Suggestion Solutions for 2022 H2 Chemistry Prelim Paper 2

1 **(a)** The enthalpy change of solution of a substance is the enthalpy change when one mole of the substance is completely dissolved to give an infinitely dilute solution, so that no further enthalpy change takes place on adding more solvent. [1]

(b) **(i)** Assuming no heat loss to surroundings,

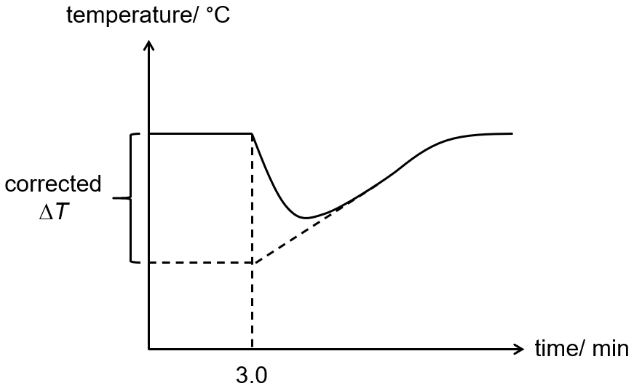
amount of $NH_4NO_3 \times 26000 = 50 \times 4.18 \times 5$

amount of $NH_4NO_3 = 0.04019$ mol

minimum mass of $NH_4NO_3 = 0.04019 \times (2(14.0) + 4(1.0) + 3(16.0))$

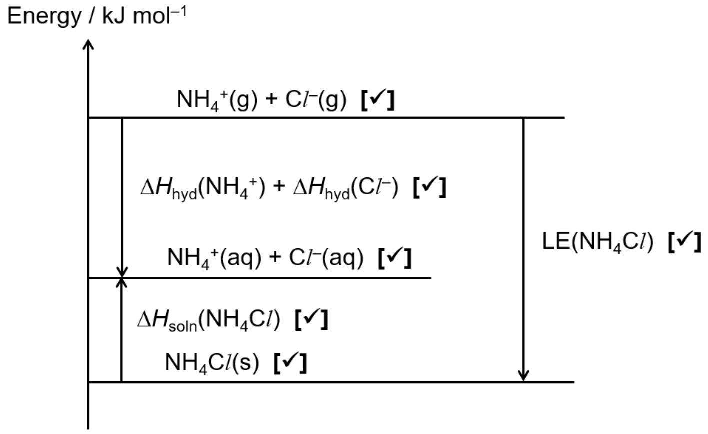
$= \underline{3.22\ g}$ [1]

(ii)



[2]

(c)



By Hess' Law,

$\Delta H_{soln}(NH_4Cl) = -(-705) + [(-307) + (-381)]$

$= \underline{+17.0\ kJ\ mol^{-1}}$ [3]

(d) Since Cl^- has a smaller ionic radius and higher charge density than Br^-, it forms stronger ion-dipole interactions with water molecules.

Thus, Cl^- has a larger magnitude of ΔH_{hyd} than Br^-. [2]

[Total: 9]

2 **(a)** It is a d-block element that is able to form one or more stable ions with a partially filled d subshell. [1]

(b) <u>Both elements have giant metallic lattice structure</u> and exhibit metallic bonding. In <u>Co, both the 4s and 3d electrons can be contributed to form the sea of delocalised electrons</u> as they are very close in energy. The resulting <u>cobalt ion has a higher positive charge and a smaller ionic radius/ higher charge density</u>. This results in <u>stronger electrostatic forces of attraction between the metal cations and the sea of delocalised electrons in Co</u> as compared to Ca, which only contributes 2 valence electrons per Ca atom to form Ca^{2+}. [2]

(c) **(i)** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$ [1]

(ii) $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ $\quad E = +0.40$ V

Overall equation:

$4[Co(NH_3)_6]^{2+} + O_2 + 2H_2O \rightarrow 4[Co(NH_3)_6]^{3+} + 4OH^-$

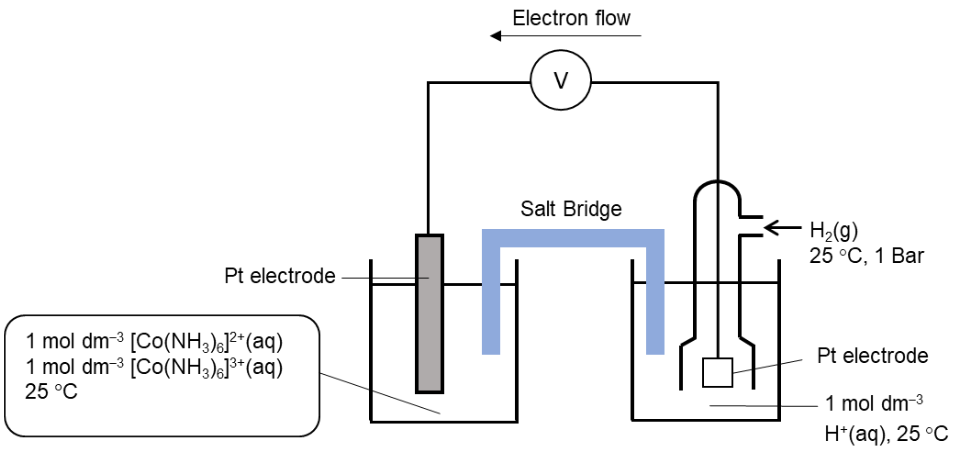
$E_{cell} = (+0.40) - (+0.11) = +0.29$ V

Since $E_{cell} > 0$, the reaction is feasible.

Hence, yellow-brown $[Co(NH_3)_6]^{2+}$ is <u>oxidised by oxygen</u> in air to produce red-brown $[Co(NH_3)_6]^{3+}$ [2]

(iii)

(iv)



[3]

[1]

(d) **(i)** Amount of **D** reacted with EDTA $= \frac{18.75}{1000} \times 0.0400$

$= 7.500 \times 10^{-4}$ mol

Amount of **D** in 3.501 g sample $= \frac{500}{25.0} \times 7.500 \times 10^{-4}$

$= 0.01500$ mol

Molar mass of **D** $= \frac{3.501}{0.01500}$

$= 233.4$ g mol^{-1} [2]

(ii) Amount of **D** reacted with $AgNO_3 = \frac{23.34}{233.4}$

$= 0.1000$ mol

Amount of $AgCl_2$ formed $= \frac{14.340}{(107)+(35.5)}$

$= 0.1000$ mol

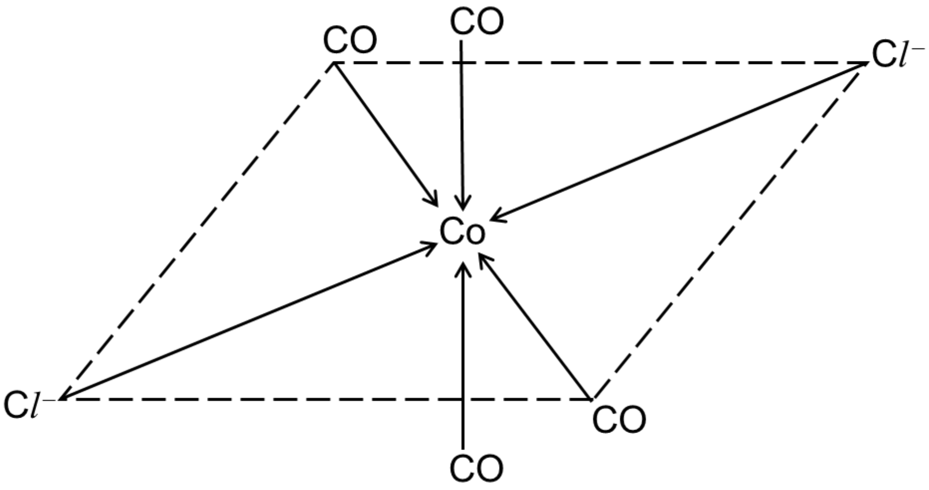
Mole ratio of **D**: $AgCl$ is 1 : 1 [1]

(iii) $17a + 35.5(3) = 233.4 - 58.9$

Solving: a = 4

Cation: $[Co(NH_3)_4Cl_2]^+$ [2]

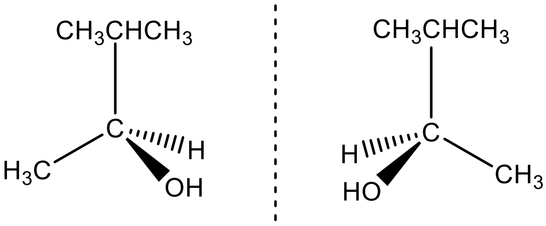
(iv)



[2]

[Total: 17]

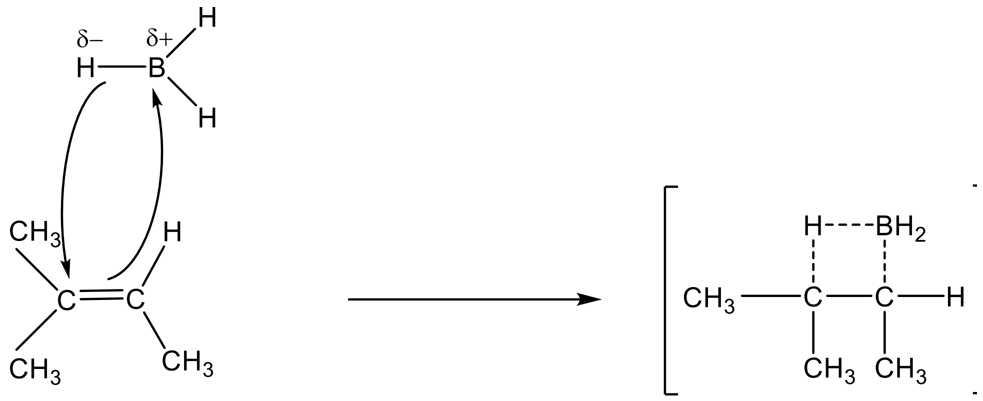
3 **(a)** **(i)** Enantiomerism



[2]

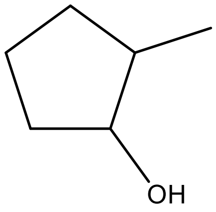
(ii) An electrophile is an <u>electron pair acceptor</u> and is electron deficient. [1]

(iii)



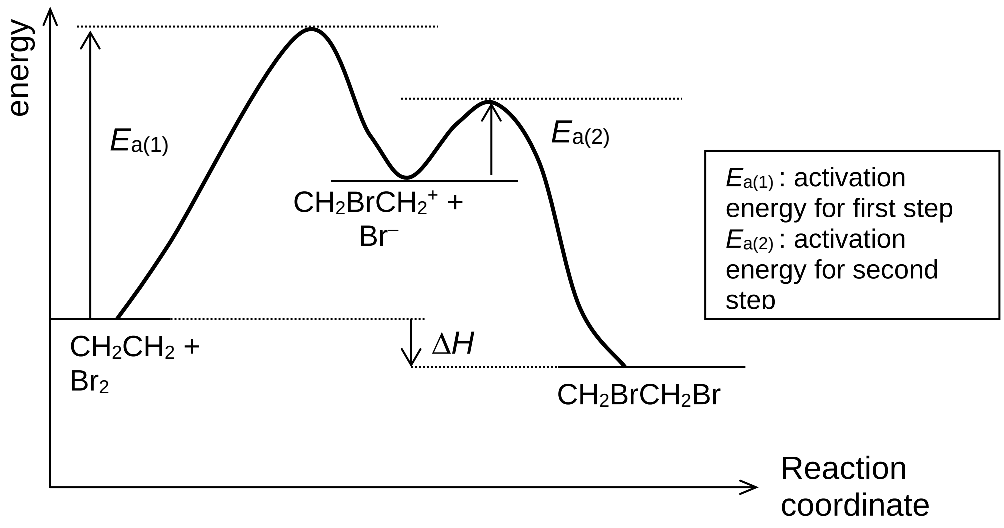
[2]

(iv)



[1]

(b)



[2]

(c) All three substances have simple molecular/ covalent structures. More energy is needed to overcome the stronger hydrogen bonds between CH_3OH molecules than the weaker instantaneous dipole-induced dipole (id-id) interactions between CH_3SH or CH_3SeH molecules. Thus CH_3OH has the highest boiling point.

As CH_3SeH has a larger number of electrons than CH_3SH, more energy is needed to over the stronger id-id interactions between CH_3SeH molecules than the weaker id-id interactions between CH_3SH molecules. Thus CH_3SeH has a higher boiling point than CH_3SH. [3]

(d) **(i)** ΔS is positive as there is an increase in disorder as the amount of gas molecules increases from 0 mol to 3 mol. [1]

(ii) $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$

$= +129 - (130 + 273)(0.332)$

= – 4.80 kJ mol^{-1}

Since $\Delta G < 0$, reaction is <u>spontaneous</u> at 130°C.

[2]

[Total: 14]

4 **(a)** **(i)** $pV = nRT$

$$pV = \frac{m}{M_r}RT$$

$$M_r = \frac{mRT}{pV}$$

$$M_r = \frac{(1.50)(8.31)(327 + 273)}{(1.60 \times 10^5)(250 \times 10^{-6})}$$

$$= 187.0$$

$$\underline{= 187\ (to\ 3\ s.f.)}$$

[1]

(ii) Let the mole fraction of $AlCl_3$ be x.

$133.5x + (1 – x)(267) = 187$

$133.5x + 267 – 267x = 187$

$133.5x = 80$

$x = 0.59925$

$x = 0.6$ (to 1 d.p)

Mole fraction of $AlCl_3 = 0.6$

Mole fraction of Al_2Cl_6

= 1 – 0.59925

= 0.40075

= 0.4 (to 1 d.p)

[1]

(iii) $P_{AlCl_3} = (0.6)(1.60 \times 10^5) = 96000\ Pa$

$P_{Al_2Cl_6} = (0.4)(1.60 \times 10^5) = 64000\ Pa$

$$K_p = \frac{(P_{AlCl_3})^2}{P_{Al_2Cl_6}}$$

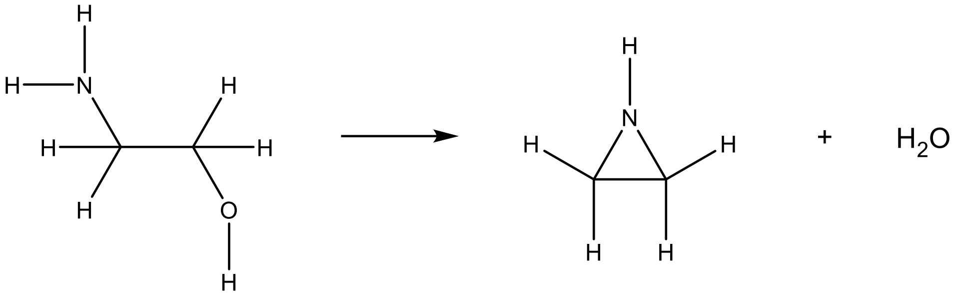
$$K_p = \frac{(96000)^2}{64000}$$

$$= 144000\ Pa$$

[3]

(b) Since the reaction is <u>endothermic</u>, increasing the temperature will <u>favour the forward reaction/ shift the position of equilibrium to the right to absorb some of the extra heat</u>.Thus <u>K_p will increase</u>. [2]

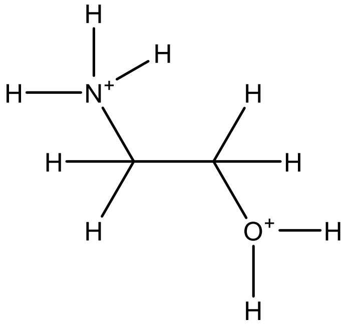
(c) **(i)**



[1]

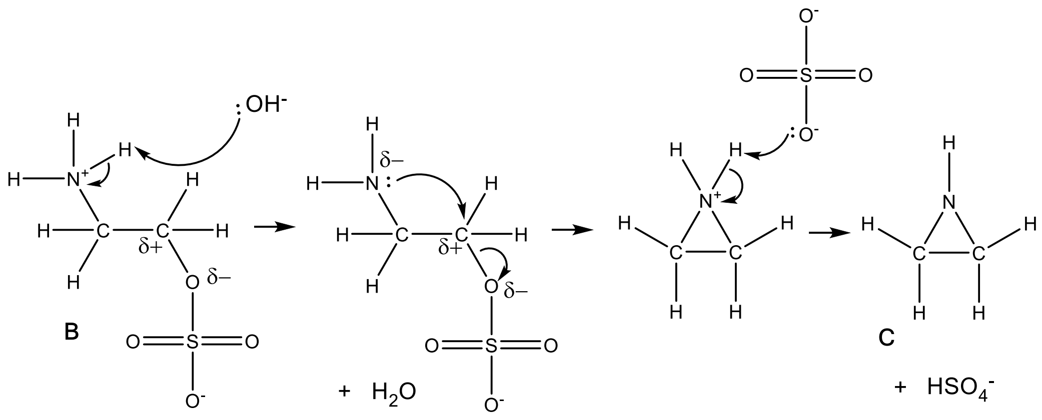
(ii) Elimination [1]

(e) **(i)**



[1]

(ii)

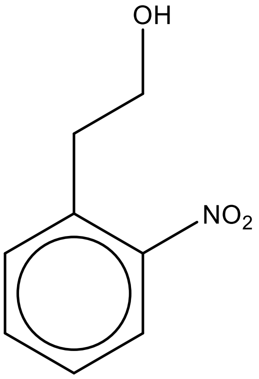


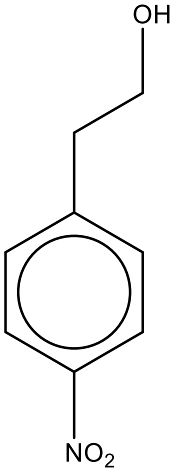
[3]

(iii) Nucleophilic substitution [1]

[Total: 14]

5 **(a)** **(i)**



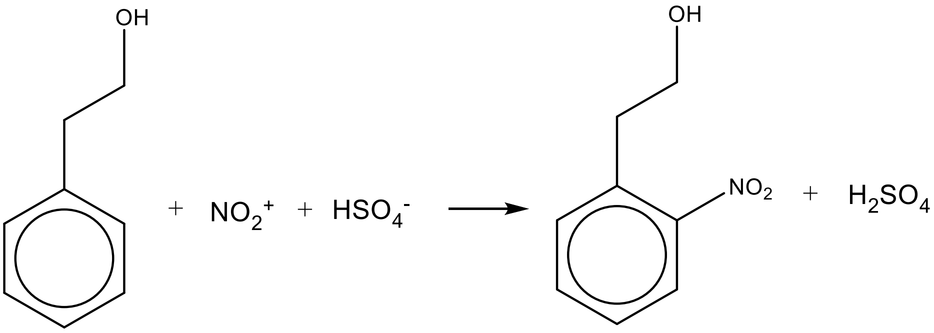


[2]

(ii) Stage I

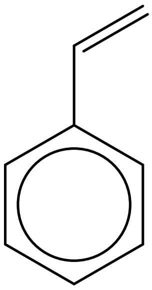
$HNO_3 + 2H_2SO_4 \ll NO_2^+ + 2HSO_4^- + H_3O^+$

Stage II



[2]

(ii)



[1]

(b) **(i)** Hydrolysis or acid-base [1]

(ii) Amount of Mg = 1.5 ÷ 24.3 = 6.17×10^{-2} mol

Amount of bromopropane = (5 × 1.35) ÷ 123 = 5.49×10^{-2} mol

Magnesium is in excess [2]

(iii) $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ [1]

(iv) Upper [2]

Butanoic acid is more soluble in diethyl ether than water and will dissolve in the organic layer [1]. As diethyl ether is less dense than water, butanoic acid will be found in the upper layer.

(v) 1-bromobutane

Butanoic acid will undergo an acid-base reaction with NaOH to form the soluble salt, sodium butanoate, which will dissolve in the aqueous layer due to the formation of favourable ion-dipole interactions. 1-bromobutane will stay in the organic layer to be removed. [3]

(vii) Water [1]

(viii) Accept any range within 154-174 °C. [1]

(c) **(i)** $K_a = \frac{[H^+][X^-]}{[HX]}$

Since $[H^+] = [X^-]$ and assuming that the degree of dissociation is small,

$10^{-4.82} \approx \frac{[H^+]^2}{0.20}$

$[H^+] = 1.74 \times 10^{-3}$ mol dm^{-3}

pH $= -\lg(1.74 \times 10^{-3})$

$= 2.76$ [2]

(d) **(i)** pH = 14.95 ÷ 2 = 7.48 [1]

(ii) $H_2O(l) \ll H^+(aq) + OH^-(aq)$ $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}

$D_2O(l) \ll D^+(aq) + OD^-(aq)$ $K_w = 1.12 \times 10^{-15}$ mol^2 dm^{-6}

The K_w value of D_2O is lower than the K_w value of H_2O. The position of equilibrium for D_2O lies more on the left/extent of ionisation of D_2O is lower than H_2O. Therefore the O-D bond is likely to be a stronger bond that is more difficult to break and dissociate. [2]

[Total: 21]