(7)

(a) Sodium, Magnesium and aluminium have a giant Metallic Structure. Their atoms are held by strong metallic bonds
From Sodium to aluminium, atomic radius reduces and the number of electrons contributed by each atom to the metallic bond increases. The strength of the Metallic bond increases. Aluminium does not contribute all its outermost electrons to the metallic bond.
Silicon has a giant covalent structure. Its atoms are held by strong covalent bonds
Phosphorus, Sulphur and Chlorine have simple molecular structure. Their molecules are held by weak Van der Waals forces.
The strength of Vander Waals forces increases with increase in molecular mass which increases from phosphorus to Sulphur and reduces to chlorine.
This is because phosphorus has P_4 molecules, Sulphur S_8 and chlorine Cl_2.

(20) (6½)

b) Magnesium reacts with steam when heated to form Magnesium oxide and hydrogen.

$$Mg_{(s)} + H_2O_{(g)} \longrightarrow MgO_{(s)} + H_{2(g)}$$

It also reacts slowly with cold water to form Magnesium hydroxide and hydrogen. (2)

$$Mg_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2(s)} + H_{2(g)}$$

Silicon reacts with steam when heated to form Silicon dioxide and hydrogen. (2)

$$Si_{(s)} + 2H_2O_{(g)} \longrightarrow SiO_{2(s)} + 2H_{2(g)}$$

(2)

Chlorine reacts with cold water to form hydrochloric acid and hypochlorous acid (chloric(I) acid)

$Cl_{2(g)} + H_2O_{(l)} \longrightarrow HCl_{(aq)} + HClO_{(aq)}$ (2)

(ii) Aluminium reacts with cold dilute sodium hydroxide to form sodium aluminate and hydrogen.

$Al_{(s)} + OH^-_{(aq)} + 3H_2O_{(l)} \longrightarrow Al(OH)^-_{4(aq)} + \frac{3}{2}H_{2(g)}$ (2)

$(Al_{(s)} + OH^-_{(aq)} + H_2O_{(l)} \longrightarrow AlO^-_{2(aq)} + \frac{3}{2}H_{2(g)})$

Silicon reacts with hot concentrated sodium hydroxide to form sodium silicate and hydrogen.

$Si_{(s)} + 2OH^-_{(aq)} + H_2O \longrightarrow SiO^{2-}_{3(aq)} + 2H_{2(g)}$ (2)

Phosphorus reacts with hot concentrated sodium hydroxide to form sodium dihydrogen phosphonate and ~~hydrogen~~ phosphine gas.

$P_{4(s)} + 3OH^-_{(aq)} + 3H_2O_{(l)} \longrightarrow 3H_2PO^-_{2(aq)} + PH_{3(g)}$ (2)

(iii) Pale yellow solution was formed.

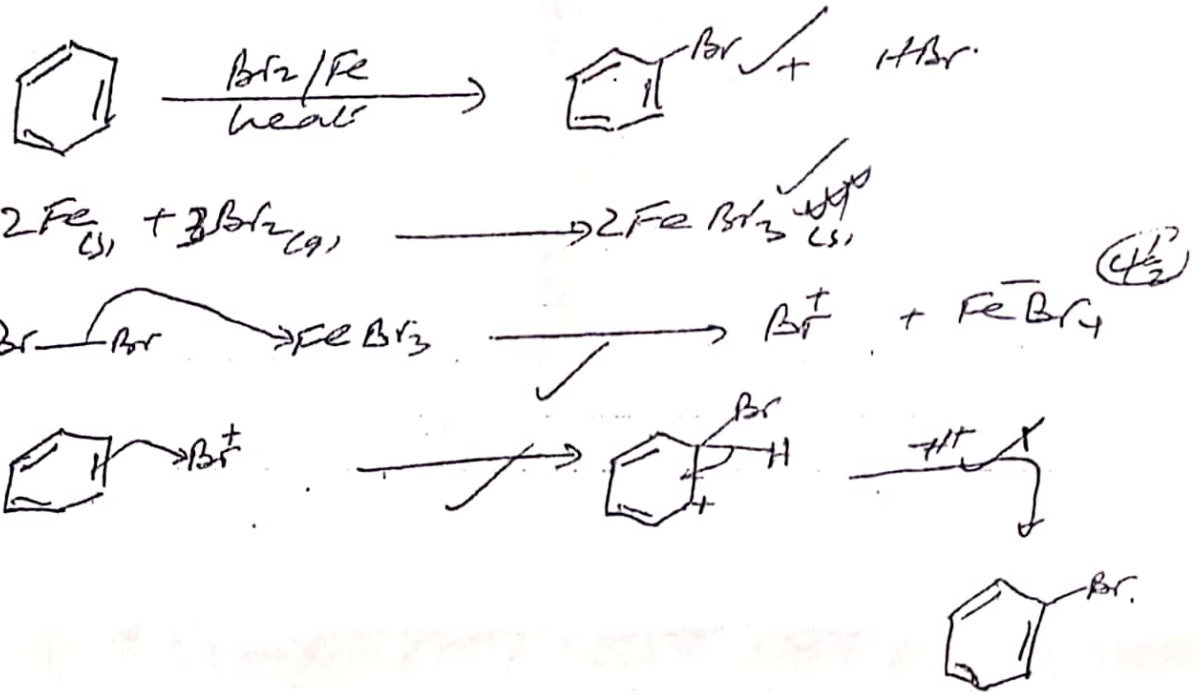
$Cl_{2(g)} + 2OH^-_{(aq)} \longrightarrow Cl^-_{(aq)} + ClO^-_{(aq)} + H_2O$

(3)

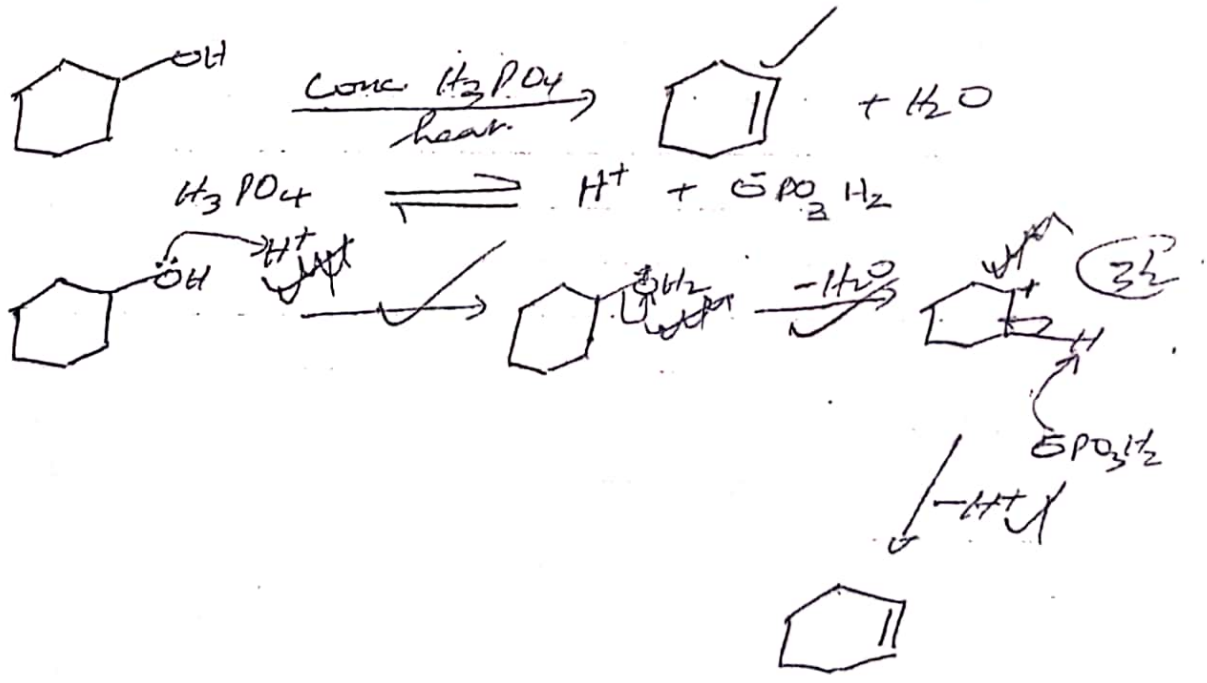
2 (a) $CH_3CH_2Br \xrightarrow[\text{Ethanol, heat}]{CH_3CH_2OK} CH_3CH_2OCH_2CH_3 + Br^-$ (2)

(2)

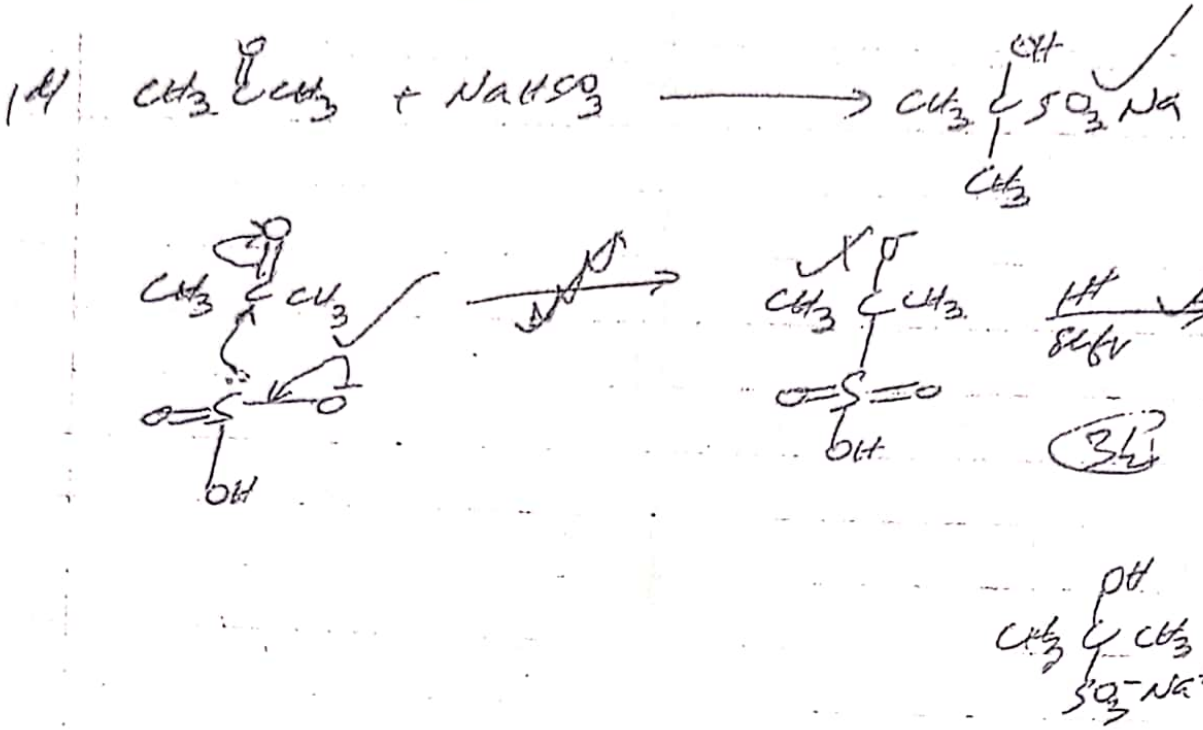
(b)

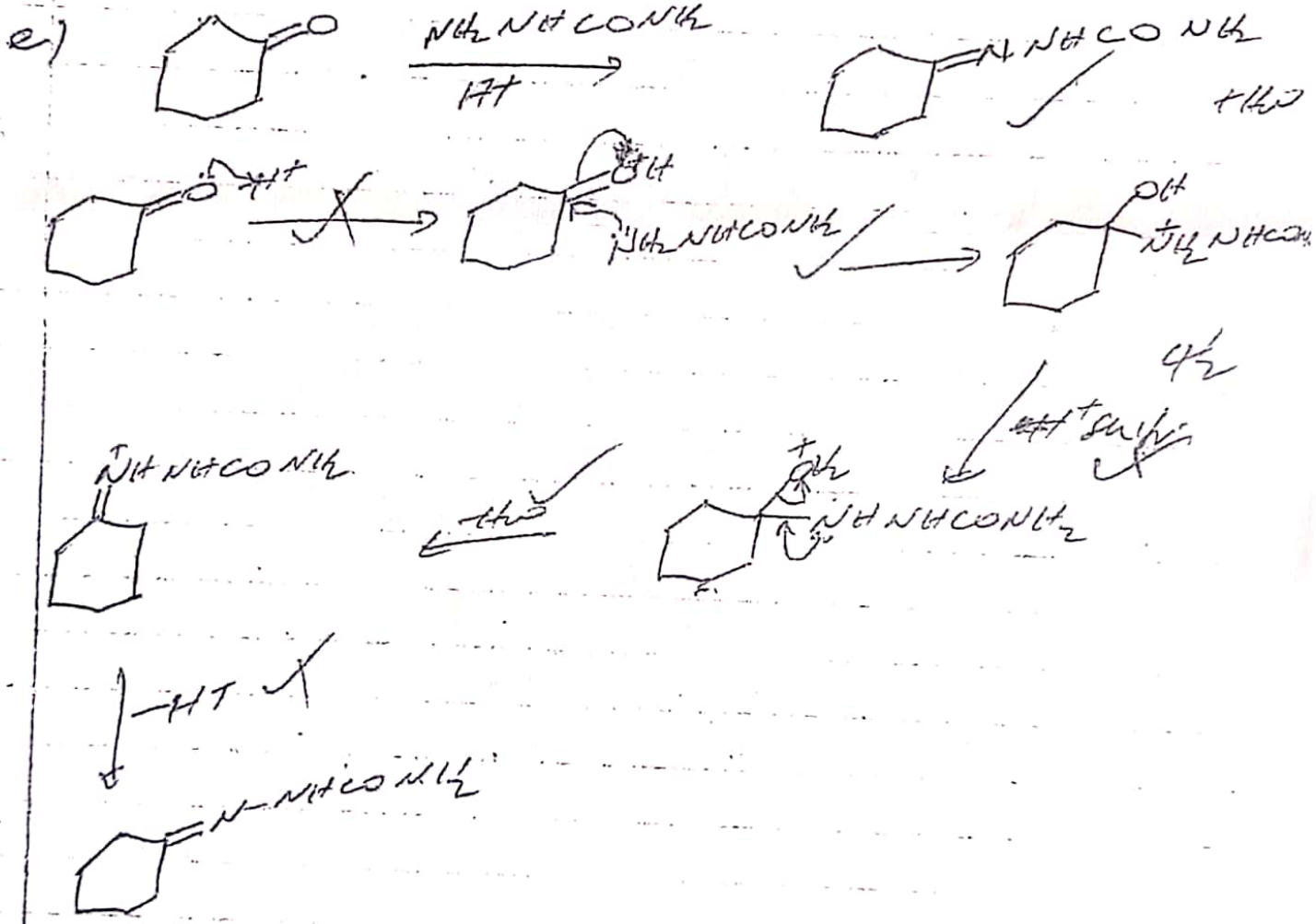


(c)



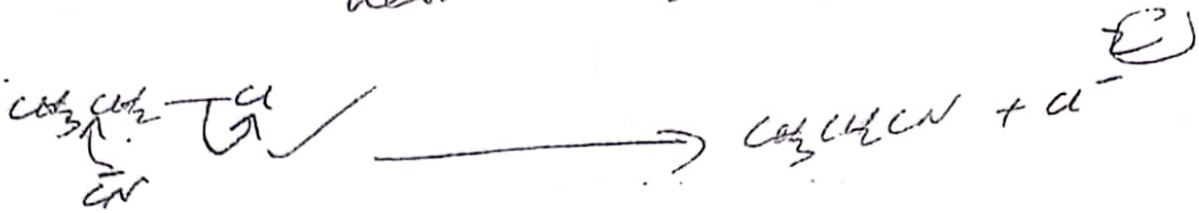
(4)

d) 

e) 

(5)

(d) $CH_3CH_2Cl \xrightarrow[\text{heat}]{KCN/\text{ethanol}} CH_3CH_2CN + Cl^-$



3) Chromium(III) ions react with hydroxide ions to form chromium(III) hydroxide which is amphoteric and insoluble.

$Cr^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Cr(OH)_{3(s)}$

Amphoteric chromium(III) hydroxide reacts with excess hydroxide ions to form a soluble complex of tetrahydroxochromate(III) ions.

$Cr(OH)_{3(s)} + OH^-_{(aq)} \longrightarrow Cr(OH)_4^-{}_{(aq)}$

(or $Cr(OH)_{3(s)} + 3OH^-_{(aq)} \longrightarrow Cr(OH)_6^{3-}{}_{(aq)}$) (6)

Hydrogen peroxide oxidises chromate(III) ions to chromate(VI) ions

$2Cr(OH)_4^-{}_{(aq)} + 2OH^-_{(aq)} + 3H_2O_{2(aq)} \longrightarrow 2CrO_4^{2-}{}_{(aq)} + 8H_2O_{(l)}$

b) Potassium nitrate is a strong electrolyte.

$KNO_{3(aq)} \longrightarrow K^+_{(aq)} + NO_3^-$

A 0.01M solution contains 0.01M potassium ions and 0.01M nitrate ions, hence it contains 0.02M particles/ions.

A 0.02M glucose does not (3) associate or dissociate. A 0.02M solution contains 0.02M molecules/particles.

The two solutions contain the same number of particles. They cause the same freezing point depression of water.

c) Water has an O–H bond that is polar. This is because oxygen has a small atomic radius and high electronegativity. Water molecules are held by hydrogen bonds. (4)

Hydrogen sulphide molecules are held by van der Waals forces which are weaker than hydrogen bonds.

d) 

Water has two O–H bonds and two lone pairs. It has a V shape. (or diagram)

Ammonia has 3 N–H bonds and 1 lone pair. It has a trigonal planar shape (or drawing) (3)

Two lone pairs cause greater repulsion of bonds reducing the bond angle.

d) Tin(II) chloride is partially covalent. It undergoes partial hydrolysis forming an acidic solution (or hydrogen ions or hydrochloric acid)

$SnCl_{2(s)} + H_2O \rightleftharpoons Sn(OH)Cl + HCl_{(aq)}$ (4)

Lead(II) chloride is ionic. It does not undergo hydrolysis

7

4. (a) (i) The position of equilibrium shifts from left to right because the forward reaction takes place with a decrease in volume (or number of moles, or pressure). (3)
The amount of ammonia increases and the amount of nitrogen and hydrogen reduces.
The individual partial pressures (or molar) concentrations adjust themselves to maintain a constant value of the equilibrium constant.

(ii) Position of equilibrium shifts from left to right because the forward reaction is exothermic. (3)
The concentration of ammonia increases whereas the concentration of nitrogen and hydrogen reduces.
The value of the equilibrium constant increases.

(iii) Iron is a catalyst. It increases the rate of both forward and backward reaction equally, hence increases the rate of attainment of equilibrium. (3)
It has no effect on the position of equilibrium and no effect on the equilibrium constant.

(8)

(b) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

No. $(1\cdot3-x)$ $3-3x$ $2x$ ✗

$3(1-x) = 1\cdot8$

$x = 0\cdot4$ ✗

∴ At equilibrium,

moles of $N_2 = 1\cdot3 - 0\cdot4 = 0\cdot9$ ✗

moles of $H_2 = 1\cdot8$ ✗

moles of $NH_3 = 2\times0\cdot4 = 0\cdot8$ ✗

Total number of moles $= 1\cdot8 + 0\cdot8 + 0\cdot9$

$= 3\cdot5$

$P_{N_2} = \frac{0\cdot9}{3\cdot5} \times 50 = 12\cdot86$ atm ✗

$P_{H_2} = \frac{1\cdot8}{3\cdot5} \times 50 = 25\cdot71$ atm ✗

$P_{NH_3} = \frac{0\cdot8}{3\cdot5} \times 50 = 11\cdot43$ atm ✗

(ii) $K_p = \frac{P^2_{(NH_3)}}{P_{(N_2)} \times P^3_{(H_2)}}$ ✗

$= \frac{(11\cdot43)^2}{12\cdot86 \times (25\cdot71)^3}$ ✗

$K_p = 5\cdot98 \times 10^{-4}$ atm^{-2} ✓ (with units)

(c)

(c) Ammonia is heated in excess air in the presence of platinum catalyst to form nitrogen monoxide

$$2NH_{3(g)} + \frac{5}{2}O_{2(g)} \xrightarrow{Pt} 2NO_{(g)} + 3H_2O_{(l)}$$

On cooling, nitrogen monoxide combines with air (oxygen) to form nitrogen dioxide.

$$NO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow NO_{2(g)} \quad (5)$$

Nitrogen dioxide is dissolved in water in the presence of excess oxygen to form nitric acid

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

5) a) They both react with sodium hydroxide solution to form hydrogen

- Their oxides and hydroxide are amphoteric
- They react with dry chlorine when heated to form anhydrous chlorides
- They react with hot concentrated sulphuric acid to form sulphates, sulphur dioxide and water

(Any correct) (20)

(ii) $2Cr_{(s)} + 2OH^-_{(aq)} + 6H_2O_{(l)} \longrightarrow 2Cr(OH)_4^-_{(aq)} + 3H_{2(g)}$

$Cr(OH)_{3(s)} + OH^-_{(aq)} \longrightarrow Cr(OH)_4^-_{(aq)}$ (3)

or $Cr_2O_{3(s)} + 2OH^-_{(aq)} + 3H_2O_{(l)} \longrightarrow 2Cr(OH)_4^-$

$2Cr_{(s)} + 3Cl_{2(g)} \longrightarrow 2CrCl_{3(s)}$

$2Cr_{(s)} + 6H_2SO_{4(l)} \longrightarrow Cr_2(SO_4)_{3(aq)} + 3SO_{2(g)} + 6H_2O$

(Any two correct)

(b) (i) A green precipitate and bubbles of a colourless gas (2½)

(ii) $Cr^{3+}_{(aq)} + 3HCO_3^-{}_{(aq)} \longrightarrow Cr(OH)_{3(s)} + 3CO_{2(g)}$

(c) (i) The yellow solution turns orange. (2½)

$2CrO_4^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightleftharpoons Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)}$

(ii) The yellow solution turns intense blue.

$CrO_4^{2-}{}_{(aq)} + H^+_{(aq)} + H_2O_{2(aq)} \longrightarrow CrO_{5(s)} + H_2O_{(l)}$ (2½)

$CrO_4^{2-}{}_{(aq)} + 2H_2O_{2(aq)} + 2H^+_{(aq)} \longrightarrow CrO_{5(s)} + 3H_2O_{(l)}$

(iii) A red precipitate (2)

$2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)} \longrightarrow Ag_2CrO_{4(s)}$

(d) (i) Blue precipitate, insoluble in excess, turns pink on standing.

$Co^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Co(OH)_{2(s)}$

$2Co(OH)_{2(s)} + \frac{1}{2}O_{2(g)} \longrightarrow Co_2O_3 \cdot 2H_2O_{(s)}$

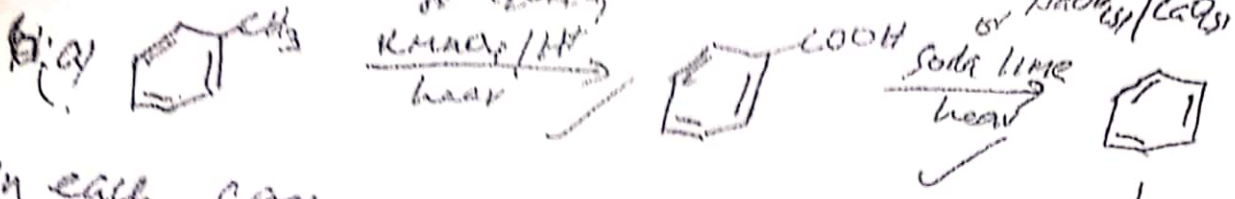
(ii) The pink solution turned blue. (2)

$Co(H_2O)_6^{2+}{}_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons CoCl_4^{2-}{}_{(aq)} + 6H_2O$

(or $Co^{2+}_{(aq)} + 4Cl^-_{(aq)} \longrightarrow CoCl_4^{2-}{}_{(aq)}$)

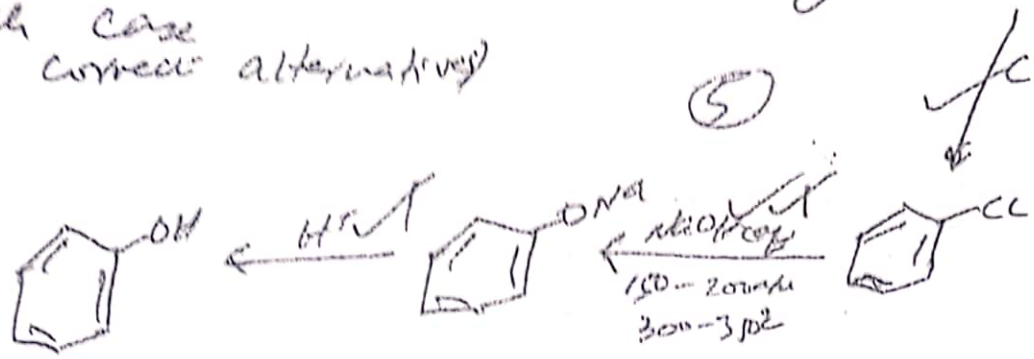
(iii) (ii)

(b) (i)



(In each case accept correct alternatives)

(5)



(ii) $CH_3CH_2OH \xrightarrow{PCl_5} CH_3CH_2Cl \xrightarrow[\text{heat}]{KCN/CH_3CH_2OH} CH_3CH_2CN$

(4)

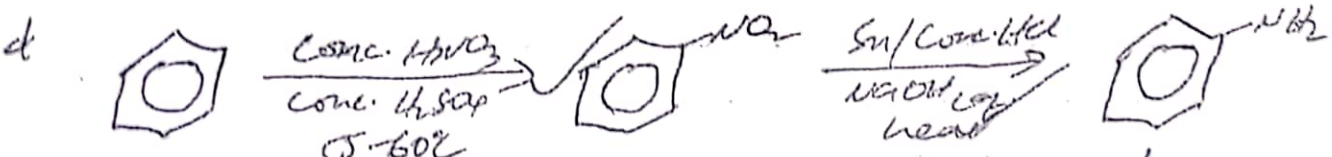
$CH_3CH_2CO_2CH_3 \xleftarrow[\text{heat}]{CH_3OH/H^+} CH_3CH_2COOH \xleftarrow{H_2O/H^+, \text{heat}}$

(c) (i) $CH_3COOH \xrightarrow{PCl_5} CH_3COCl \xrightarrow{NH_3} CH_3CONH_2$

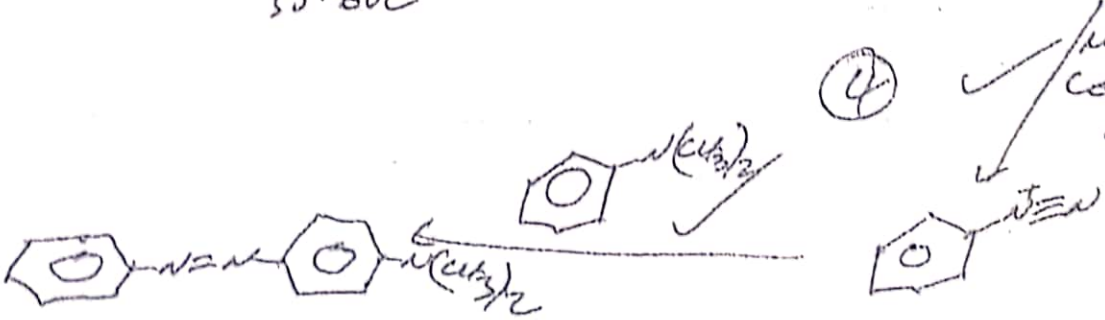
(3)

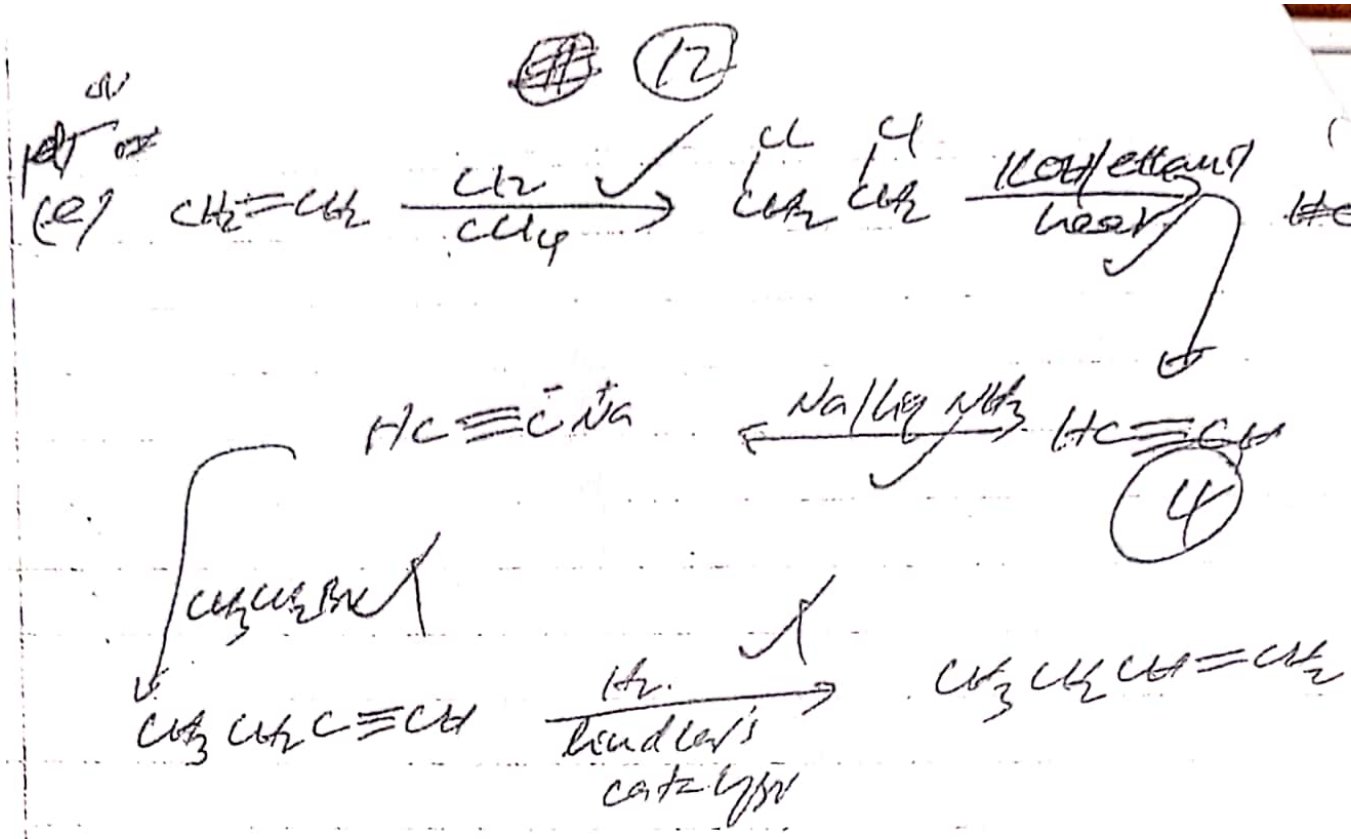
$CH_3OH \xleftarrow[\text{conc HCl}]{NaNO_2} CH_3NH_2 \xleftarrow{Br_2/NaOH(aq)}$

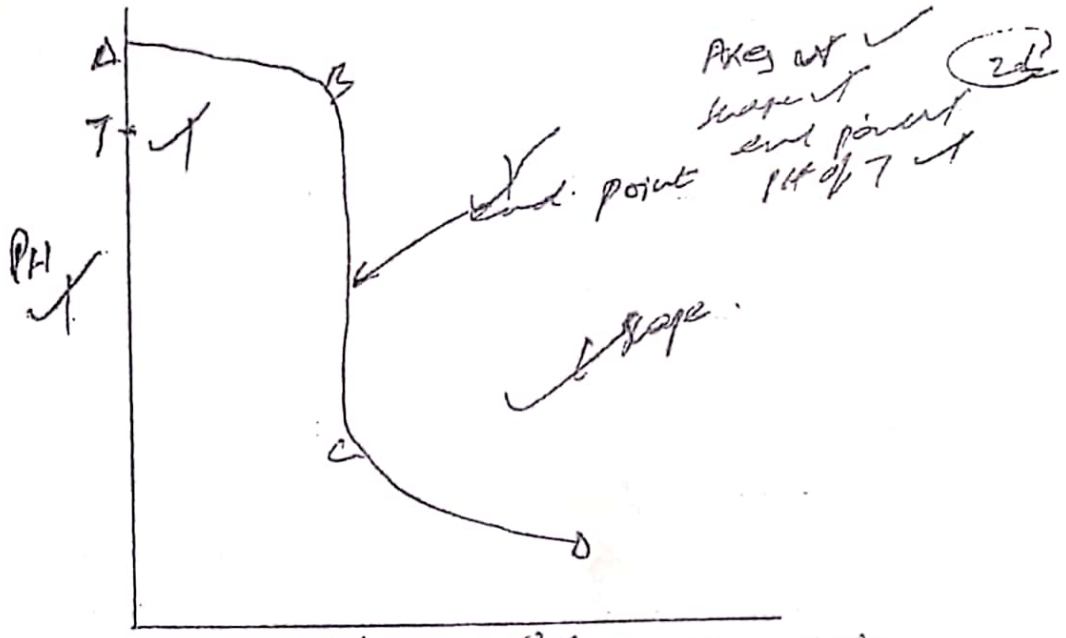
(d)



(4)







The initial PH of ammonia is fairly high since it is a weak base.
PH reduces gradually from A to B because the hydroxide ions of ammonia are being neutralised by hydrogen ions of the acid but ammonia is still in excess. Also a buffer solution is formed as it contains ammonia and ammonium chloride.
At B, there is complete neutralisation.
A small amount of excess strong acid causes a sharp decrease in PH from B to C which indicates complete neutralisation.
At the end, the PH of the solution is less than 7 because the salt formed ammonium chloride undergoes hydrolysis to form an acidic solution.

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

PH reduces gradually from C to D due to addition of excess strong acid.

(13)

b) moles of HCl = $\frac{30 \times 0.1}{1000}$ = 0.003. ✓

moles of NH_3 = $\frac{50 \times 0.1}{1000}$ = 0.005 ✓

$NH_{3(aq)} + HCl_{(aq)} \longrightarrow NH_4Cl_{(aq)}$

Mole of NH4Cl formed = 0.003 ✓

Mole of NH_3 left = 0.005 − 0.003 = 0.002. ✓

$[NH_3] = \frac{0.002}{80} \times 1000 = 0.025$ ✓

$[NH_4^+] = \frac{0.003}{80} \times 1000 = 0.0375$ ✓

$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+_{(aq)} + OH^-_{(aq)}$ ✓ (5)

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$ ✓ or $pOH = pK_b + \log \frac{[Salt]}{[Base]}$

$[OH^-] = K_b \times \frac{[NH_3]}{[NH_4^+]}$

$= 1.78 \times 10^{-5} \times \frac{0.025}{0.0375}$ ✓

$= 1.19 \times 10^{-5}$

$pOH = 4.93$

$pH = 14 - 4.93$

$= 9.07$ ✓

(12)

c) Ammonium Sulphate is a salt of a strong acid and weak base. It undergoes hydrolysis to form an acidic solution

$NH_4^+_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + H_3O^+_{(aq)}$

or $NH_4^+ \rightleftharpoons NH_{3(aq)} + H^+_{(aq)}$

Magnesium powder react with the acidic solution to form hydrogen

$Mg_{(s)} + 2H^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + H_{2(g)}$

Sodium ethanoate is a salt of a weak acid and strong base.

It undergoes hydrolysis to form an alkaline solution.

$CH_3COO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COOH + OH^-_{(aq)}$

~~It reacts~~ The hydroxide ions react with magnesium ions to form insoluble magnesium hydroxide.

$Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Mg(OH)_{2(s)}$

13

(15)

(15)

8 (a) A vegetable oil is an unsaturated liquid ester of a long chain carboxylic acid (1) and propan-1,2,3-triol (Glycerol) which occurs in plants.

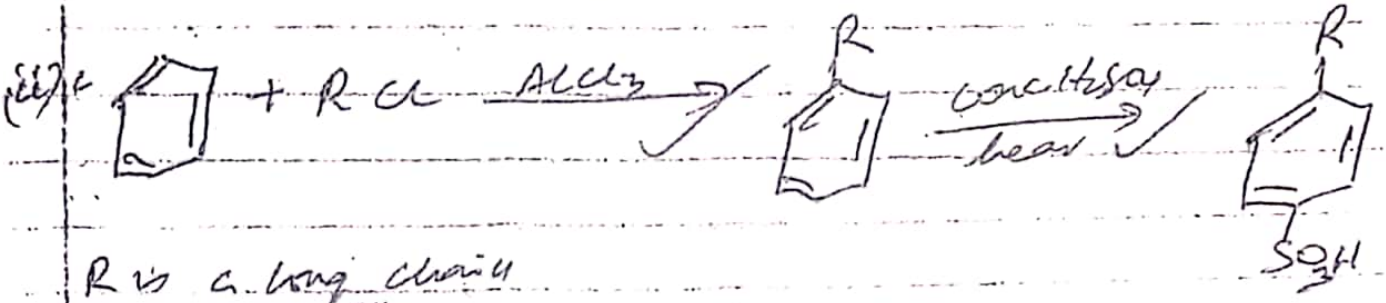
An animal fat is a saturated solid ester (1) of a long chain carboxylic acid and propan-1,2,3-triol and it occurs in animals

(b) (i) An oil/fat is boiled with concentrated Sodium hydroxide solution while stirring until a uniform solution is formed. (3½)
It is left to cool. Brine (concentrated Sodium chloride solution) is added.
Soap precipitates and floats on the surface.
It is skimmed off and dried.

(ii) $RCOOCH_2$
$RCOOCH + 3NaOH_{(aq)} \rightarrow 3RCOONa_{(aq)} + CH_2OH-CHOH-CH_2OH$ (1)
$RCOOCH_2$

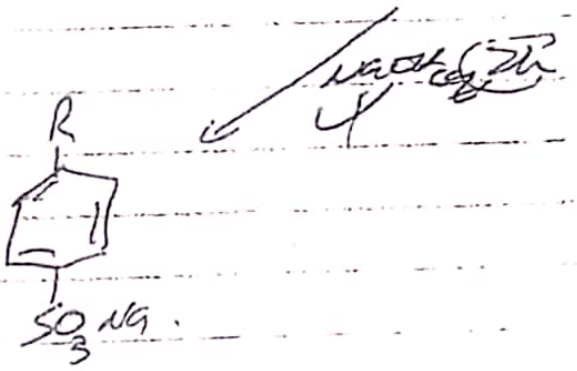
b) Soap is a Sodium (or potassium) salt of a long chain carboxylic acid. It has a carboxylate group ($-COO^-$) as a water soluble group (1)

A soapless detergent is a sodium salt (or potassium) of a long chain alkyl benzene sulphonate ~~acid~~ or alkyl hydrogen sulphate. (or other correct acid). It has other (1) water soluble groups other than carboxylate



R is a long chain

eg. $CH_3(CH_2)_{11}$ —



(Any Correct)

c) Addition polymerisation is combination of a large number of unsaturated monomers to form a polymer as the only product (or ①) ~~with~~ without loss of simple molecules

Condensation polymerisation is the combination of many (usually different) monomers, each with 2 functional groups to form a ① polymer with loss of simple molecules

(ii) Nylon 6.10

A: $HOOC(CH_2)_8COOH$ Decane dioic acid

$H_2N(CH_2)_6NH_2$ Hexane-1,6-diamine

B: $CH_2=C(CH_3)-CH=CH_2$ Neoprene

$CH_2=C(Cl)-CH=CH_2$ 2-Chlorobuta-1,3-diene

C: Perspex. (4)

$CH_2=C(CH_3)COOCH_3$ Methyl-2-Methyl propenoate.

(iii) $n\,HO\overset{O}{\overset{\|}{C}}(CH_2)_{10}\overset{O}{\overset{\|}{C}}OH + n\,H_2N(CH_2)_6NH_2$ (1)

$\rightarrow (2n-1)H_2O + -\left(\overset{O}{\overset{\|}{C}}(CH_2)_{10}\overset{O}{\overset{\|}{C}}NH(CH_2)_6NH\right)_n-$

$n\,CH_2=C(Cl)-CH=CH_2 \xrightarrow{Si^{2+}} -\left(CH_2-C(Cl)=CH-CH_2\right)_n-$ (1)

$n\,CH_2=C(CH_3)COOCH_3 \xrightarrow[\text{inert solvent}]{\text{Peroxide}} -\left(CH_2-C(CH_3)(COOCH_3)\right)_n-$ (1)

7