2023 H2 Chemistry Preliminary Exams Paper 4 – Suggested Solutions

Qn 1

(a)

Expt	Volume of **FA 1** / cm^3	Volume of deionised water / cm^3	*t* / s	part **(c)** rate / mol dm^{-3} s^{-1}
1	5.0	25.0	29.0	2.46×10^{-5}
2	8.0	22.0	16.2	4.41×10^{-5}
3	11.0	19.0	12.2	5.85×10^{-5}
4	15.0	15.0	9.4	7.60×10^{-5}

(b) Amount of $S_2O_3^{2-}$ added = $0.00500 \times \frac{20}{1000} = 1.000 \times 10^{-4}$ mol

Amount of I_2 reacted with $S_2O_3^{2-}$ added = $\frac{1}{2} \times 1.000 \times 10^{-4}$

= $\underline{5.00 \times 10^{-5}}$ mol

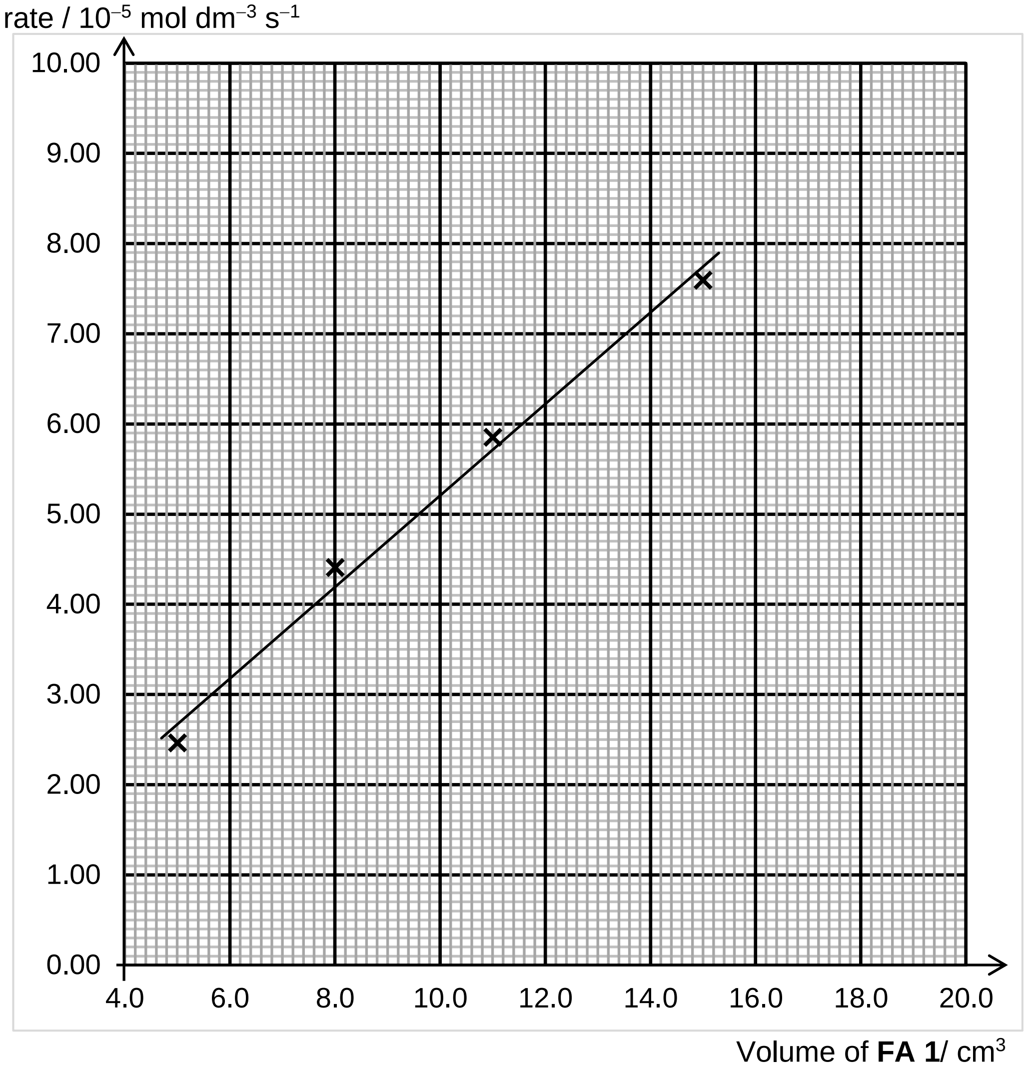
= Amount of I_2 produced just before the first appearance of blue-black colour

Concentration of I_2 in reaction mixture = $5.00 \times 10^{-5} \div \frac{70}{1000}$

= $\underline{7.14 \times 10^{-4}}$ mol dm^{-3}

(c) See table in part **(a)**.

(d)(i)



(d)(ii) Since total volume of reaction mixture is kept constant, volume of **FA 1** is directly proportional to [Fe^{3+}] in the mixture. Since the graph is a straight line with a positive gradient, rate is directly proportional to [Fe^{3+}], the reaction is first order with respect to Fe^{3+}.

(e) Agree with student. The reaction time would be longer since more time is required to produce more iodine to react with the larger amount of thiosulfate ions present, and so the percentage error is reduced.

(f)(i) rate = $k[Fe^{3+}][I^-]^2$

(f)(ii) From the slow step, the rate equation is: rate = $k'[[FeI]^{2+}][I^-] = k[Fe^{3+}][I^-]^2$.
This matches the rate equation for the reaction. Hence the proposed mechanism is consistent with the observed kinetics data.

Qn 2

(a)(i)

Table 2.1

	test	observations
1	Test solution **FA 4** with Universal Indicator paper.	UI paper turned orange, pH is 3
2	To 1 cm depth of **FA 4** in a clean test-tube, add 1 cm depth of aqueous sodium carbonate.	White ppt formed. Effervescence observed. CO_2 gas evolved gave a white ppt in limewater.
3	Add 1 cm depth of **FA 4** into a clean test-tube. Add aqueous sodium hydroxide, slowly with shaking, until no further change is seen.	White ppt. formed, soluble in excess NaOH(aq) to give a colourless solution.

(a)(ii) **Cation:** Al^{3+}

Evidence:
In test 2, **FA 4** reacted with Na_2CO_3 to form a white ppt of $Al(OH)_3$ together with the effervescence of CO_2 gas.
OR
From test 1 / test 2, **FA 4** contained an acidic ion. Additionally, in test 3, **FA 4** reacted with NaOH to form a white ppt of $Al(OH)_3$ which was soluble in excess NaOH to form the colourless complex ion, $[Al(OH)_4]^-$.

(a)(iii)

test	observations
To 1 cm depth of **FA 4**, add a few drops of $AgNO_3$.	No ppt / No observable change
To 1 cm depth of **FA 4** in a boiling tube, add 1 cm depth of aqueous NaOH and a piece of Al foil. Heat cautiously.	White ppt formed, soluble in excess NaOH to form a colourless solution. Effervescence of H_2 was observed. Upon heating, pungent NH_3 evolved turned damp red litmus paper blue.

(a)(iv) Anion: NO_3^-

(b)(i)

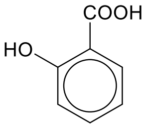
Table 2.2

	test	observations
1	To 1 cm depth of neutral iron(III) chloride, add 10 drops of **FA 5** and shake the test-tube. This solution is **FA 6**. Proceed to test 2 using this solution.	Solution turned violet.

2	To the solution of **FA 6,** add aqueous sodium hydroxide dropwise, with shaking, until no further change is seen.	Violet solution decolourised. Red-brown ppt formed, insoluble in excess NaOH(aq).

(b)(ii) Phenol

(b)(iii)



(b)(iv) $[Fe(H_2O)_6]^{3+} + L^{2-} \rightleftharpoons [Fe(H_2O)_4L]^{+} + 2H_2O$

(b)(v) When NaOH was added, the red-brown ppt of $Fe(OH)_3$ was formed. Thus, the concentration of $[Fe(H_2O)_6]^{3+}$ decreases and the position of equilibrium of the equation in **(iv)** shifted to the left, decreasing the concentration of $[Fe(H_2O)_4L]^{+}$ and causing the violet solution to decolourise.

Qn 3

(a)(i)

Dilution of FA 7

Final burette reading / cm^3	30.50
Initial burette reading / cm^3	0.00
Volume of **FA 7** used / cm^3	30.50

Titration results

Titration number	1	2
Final burette reading / cm^3	24.20	24.20
Initial burette reading / cm^3	0.00	0.00
Volume of **FA 8** used / cm^3	24.20	24.20
Values used (✓)	✓	✓

(a)(ii) Average volume of **FA 8** used = $\frac{24.20 + 24.20}{2}$ = $\underline{24.20\ cm^3}$ (2 d.p.)

(b)(i) Amount of MnO_4^- ions = $\frac{24.20}{1000}$ x 0.00500 = $\underline{1.21 \times 10^{-4}\ mol}$ (3 s.f.)

(b)(ii) Amount of Fe^{2+} ions in 250 cm^3 of **FA 10**
= $1.21 \times 10^{-4} \times 5 \times \frac{250}{25.0}$
= $\underline{6.05 \times 10^{-3}\ mol}$ (3 s.f.)

(b)(iii) Amount of Fe^{2+} ions in 250 cm^3 of **FA 7** = $6.05 \times 10^{-3} \times \frac{250}{30.50}$
= 0.04959 mol
= $\underline{0.0496\ mol}$ (3 s.f.)

(b)(iv)

Either	Or
Amount of FeO in magnetite = 0.04959 mol	Amount of magnetite, Fe_3O_4 = 0.04959 mol
Mass of FeO = 0.04959 x (55.8 + 16.0) = 3.5606 g	Mass of magnetite in sample **A** = 0.04959 x (3(55.8) + 4(16.0)) = 11.4752 g
Amount of Fe_2O_3 in magnetite = 0.04959 mol	

Mass of Fe_2O_3 = 0.04959 x (2(55.8) + 3(16.0)) = 7.9146 g Mass of magnetite in sample **A** = 3.5606 + 7.9146 = 11.4752 g	

Percentage by mass of magnetite in sample **A**
$= \frac{11.4752}{15.0} \times 100$
= <u>76.5%</u> (3 s.f.)

(c)(i) $E^\ominus_{cell} = +1.33 - (0.77) = +0.56$ V
Since $E^\ominus_{cell}$ is > 0, reaction is feasible.

(c)(ii) The titration result may be inaccurately determined as the <u>end-point colour change is not distinct</u>. It is difficult to detect one drop of excess orange $K_2Cr_2O_7$ solution in a yellow-green solution (containing Fe^{3+} & Cr^{3+}).

(d)(i) Percentage error $= \frac{6.03-5.95}{6.03} \times 100 = 1.33\%$

(d)(ii) The student performed the experiment <u>well</u> as the <u>calculated percentage error is less than the maximum percentage error</u> of the whole experimental procedure.

Qn 4

(a) Let V cm^3 be the volume of solution **B** (containing Al^{3+}) and (60.0 − V) cm^3 be the volume of solution **Z** (containing Na^+) used at which stoichiometric amount of Al^{3+} and Na^+ react.

Amount of Al^{3+} in V cm^3 of solution **B**
= Amount of Na^+ in (60.0 − V) cm^3 of solution **Z**

$\frac{V}{1000} \times 0.120 = \frac{60 - V}{1000} \times 0.075$
$0.120V = 4.5 - 0.075V$
$V = 23.1$ cm^3

Approximate equivalence volume of solution **B** = 23.1 cm^3

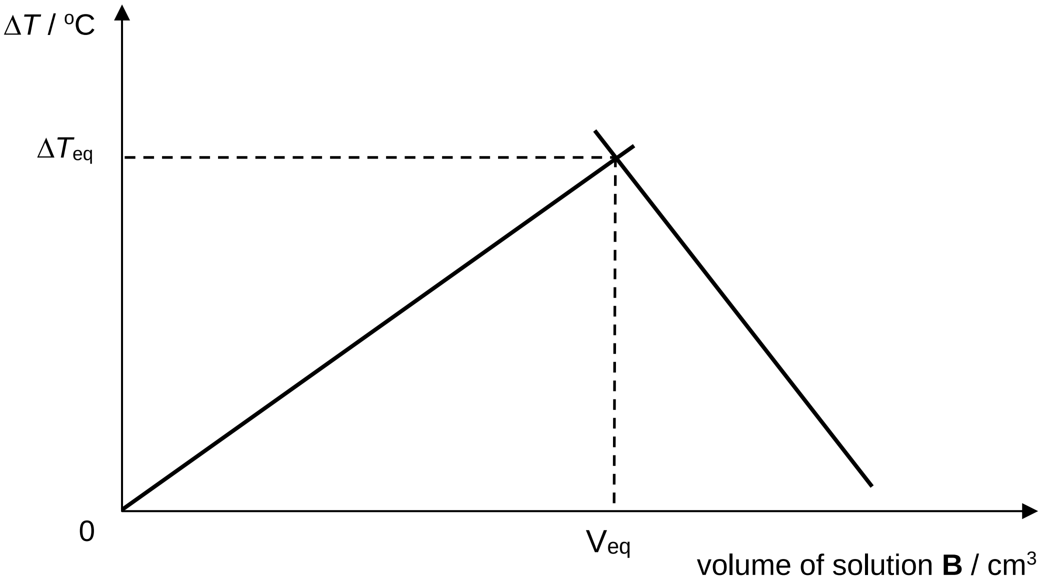
(b)

Experiment	volume of solutions added / cm^3		initial temperature of solution **Z** / °C	highest temperature of resultant solution / °C	ΔT / °C
	Z	**B**			
1	50.0	10.0			
2	45.0	15.0			
3	42.0	18.0			
4	40.0	20.0			
5	38.0	22.0			
6	36.0	24.0			
7	34.0	26.0			
8	30.0	30.0			
9	25.0	35.0			
10	20.0	40.0			

<u>Procedure</u>

1. Using a 50 cm^3 measuring cylinder, measure 50.0 cm^3 of solution **Z** into a clean and dry Styrofoam cup supported in a 250 cm^3 beaker.
2. Use a thermometer to measure and record the steady initial temperature of solution **Z**.
3. Using another 50 cm^3 measuring cylinder, measure 10.0 cm^3 of solution **B**.
4. Add solution **B** from the measuring cylinder to solution **Z** in the cup, use the thermometer to stir the mixture gently. Measure and record the highest temperature of the resultant solution.
5. Empty, wash and carefully dry the cup.
6. Repeat steps 1 to 5 using volumes of solution **Z** and solution **B** in the table above so that the total volume of the mixture is 60.0 cm^3.
7. Record the temperature increase, ΔT, for each experiment by taking highest temperature – initial temperature.

(c)



(d) Stoichiometric amount of Al^{3+} to react with Na$^+$

$$= \frac{V_{eq}}{1000} \times 0.120 \text{ mol}$$

= Amount of Na$^+$

$$[\text{Na}^+] = \frac{\frac{V_{eq}}{1000} \times 0.120}{\frac{60.0 - V_{eq}}{1000}}$$

$$= \frac{0.120\, V_{eq}}{(60.0 - V_{eq})} \text{ mol dm}^{-3}$$

$$q = \frac{60.0 \times 4.18 \times \Delta T_{eq}}{1000} \text{ kJ}$$

$$\Delta H_{\text{reaction}} = -\frac{\frac{60.0 \times 4.18 \times \Delta T_{eq}}{1000}}{\frac{V_{eq}}{1000} \times 0.120}$$

$$= -\frac{2090\, \Delta T_{eq}}{V_{eq}} \text{ kJ mol}^{-1}$$