1

P525/2 SUGGESTED MARKING GUIDE 2023

Joseph J. Kaypiro 0753247098/0782601038.

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 (more than one phase) appear. (2)

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

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} \text{ --- (i)}; \quad K_p = \frac{(P_{NH_3})^2}{P_{N_2} \times (P_{H_2})^3} \text{ --- (ii)}$$

If the gases are ideal;

$pV = nRT \Rightarrow p = \frac{n}{V}RT$ but $\frac{n}{V} = c$ (concentration)

Hence ~~$pV = cRT$~~ $p = cRT$

$P_{NH_3} = [NH_3]RT$

$P_{N_2} = [N_2]RT \qquad P_{H_2} = [H_2]RT$

Substituting P_{NH_3}, P_{N_2} and P_{H_2} in equation (ii);

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

$$K_p = \frac{[NH_3]^2}{[N_2][H_2]^3}\left(\frac{(RT)^2}{(RT)^4}\right) = K_c(RT)^{2-4}$$

(3)

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

or $K_c = K_p(RT)^2$

(ii) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -92.4\ kJmol^{-1}$

Temperature;

Since forward reaction is exothermic, increasing temperature will shift equilibrium position to the left, favouring backward reaction, which is endothermic.

Reducing temperature will shift equilibrium to the right, favouring the forward reaction, which is exothermic. (3)

Pressure;

Reducing pressure shifts equilibrium to the left, favouring backward reaction which occurs by an increase in volume.

Increasing pressure shifts equilibrium to the right, favouring the forward reaction, which occurs by a decrease in volume. (3)

(c)(i) $CH_3CH_2OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$ 1/2

$$K_c = \frac{[CH_3CH_2OOCCH_3][H_2O]}{[CH_3CH_2OH][CH_3COOH]}$$ 1/2

−1/2 for wrong states
Deny all marks if ($\rightarrow$) is used.

(ii) $CH_3CH_2OH(l) + CH_3COOH(l) \rightleftharpoons CH_3CH_2OOCCH_3(l) + H_2O(l)$

	CH_3CH_2OH	CH_3COOH	$CH_3CH_2OOCCH_3$	H_2O
Initial moles	1	1	0	0
moles at equilibrium	(1−0.67) = 0.33	(1−0.67) = 0.33	0.67	0.67
[ ] at equilibrium	$\frac{0.33}{1}$	$\frac{0.33}{1}$	$\frac{0.67}{1}$	$\frac{0.67}{1}$

$$K_c = \frac{(0.67)^2}{(0.33)^2} = 4.122$$ (2)

$$CH_3CH_2OH_{(l)} + CH_3COOH_{(l)} \rightleftharpoons CH_3COOCH_2CH_{3(l)} + H_2O_{(l)}$$

Initial moles	2.0	1.5	0	0

Let number of moles of ester at equilibrium be x

moles at equilibrium	$(2.0-x)$	$(1.5-x)$	x	x
[ ]	$\frac{2.0-x}{1}$	$\frac{1.5-x}{1}$	$\frac{x}{1}$	$\frac{x}{1}$

$$K_c = 4.122 = \frac{x^2}{(2.0-x)(1.5-x)} \Rightarrow x^2 = 4.122(3-3.5x+x^2)$$

$$\cancel{3.122x^2} \quad 3.122x^2 - 14.427x + 12.366 = 0$$

$$x = \frac{-(-14.427) \pm \sqrt{(-14.427)^2 - 4(3.122 \times 12.366)}}{2 \times 3.122}$$

5

$x = 3.48$ or 1.14.

But $x \neq 3.48$ because moles at equilibrium can't be greater than original moles.

$\therefore x = 1.14$

Molar mass of $CH_3COOCH_2CH_3 = (12\times4) + (16\times2) + (8\times1) = 88g$.

Mass of ester formed $= 88 \times 1.14 = 100.32g$.

CamScanner

QN 2

Accept $-OH$ reject hydroxide

(a) (i) W — Hydroxyl group ✓ Accept OH; reject C=O

X — Carbonyl group ✓ Accept $>C=O$

Y — Carbon to carbon triple ✓ bond ✓ Accept $-C\equiv C-$ reject tripple

Z — Amino group ✓

Accept $-NH_2$ reject NH_2

Accept imino group or $>NH$

(ii) isomers of C_3H_8O (W)

$CH_3CH_2CH_2OH$ ½ reject any other isomer

$CH_3CH(OH)CH_3$ ½ (1)

isomers of C_3H_6O (X)

CH_3CH_2CHO ½ reject any other isomer.

CH_3COCH_3 ½ (1) in (a) case; reject isomers if names included.

isomers of C_4H_6 (Y)

$CH_3CH_2C\equiv CH$ ½ reject isomeric dienes.

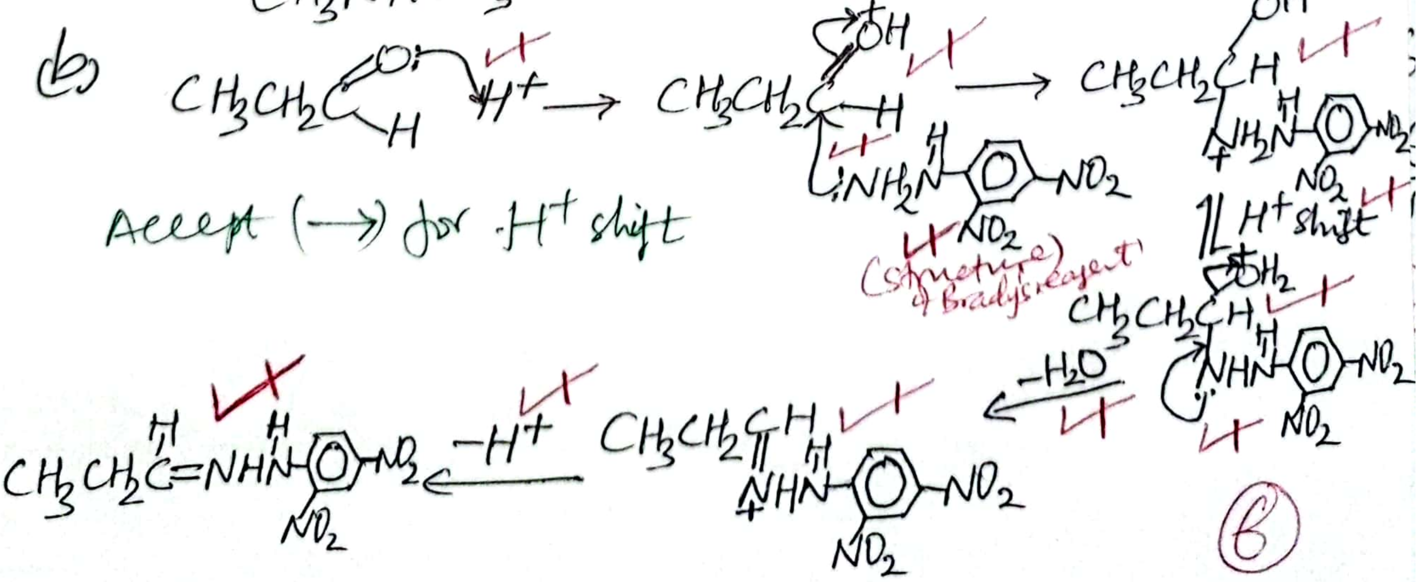
$CH_3C\equiv CCH_3$ ½ (1)

isomers of C_2H_7N (Z)

$CH_3CH_2NH_2$ ½

CH_3NHCH_3 ½ (1)

(b)

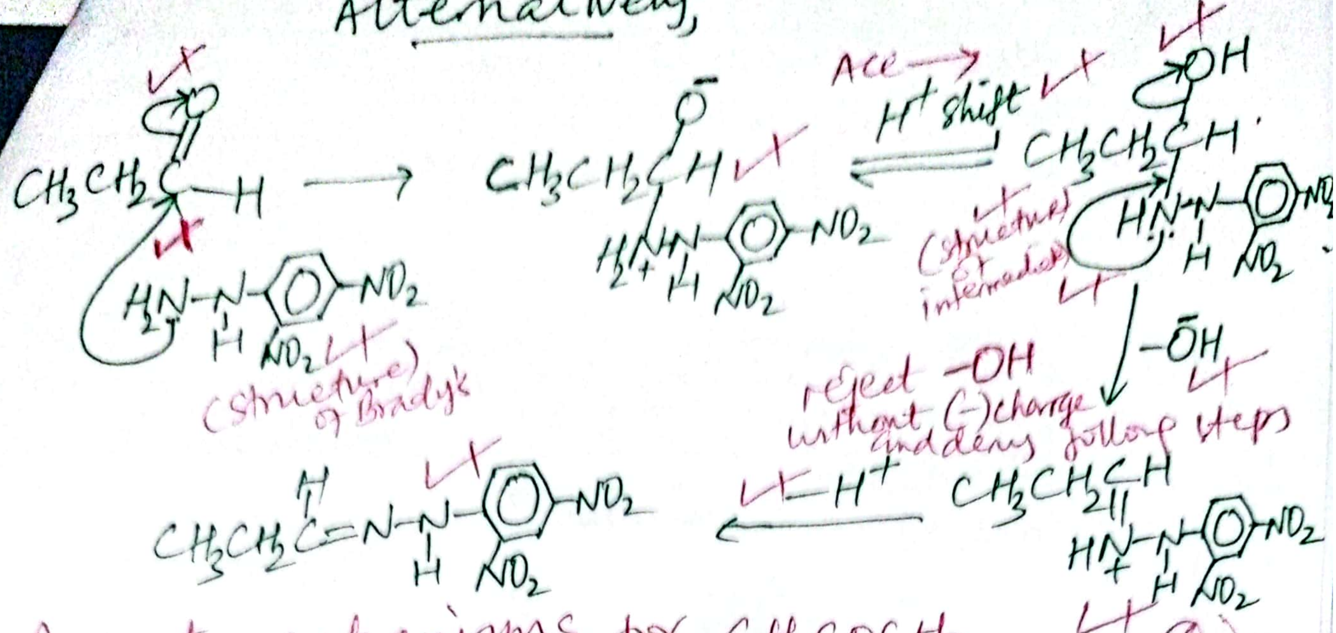


Accept (→) for H^+ shift

(structure of Brady's reagent)

(6)

Alternatively;



Accept mechanisms for CH_3COCH_3 and award accordingly

reject hanging arrow, bonds; wrong benzene rings.

(c) (i) Anhydrous zinc chloride and concentrated hydrochloric acid at room temperature

$CH_3CH_2CH_2OH$ — No observable change

Accept two layers after ----

$CH_3CH(OH)CH_3$ — cloudy solution after (5–10) minutes

Accept Lucas reagent

reject both reagent and observation for unhydrous, an hydrous, zinc(II) chloride, zinc chloride solution, dilute acid formulae, room temperature not specified

reject cloudiness

(ii) Sodium nitrite and concentrated (dilute) hydrochloric acid at 0°C

$CH_3CH_2NH_2$ — Bubbles of a colourless gas

CH_3NHCH_3 — Yellow oil formed.

Accept any order of reagents, ice cold mixture of ---

yellow oily liquid

reject nitrous acid.

QN 3.

@ A liquid mixture which at constant temperature will solidify (freeze) at a constant pressure to form a solid mixture without change in composition

or

A solid mixture which at a constant temperature will melt to form a liquid mixture of the same composition at a constant pressure.

b, i, check graph paper.

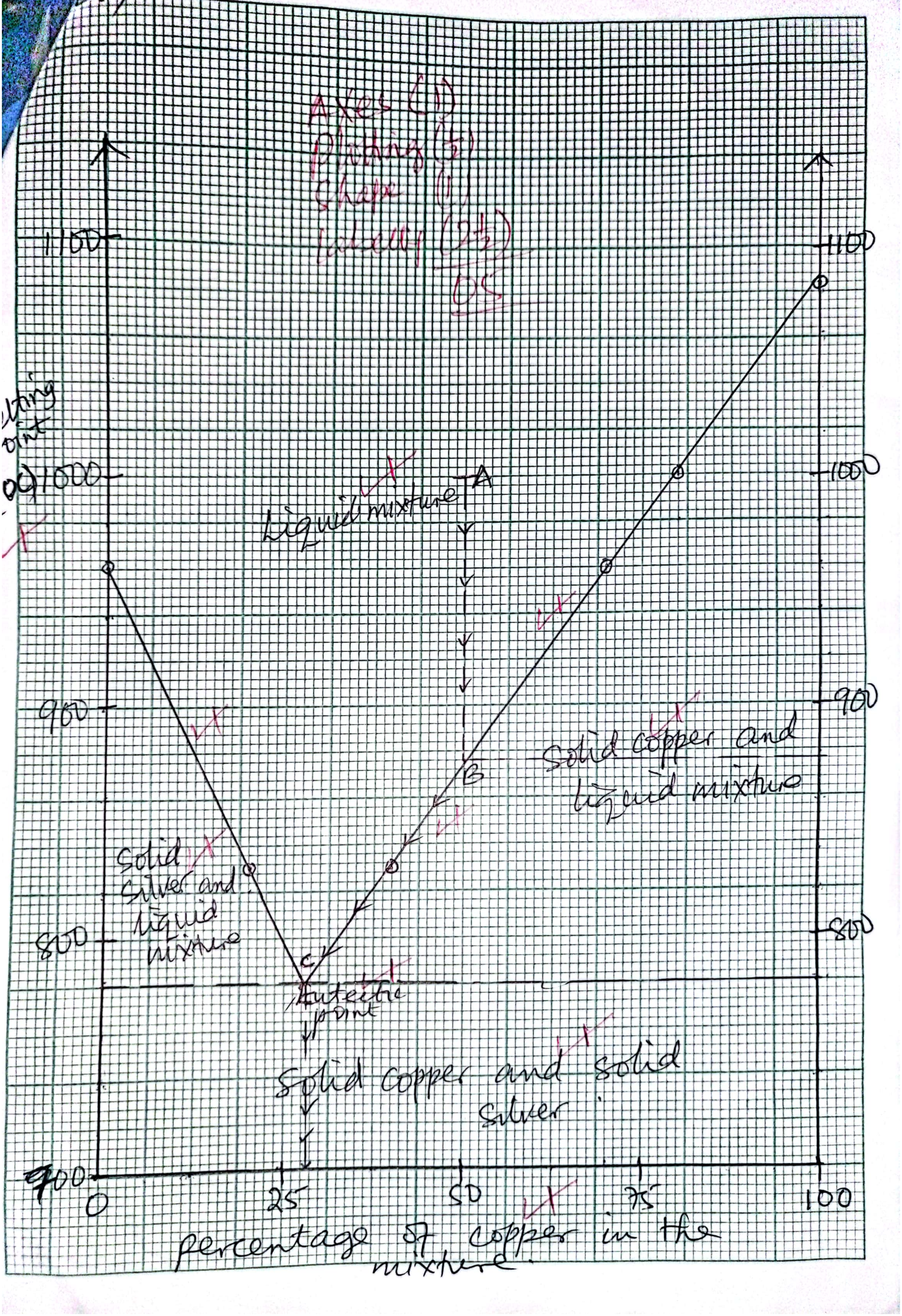
(ii) Eutectic temperature is 780°C ±4

Composition of eutectic mixture is (28.125% Copper and 71.875% Silver) 1½
±2 ±2

(c) From A(1000°C), the liquid mixture cools to point B(876°C) without change in phase.
At B(876°C), copper begins to solidify/freeze as the composition of silver in the liquid mixture increases.
As the liquid mixture is cooled further, more copper solidifies, the liquid mixture becoming richer in silver and the freezing point decreases along BC (from 876°C to 780°C) up to the eutectic point.
At the eutectic point (780°C), silver also begins to solidify and the temperature and composition remain constant until the whole system solidifies.
The solid mixture then cools with no change in phase up to 700°C

Accept either use of letters or quoting of temperatures. 4½

2(ii)


Axes (1)
Plotting (½)
Shape (1)
Labelling (2½)
05
Melting point (°C)
1100
1000
900
800
700
0
25
50
75
100
Liquid mixture
A
B
C
Solid copper and liquid mixture
Solid silver and liquid mixture
Eutectic point
Solid copper and solid silver
Percentage of copper in the mixture

i) $Cu_{(s)} + 2Ag^+_{(aq)} \longrightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$ ✓ (1)

ii) $E^\ominus_{cell} = E^\ominus_{right} - E^\ominus_{left}$

or $E^\ominus_{cathode} - E^\ominus_{anode}$ ✓ (1)

$= 0.80 - 0.34 = +0.46V$

(Accept only with + and units.)

iii) $\Delta G^\ominus = -nFE^\ominus_{cell} = -2 \times 96500 \times 0.46$

$= -88,780 J$

Accept $-88.78 kJ$ (2)

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

Deny (½ mk) if reason is linked to $E^\ominus cell$.

e) Copper doesnot react with dilute sulphuric acid.

Copper reacts with hot concentrated sulphuric acid to form copper(II) sulphate, sulphur dioxide and water

$Cu_{(s)} + 2H_2SO_{4(aq) \text{ or } (l)} \rightarrow CuSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(l)}$. (4)

~~attempt~~

QN 4 (1)

(a) An element whose outermost electrons fill the d-subenergy level of its atom.

b(i) Cu – $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$
or $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ reject $[Ar] 4s^1 3d^{10}$ or ~ $4s^2 3d^9$

Fe^{2+} – $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ (1½)

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

(ii) The iron(II) ion has a partially filled 3d-subenergy level, with 6 electrons, thermodynamically unstable hence readily oxidised to the iron(III) ion which has a half filled 3d-subenergy level with 5 electrons, thermodynamically more stable, in order to attain a more stable electronic configuration.

The manganese(II) ion has a half filled 3d-subenergy level ~~which is~~ with 5 electrons, thermodynamically more stable than the manganese(III) ion, which has a partially filled 3d subenergy level, with 4-electrons, thermodynamically unstable. This will lead to changing from a relatively more stable oxidation state to a less stable one. (5)

Fe^{3+} – $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$.

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

(i) Mn_2O_7 ✓ 1

$KMnO_4$

$NaMnO_4$ or MnO_4^- Accept any one. reject wrong symbols, names

$HMnO_4$

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

The manganese atom can lose both the 5 electrons in the 3d subenergy level and the two electrons in the 4s sub energy level due to the very small energy difference between the 3d and 4s subenergy levels. 2

Accept subenergy levels | sub-shells or orbitals

reject energy levels / shells

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

3d

↑	↑	↑	↑	↑

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

3d

↑↓	↑↓	↑↓	↑↓	↑↓

The manganese atom has 5 unpaired electrons in the 3d subenergy level which a spin on their axes, inducing a high magnetic moment. The copper atom has 10 electrons in the 3d subenergy level which are all paired. Therefore no magnetic moment is induced. Magnetic moment increases with increase in number of unpaired electrons in the 3d subenergy level. 4

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

3d

↑↓	↑	↑	↑	↑

~~I~~ Iron atom has a total of 8 valence electrons in 4s and 3d subenergy levels and also availability of d-orbitals of suitable energy that facilitate formation of temporary bonds with reactant particles. 2

(b) — Cobalt has variable oxidation states for example +2 and +3.

−1 for (a) extra wrong. — Cobalt(III) ions are used as catalyst in oxidation of 2,3-dihydroxybutanedioate by hydrogen peroxide.

Any (3) ½ if no example given. — Cobalt forms complex ions like $Co(NH_3)_6^{2+}$, $Co(H_2O)_6^{2+}$, $CoCl_4^{2-}$, etc.

— Cobalt forms coloured compounds like green Cobalt(II) oxide, Cobalt(II) Chloride is blue

— The cobalt(II) ion is paramagnetic

½

Section B:

QN 5.

(a) (i) Heat given out when one mole of a compound is completely burnt in oxygen under standard conditions. ① S

reject heat change

(ii) Standard enthalpy of atomisation is the heat given out when one mole of an compound in its normal physical state is formed from free gaseous atoms under standard conditions ①

or

Heat absorbed when one mole of a compound in its standard state is formed from free gaseous atoms under standard conditions.

reject heat change

or

Heat absorbed when an element in its normal physical state is converted to one mole of free gaseous atoms under standard conditions.

(b) A known volume, V cm³ of water is put in a thin metallic can. The can is fitted with a thermometer and stirrer. ✓1

Accept logical/ Coherent flow

The ~~initial~~ water is stirred and its initial temperature is read and recorded from the thermometer as T_1 °C. ✓1

An improvised spirit lamp is filled halfway with ethanol ✓1 and the mass of the lamp and its contents measured and recorded as x g. ✓1

The can having water is ~~placed~~ clamped directly over the lamp protected by card board shields. ✓1

The lamp is lit and the flame adjusted to just touch ~~the~~ ✓1 the bottom of the metallic can.

The water is heated while stirring ✓1 until a reasonable/appreciable rise in temperature occurs.

The lamp is extinguished/put off/blown off and the final temperature of the water, T_2 °C is noted.

The lamp is allowed to cool and reweighed with its contents, mass recorded as y g

Treatment of results

Density of water = $1 gcm^{-3}$.

mass of water = $(V \times 1)$ g.

mass of ethanol burnt = $(x-y)$ g.

Temperature rise = $(T_2 - T_1)$ °C = ΔT.

Assumptions:

- No heat is lost to surroundings
- Heat capacity of the can is negligible.

Heat produced by ethanol = heat absorbed by water.

Heat absorbed by water = $(V \times 4.2 \Delta T)$ J

$(x-y)$ g of ethanol evolve $4.2 V \Delta T$ J.

RFM of $C_2H_5OH = 24 + 6 + 16 = 46$

46 g of ethanol evolve $\left(\frac{46 \times 4.2 V \Delta T}{x-y}\right)$ J

Molar Heat of combustion of ethanol is $-\left(\frac{193.2 V \Delta T}{x-y}\right) J mol^{-1}$

emphasize (−) sign

or $-\left(\frac{0.1932 V \Delta T}{x-y}\right) kJ mol^{-1}$

10

i) $C_{(s)} + O_{2(g)} \xrightarrow{-393\,kJmol^{-1}} CO_{2(g)}$

$\Delta H_{f_{CO}}$, $\frac{1}{2}O_{2(g)}$: $C_{(s)} \rightarrow CO_{(g)}$

$CO_{(g)} \xrightarrow[-283\,kJmol^{-1}]{\frac{1}{2}O_{2(g)}} CO_{2(g)}$

(3)

-1 for @ unbalanced equation.
$-\frac{1}{2}$ for @ wrong physical state.
$-\frac{1}{2}$ for @ missing enthalpy value.

By Hess' law;

ii) $\Delta H_{f_{CO}} + (-283) = -393$

$\Delta H_{f_{CO}} = -393 + 283 = -110\,kJmol^{-1}$

$-\frac{1}{2}$ for wrong or missing units (2)

(d) If the enthalpy change of a reaction is exothermic (negative), then the reaction is feasible at all temperatures (spontaneous/easily occurs)
If the enthalpy change of a reaction is endothermic (positive), the reaction is not feasible at all temperatures. non spontaneous doesn't easily occur.
If the enthalpy change of a reaction is 0 (zero), reaction doesn't ~~take~~ place

(3)

Qn 6

a) Iron(II) ions reduce chlorine to chloride ions as they are oxidised to iron(III) ions

$2Fe^{2+}_{(aq)} + Cl_{2(aq)} \rightarrow 2Fe^{3+}_{(aq)} + 2Cl^-_{(aq)}$

The green solution therefore turns yellow/brown. This is because the reduction potential of chlorine is more positive than that of iron(III) ions, making the reaction feasible.

The iron(III) ions then react with hydroxide ions to form iron(III) hydroxide, which is insoluble. A yellow/brown precipitate is therefore formed.

6

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

Accept molecular equation

b) Potassium iodide/Iodide ions reduce copper(II) ions/copper(II) sulphate to copper(I) iodide which is insoluble as they are oxidised to iodine. A white precipitate in a brown solution is therefore formed.

$4I^-_{(aq)} + 2Cu^{2+}_{(aq)} \rightarrow Cu_2I_{2(s)} + I_{2(aq)}$

or

$4I^-_{(aq)} + 2Cu^{2+}_{(aq)} \rightarrow 2CuI_{(s)} + I_{2(aq)}$

The hexane layer turns violet/purple due to hexane being non-polar, dissolving the non-polar iodine formed.

5

c) Dilute copper(II) sulphate contains the tetraaquacopper(II) ion, which is blue. On addition of concentrated hydrochloric acid, excess chloride ions reacts with the tetraaquacopper(II) ion to form tetrachlorocuprate(II) ions, which are yellow. This is due to replacement of aqua ligands by chloro ligands. (ligand exchange)

3½

$Cu(H_2O)_4^{2+}{}_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons CuCl_4^{2-}{}_{(aq)} + 4H_2O_{(l)}$

Accept ($\longrightarrow$)

(d) chromium (III) hydroxide is amphoteric hence reacts with dilute hydrochloric acid to form chromium (III) chloride and water

$Cr(OH)_3(s) + 3HCl(aq) \rightarrow CrCl_3(aq) + 3H_2O(l)$

It also reacts with sodium hydroxide, an alkaline solution to form tetrahydroxochromate(III) ions.

$Cr(OH)_3(s) + OH^-(aq) \rightarrow Cr(OH)_4^-(aq)$

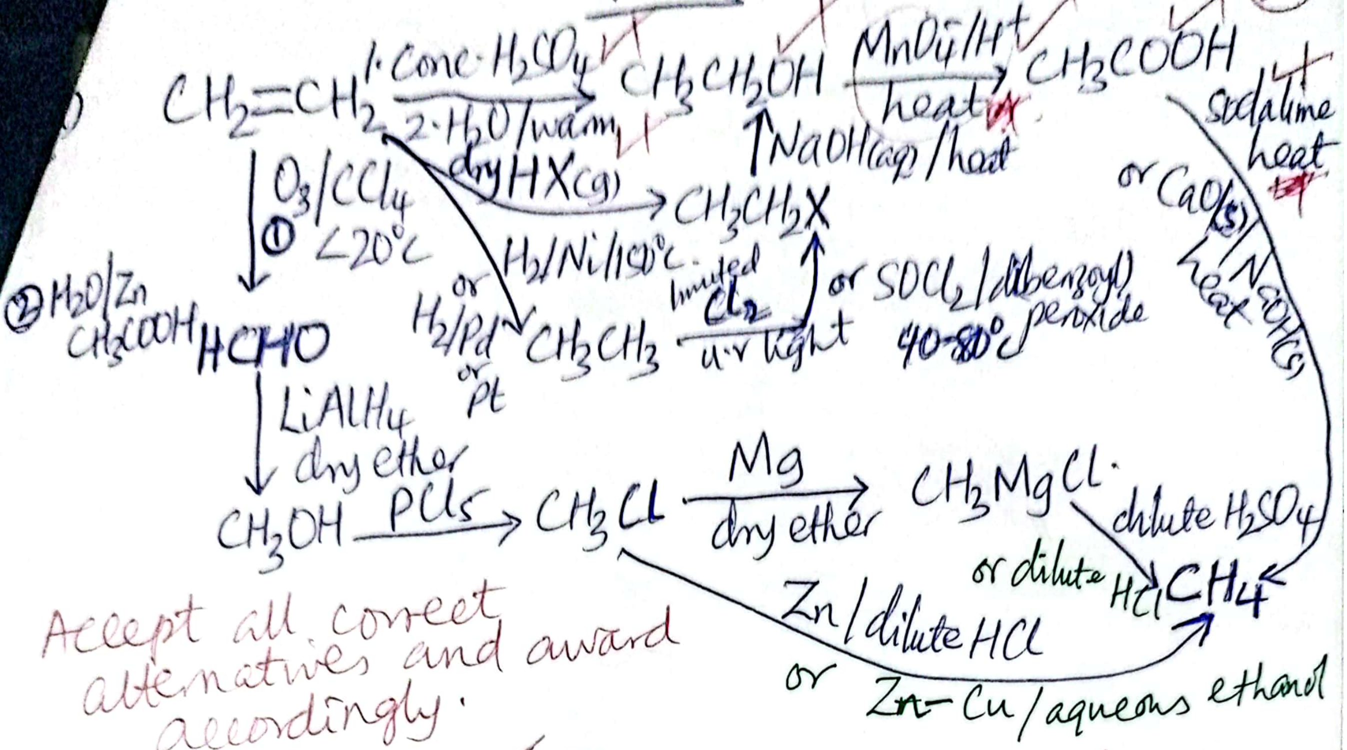
or $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow Cr(OH)_6^{3-}(aq)$ 5½

or $Cr(OH)_3(s) + NaOH(aq) \rightarrow NaCr(OH)_4(aq)$

or $Cr(OH)_3(s) + 3NaOH(aq) \rightarrow Na_3Cr(OH)_6(aq)$

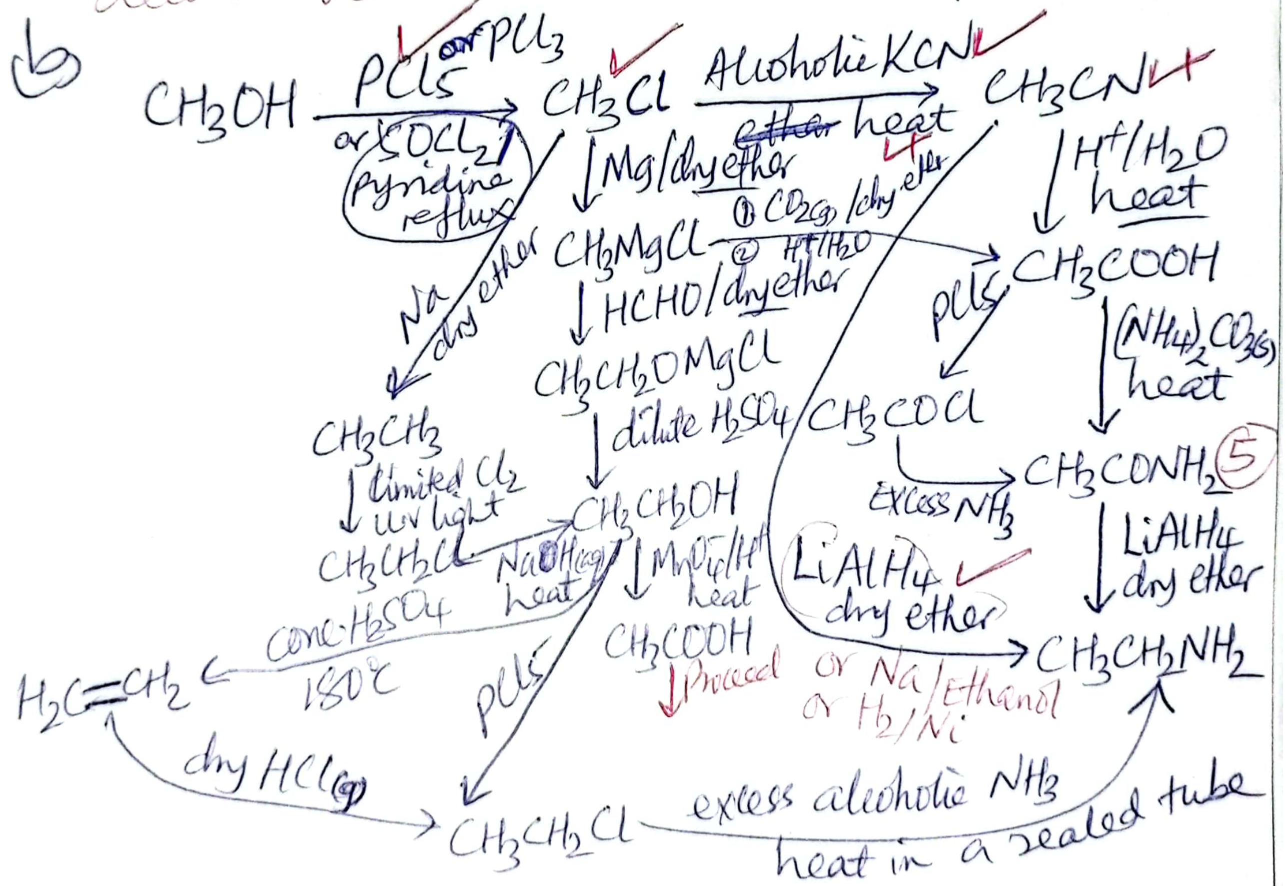
QN7:

(a)

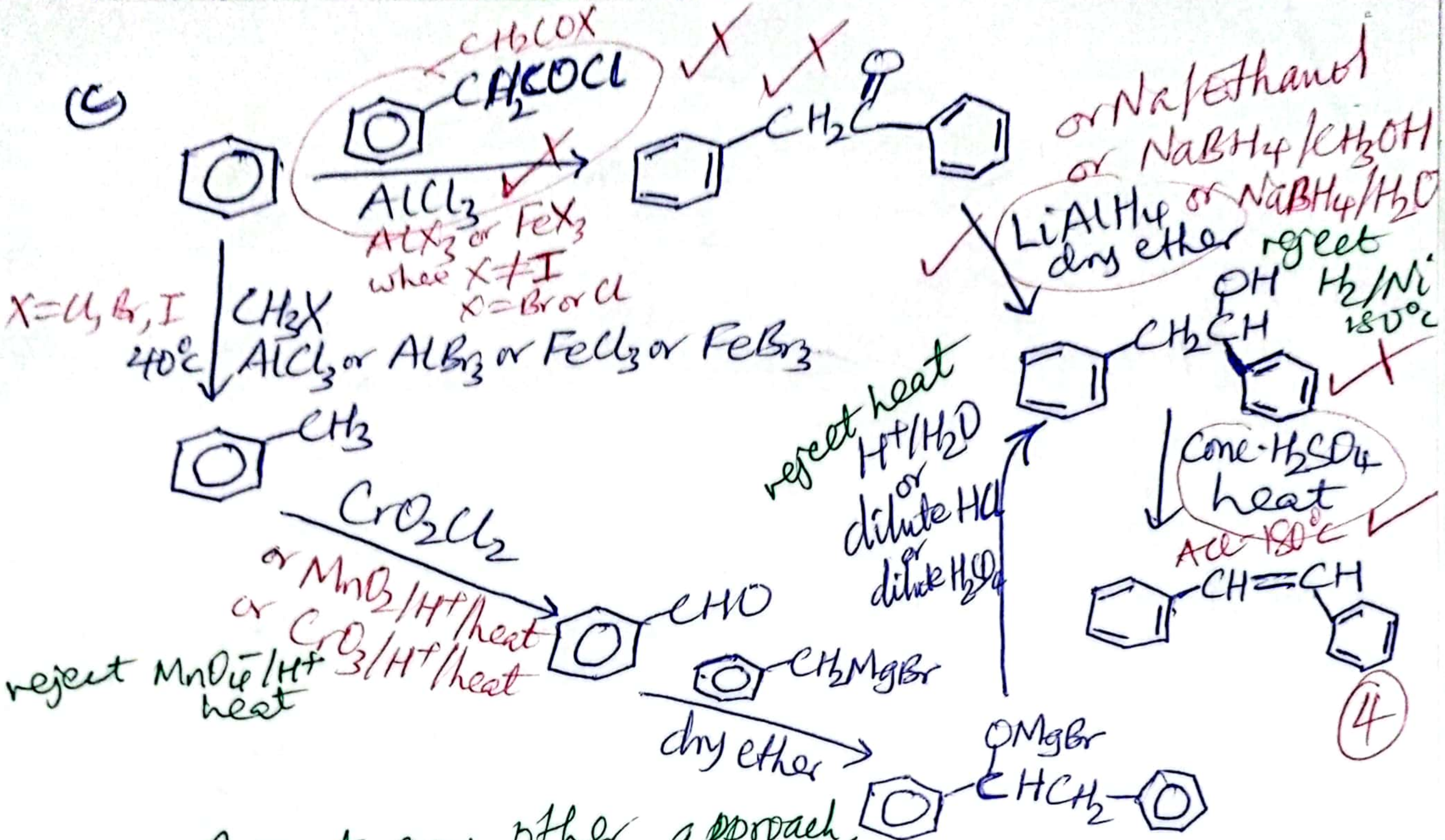


Accept all correct alternatives and award accordingly.

(b)



(c)



Reject any other approach.

(d) $CH_3CH{=}CH_2 \xrightarrow[ROOR']{HBr} CH_3CH_2CH_2Br$

$CH_3CH_2CH_2Br \xrightarrow[\text{heat}]{\text{Alcoholic KOH}} CH_3CH_2CH_2CN$

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

4½

$CH_3CH{=}CH_2 \xrightarrow[CCl_4]{Cl_2 \text{ or } Br_2} CH_3\underset{X}{C}HCH_2X$

$CH_3CHXCH_2X \xrightarrow[\text{heat}]{\text{KOH/Ethanol}} CH_3C{\equiv}CH$

$CH_3C{\equiv}CH \xrightarrow{Na/NH_3(l)} CH_3C{\equiv}C^-Na^+$

$CH_3C{\equiv}C^-Na^+ \xrightarrow{CH_3Br} CH_3C{\equiv}CCH_3$

$CH_3C{\equiv}CCH_3 \xrightarrow{H_2/Ni/150^\circ C} CH_3CH_2CH_2CH_3$

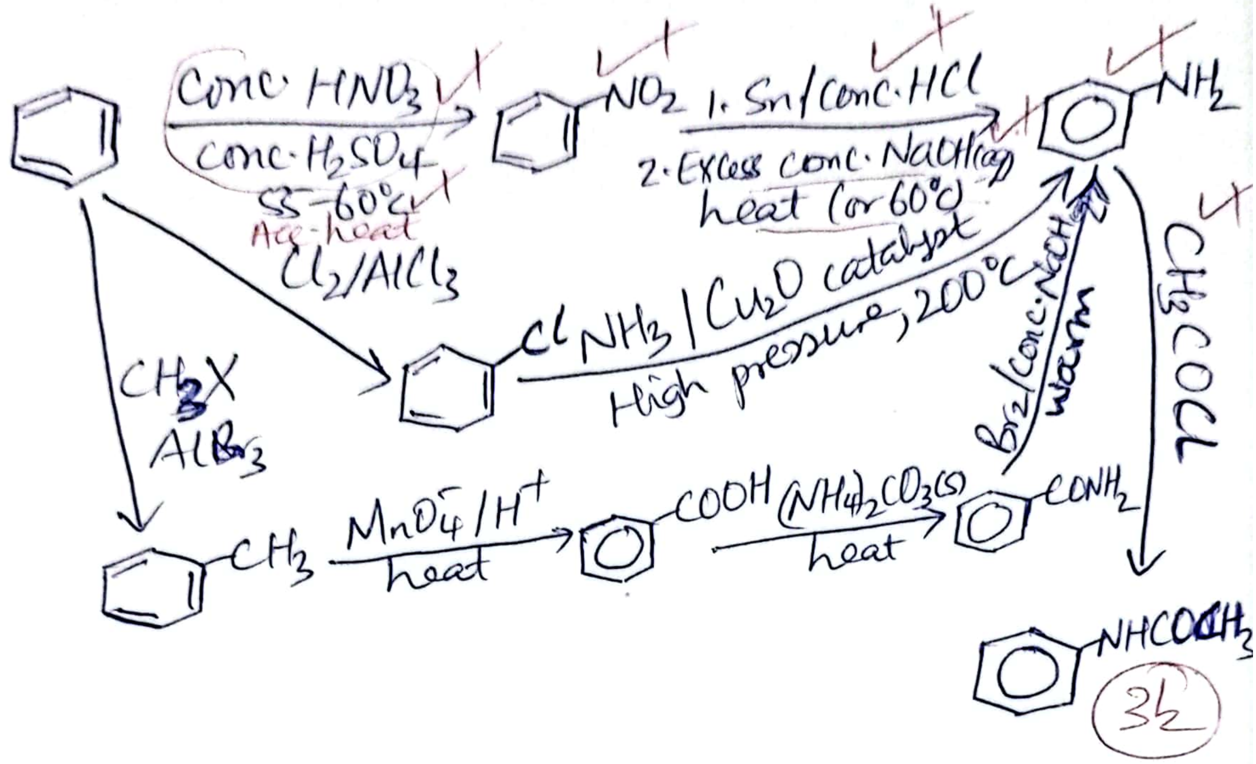
$CH_3C{\equiv}CCH_3 \xrightarrow{H_2/\text{Lindlar's catalyst}} CH_3CH{=}CHCH_3 \longrightarrow CH_3CH_2CH_2CH_3$

$CH_3CH_2CH_2CH_3 \xrightarrow{\text{limited } Cl_2/\text{U-V light}} CH_3CH_2CH_2CH_2Cl$

$CH_3CH_2CH_2CH_2Cl \xrightarrow[\text{heat}]{NaOH(aq)} CH_3CH_2CH_2CH_2OH$

$CH_3CH_2CH_2CH_2OH \xrightarrow[\text{heat}]{MnO_4^-/H^+} CH_3CH_2CH_2COOH$

e)


Conc. HNO3
conc. H2SO4
55-60°C
Acc. heat
NO2
1. Sn/conc. HCl
2. Excess conc. NaOH(aq)
heat (or 60°C)
NH2
Cl2/AlCl3
Cl
NH3 | Cu2O catalyst
High pressure, 200°C
Br2/conc. NaOH(aq)
warm
CH3COCl
CH3X
AlBr3
CH3
MnO4⁻/H+
heat
COOH
(NH4)2CO3(s)
heat
CONH2
NHCOCH3
3½

QN 8

(a) Fluorine atom has the smallest atomic radius, highest electronegativity and cannot expand its octet.
Fluorine has the largest positive standard electrode potential (reduction potential)
The fluorine molecule has ~~the~~ an abnormally low value of bond dissociation energy.

Acc. - highest hydration energy of fluoride ions
- Greatest lattice energy of fluoride salts.

reject lowest BDE

Accept only superlative comparison for other options.
- words atom and ion sh'd be appropriately used to award.

$2\frac{1}{2}$

(b) (warming) Heating a solid potassium halide or sodium halide salt with concentrated sulphuric acid in presence of manganese(IV) oxide

$3\frac{1}{2}$

$$2X^-_{(s)} + MnO_{2(s)} + 2H_2SO_{4(l)} \rightarrow X_{2(l,g\ or\ s)} + 2H_2O_{(l)} + Mn^{2+}_{(aq)} + 2SO^{2-}_{4(aq)}$$

or

$$2X^-_{(s)} + MnO_{2(s)} + 3H_2SO_{4(l)} \rightarrow X_{2(l,g\ or\ s)} + 2HSO^-_{4(aq)} + Mn^{2+}_{(aq)} + SO^{2-}_{4(aq)} + 2H_2O_{(l)}$$

or

$$2KX_{(s)} + MnO_{2(s)} + 2H_2SO_{4(l)} \rightarrow X_{2(l,g\ or\ s)} + MnSO_{4(aq)} + 2H_2O_{(l)} + K_2SO_4$$

where $X = Cl, Br$ or I reject $X = Cl^-, Br^-, I^-$ or Cl_2, Br_2, I_2

(c) Lattice energies decrease (become less exothermic) from silver fluoride to silver iodide. This is because anionic radius increases from the fluoride ion to the iodide ion. The halide ions become less attracted by the silver ion from fluoride ion to iodide ion. Thus a decreasing amount of energy is evolved when the silver halides are formed from free gaseous atoms.

reject down the group and deny all marks

$3\frac{1}{2}$

d(i) Sodium hydroxide is a strong electrolyte completely dissociates to form many hydroxide ions

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + \bar{O}H_{(aq)}$$

Chlorine reacts with the many hydroxide ions to form chlorate(I) ions and chloride ions (Acc. NaClO and NaCl) which are both more soluble in water than the chlorine itself.

$$Cl_{2(g)} + 2\bar{O}H_{(aq)} \rightarrow Cl^-_{(aq)} + ClO^-_{(aq)} + H_2O_{(l)}$$

However, water is a very weak electrolyte, only very slightly ionises to give very few hydroxide ions

4

(ii) Iodine reacts with potassium iodide to form a soluble complex of potassium triiodide

$$I_{2(aq)} + I^-_{(aq)} \rightarrow I_3^-{}_{(aq)} \text{ or;}$$

$$I_{2(aq)} + KI_{(aq)} \longrightarrow KI_{3(aq)}$$

Iodine is non-polar yet water is polar. The intermolecular forces of attraction between individual molecules of water (hydrogen bonds) and forces of attraction between individual molecules of iodine (Van der waals forces) are on average stronger than intermolecular forces of attraction between water molecules and iodine molecules. When iodine is added to water, the molecules repel each other

4½

(e) Pale yellow precipitate

2

$$CH_3COCH_2CH_3 \xrightarrow{I_{2(aq)}/\bar{O}H_{(aq)}} CHI_3 + CH_3CH_2CO\bar{O}Na^+$$

Acc. balanced eqn. emphasise only