq)\ /\ Pb(s);\ E^{0}_{cell} = +1.53\,V$

(i) State what the symbol / represents. (1 mark)

Phase boundary / interphase between the electrode and electrolyte

(ii) Write the equation for the cell reaction. (1 mark)

$2Al_{(s)} + 3Pb^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Pb_{(s)}$

(iii) Given that E^{0} value for $Pb^{2+}(aq)\ /\ Pb(s)$ is $-0.13\,V$ calculate the E^{0} value for $Al^{3+}(aq)/Al(s)$. (2 marks)

$E_{cell} = E_{red} - E_{ox}$

$1.53 = -0.13 - x$

$x = -0.13 - 1.53 = -1.66\,V$

(iv) State one use of electrochemical cells. (1 mark)

- Making batteries
- Source of electrical energy
- Making dry cells, car batteries, other batteries, etc.

Any 1 ✓

(b) Figure 2 shows a cell used to electrolyse water.

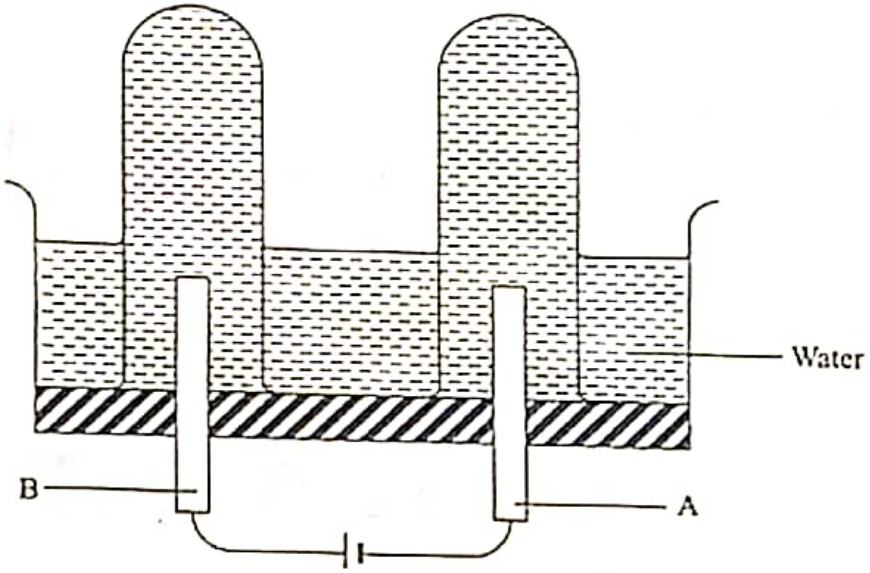


Figure 2

(i) State why it is necessary to add dilute sulphuric(VI) acid to the water. (1 mark)

- To ionise the water ✓ OR
- To make water an electrolyte

(ii) State the electrode at which oxygen is produced and give a reason. (1 mark)

- B ✓
- Its the anode/OH^- ions migrate to anode

(iii) Write an equation for the formation of oxygen. (1 mark)

$4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e^-$ ✓✓

(iv) After electrolysing the water for 88 seconds, the volume of oxygen gas collected was 23.0 cm^3. Determine the:

I. volume of hydrogen gas collected (1 mark)

Vol ratio $O_2 : H_2$
1 : 2
Vol of $H_2 = 23 \times 2 = 46\ cm^3$

II. amount of current used (3 marks)
(1 Faraday = 96500C)

MGV = 24000
Mol of $O_2 = \frac{23}{24000} = 9.6 \times 10^{-4}$ mol (0.00096 mol)
1 mol $O_2 \Rightarrow$ 4 faradys
$9.6 \times 10^{-4} = \frac{I \times 88}{4 \times 96500}$
$= 4.2\ A$

4. (a) State and explain how a catalyst affects:

(i) rate of a reaction (2 marks)

- Catalyst increase the rate of a reaction.
- It lowers the activation energy of the reactants.

(ii) yield of the products (1 mark)

No effect on the yield

(b) Rates of reactions are measured using various methods. In the decomposition of hydrogen peroxide, the rate is measured by recording the volume of oxygen gas produced with time.

Other than measuring volume of gas produced, describe a method that can be used to measure the rates of each of the following reactions.

(i) Sodium thiosulphate with hydrochloric acid.

$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$ (2 marks)

React sodium thiosulphate with hydrochloric acid in a beaker placed on paper with a cross ✓ Record time it takes for cross to be obscured / disappear ✓ //

OR: {At the bottom}

(ii) Acidified potassium manganate(VII) with iron(II) sulphate.

$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$ (1 mark)

Measure time it takes for the purple colour of $KMnO_4/H^+$ to change to colourless ✓ //

b(i) - Place mixture of sodium thiosulphate and hydrochloric acid on a balance ✓ //
- Record the mass of the contents of the beaker after some time ✓ //

(c) In an experiment, the rate of decomposition of 50 cm^3 of hydrogen peroxide in the presence of manganese(IV) oxide was measured. **Figure 3** shows a graph of the results obtained.

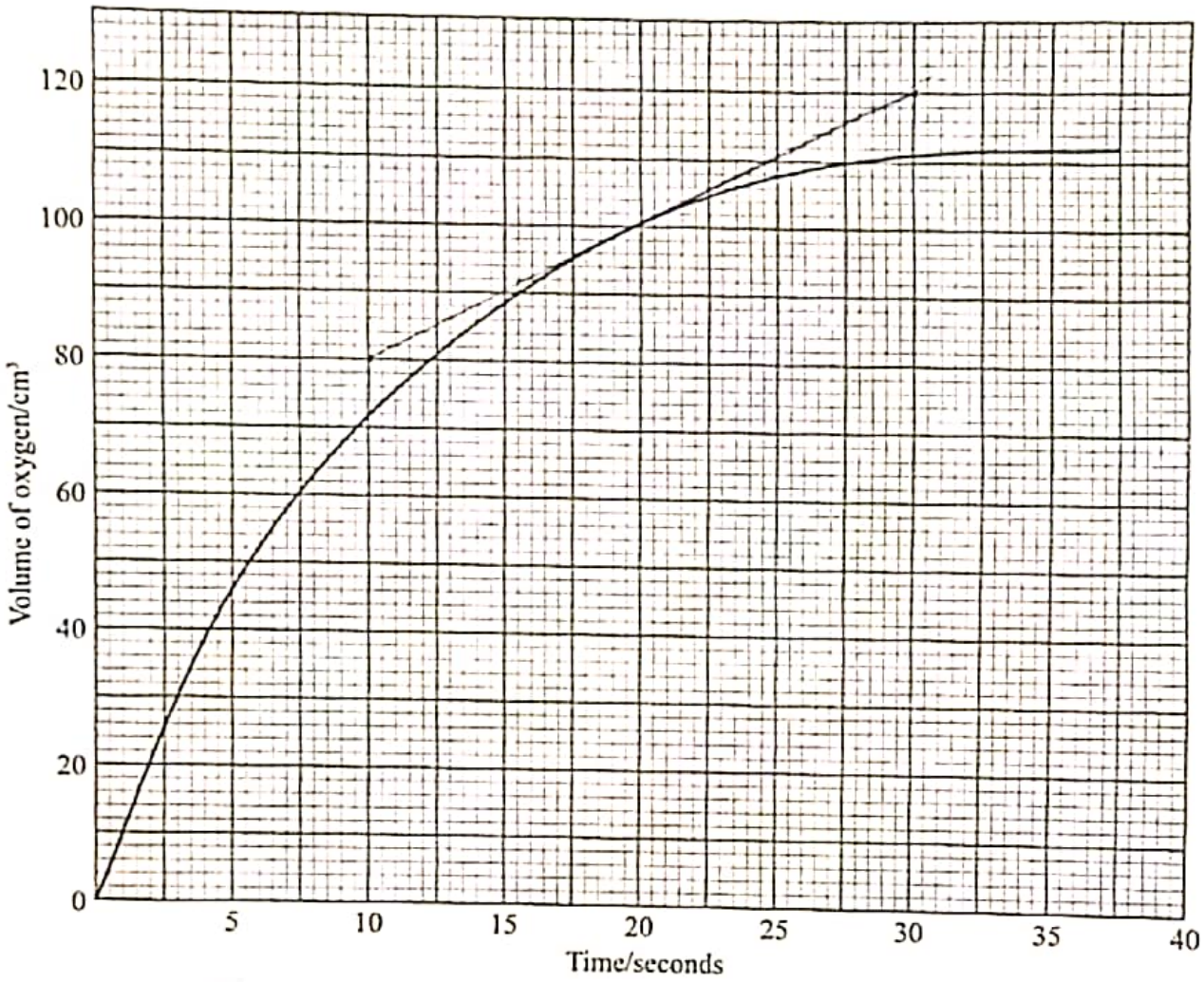


Figure 3

(i) Write an equation for the reaction. (1 mark)

$2H_2O_{2(aq)} \xrightarrow{MnO_2} 2H_2O_{(l)} + O_{2(g)}$

✓1

Catalyst must a must.

(ii) Using the graph, determine the maximum number of moles of oxygen produced. (Molar gas volume at room temperature and pressure = 24 dm³). (2 marks)

Volume of O_2 produced = 112 cm^3 ✓½

Moles of O_2 = $\frac{112}{24000}$ ✓1 = 0.00467

= 0.00467 mol ✓½

(4.67×10^{-3})

(iii) Calculate the concentration in moles per litre of hydrogen peroxide. (2 marks)

Mole ratio $O_2 : H_2O_2$

1 : 2

Moles of H_2O_2 = 0.00467 × 2 ✓½

= 0.00934 ✓ (9.34×10^{-3})

Moles in 1000 cm^3 = $\frac{0.00934 \times 1000}{50}$ ✓1

= 0.1868 M ✓½

(iv) Determine the rate of decomposition at the 18th second. (1 mark)

Tangent at 18th sec

Rate = $\frac{\Delta Y}{\Delta X}$ ✓½

= $\frac{120 - 80}{30 - 10} = \frac{40}{20}$ ✓½ = 2 cm^3/s

(v) State and explain one factor that would increase the rate of decomposition of 50 cm^3 of the hydrogen peroxide. (1 mark)

- Heat/increase in temperature ✓½ increases the kinetic energy ✓½ of the molecules

OR

Increase in concentration ✓½ of H_2O_2 which increases rate ✓½ of effective collisions

5. (a) Explain how concentrated sulphuric(VI) acid can be prepared from sulphur(VI) oxide gas and distilled water. (2 marks)

- Bubble SO_3 gas in cold distilled water using an inverted funnel ✓ The reaction of SO_3 with water is highly exothermic. ✓

OR Dissolve SO_3 gas in conc. H_2SO_4 to form oleum ✓ The oleum then diluted with distilled to form conc. H_2SO_4 ✓

(b) Concentrated sulphuric(VI) acid acts as a dehydrating and as a drying agent.

(i) Give an example of a gas that can be dried using concentrated sulphuric(VI) acid. (1 mark)

All gases except NH_3 gas and H_2S gas ✓

(ii) Complete the following equations to show how concentrated sulphuric(VI) acid acts as a dehydrating agent.

I. $C_{12}H_{22}O_{11} \longrightarrow 12C + 11H_2O$ ✓ (1 mark)

II. $CoCl_2 \cdot 6H_2O \longrightarrow CoCl_2 + 6H_2O$ ✓ (1 mark)

(iii) State the observations made when concentrated sulphuric(VI) acid dehydrates:

I. $C_{12}H_{22}O_{11}$ (1 mark)

A black solid/brown solid formed ✓

II. $CoCl_2 \cdot 6H_2O$ (1 mark)

Pink crystals changes to blue powder ✓

(c) State the properties of concentrated sulphuric(VI) acid which are illustrated by the following reactions:

(i) $S(s) + 2H_2SO_4(l) \rightarrow 3SO_2(g) + 2H_2O(l)$ (1 mark)

Oxidation/oxidising agent ✓

(ii) $NaNO_3(s) + H_2SO_4(l) \rightarrow HNO_3(aq) + NaHSO_4(s)$ (1 mark)

Volatility / has low volatility compared to HNO_3

(d) When a mixture of 5 cm^3 ethanol, 1 cm^3 concentrated sulphuric(VI) acid and 5 cm^3 ethanoic acid was heated in a beaker, a pleasant smelling compound was formed.

(i) state the role of the concentrated sulphuric(VI) acid (1 mark)

Catalyst / catalyses the reaction

OR Dehydrating agent

(ii) write the formula of the pleasant smelling compound. (1 mark)

$CH_3COOC_2H_5$

6. Various types of cells are used to electrolyse concentrated sodium chloride. One of them is the mercury cell.

(a) Name another type of cell used. (1 mark)

The diaphragm cell // membrane cell

(b) The mercury cell uses titanium or graphite as anode and mercury as cathode. State why steel is not used for the anode. (1 mark)

Iron in steel reacts with chlorine to form $FeCl_3$

OR Steel react with chlorine present at anode

(c) At the anode, chloride ions and not hydroxide ions are oxidised. Give a reason. (1 mark)

Concentration of Cl^- ions is higher than that of OH^- ions

(d) Describe using equations, how sodium hydroxide and hydrogen are produced in the cell. (3 marks)

- $Na^+_{(l)} + e^- \rightarrow Na_{(l)}$ ✓1
- $Na_{(l)} + Hg_{(l)} \rightarrow NaHg_{(s)}$ ✓1
- $2NaHg_{(l)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)} + 2Hg$ ✓1(c)

Accept explanations without equns but award ½mk

(e) Give two reasons why it is necessary to recycle the mercury used in the cell. (2 marks)

- Mercury is expensive ✓
- Mercury is poisonous ✓

(f) The products of electrolysis of concentrated sodium chloride find extensive use in industries. State the role of chlorine and sodium hydroxide in the paper industry.

(i) Chlorine (1 mark)

Chlorine used to bleach wood pulp ✓1

(ii) Sodium hydroxide (1 mark)

Sodium hydroxide used to digest / decompose / breakdown the wood pulp ✓1

7. (a) (i) Give the formulae of two ionic compounds that can be used to prepare lead(II) sulphide salt. (1 mark)

$Pb(NO_3)_2$ / $Pb(C_2H_3O_2)_2$ ✓½

Na_2S / Aqueous H_2S ✓½

(ii) Two moles of aqueous ammonia reacted with one mole of phosphoric(V) acid. Write an equation for the reaction that took place. (1 mark)

$2NH_{3(aq)} + H_3PO_4 \rightarrow (NH_4)_2HPO_4$ ✓

(b) Solid copper(II) sulphate is available either as anhydrous or hydrated salt. **Figure 4** shows enthalpy changes involved when water is added to each solid.

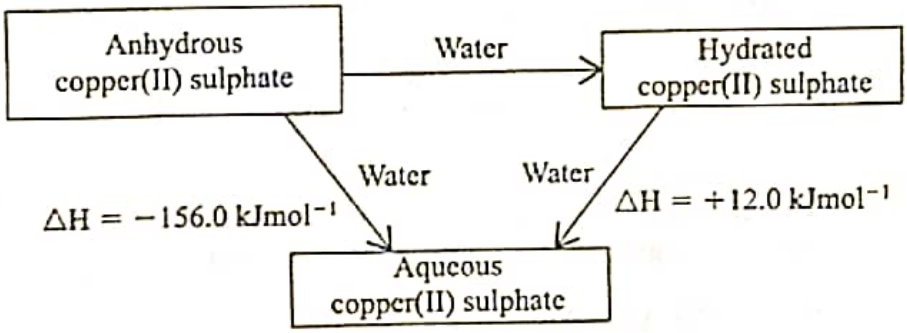


Figure 4

(i) Calculate the enthalpy change for the process:

$$CuSO_4(s) \xrightarrow{\text{Water}} CuSO_4 \cdot 5H_2O(s)$$ (1 mark)

$\Delta H = (-156.0) - (12.0)$ ✓½

$= -168 KJmol^{-1}$ ✓½

(ii) Describe how each of the following can be prepared starting with aqueous copper(II) sulphate.

678

I. hydrated copper(II) sulphate. (2 marks)

Heat aqueous copper (II) sulphate to saturation ✓½
Allow saturated solution to cool ✓½ to crystallise ✓½

II. anhydrous copper(II) sulphate. (1 mark)

Heat aqueous $CuSO_4$ to dryness ✓

OR

Heat ✓½ hydrated $CuSO_4$ crystals until they change from blue to white ✓½

(c) Aluminium hydroxide is used as an antacid.

(i) Name another compound that is used as an antacid. (1 mark)

Magnesium hydroxide ✓

0329

(ii) The concentration of hydrochloric acid in the stomach is 0.01 M. If an antacid containing aluminium hydroxide is used, calculate the mass of the antacid required to neutralise 100.0 cm^3 of the stomach acid

(Al = 27.0; O = 16.0; H = 1.0). (3 marks)

Mole ratio of $Al(OH)_3 : HCl = 1:3$ ✓½
RFM of $Al(OH)_3 = 27+1+48+3 = 78$ ✓½
Moles of the acid $= \frac{100 \times 0.01}{1000}$ ✓½ $= 0.001$ mol
Moles of $Al(OH)_3 = \frac{0.001}{3}$ ✓½ $= 0.0003333$
Mass of $Al(OH)_3 = 0.00033 \times 78$ ✓½
$= 0.025749$ g ✓½

{Penalise ½mk for wrong or missing unit}

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