UACE CHEM 2 PROPOSED GUIDE 2023

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Qn 1

[a]

A homogeneous system is one in which all the reactants and products of a reaction are in the same phase.

A heterogeneous system is one in which two or more phases are involved in a reaction.

01

[b]

[i]

$$K_p = \frac{(P_{NH_3})^2}{(P_{N_2})(P_{H_2})^3}, \quad K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

If gases are ideal, $P = \frac{n}{V}RT$, But $\frac{n}{V}$ = Concentration (C)

$$P = CRT$$

$$P_{NH_3} = [NH_3]RT$$
$$P_{N_2} = [N_2]RT$$
$$P_{H_2} = [H_2]RT$$

03

$$\Rightarrow K_p = \frac{[NH_3]^2 \cdot (RT)^2}{[N_2]\cdot RT \cdot [H_2]^3 \cdot (RT)^3}$$

$$= \frac{[NH_3]^2}{[N_2][H_2]^3 \cdot (RT)^2}$$

$$K_p = \frac{K_c}{(RT)^2}$$

$$K_c = (RT)^2 \cdot K_p$$

b [ii]

Effect of temperature on the above reaction:

When the temperature is increased, the equilibrium position shifts from right to left. This is because the backward reaction is endothermic.

When the temperature is lowered, the equilibrium position shifts from left to the right since the forward reaction is exothermic. 03

Effect of pressure

Increase in pressure shifts the equilibrium position from left to right. This is because the forward reaction is accompanied by 03 a decrease in volume (or number of moles).

Decrease in pressure shifts the equilibrium position from right to left. This is because the backward reaction is accompanied by an increase in volume (or number of moles).

c] [i]

$$CH_3CO_2H_{(l)} + C_2H_5OH_{(l)} \rightleftharpoons CH_3CO_2C_2H_{5(l)} + H_2O_{(l)}$$ 01

Ignore state symbols

$$K_c = \frac{[CH_3CO_2C_2H_5][H_2O]}{[CH_3CO_2H][C_2H_5OH]}$$ 01

Emphasize square brackets [ ]

c [ii]

At equilibrium;

$[CH_3CO_2C_2H_5] = [H_2O] = 0{\cdot}67\ M$

$[CH_3CO_2H] = [C_2H_5OH] = 1 - 0{\cdot}67$

$= 0{\cdot}33\ M$

$$K_c = \frac{[CH_3CO_2C_2H_5][H_2O]}{[CH_3CO_2H][C_2H_5OH]}$$

$$= \frac{0{\cdot}67 \times 0{\cdot}67}{0{\cdot}33 \times 0{\cdot}33}$$ 02

$$= 4{\cdot}12213$$

c [iii]

Let x moles of ethanoic acid react.

	$CH_3CO_2H_{(l)}$ +	$C_2H_5OH_{(l)}$ ⇌	$CH_3CO_2C_2H_{5(l)}$ +	$H_2O_{(l)}$
Initial moles	1·5	2·0	0	0
Equilibrium moles	$1{\cdot}5 - x$	$2{\cdot}0 - x$	x	x

$$K_c = \frac{[CH_3CO_2C_2H_5][H_2O]}{[CH_3CO_2H][C_2H_5OH]}$$

At equilibrium

$[CH_3CO_2H] = 1.5 - x$

$[C_2H_5OH] = 2 - x$

$[CH_3CO_2C_2H_5] = [H_2O] = x$

$$\Rightarrow 4.12213 = \frac{x \times x}{(1.5-x)(2-x)}$$

$$x^2 = 4.12213\,[3 - 3.5x + x^2]$$

$$x^2 = 12.36639 - 14.427455x + 4.12213x^2$$

$$3.12213x^2 - 14427455x + 12.36639 = 0$$

$$x = \frac{14.427455 \pm \sqrt{(-14.427455)^2 - 4(3.12213)(12.36639)}}{2(3.12213)}$$

05

Either $x = 3.4842$

or $x = 1.1368$

3.4842 is discarded since its greater than the initial moles.

$\therefore x = 1.1368$

Molar mass of $CH_3CO_2C_2H_5$

$= (12 \times 4) + (8 \times 1) + (2 \times 16)$

$= 88g$

1 mole of the ester weighs 88g

1.1368 moles of the ester will weigh (88×1.1368)g

$= \underline{\underline{100.0384\ g}}$

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Qn. 2 [a] [i]

Compound	Functional group
W	Hydroxyl group Accept $-OH$
X	Carbonyl group Accept $-\overset{O}{\overset{\|}{C}}-$
Y	Carbon to carbon triple bond Accept $-C\equiv C-$
Z	Amino group Accept $-NH_2$

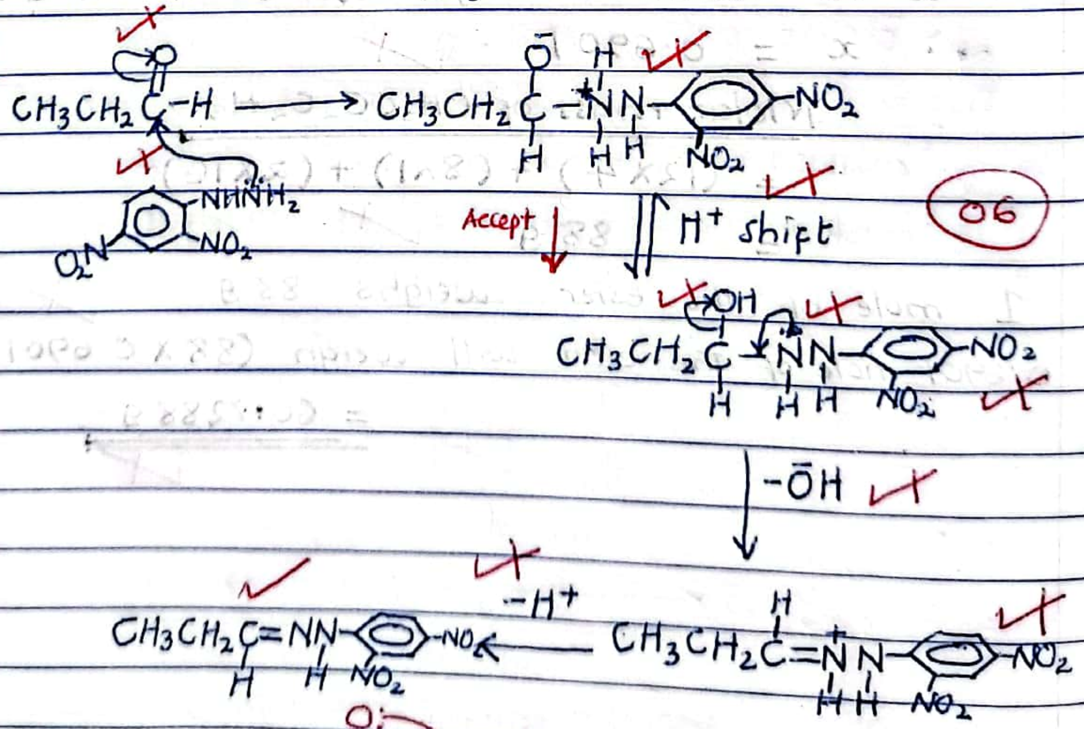
04

a [ii]

Compound	Isomers	
W	$CH_3CH_2CH_2OH$, $CH_3\underset{OH}{\underset{\|}{C}}HCH_3$	01
X	CH_3CH_2CHO, $CH_3\underset{O}{\underset{\|\|}{C}}CH_3$	01
Y	$CH_3CH_2C\equiv CH$, $CH_3C\equiv CCH_3$	01
Z	$CH_3CH_2NH_2$, $CH_3\underset{H}{\underset{\|}{N}}CH_3$	01

04

[b]



06

Accept $CH_3CH_2\overset{O}{\overset{\|}{C}}-H$ H^+

Also with $CH_3\overset{O}{\overset{\|}{C}}CH_3$

[c] (i)

sp. rej. An hydrous

Reagent : Anhydrous zinc chloride and concentrated hydrochloric acid

Observations:

With $CH_3CH_2CH_2OH$ - No observable change at room temperature. Emphasize.

03

With CH_3CHCH_3 (OH on middle C) - Cloudy solution is formed within 5-10 minutes.

Accept

Emphasize spelling rej. l or ι, Accept I or i

Reagent : Iodine solution and sodium hydroxide solution.

06

Observations

With $CH_3CH_2CH_2OH$ - No observable change

With CH_3CHCH_3 (OH on middle C) - Yellow precipitate is formed.

[c] (ii)

Reagent : Sodium nitrite and concentrated hydrochloric acid.

Observations:

With $CH_3CH_2NH_2$ - A colourless solution and bubbles of a colourless gas.

03

With CH_3NCH_3 (H on N) - A yellow oil is formed.

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Qn.3

[a]

A eutectic mixture is a liquid mixture 01 which at constant pressure, will solidify at constant temperature to form a solid mixture without change in composition.

Or A eutectic mixture is a solid mixture which melts at constant temperature to form a liquid mixture without change in composition.

[b] [ii]

Eutectic temperature is 780°C 01½

Composition of the eutectic mixture is 28 % copper and 72 % silver

[c]

The mixture cools up to 875 (point L) without change in phase. At 875°C copper begins to crystallize. The composition of silver in the mixture increases causing a further decrease in freezing point along LM on the curve. At M, silver also begins to crystallise out. The freezing temperature and composition remain constant until all the liquid mixture freezes. Thereafter, the solid mixture cools up to 700°C without change in phase.

4½

[d]

[i]

$$Cu_{(s)} + 2Ag^{+}_{(aq)} \longrightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$$ 01

[ii]

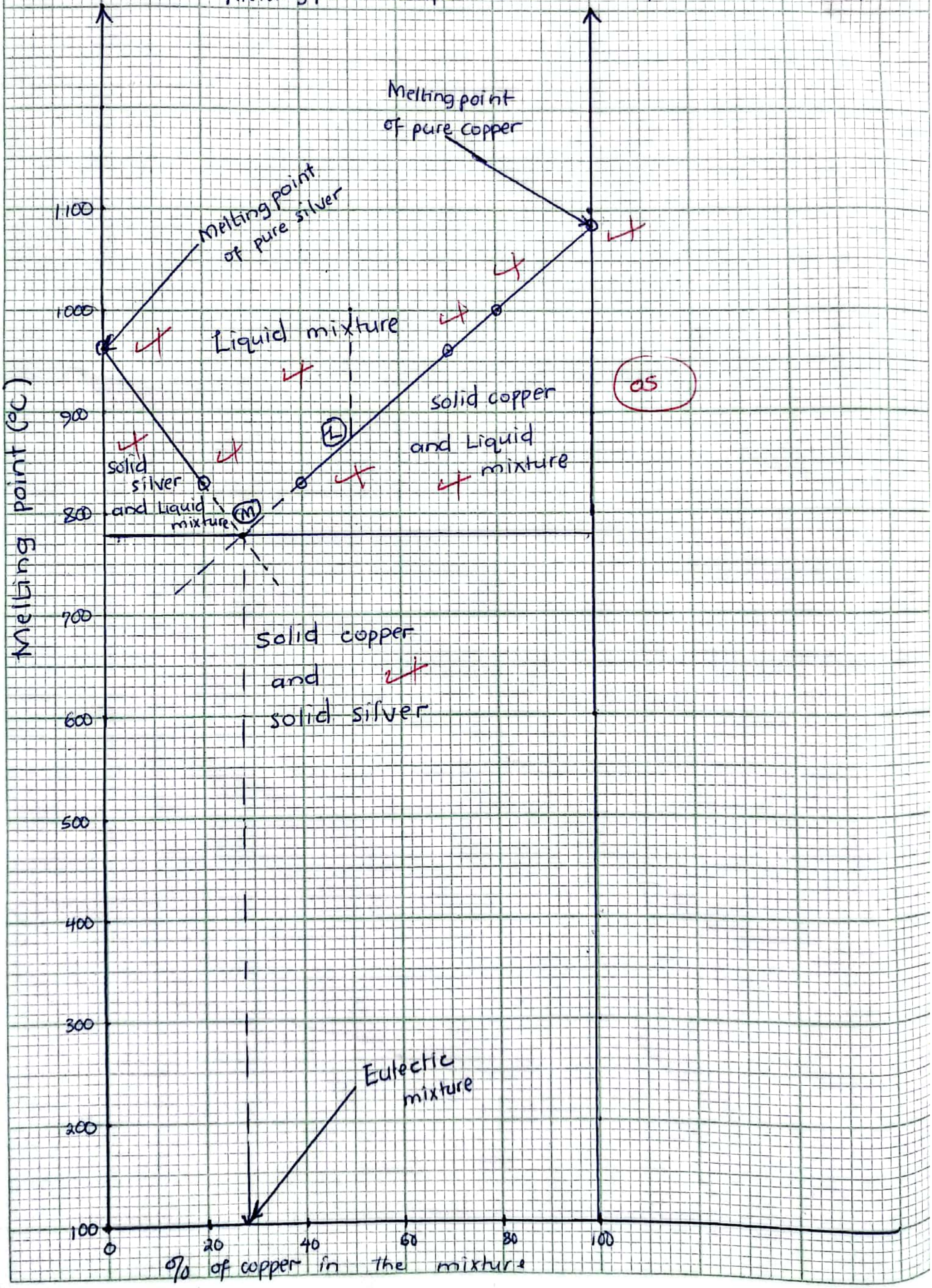
$$E^{\theta}_{cell} = E^{\theta}_{Right} - E^{\theta}_{Left}$$

$$= +0.80 - (+0.34)$$ 01

$$= \underline{+0.46\ V}$$

Qn 3 (b)(i).

Melting point-composition diagram for copper-silver system.



[d] [iii]

$$\Delta G^{\theta} = -nFE^{\theta}_{cell}$$
$$= -2 \times 96500 \times (+0.46)$$
$$= -88{,}780\ J$$ 02

The reaction is feasible since Gibb's free energy is negative

[e]

Copper does not react with dilute sulphuric acid since it's less reactive than hydrogen hence can not displace it from the acid. Hot concentrated sulphuric acid oxidises copper to copper(II) sulphate and itself reduced to sulphur dioxide and water. 04

$$Cu_{(s)} + 2H_2SO_{4(l)} \longrightarrow CuSO_{4(aq)} + 2H_2O_{(l)} + SO_{2(g)}$$

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Qn. 4

[a]

A d-block element is one in which the outermost electrons fill the d subenergy level. Rej. 3d or 4d.

[b] [i]

Cu - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ Accept - 3d^{10}4s^1 1½

Fe^{2+} - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ Accept - 4s^{0}3d^6

Mn^{2+} - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ Accept - 4s^{0}3d^5

b[ii]

Fe^{2+} - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

Fe^{3+} - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ 05½

Mn^{2+} - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

Mn^{3+} - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$

Iron(II) ion has 6 electrons in the 3d subenergy level hence thermodynamically unstable while iron(III) ion has 5 electrons in the 3d subenergy level which is more thermodynamically stable. Iron(II) ions are readily oxidised to iron(III) ion in

order to attain a more stable electronic configuration.
The manganese(II) ion has 5 electrons in the 3d subenergy level which is thermodynamically more stable than the manganese(III) ion that has 4 electrons in 3d subenergy level hence thermodynamically unstable. The manganese (II) ion is not readily oxidised to manganese (III) because the oxidation state will be changing from a relatively more stable one to less stable one.

c [i]

Mn_2O_7 or MnO_4^-

c [ii]

$Mn - 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$

Manganese uses both the two electrons in the 4s subenergy level and the five unpaired electrons in the 3d subenergy level in bond formation due to small energy difference between the 4s and 3d ~~[d] [i]~~ subenergy levels.

[d] [i]

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

$Mn - 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$

The magnetic moment increases with increase in the number of unpaired electrons in the 3d subshell. These unpaired electrons spin on their axes thus inducing a magnetic moment.
An atom of manganese has five unpaired electrons in the 3d subshell which spin ~~oth~~ on their axes, thus inducing a magnetic moment as a result can be magnetised.
An atom of copper has ten paired electrons in the 3d subshell hence incapable of

spinning on their axes. As a result no magnetic moment is induced hence copper can't be magnetised

(d)(iii)

$Fe - 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

An iron atom has six electrons in the 3d subshell which enable it to form temporary bonds with the reactant molecules.

02

(f)

~~Com~~ - Cobalt forms complex ions such as $CoCl_4^{2-}$, $Co(H_2O)_6^{2+}$ etc.

- Cobalt forms coloured compounds such as cobalt(II) chloride which is blue in colour.

03

- Cobalt has variable oxidation states such as +2 and +3.

- Accept any other correct properties with examples.

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Qn. 5 (a)(i)

- Amount of heat evolved when 1 mole of a substance is completely burnt in oxygen at 298K and 1 atmosphere (or under standard conditions) 01

Accept correct alternative definitions.

a (ii)

- Amount of heat absorbed when an element in its normal physical state is converted into 1 mole of free gaseous atoms at 298K and 1 atmosphere (or under standard conditions) 01

Accept correct alternative definitions.

(b)

- A given volume, V cm^3 of water is measured in a measuring cylinder and then added to a thin walled metal can.
- Ethanol is added to a small bottle fitted with cork and wick to form a simple lamp.
- The lamp is weighed and its mass m_1g noted.
- The initial temperature θ_1°C of the water is noted.
- The ~~temperature~~ lamp is lit and allowed to heat the water in the can directly until the temperature rises by about 30°C.
- The flame is extinguished and temperature θ_2°C of the water in the can noted.
- The mass m_2g of the lamp when it has cooled is also measured.

Treatment of results :

Assumptions.

- The can has negligible heat capacity
- No heat is lost to the surroundings

Density of water $= 1\ g\ cm^{-3}$

Mass of water heated = density x volume

$= 1 \times V$

$= V\ g$

Temperature change $= (\theta_2 - \theta_1)\ ^\circ C$

Mass of ethanol burnt $= (m_1 - m_2)\ g$

Heat absorbed by water = Mass of water x Specific heat capacity of water x Temperature change

$= [V \times 4.2 \times (\theta_2 - \theta_1)]\ J$

Molar mass of C_2H_5OH

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

$= 46\ g$

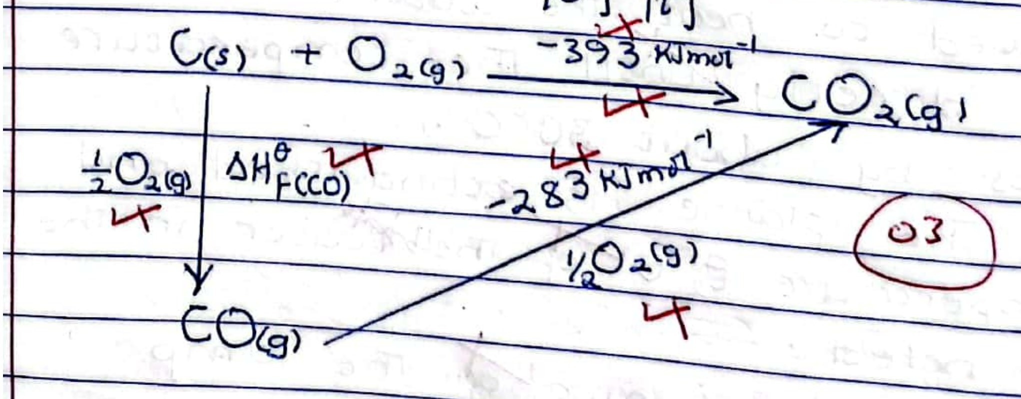
10

$(m_1 - m_2)\ g$ of ethanol evolve $[V \times 4.2 \times (\theta_2 - \theta_1)]$ J of heat

46 g of ethanol will evolve $\left[\dfrac{V \times 4.2 \times (\theta_2 - \theta_1) \times 46}{(m_1 - m_2)}\right]$ J of heat

$\therefore$ The molar enthalpy of combustion of ethanol is $-\left[\dfrac{V \times 4.2 \times (\theta_2 - \theta_1) \times 46}{(m_1 - m_2)}\right] J\ mol^{-1}$.

[C] [2]



03

[c] [iii]

From Hess's law

$-393 = \Delta H^{\theta}_{f(CO)} + (-283)$

02

$\Delta H^{\theta}_{f}(CO) = -110\ KJmol^{-1}$

[d]

- For negative (exothermic) enthalpy change, the reaction is feasible
- For positive (endothermic) enthalpy change, the reaction is not feasible.
- For zero enthalpy change, the reaction does not occur.

03

20

Qn. 6 [a]

Observation:

The green solution of iron(II) ions turned brown (yellow) on addition of aqueous chlorine. When sodium hydroxide solution was added, a reddish brown precipitate was formed.

Explanation:

The green solution of iron(II) ions turned brown on addition of aqueous chlorine because aqueous chlorine is a stronger oxidising agent than iron(II) ions since chlorine in aqueous state has more positive value of reduction potential than iron II ions. Hence chlorine oxidises iron(II) ions which are green in solution are oxidised to iron(III) ions which are brown (yellow) in solution and chlorine is reduced to chloride ions

06

$2Fe^{2+}(aq) + Cl_2(aq) \longrightarrow 2Fe^{3+}(aq) + 2Cl^-(aq)$ 01

Now the iron(III) ions formed react with sodium hydroxide 4 precipitating iron(III) hydroxide which is reddish brown.

$Fe^{3+}(aq) + 3\bar{O}H(aq) \longrightarrow Fe(OH)_3(s)$ 01

[b]

$2Cu^{2+}(aq) + 4I^-(aq) \longrightarrow 2CuI(s) + I_2(aq)$ 01

Or

$2Cu^{2+}(aq) + 4I^-(aq) \longrightarrow Cu_2I_2(s) + I_2(aq)$

The copper(II) ions from copper(II) sulphate oxidise 4 iodide ions from potassium iodide to iodine 4 which is a brown 4 solution and copper(II) ions are reduced 4 to copper(I) 4 iodide which is a white solid 4

05

Since iodine formed is a covalent molecule and hence non-polar, it dissolves in hexane which is also a non-polar 4 solvent turning it purple 4 (violet) in colour.

[c]

The blue colour of dilute copper(II) sulphate is due to the presence of hexaaquacopper(II) ions ($Cu(H_2O)_6^{2+}$). On addition of excess concentrated hydrochloric acid, the chloride ions from the acid react with the hexaaquacopper(II) ions forming a soluble complex of tetrachlorocuprate(II) ion which is a yellow solution. In this reaction, the chloro ligands replace the aqua ligands.

$Cu(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CuCl_4^{2-}(aq) + 6H_2O(l)$

Accept tetraaquacopper(II) ion instead of hexaaquacopper(II) ion and the corresponding equation.

$Cu(H_2O)_4^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CuCl_4^{2-}(aq) + 4H_2O(l)$

[d]

Chromium hydroxide reacts with both dilute hydrochloric acid and sodium hydroxide solutions because it is amphoteric in nature.

It reacts with dilute hydrochloric acid forming chromium(III) chloride and water.

$$Cr(OH)_{3(s)} + 3HCl_{(aq)} \longrightarrow CrCl_{3(aq)} + 3H_2O_{(l)}$$

It also reacts with sodium hydroxide solution forming soluble complex.

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

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

Accept molecular equations.

5½

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Qn. 7

[a]

$$H_2C{=}CH_2 \xrightarrow[\text{warm or heat}]{H^+/H_2O} CH_3CH_2OH \xrightarrow[\text{heat}]{\text{Excess } Cr_2O_7^{2-}/H^+} CH_3COOH$$

$$CH_3COOH \xrightarrow[\text{or } NaOH_{(s)}/CaO_{(s)} \text{ heat}]{\text{Soda lime, heat}} CH_4$$

Reject without state symbols.

Accept other alternative routes which are correct.

03

[b]

$$CH_3OH \xrightarrow{PCl_5} CH_3Cl \xrightarrow[\text{Heat}]{KCN/\text{Ethanol}} CH_3CN$$

$$CH_3CN \xrightarrow[\text{Heat}]{\text{Excess } H^+/H_2O} CH_3COOH$$

Rej. without excess

$$CH_3COOH \xrightarrow[\text{Heat}]{(NH_4)_2CO_{3(s)}} CH_3CONH_2$$

Rej without solid

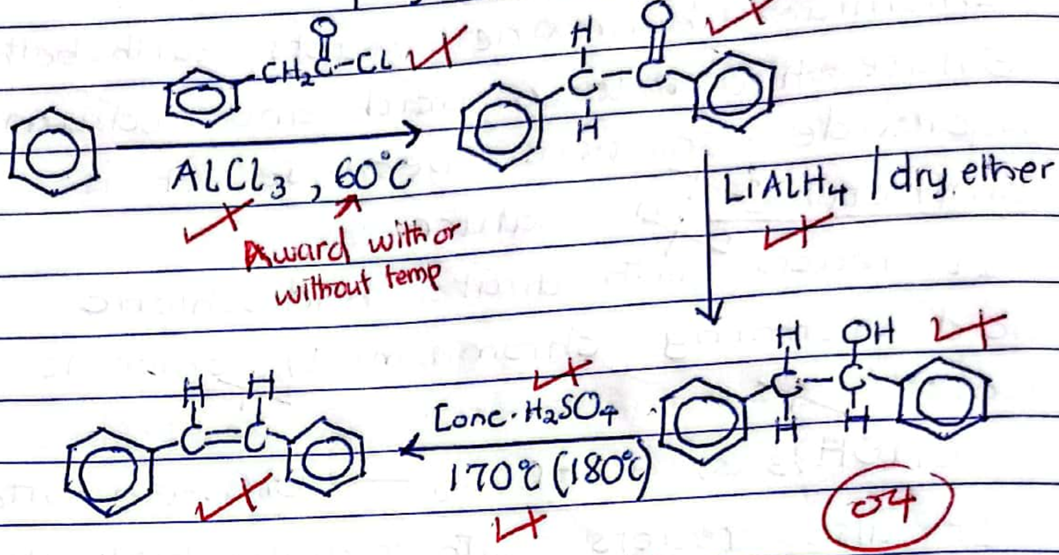
$$CH_3CONH_2 \xrightarrow[\text{dry ether}]{LiAlH_4} CH_3CH_2NH_2$$

$$CH_3CN \xrightarrow[\text{dry ether}]{LiAlH_4} CH_3CH_2NH_2$$

05

Accept correct alternative routes.

[c]



04

[d]

$CH_3CH{=}CH_2 \xrightarrow[\text{organic peroxide}]{HBr} CH_3CH_2CH_2Br \xrightarrow[\text{Heat}]{KCN/\text{Ethanol}} CH_3CH_2CH_2CN$

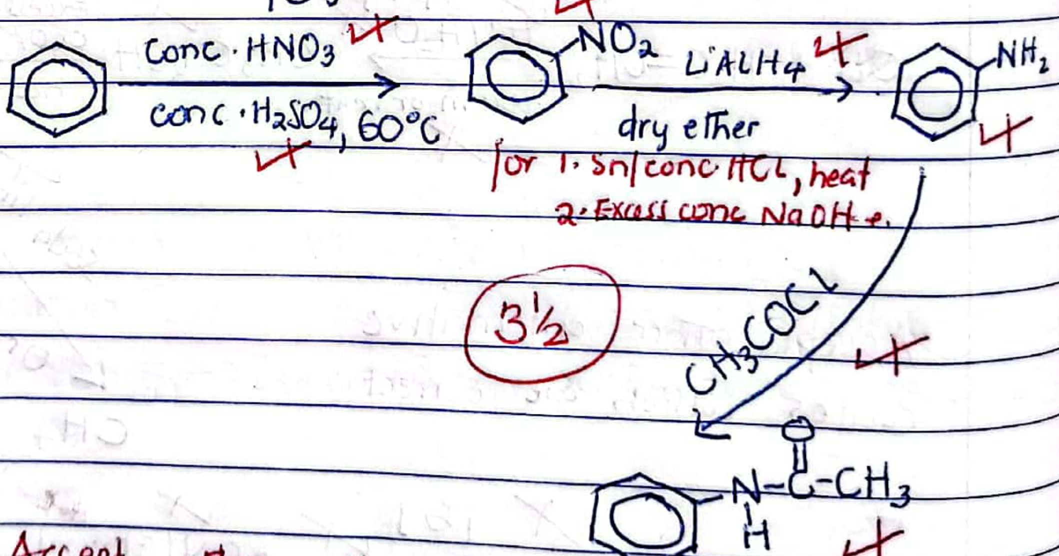
Rej HCl or HI

$CH_3CH_2CH_2CN \xrightarrow[\text{heat}]{\text{Excess } H^+/H_2O} CH_3CH_2CH_2COOH$

Rej without excess

04½

[e]



3½

Accept other alternative correct routes.

20

Qn. 8

[a]

- Flourine atom has the largest positive standard electrode potential
- Flourine atom has the highest electronegativity.
- Flourine atom has the smallest atomic radius
- Flourine molecule has the lowest bond dissociation energy.
- Flourine atom lacks vacant d-orbitals.

2½

[b]

Chlorine, bromine and iodine are generally prepared by heating a solid chloride, bromide or iodide of sodium or potassium respectively with concentrated sulphuric acid and manganese(IV) oxide

3½

$2Cl^-_{(s)} + 4H^+_{(aq)} + MnO_{2(s)} \longrightarrow Cl_{2(g)} + Mn^{2+}_{(aq)} + 2H_2O_{(l)}$

$2Br^-_{(s)} + 4H^+_{(aq)} + MnO_{2(s)} \longrightarrow Br_{2(aq)} + Mn^{2+}_{(aq)} + 2H_2O_{(l)}$

$2I^-_{(s)} + 4H^+_{(aq)} + MnO_{2(s)} \longrightarrow I_{2(s)} + Mn^{2+}_{(aq)} + 2H_2O_{(l)}$

[c]

The lattice energies decrease from silver flouride to silver iodide. This is because the ~~an~~ radius of the anions ~~&~~ increases from a flouride ion to an iodide ion. The bigger the anionic radius, the less it is attracted to the silver ion and the less the energy evolved during its formation from gaseous atoms.

3½

d(i)

Chlorine is non-polar and sparingly dissolves in water to give the equilibrium below. $Cl_2 + H_2O_{(l)} \rightleftharpoons HCl_{(aq)} + HOCl_{(aq)}$

In sodium hydroxide solution, the hydroxyl ions from sodium hydroxide ~~solution~~ react with the hydrogen ions from hydrochloric acid at equilibrium.

$H^+_{(aq)} + \bar{O}H_{(aq)} \longrightarrow H_2O_{(l)}$ ½✗

Hence more chlorine dissolves to replace the hydrogen ions ~~thus~~ which shifts the equilibrium from left to right. ½✗ (04)

This increases its solubility in sodium hydroxide solution.

d (ii)

Iodine is covalent molecule which is non-polar ½✗ thus it is almost insoluble in water which is a polar ½✗ solvent.

However it readily dissolves in potassium iodide solution because iodine ½✗ reacts with iodide ½✗ ions from potassium iodide solution forming a soluble ½✗ complex of triiodide ½✗ ions

$I_{2(s)} + I^-_{(aq)} \rightleftharpoons I^-_{3(aq)}$ ½✗ (04½)

Accept molecular equation.

Complex formation therefore increases ~~in~~ its solubility.

(e)

Observation: A yellow ½✗ precipitate.

Equation. (02)

$CH_3CH_2\underset{\underset{O}{\|}}{C}CH_{3(l)} + 3I_{2(aq)} + 4\bar{O}H_{(aq)} \longrightarrow CHI_{3(s)} + CH_3CH_2CO\bar{O}_{(aq)} + 3I^-_{(aq)} + 3H_2O_{(l)}$ ½✗ ½✗

Accept molecular equation

Reject unbalanced equation