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545/1
CHEMISTRY
Paper 1
Jul./Aug. 2022
2 ¾ hours.

S.5

THE CHEMISTRY DEPARTMENT

END OF TERM TWO- 2022

CHEMISTRY
Paper 1
2 hours 45 minutes

INSTRUCTIONS:

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

***All** questions must be written 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 equations where applicable.

Where necessary, use the following;

Molar gas constant, R=8.31 JK-1mol^{-1}.
Molar volume of a gas at s.t.p is 22.4 litres.
Standard temperature = 273K.
Standard pressure = 101325Nm^{-2}

For Teachers' Use Only																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
2																	

SECTION A (46 MARKS)

Answer all questions in this section

1. Complete the following nuclear reactions.

(a) $^{233}_{91}Pa$ ✓ + ✗ reject wrong symbols ⟶ $\beta + {}^{233}_{92}U$ (½ mark)

(b) $^{223}_{88}Ra$ ✓ + ✗ ⟶ $^{219}_{86}Rn + {}^{4}_{2}He$ (½ mark)

(c) $^{207}_{81}Tl$ ⟶ $^{0}_{-1}e$ ✓ reject (1 or −1) reject β + $^{207}_{82}Pb$ (½ mark)

(d) $^{216}_{85}At$ ⟶ $^{212}_{83}Bi$ ✓ + ✗ + $^{4}_{2}He$ (½ mark)

2. (a) What is meant by the term **ebullioscopic constant?** (01 mark)

The elevation in boiling point caused when one mole of a non-volatile solute is dissolved in 1000g of pure solvent ✓ reject if key words missing

(b) (i) 2.7g of ethanamide(CH_3CONH_2) was dissolved in 75g of ethanol. Calculate the boiling point of the resultant solution. (2 ½ marks) reject if Constant temp mentioned

[*Ebullioscopic constant, K_b of ethanol is 1.15°Cmol^{-1}kg^{-1} and the boiling point of ethanol is 78°C*]

75g of ethanol dissolve 2.7g of ethanamide ✓

1000g of ethanol will dissolve $\left(\frac{1000\times2.7}{75}\right)$g of CH_3CONH_2 ✓

Molar mass of $CH_3CONH_2 = (2\times12)+(5\times1)+(1\times16)+(14\times1) = 59$g

45g of CH_3CONH_2 elevate boiling point by 1.15°C ✓

$\left(\frac{1000\times2.7}{75}\right)$g of CH_3CONH_2 elevate boiling point by $\left(\frac{1000\times2.7\times1.15}{75\times59}\right)$°C ✓

Boiling point of solution = $(78+0.702)$ ✓ $= 0.702$°C ✓

reject use of formula. Accept to atleast one dp.

$= 78.702$°C ✓ 2½

(ii) State any **two** assumptions made in b(i) above. (01 mark)

Ethanamide does not associate or dissociate in solution
Ethanamide is non-volatile
The solution is dilute.

-½ for @ extra wrong. Any correct 2

3. Complete the following organic reactions and give the **IUPAC** names of the main organic product in each case.

(a) $(CH_3)_2C=CH_2 \xrightarrow{HCl} (CH_3)_2\overset{Cl}{C}CH_3$ (1 ½ marks)

Name of product: 2-chloro-2-methylpropane Shd be one word

(b) $CH_3C\equiv CCH_3 \xrightarrow[Hg^{2+}/60°C]{H_2O/H^+} CH_3COCH_2CH_3$ (1 ½ marks)

Name of product: Butanone reject Butan-2-one

(c) $(CH_3)_2\overset{H}{C}Cl \xrightarrow[Heat]{NaOH(aq)} CH_3\overset{CH_3}{\underset{OH}{C}}H$ (1 ½ marks)

Name of product: Propan-2-ol

4. (a) State what is meant by the term **bond energy**? (01 mark)

Heat given out when one mole of a single covalent bond of a diatomic molecule is formed from free gaseous atoms.
or Heat required to break one mole of a single covalent bond of a diatomic molecule to form free gaseous atoms

(b) Gaseous ethanal burns as shown by the equation;

$$CH_3CHO(g) + 2\tfrac{1}{2}O_2(g) \longrightarrow 2H_2O(g) + 2CO_2(g)$$

Use the mean bond enthalpy data given below to calculate the enthalpy change for the complete combustion of ethanal. (05 marks)

Bond	Mean bond enthalpy($kJmol^{-1}$)
$C-H$	+413
$C-C$	+347
$C=O$	+736
$O=O$	+498
$O-H$	+464

$H-\underset{H}{\overset{H}{C}}-\underset{O}{C}-H(g) + \frac{5}{2}(O=O) \longrightarrow 2\,H-O-H + 2(O=C=O)$

$\Delta H_{reaction} = \sum$ bond enthalpies of bonds broken $- \sum$ bond enthalpies of bonds formed

$= [\frac{5}{2}(O=O) + 4(C-H) + (C-C) + (C=O)] - [2(O-H) + 2(C=O)]$

$= [5/2(498) + (4 \times 413) + 347 + 736] - [(4 \times 464) + 4(736)]$

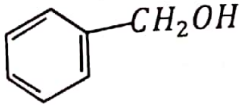
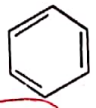
$= (3980 - 4800)$

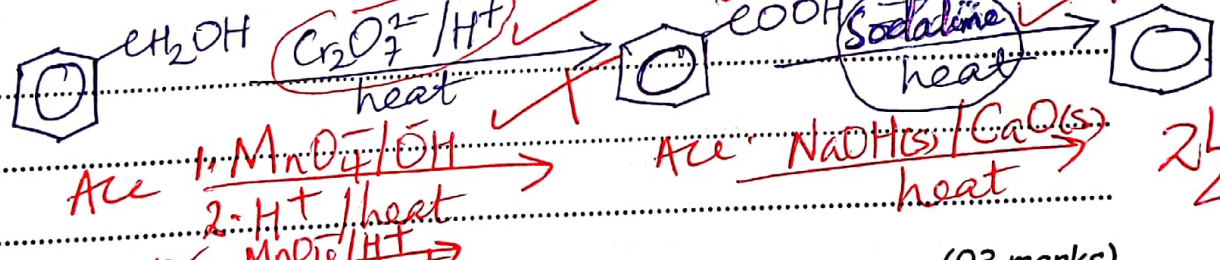
$= -820$

ΔH combustion is therefore $-820\ kJ\,mol^{-1}$ (5)

reject -820, -820 $-\frac{1}{2}$ if units missing or wrong

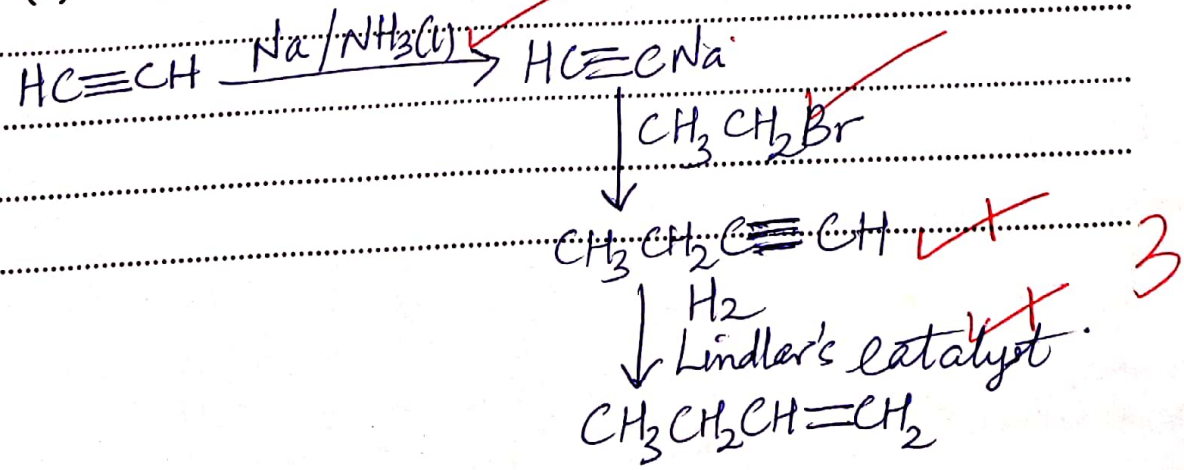
5. Write equations to show how the following conversions can be effected.

(a)  to  (2 $\frac{1}{2}$ marks)



2½

(b) $CH_3CH_2CH=CH_2$ from ethyne (03 marks)



3

6. Beryllium, magnesium and calcium are group (II) elements.

(a) Write the general outermost configuration of the elements.

(01 mark)

ns^2 ✓ 1

(b) Each of the above elements reacts with carbon (recheck) to form carbides. Write the equation for the reaction that occurs when each carbide reacts with water.

(4 ½ marks)

$Be_2C_{(s)} + 4H_2O_{(l)} \longrightarrow 2Be(OH)_{2(aq)} + CH_{4(g)}$ ✓✓

(*) $Mg_2C_{3(s)} + 4H_2O_{(l)} \longrightarrow 2Mg(OH)_{2(aq)} + CH_3C{\equiv}CH_{(g)}$ ✓✓

$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + HC{\equiv}CH_{(g)}$ ✓✓

Ace: C_3H_4 and C_2H_2 4½

7. Both aluminium and phosphorus form compounds in the oxidation state of +3.

(a) Briefly explain in terms of electronic configuration why aluminium conducts electricity but all common allotropes of phosphorus do not.

(03 marks)

$_{13}Al - 1s^2 2s^2 2p^6 3s^2 3p^1$ ✓ ✓ $_{15}P - 1s^2 2s^2 2p^6 3s^2 3p^3$ ✓

The aluminium atom has its 3p subenergy level having only one electron, neither completely filled nor half filled ✓, thermodynamically unstable. This electron can be delocalised ✓ to conduct electricity since it's loosely held. However, the phosphorus atom has its 3p subenergy level with 3 electrons half filled ✓ and thermodynamically stable. These electrons are strongly held and cannot be delocalised ✓ for electrical conduction. 3

reject $3p^1$ or $3p^3$ subenergy level

Accept molecular equations.

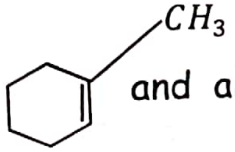
(b) Write equation for the reaction between each of the elements aluminium and phosphorus with sodium hydroxide solution. (03 marks)

$2Al(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 2Al(OH)_4^-(aq) + 3H_2(g)$ ✓✓

$P_4(s) + 3OH^-(aq) + 3H_2O(l) \rightarrow 3H_2PO_2^-(aq) + PH_3(g)$ ✓✓

or $2Al(s) + 2OH^-(aq) + 2H_2O(l) \rightarrow 2AlO_2^-(aq) + 3H_2(g)$

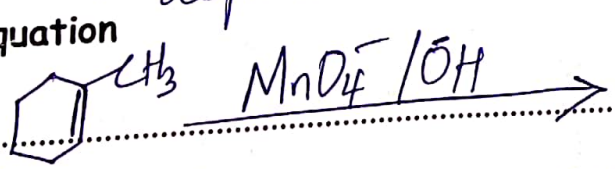
8. State what would be observed and in each case write equation for the reaction in each case when the following pairs of compounds are mixed.

(a)  and alkaline potassium manganate(VII) solution. (02 marks)

Observation

Purple solution turns green and a brown solid deposited. ✓✓

Equation



✓ reject if heat included.

Ace. $2 + 2MnO_4^-(aq) + 2H_2O(l) \rightarrow 2 + MnO_2(s) + MnO_4^{2-}(aq)$ (02 mark)

(b) Propyne and ammoniacal silver nitrate solution.

Observation

White precipitate ✓

Equation

$CH_3C{\equiv}CH(g) + NH_3(aq) + AgNO_3(aq) \rightarrow CH_3C{\equiv}CAg(s) + NH_4NO_3(aq)$ ✓

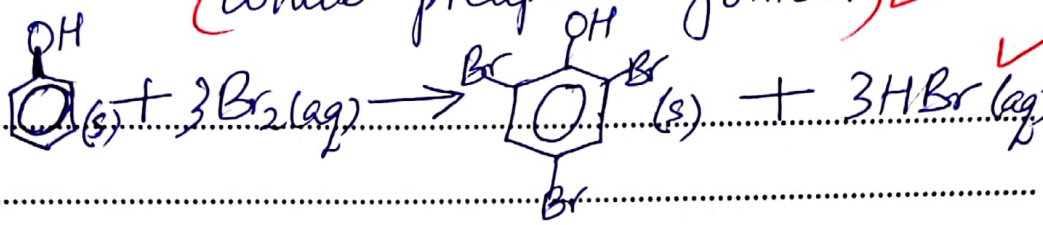
ignore states.

(c) Hydroxybenzene and bromine water. *(02 marks)*

Observation

Reddish brown solution turns colourless and a (white precipitate formed);

Equation



$$C_6H_5OH_{(s)} + 3Br_{2(aq)} \rightarrow C_6H_2Br_3OH_{(s)} + 3HBr_{(aq)}$$

9. (a) State what is meant by the term **first electron affinity.**

(01 mark)

The heat given out when an electron is added to a gaseous atom to form a uninegatively charged gaseous ion

or; Heat given out when one mole of electrons is added to one mole of gaseous atoms to form one mole of uninegatively charged gaseous ions.

(b) The table below shows the values of first electron affinities of group VII elements.

Element	First electron affinity ($kJmol^{-1}$)
Fluorine	−328
Chlorine	−349
Bromine	−325
Iodine	−295

State and explain the trend in first electron affinities of the elements. *(05 marks)*

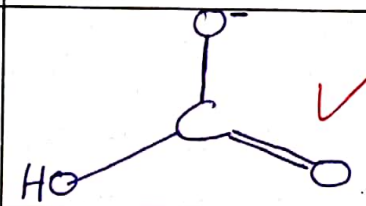
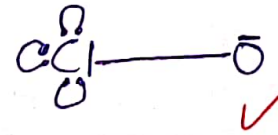
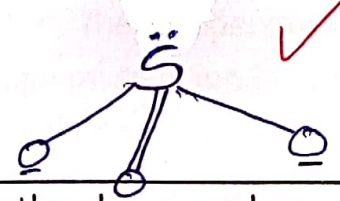
First electron affinity increases from fluorine to chlorine and then gradually decreases from chlorine to iodine.

Fluorine has abnormally lower first electron affinity than Chlorine because its atom has the smallest atomic radius, ↑ highest electron density hence strongly repels the incoming electron and some energy is consumed to add the electron. From chlorine to iodine, nuclear charge increases from one element to another, screening effect increases due to an extra energy level completely filled with electrons added from element to element. Increase in screening effect outweighs increase in nuclear charge. Effective nuclear charge decreases, atomic radius increase, and the incoming electron experiences a decreasing attraction. ↓ Low amount of energy. -5

SECTION B: (54 MARKS)

Answer any **six** *questions from this section.*

10. (a) Draw the structures and name the shapes adopted by each of the following species. *(4 ½ marks)*

Species	Structure	Shape
HCO_3^-		Trigonal planar ✓
ClO^-		Linear ✓
SO_3^{2-}		Trigonal pyramidal ✓

4½

(b) Explain why ClO^- adopts the shape you have stated in (a) above.

(03 marks)

The chlorate(I)/ClO^- ion has one bonding pair of electrons and three lone pairs on the central atom. The lone pairs of electrons repel each other greatly and there is also lone pair-bond pair repulsion. Since the lone pair-lone pair repulsion is greater than lone pair-bond pair repulsion, the maximum repulsion between lone pairs is greater and makes the molecule have a bond angle of 180° and linear. 3

(c) Write equation for the reaction between aqueous aluminium nitrate and potassium hydrogen carbonate solution.

$Al(NO_3)_{3(aq)} + 3KHCO_{3(aq)} \rightarrow Al(OH)_{3(s)} + 3KNO_{3(aq)} + 3CO_{2(g)}$ (1 ½ marks)

or $Al(H_2O)^{3+}_{6(aq)} + 3HCO^-_{3(aq)} \longrightarrow Al(H_2O)_3(OH)_{3(s)} + 3CO_{2(g)} + 3H_2O_{(l)}$

or $Al^{3+}_{(aq)} + 3HCO^-_{3(aq)} \longrightarrow Al(OH)_{3(s)} + 3CO_{2(g)}$.

11. (a) Define the term **enthalpy of solution.** (01 mark)

The heat evolved or absorbed when one mole of a solute is dissolved in a specified number of moles of water.

(b) In an experiment to determine the enthalpy of solution of anhydrous and hydrated copper(II) sulphate salts, 4.0 g of the anhydrous salt was added to 50g of water and the temperature of water rose by 8.0 ^oC. When 4.0 g of the hydrated salt ($CuSO_4.5H_2O$) was added to 50 g of water, the temperature of water dropped by 1.3 ^oC. calculate the enthalpy of solution in $kJmol^{-1}$ of;

(i) anhydrous copper(II) sulphate.

(***Specific heat capacity of solution is*** $4.2Jg^{-1}\ ^oC^{-1}$) (2 ½ marks)

Heat change = mass of solution × specific heat capacity of solution × Temperature rise

$= (4+50) \times 4.2 \times 8 = 1814.4\,J$

Molar mass of $CuSO_4 = 63.5 + 32.1 + (4\times16) = 159.6\,g$

4.0 g of $CuSO_4$ evolve 1814.4 Joules.

159.6 g of $CuSO_4$ evolve $\left(\frac{159.6 \times 1814.4}{4.0}\right) = 72394.56\,J$

Enthalpy of solution of anhydrous copper(II) sulphate $= -72394.56\,J\,mol^{-1}$

$= -72.394\,kJ\,mol^{-1}$

(02 marks)

(ii) Hydrated copper(II) sulphate.

Heat change $= (50+4) \times 4.2 \times 1.3 = 294.84\,J$

Molar mass of $CuSO_4.5H_2O = 159.6 + (5\times18) = 249.6\,g$.

4.0 g of $CuSO_4.5H_2O$ absorb 294.84 Joules.

249.6 g of $CuSO_4.5H_2O$ absorb $\left(\frac{249.6 \times 294.84}{4}\right)$

Enthalpy of solution of hydrated copper(II) sulphate $= +18398.02\,J\,mol^{-1}$

$= +18.398\,kJ\,mol^{-1}$

(02 marks)

(iii) Comment on the difference in values of enthalpy of solution calculated in (b)

Enthalpy of solution of anhydrous copper(II) sulphate is exothermic whereas enthalpy of solution of hydrated copper(II) sulphate is endothermic. This is because the ions in hydrated copper(II) sulphate are already partly hydrated. On dissolution lattice energy outweighs hydration energy making enthalpy of solution positive. For the anhydrous salt, hydration energy outweighs lattice energy, making enthalpy of solution negative.

(02 marks)

(d) Calculate the enthalpy change for the reaction; (1 ½ marks)

$CuSO_4\,(aq) + 5H_2O(l) \longrightarrow CuSO_4.5H_2O(s)$

$CuSO_{4(s)} \xrightarrow{-72.395\ kJmol^{-1}} Cu^{2+}_{(aq)} + SO^{2-}_{4(aq)}$

$CuSO_{4(s)} \xrightarrow{\Delta H^{\ominus}_{hydration}} CuSO_4.5H_2O_{(s)}$; $CuSO_4.5H_2O_{(s)} \xrightarrow{+18.398\ kJmol^{-1}} Cu^{2+}_{(aq)} + SO^{2-}_{4(aq)}$

By Hess' law;

$\Delta H^{\ominus}_{hydration} + 18.398 = -72.395$

$\Delta H^{\ominus}_{hydration} = -72.395 - 18.398 = -90.793\ kJmol^{-1}$

12. Nitrogen and hydrogen react to form ammonia according to the following equation.

$3\,H_2\,(g) + N_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\ kJ$

(a) State the industrial conditions used to obtain a maximum yield of ammonia. (1 ½ marks)

Pressure between 200-500 atm.

Temperature about 450-~~550~~ °C.

Finely divided iron catalyst.

(b) During the manufacture of nitric acid, ammonia is catalytically oxidized to **P** which is further oxidized to **Q**. **Q** is then reacted with water to produce nitric acid.

(i) Name **P** and **Q**

Reject formulae. Accept nitrogen(II) oxide

P is Nitrogen monoxide (½ mark)

Accept nitrogen(IV) oxide

Q is Nitrogen dioxide (½ mark)

(ii) Write equations for the formation of :

P

(1 ½ marks)

$4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(l)}$

Acc $2NH_{3(g)} + \frac{5}{2}O_{2(g)} \rightarrow 2NO_{(g)} + 3H_2O_{(l)}$.

Q

(1 ½ marks)

$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

Acc $NO_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow NO_{2(g)}$

Nitric acid

(1 ½ marks)

$4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \longrightarrow 4HNO_{3(aq)}$

(c) Write equations for the reaction of concentrated nitric acid and:

(i) sulphur

(1 ½ marks)

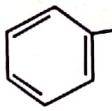
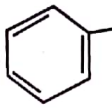
$S_{(s)} + 6HNO_{3(aq)} \longrightarrow H_2SO_{4(aq)} + 6NO_{2(g)} + 2H_2O_{(l)}$.

(ii) Copper

(1 ½ marks)

$Cu_{(s)} + 4HNO_{3(aq)} \longrightarrow Cu(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$

13. Name the reagents that can be used to distinguish each of the following pairs of compounds. State what would be observed in each case.

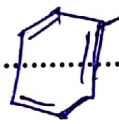
(a)  and  (03 marks)

emphasize spellings and state of the reagent(s)

Reagent;

Ammoniacal silver nitrate solution ✓
or Ammoniacal copper(I) chloride solution.

Observation(s);

 — White precipitate ✓ or Red precipitate

 — No observable change ✓ No observable change

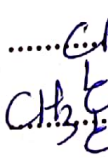
(b) $(CH_3)_3COH$ and $(CH_3)_3CCH_2OH$. (03 marks)

Reagent:

Anhydrous Zinc chloride and concentrated hydrochloric acid ✓
reject; un hydrous, an hydrous, Zinc(II) chloride, Zinc chloride solution

Observation(s):

$(CH_3)_3COH$ — cloudy solution formed immediately ✓

 — No observable change at room temperature ✓

(c) CH_3CH_2CHO and CH_3COCH_3 . (03 marks)

Reagent:

6

① Ammoniacal silver nitrate solution / Tollen's reagent
② or Fehling's solution
③ or Iodine solution and sodium hydroxide solution and heat

Observation(s):

① CH_3CH_2CHO – Silver mirror deposited
CH_3COCH_3 – NO observable change

② CH_3CH_2CHO – Reddish brown precipitate
CH_3COCH_3 – NO observable change

③ CH_3CH_2CHO – NO observable change
CH_3COCH_3 – Yellow precipitate

14. Complete the following equations and write the mechanism for each reaction.

(a) $CH_3CH_2CH_2CH_2OH \xrightarrow[Heat]{Conc.\ H_2SO_4}$ (3 ½ marks)

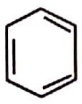
$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$

$CH_3CH_2CH_2CH_2OH + H^+ \longrightarrow CH_3CH_2CH_2CH_2\overset{+}{O}H_2$

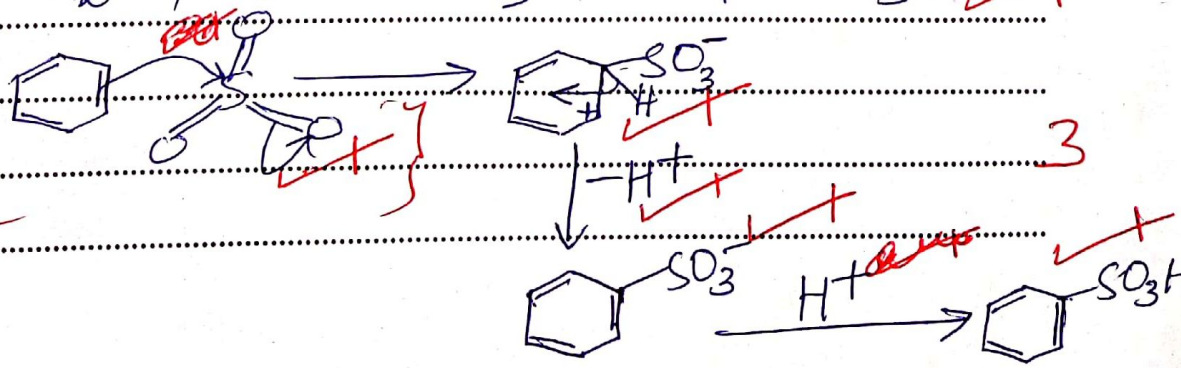
$CH_3CH_2CH_2CH_2\overset{+}{O}H_2 \xrightarrow{-H_2O} CH_3CH_2CH_2\overset{+}{C}H_2$

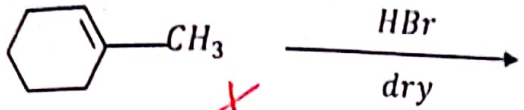
$CH_3CH_2CH_2\overset{+}{C}H_2 \rightleftharpoons CH_3CH_2\overset{+}{C}HCH_3$ (Hydride shift)

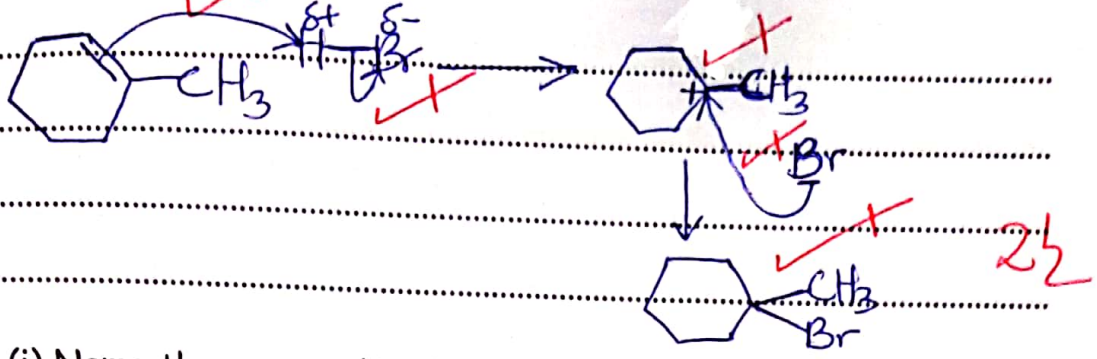
$CH_3CH_2\overset{+}{C}HCH_3 + HOSO_3H \longrightarrow CH_3CH{=}CHCH_3 + H_2SO_4$

(b)  $\xrightarrow[35°C]{fuming\ H_2SO_4}$ (03 marks)

$2H_2SO_4 \rightleftharpoons SO_3 + HSO_4^- + H_3O^+$



(c)  (2 ½ marks)



15. (a) (i) Name the ore used in the extraction of aluminium (½ mark)

Bauxite ✓ reject formular

(ii) Write the formula of the ore named in (a)(i) above.

$Al_2O_3 \cdot 2H_2O$ ✓ (½ mark)

(b) During the process of extraction, the ore is treated with hot concentrated sodium hydroxide solution.

(i) Briefly state what happens to the ore when treated with sodium hydroxide solution. (02 marks)

The amphoteric aluminium oxide reacts with sodium hydroxide to form sodium aluminate. The silicon(IV) oxide impurity also reacts with the sodium hydroxide to form sodium silicate.

(ii) Write equation(s) for the reaction(s) that take place in (b)(i) above. (2 ½ marks)

$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)_4^-(aq)$

$SiO_2(s) + 2OH^-(aq) \rightarrow SiO_3^{2-}(aq) + H_2O(l)$

or $Al_2O_3(s) + 6OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)_6^{3-}(aq)$

or $Al_2O_3(s) + 2OH^-(aq) \rightarrow 2AlO_2^-(aq) + H_2O(l)$

Accept molecular equations

(c) The soluble complex salt of aluminium obtained in (b) is taken through several reactions to form pure aluminium oxide.

(i) State how the purified aluminium oxide is treated to form pure aluminium. (1 ½ marks)

Pure aluminium oxide is electrolysed using graphite electrodes in the presence of molten cryolite to lower its melting point. A low voltage and high current density is used. Aluminium is obtained at the cathode.

(ii) Write equation for the reaction that takes place. (01 mark)

$Al^{3+}(l) + 3e \longrightarrow Al(s)$

(iii) Explain one use of aluminium. (1 ½ marks)

Light and high tensile strength hence used to make Duralumin for aircraft construction. Light, good heat conductivity for making cooking utensils malleable, ductile and light hence used to make aluminium foil for packaging.

16. Successive ionisation energies($kJmol^{-1}$) for some elements in Period 3 of the periodic Table are shown in the table below.

Element	Ionisation energy				
	1st	2nd	3rd	4th	5th
Silicon	787	1577	3230	4355	16090
Phosphorus	1060	1896	2908	4954	6272
Sulphur	1000	2258	3381	4565	6995

17. $30cm^3$ of a gaseous hydrocarbon Z was exploded with $200cm^3$ of oxygen, which was in excess. The residual gas volume was found to be $155cm^3$ on cooling to room temperature. The volume of the residual gas reduced to $35cm^3$ on treatment with concentrated potassium hydroxide solution.

(a)(i) Write the general equation for the reaction between Z and oxygen. (1 ½ marks)

$C_xH_y(g) + \left(x + \frac{y}{4}\right)O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$ ✓ ½

(ii) Calculate the molecular formula of Z. (2 ½ marks)

Volume of O_2 used $= 200 - 35 = 165cm^3$

Volume of CO_2 formed $= 155 - 35 = 120cm^3$

$30cm^3$ of Z form $120cm^3$ of CO_2 ✓

1 volume of Z forms x volumes of CO_2 ½

$\frac{120}{30} = \frac{30x}{30}$ ½

$x = 4$ ✓

$30cm^3$ of Z react with $165cm^3$ of O_2

1 volume of Z reacts with $(4 + \frac{y}{4})$ volumes of O_2 ½

$165 = 30(4 + \frac{y}{4})$ ½

$y = (\frac{165}{30} - 4)4 = 6$ ½

Molecular formula of Z is C_4H_6 ½ 2½

(b) When Z was treated with ammoniacal copper(I) chloride solution, a red precipitate was formed.

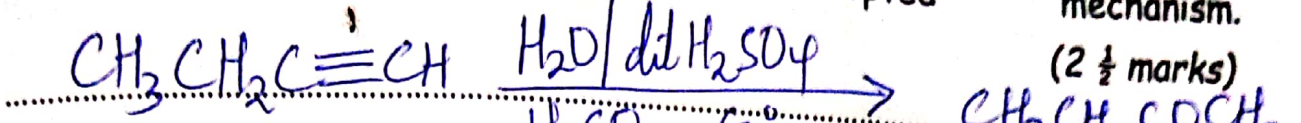
(i) Identify Z. (01 mark)

$CH_3CH_2C{\equiv}CH$ ✓ Accept But-1-yne. 1

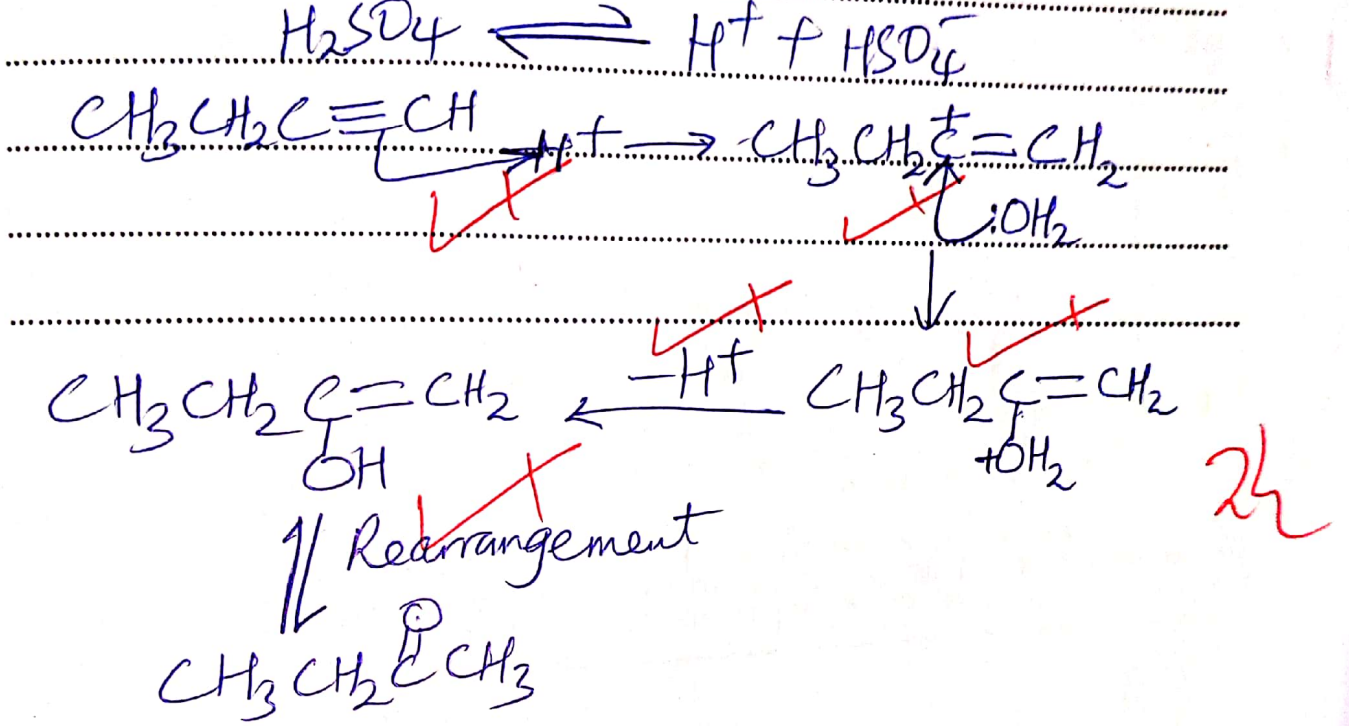
(ii) Write equation for the formation of the red precipitate. (1 ½ mark)

$2CH_3CH_2C{\equiv}CH(g) + Cu_2Cl_2(aq) + 2NH_3(aq) \rightarrow 2CH_3CH_2C{\equiv}CCu(s) + 2NH_4Cl(aq)$ ½ 1

(c) Z was reacted with water in the presence of dilute sulphuric acid and mercury(II) sulphate at 60°C. Write equation for the reaction and the accepted mechanism. (2 ½ marks)



Mechanism:



2½