HWA CHONG INSTITUTION
2019 C2 H2 CHEMISTRY PRELIMINARY EXAM
SUGGESTED SOLUTIONS

Paper 4

1 (a) (i)

- Tabulates volumes and temperature data in **(a)(i)**
  Table should contain correct headers and units. Data headers to include volume of **FA 1,** volume of **FA 2**, T_{FA1}, T_{max} and ΔT. **[1]**

Volume of **FA 1** / cm^3	Volume of **FA 2** / cm^3	$T_{FA\,1}$ / °C	T_{max} / °C	ΔT / °C
10.0	40.0	32.0	36.0	4.0
20.0	30.0	32.0	39.5	7.5
25.0	25.0	32.0	41.5	9.5
30.0	20.0	32.0	41.0	9.0
35.0	15.0	32.0	38.5	6.5
40.0	10.0	32.0	36.0	4.0

- Complete 6 sets of volume/temperature readings in **(a)(i)**
  Required volumes: Volume of **FA 1** = 10.0 cm^3, 20.0 cm^3, 25.0 cm^3, 30.0 cm^3, 35.0 cm^3 and 40.0 cm^3
  and
  use appropriate volume of **FA 2** such that the total volume of reacting mixture in each set of data is 50 cm^3 **[1]**

- Records all temperature data in **(a)(i)** to 0.5°C,
  all volumes for **FA 1** and **FA 2** in **(a)(i)** to 1 d.p. **[1]**

- Correctly calculates all ΔT values to 1 d.p. in **(a)(i)** **[1]**

(a) (ii)

- Axes correct way round **and** correct labels **and** units **and** scale **[1]**
  Note: Scale chosen must allow for the lines to be extrapolated to cross each other. The plotted points should occupy at least half the grid in both directions.

- All points are correctly plotted to within ± ½ small square. **[1]**
- All drawn graph lines are <u>straight</u> best-fit lines and are extrapolated to cross each other.
  and
  there are at least three points on each side of the graphically determined ΔT_{max}
  [1]

(a) **(iii)** $\Delta \boldsymbol{T}_{\mathbf{max}}$ and $\boldsymbol{V}_{\mathbf{max}}$ are read correctly to ± ½ small square from graph

From the sample graph, $\Delta \boldsymbol{T}_{\mathbf{max}} = 10.4\ ^\circ\text{C}$ $\boldsymbol{V}_{\mathbf{max}} = V(H_2SO_4) = 27.25\ \text{cm}^3$

[1]

(b) **(i)** $H_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2\ H_2O$

$V(NaOH) = 50.0 - 27.25 = 22.75\ \text{cm}^3$
$n(NaOH) = 1.50 \times (22.75/1000) = 0.03413\ \text{mol}$

$n(H_2SO_4) = 0.03413 / 2 = 0.01706\ \text{mol}$
$[H_2SO_4] = 0.01706 / (27.25/1000) = 0.626\ \text{mol dm}^{-3}$ **[1]**

(ii) Heat change = $m_{\text{solution}} c \Delta \boldsymbol{T}_{\mathbf{max}} = 50.0 \times 4.18 \times 10.4 = 2174\ \text{J}$ **[1]**

(c) $n(H_2O) = n(NaOH) = 0.03413\ \text{mol}$
$\Delta \boldsymbol{H}_{\mathbf{neut}} = -\ 2174 / 0.03413 = -\ 6.37 \times 10^4\ \text{J mol}^{-1} = -\ 63.7\ \text{kJ mol}^{-1}$ (Sign must be negative) **[1]**

(d) $\Delta \boldsymbol{H}_{\mathbf{neut}}$ would be <u>less exothermic</u> as malonic acid is a <u>weak acid</u>. <u>Energy is absorbed</u> to <u>ionise</u> the un-ionised weak acid. **[1]**

(e) Suggested sources of errors **and** its appropriate improvements: **[1]**

heat loss to the surrounding **and** use a cup lid to minimise heat exchange with the surrounding air

$V_{\mathbf{FA\,1}}$ and $V_{\mathbf{FA\,2}}$ is to 1 d.p. as measured using less precise measuring cylinders **and** can be measured using more precise burettes to give 2 d.p.

initial temperature of **FA 2** was not accounted for **and** weighted initial temperature should be calculated where

$$\boldsymbol{T}_{\textbf{weighted initial}} = \frac{(\text{Volume of } \textbf{FA 1} \times T_{\mathbf{FA1}}) + (\text{Volume of } \textbf{FA 2} \times T_{\mathbf{FA2}})}{\text{Volume of } \textbf{FA 1} + \text{Volume of } \textbf{FA 2}}$$

heat capacity of the calorimeter (Styrofoam cup) was not accounted for **and** heat absorbed by the styrofoam cup can be included in the calculation of heat change

2 **(a)**

Mass of weighing bottle and **FA 3** / g	
Mass of weighing bottle and residual **FA 3** / g	
Mass of **FA 3** used / g	

Tables have correct **headers and units** (*included in the header or with <u>each entry</u> in the table*) **[1]**

(b) Effervescence observed. **[0.5]**
and
Yellow / greenish yellow / yellow green solution turned colourless / very pale green. **[0.5]**

(c) (i)

Final burette reading / cm^3	
Initial burette reading / cm^3	
Volume of **FA 4** used / cm^3	

- Tables have correct headers and units (included in the header or with each entry in the table) **[1]**
  Note: Mark is lost if any final and initial burette readings are inverted or 50 is used as the initial burette reading.

- All mass reading in **(a)** are recorded to the nearest **0.01 g** and burette readings & volume used for all accurate titres in the titration table are recorded to the nearest **0.05 cm^3**. **[1]**

- At least two uncorrected titres for end-point within ±0.10 cm^3. **[1]**

(c) (ii)
- Student obtains average titre, to **2 d.p.**, from any experiments with end-point titre values within 0.10 cm^3 **[1]**

Mark is lost if there are arithmetic errors in the table.
Mark is lost if the titres used are not identified either in the table (by, for example, a tick) or in a calculation.

- Accuracy

  Supervisor's $V_{FA\ 4}$ / $m_{FA\ 3}$ = 1.530
  Difference between student's and supervisor's $V_{FA\ 4}$ / $m_{FA\ 3}$
  If difference is ≤ **0.045 cm^3 g^{-1}** **[2]**
  If difference is **> 0.045** but ≤ **0.075 cm^3 g^{-1}** **[1]**
  For a difference **> 0.075** **[0]**

(d) (i) If $V_{FA\ 4}$ = 10.10 cm^3

$\eta(Fe^{2+}) = 10.10 \times 10^{-3} \times 0.020 \times 5 = 1.01 \times 10^{-3}$ mol (3 s.f) **[1]**

(d) (ii) $\eta(Fe^{3+}) = 1.01 \times 10^{-3} \times 250 / 10.0 = 0.0253$ mol (3 s.f) **[1]**

(d) (iii) $m_{\mathbf{FA\ 3}}$ = 6.60 g

Mole ratio of $Fe_2(SO_4)_3.nH_2O$: Fe^{3+} = 1 : 2

Number of moles of $Fe_2(SO_4)_3.nH_2O$ = 0.0253 ÷ 2 = 0.01265 mol

M_r of $Fe_2(SO_4)_3.nH_2O$ = 6.60 / 0.01265 = 521.7 **[1]**

$n = \{521.7 - [2(55.8) + 3(32.1) + 12(16.0)]\} \div 18.0$
$= 7$ (nearest whole number) **[1]**

- Shows working in **1(b)(i)**, **1(b)(ii)**, **1(c)**, **2(d)(i)**, **2(d)(ii)** and **2(d)(iii)**. All calculations must be relevant although they may not be complete or correct. ***Any calculation not attempted loses this mark.*** **[1]**

- Shows appropriate significant figures (3 or 4 sf) in all final answers (in the blank) in **1(b)(i)**, **1(b)(ii)**, **1(c)**, **2(d)(i)** and **2(d)(ii)**. For **2(d)(iii)**, M_r can be given to 1 d.p. or 3 s.f. but n should be given as a whole number. ***Any calculation not attempted loses this mark.*** **[1]**

- Shows appropriate units in all final answers (in the blank) in **1(a)(iii)** (°C, cm^3), **1(b)(i)** (mol dm^{-3}), **1(b)(ii)** (J or kJ), **1(c)** (J mol^{-1} or kJ mol^{-1}), **2(c)(ii)** (cm^3), **2(d)(i)** (mol), **2(d)(ii)** (mol). Units should not be given for M_r or n in **2(d)(iii)**. ***Any calculation not attempted loses this mark.*** **[1]**

(e) Effervescence was observed as zinc reacted with acid to form H_2 gas. **[0.5]**

Yellow solution turned colourless / very pale green as Fe^{3+} was reduced to Fe^{2+}. **[0.5]**

(f) Zinc metal that is not removed will continue to reduce Fe^{3+} formed during the titration to Fe^{2+}, resulting in a higher than expected titre. **[1]**

3 (a)

$$K_c = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^{-}]}$$ **[1]**

(b) no. of moles of $FeSCN^{2+}$ formed $\approx$ no. of moles of SCN^- added

$= 2.00 \times 10^{-3} \times (5/1000) = 1.00 \times 10^{-5}$ mol

$[FeSCN^{2+}] = (1.00 \times 10^{-5})/(10/1000) = 1.00 \times 10^{-3}$ mol dm^{-3} **[1]**

Large excess of Fe^{3+} is used to drive the equilibrium **almost completely** to the right. **[1]**
Hence, the amount of $FeSCN^{2+}$ produced will be essentially equal to the amount of SCN^- added.

(c) **Procedure** (sample answer)

1. Using separate burettes, transfer 5.00 cm^3 of $Fe(NO_3)_3$ and 5.00 cm^3 of KSCN into a boiling tube. Stopper and shake to ensure a homogeneous solution.
2. Rinse and fill a cuvette with 3 cm^3 of the mixture.
3. Place the cuvette in a thermostatically controlled water bath maintained at 50 °C for about 5 min.
4. Measure and record the temperature of the solution using a thermometer.

5. Remove the cuvette from the water bath, and immediately measure and record the absorbance (at wavelength of blue light 447 nm) using a spectrophotometer.
6. Repeat steps 3 – 5 at 40 °C, 30 °C, 20 °C and 10 °C.
   or
   Repeat steps 2 – 5 (total volume must then be at least $5\times3=15$ cm^3) at 40 °C, 30 °C, 20 °C and 10 °C.

M1 – Logical sequence [1] (minus ½ mark for each missing point)

- Mixing known volumes of $Fe(NO_3)_3$ and KSCN, amount of Fe^{3+} not more than 10 times of SCN^-, total volume > 3 cm^3
- Measure (and record) the temperature of the mixture
- Measure (and record) the absorbance of the mixture

M2 – Apparatus [1] (½ mark for each point)

- separate burettes for $Fe(NO_3)_3$ and KSCN (or other precise apparatus e.g. micropipette or pipette)
- thermostatically controlled water bath

M3 – Essential details [1] (½ mark for each point)

- Shake boiling tube / test-tube/ swirl conical flask (with stopper) or stir beaker (with glass rod)
- Allow time for the mixture to equilibrate in the water bath (e.g. 5 - 10 min) **and** measure absorbance immediately

M4 – Choice of temperatures [1] (½ mark for each point)

- at least 5 different temperatures
- with at least 5 °C difference, 0 °C < T < 100 °C

M5 and M6 – Treatment of results [2] (½ mark for each point)

- use calibration line to determine $[FeSCN^{2+}]$ (accept if show how on calibration line)
- correct $[Fe^{3+}]_{initial}$ and $[SCN^-]_{initial}$
- correct $[Fe^{3+}]_{eqm}$ and $[SCN^-]_{eqm}$; ecf from initial conc
- correct expression for K_c in terms of $[FeSCN^{2+}]_{eqm}$; ecf from eqm conc

Sample answer:

For each absorbance obtained, read off the calibration line to determine the corresponding $[FeSCN^{2+}]$ at each temperature.

	Fe^{3+}	+	SCN^-	$\rightleftharpoons$	$FeSCN^{2+}$
initial / mol dm^{-3}	$\frac{2\times10^{-3}\times5}{10}$ $= 1.00\times10^{-3}$		$\frac{2\times10^{-3}\times5}{10}$ $= 1.00\times10^{-3}$		0
change / mol dm^{-3}	– x		– x		+ x
eqm / mol dm^{-3}	0.001 – x		0.001 – x		$[FeSCN^{2+}]$ = x

$K_c = \frac{x}{(0.001-x)^2}$

(d) (i)

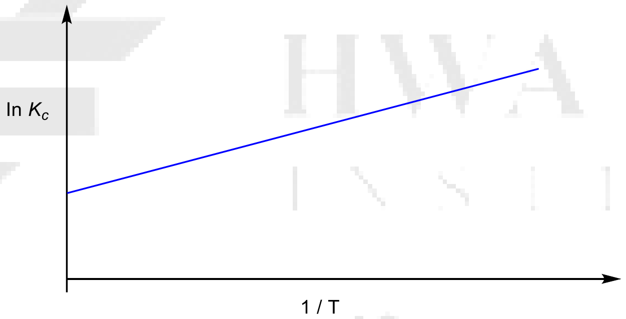

Fig. 3.1 **[1]**

Compare the equation given to y = mx + c, <u>gradient = −Δ*H* / *R*</u>.
As <u>Δ*H* < 0</u> and *R* > 0, <u>gradient is positive</u> **[1]**

Accept correct explanation using LCP.
Mark for explanation may be lost if graph is incorrect.

(d) (ii) gradient = Δy / Δx = −Δ*H* / *R*
Hence, <u>Δ*H* = − gradient × *R*</u> = − gradient × 8.31 **[1]**

y-intercept = Δ*S* / *R*
Hence, <u>Δ*S* = y-intercept × *R*</u> = y-intercept × 8.31 **[1]**

Correct expressions for Δ*H* and Δ*S* (i.e. both must be the subject). Accept correct descriptions instead of expressions.

4 (a)

1. <u>Black/dark brown/grey</u> residue obtained.
2. <u>Brown/orange/yellow</u> filtrate obtained.
3. <u>Off-white/light brown/yellow/orange ppt</u> formed i<u>nsoluble</u> in excess NaOH(aq). (REJECT: brown ppt).
4. Off-white ppt which turned <u>brown/darkened</u> on standing (must appear at least once either with NaOH(aq) or NH_3(aq)).
5. <u>Off-white/light brown/yellow/orange ppt</u> formed i<u>nsoluble</u> in excess NH_3(aq) (insoluble must appear at least once in point 3 or 5).

(c)

6. <u>Effervescence</u> observed (REJECT: gas evolved).
7. Gas <u>relit glowing splint</u>.

(f)

8. Solution turned <u>green</u>
9. Then <u>darker green</u>.
10. Dark <u>blue</u>/dark <u>green</u>/<u>blue-green</u> residue obtained.
11. <u>Colourless</u> filtrate.

(g)

12. <u>Purple/Pink</u> filtrate obtained.
13. Residue turned <u>brown/black/grey</u> (must show a change in colour from point 10)

Observation points
11 – 13 = 6 marks
9 – 10 = 5 marks
7 – 8 = 4 marks
5 – 6 = 3 marks
3 – 4 = 2 marks
1 – 2 = 1 mark
0 = 0 mark **[6]**

(b) Oxidising agent **[1]**
Evidence 1: Since a brown/orange/yellow solution is formed that decolourises with $S_2O_3^{2-}$, I^- was oxidised to I_2. **[½]**
Evidence 2: MnO_2 was reduced to Mn^{2+}, as seen by the off-white/light brown ppt formed with NaOH(aq) that darkened on standing. **[½]**

(d) Since there was no ppt with NaOH(aq), MnO_2 was not reduced to Mn^{2+} or an off-white ppt will be formed, hence it is not acting as an oxidising agent. **[1]**

(e) Heterogeneous catalyst **[½]**
Since there was brisk effervescence, it indicates that rate of decomposition of H_2O_2 is faster. **[½]**

(h) **X**: MnO_2 **[½]**
Y: MnO_4^- **[½]** (no credit if colour of filtrate is not correct)

(i) $BaSO_4$. **[1]**