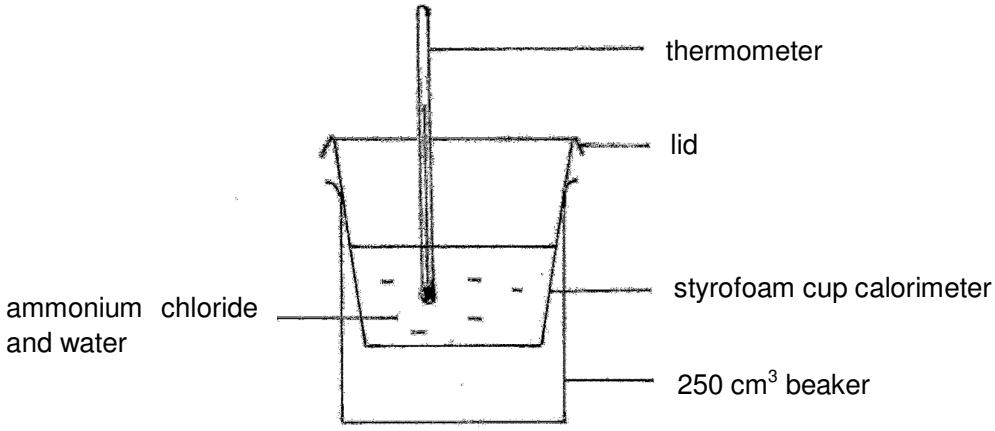
Hwa Chong Institution
2011 Prelim Paper 2 Answers

1(a)



(b) **(i)** 100 cm^3 (*accept 10 cm^3 to 200 cm^3*)

(ii) The maximum mass that can dissolve in 100 cm^3 of water
= (6.95 / 1000) x 100 x 53.5 = 37.2 g

(c) Assuming a temperature change of 5 ^oC to be measured and no heat loss to surroundings,
n_{salt} x 15 000 = 100 x 4.3 x 5 $\Rightarrow$ n_{salt} = 0.143 mol
minimum mass to use = 0.143 x 53.5 = 7.65 g

(d)

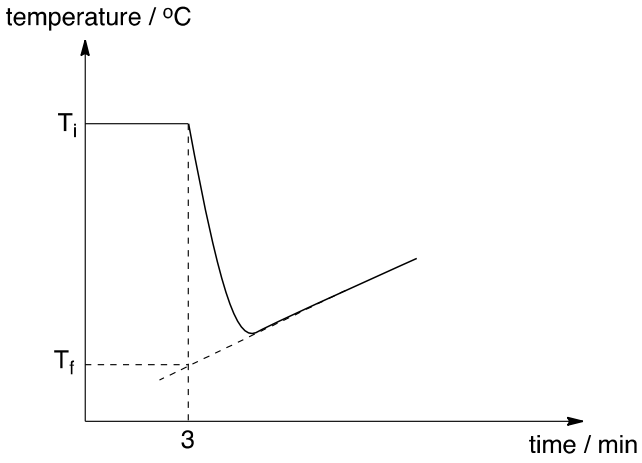
1. Weigh accurately 8.00 g of ammonium chloride in a weighing bottle, using a weighing balance.
2. Using a 100 cm^3 measuring cylinder, add 100 cm^3 of water into a dry styrofoam cup calorimeter. Support the styrofoam cup on a 250 cm^3 beaker.
3. Stir the water gently using the thermometer.
4. Start the stopwatch.
5. Record the temperature of the water in the styrofoam cup using a 0.1 ^oC thermometer, at 30 s intervals (*accept 1 min*) until 2.5 min.
6. At exactly 3 min (*accept 1–5 min*), tip the ammonium chloride into the water. Do not measure the temperature at this time.
7. Stir the solution gently and record the temperature of the solution at 3.5 min. Continue to stir and record the temperature at 30 s intervals until solution returns to room temperature.
8. Reweigh the weighing bottle.

Table with headings:

Mass of weighing bottle and salt / g	m_1
Mass of weighing bottle after experiment / g	m_2

Time / min	Temperature of solution / ^oC
0.0	
0.5	
1.0	
1.5	
2.0	
2.5	
3.0	
3.5	
.	

(e)



(f) $\Delta H_{solution}$ (in J mol^{-1}) $= +\dfrac{v \times 4.3 \times T}{\left(\dfrac{m}{53.5}\right)}$

(g) The salt with the more endothermic enthalpy change of solution will be the more effective ingredient in the cold pack.
OR
The salt that gives the fastest drop in temperature will be the more effective ingredient.

2 **(a)** **(i)** Examples of possible answers :

Category of reaction	*Equation from Group II or Group VII*
Decomposition	$2Mg(NO_3)_2$ (s) → $2MgO(s) + 4NO_2(g) + O_2(g)$ $2HCl(g) \rightarrow H_2(g) + Cl_2(g)$
Single displacement	$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$ $Cl_2(g) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(aq)$
Double displacement	$Na_2SO_4(aq) + Ba(NO_3)_2(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ $NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

(ii) Type of reaction : redox
Equation : $4KI(aq) + 2CuSO_4(aq) \rightarrow 2K_2SO_4(aq) + 2CuI(s) + I_2(aq)$

(iii) $NaBr(s) + H_2SO_4(l) \rightarrow HBr(g) + NaHSO_4(s)$
$2HBr(g) + H_2SO_4(l) \rightarrow Br_2(g) + SO_2(g) + 2H_2O(l)$

(b) **(i)** $K_a = \dfrac{[H^+][Mg(H_2O)_5(OH)^+]}{[Mg(H_2O)_6{}^{2+}]}$

(ii) I. The <u>solubility equilibrium</u> $Mg^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Mg(OH)_2(s)$ keeps <u>$[OH^-]$ constant</u> (pH is constant at 9).

II. The Mg^{2+} has been <u>completely precipitated / reacted</u>, and the excess (drop of) NaOH increases the $[OH^-]$ / pH <u>drastically</u>.

(iii) Initial $[Mg^{2+}] = ½ \times \dfrac{1.00 \ x \ 20.0}{50.0}$
$= 0.20$ mol dm^{-3}

$K_a = \dfrac{[H^+]^2}{0.20 - [H^+]}$ where $[H^+] = 10^{-6}$ mol dm^{-3}
$= 5.00 \times 10^{-12}$ mol dm^{-3}

Note that the $[H^+]$ in the denominator is negligible.

(iv) I. pOH = 14 – 9 = 5
$[OH^-] = 10^{-5}$ mol dm^{-3}

II. At half-completion, $[Mg^{2+}] = \dfrac{\frac{1}{2} x \frac{50}{1000} x 0.20}{\frac{60}{1000}}$
$= 0.0833$ mol dm^{-3}

Hence, $K_{sp} = [Mg^{2+}][OH^-]^2 = 0.0833 \times (10^{-5})^2$

$= 8.33 \times 10^{-12}$ mol^3 dm^{-9}

(c) **(i)** A complex is the combination of a central metal atom / cation by dative bonds to a number of ligands
Coordination no. = 6

(ii) Colour of solution turns (from pink) to <u>bright blue</u> (with KSCN) and then <u>pink</u> / <u>decolourises</u> (with edta).

Ligand exchange occurs with H_2O replaced successively by SCN^- and edta. This is allowed by the <u>high</u> lg K_{stab} of the SCN^- complex; and subsequently by the <u>higher</u> lg K_{stab} of the edta complex. (accept if student states SCN^- is stronger ligand than H_2O <u>and</u> edta is stronger ligand than SCN^-; no need reference to K_{stab})

(iii) With the replacement of H_2O ligands by NH_3, the $E^{\ominus}$ for the Co^{3+} / Co^{2+} system <u>becomes less positive/decreases</u>
(literature values : $E^{\ominus}$ changes from +1.82 V to +0.10 V).

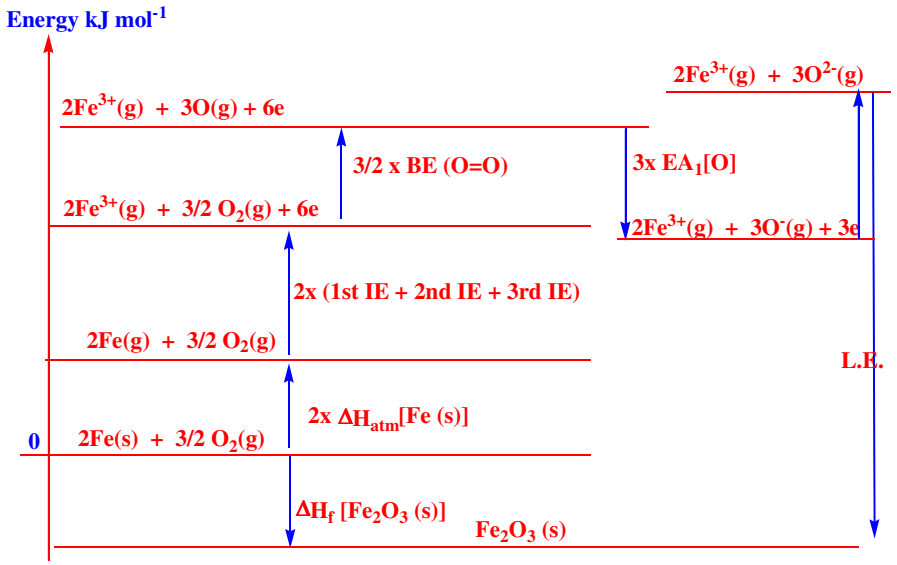
lg K_{stab} for $[Co(NH_3)_6]^{3+}(aq)$ is <u>much higher than</u> for $[Co(NH_3)_6]^{2+}(aq)$; hence the reduction process is not favoured. (accept: NH_3 ligand stabilises Co^{3+} much more than Co^{2+})

(iv) From the formula of $[Co(SCN)_4]^{2-}$, the mole ratio of Co^{2+} to SCN^- = 1 : 4.

The sketch has an <u>inverted V shape</u> and shows a <u>maximum absorbance</u> at volume of $CoCl_2$ = <u>2.0 cm^3</u>.

(v) The stated equilibrium is endothermic, i.e. ΔH is positive.

3(a)



By Hess' Law,

$\Delta H_f = 2(414) + 2(762 + 1560 + 2960) + 3/2\ (496) + 3\ (-141) + 3\ (844) + L.E.$

$L.E. = -\ 1.51 \times 10^4\ kJ\ mol^{-1}$

(b)

- As the CN^- ligand approach the iron ion, the degenerate **d-orbitals split** into two energy levels, giving rise to a ΔE, that corresponds to the visible light region of the electromagnetic spectrum.
- In a partially filled d-orbitals, an electron from the lower energy level d-orbital will absorb energy corresponding to ΔE and get **promoted** up to the vacant higher energy level d-orbital.
- The color of the iron compounds is the **complementary color** to the one absorbed.

(c)

[R] $FeO_4^{2-}(aq) + 8H^+(aq) + 3e \rightleftharpoons Fe^{3+}(aq) + 4H_2O(l)$ +2.00 V

[O] $Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$ +1.33 V

$E^{\ominus}_{cell} = +2.00 - (+1.33) = +0.67\ V > 0$

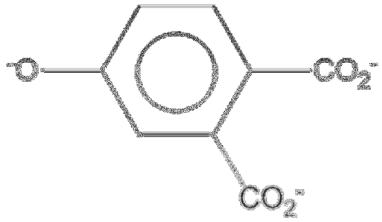
Overall equation:

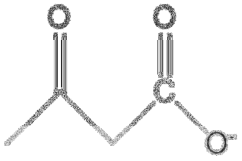
$2FeO_4^{2-} + 2Cr^{3+} + 2H^+ \rightarrow 2Fe^{3+} + Cr_2O_7^{2-} + H_2O$

Observation:

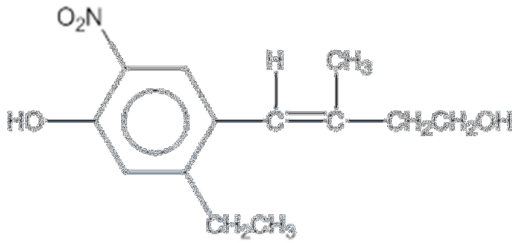
The resultant solution should be yellowish-orange

(d)(i)

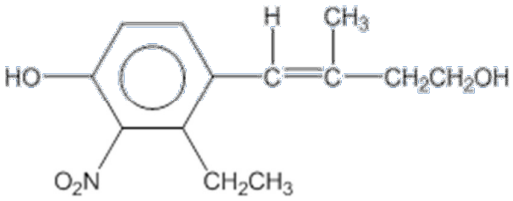




(ii)

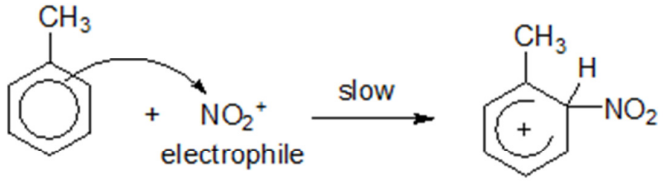


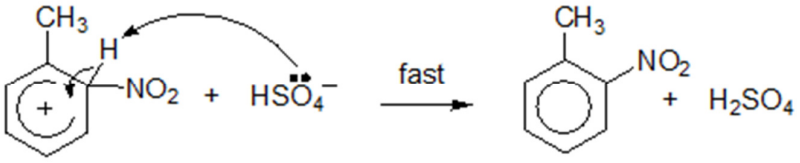
OR



(e) Electrophilic substitution

$$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+ \quad \text{(not required)}$$





4 (a) Phosphorus burns vigorously in O_2 to give a **bright flame**, forming a **white solid**.

$4P(s) + 3O_2(g) \rightarrow P_4O_6(s)$ or $4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$

Accept P_4 in these equations

(b)

$$P_4O_6(s) + 6HCl(g) \xrightarrow{(+177)} 2H_3PO_3(l) + 2PCl_3(g)$$

$(+729)$ $+6\ H_2O$ ↘ ↙ $(2x)$ $+6\ H_2O$

$$4\ H_3PO_3(l) + 6\ HCl(g)$$

Let x be the ΔH_{rxn} for the reaction of PCl_3 with steam

By Hess' Law,

$+177 = +729 - 2x$

$x = +276\ kJ\ mol^{-1}$

(c) Energy released in bond formation for structure **B**

$= 322 + 544 + 2(335) + 2(460)$

$= 2456\ kJ\ mol^{-1}$

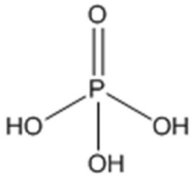
Energy released in bond formation for structure **C**

$= 3(335) + 3\ (460)$

$= 2385\ kJ\ mol^{-1}$

Structure **B** is more likely to be formed as more energy is released during bond formation. (accept if student only compares forming P=O and P–H with forming P–O and O–H bonds)

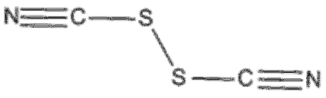
(d)(i)



(ii) The electron withdrawing effect of oxygen in P=O in H_3PO_4 is spread out over three OH groups as compared to two OH groups in H_3PO_3.

5(a)(i)

(ii)

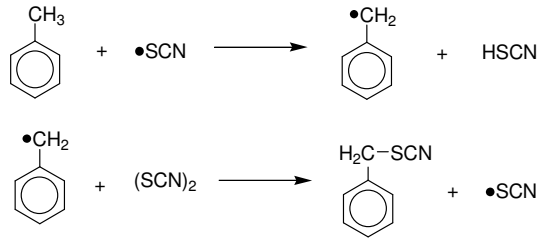


(iii) $Cl_2 + 2NaSCN \rightarrow 2NaCl + (SCN)_2$

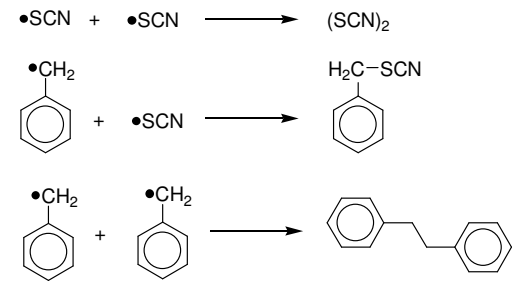
(b)(i)

Initiation $(SCN)_2 \xrightarrow{uv} 2\ \bullet SCN$

Propagation

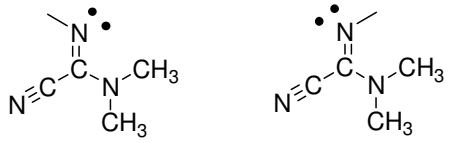


Termination

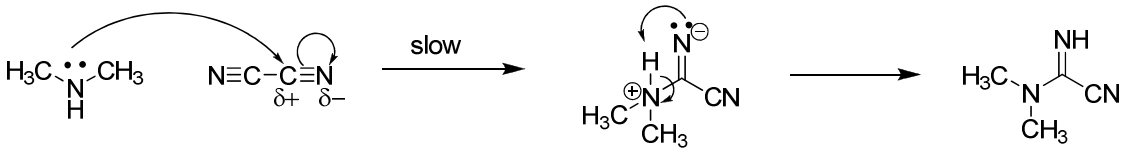


(ii) Delocalization of electrons in the thiocyanate radical allows an isomer, the isothiocyanate radical, S=C=N •, to be formed, resulting in such a side product.

(c)(i)



(ii) Nucleophilic Addition



(iii) Cyanide can act as a **ligand that binds irreversibly to haemoglobin** in blood. This reduces the amount of oxygen-carrying haemoglobin in the body.