2024 JC 2 H2 Chemistry 9729 Prelim Exam Paper 4

Suggested Solutions

1 (a)

Titration number	1	2
Final burette reading /cm ³	25.05	25.15
Initial burette reading /cm ³	0.00	0.00
Volume of FA 2 (added) /cm ³	25.05	25.15

(b) average volume of **FA 2** used =
$$\frac{25.05 + 25.15}{2}$$

= 25.10 cm³

volume of **FA 2** used =25.10 cm³.....

(c) (i) amount of MnO₄⁻ used =
$$\frac{25.10}{1000} \times 0.010$$

= 2.51×10^{-4} mol

amount of $MnO_4^- = \dots 2.51 \times 10^{-4} \text{ mol} \dots$

(ii) amount of Fe²⁺ in 25.0 cm³ of FA 4 =
$$2.51 \times 10^{-4} \times 5$$

= 1.255×10^{-3}
= 1.26×10^{-3} mol

amount of Fe^{2+} =1.26 × 10⁻³ mol.....

(iii) amount of Fe²⁺ in 250 cm³ of **FA 4** = $1.255 \times 10^{-3} \times \frac{250}{25.0}$

concentration of Fe²⁺ in **FA 1** =
$$\frac{1.255 \times 10^{-2}}{\frac{25.0}{1000}}$$

 $= 0.502 \text{ mol dm}^{-3}$

concentration of $Fe^{2+} = \dots 0.502 \text{ mol } dm^{-3} \dots$

(iv) Mass of $Fe(NO_3)_2$ in 1 dm³ of **FA 1** = 0.502 × (55.8 + 2(14.0) + 6(16.0))

= 90.26 g Percentage by mass of Fe(NO₃)₂ = $\frac{90.26}{125.4} \times 100\%$ = 72.0%

percentage by mass of $Fe(NO_3)_2 = \dots 72.0\%$

(d) The titre value will be <u>lower</u>, because <u>some of the Fe²⁺ in **FA 1** would have been oxidised to Fe³⁺. Hence, less Fe²⁺ would be available for titration with KMnO₄.</u>

Note: Sulfuric acid is added to prevent the oxidation of Fe^{2+} to Fe^{3+} .

- (e) (i) In the titration of Fe²⁺(aq) with MnO₄⁻(aq) in acidic medium, <u>vellow Fe³⁺(aq) and colourless Mn²⁺(aq) are formed</u>. The end-point is reached when <u>one excess drop of purple MnO₄⁻(aq)</u> is added, turning the solution from yellow to orange.
 - (ii) There is <u>no distinct/visible/significant colour change at the end-point</u>. Hence, it would be impossible to know when the reaction is completed.

OR

 H_2O_2 undergoes <u>disproportionation/ decomposition</u>, hence a higher volume of titrant will required.

OR

<u>Fe²⁺/Fe³⁺</u> present in the solution <u>catalyses the decomposition of H_2O_2 .</u>

- (f) (i) % uncertainty in pipette = $\frac{0.06}{25.0} \times 100\% = 0.240\%$ % uncertainty in burette = $\frac{0.05 + 0.05}{29.70} \times 100\% = 0.337\%$ % uncertainty in measuring cylinder = $\frac{0.25}{25.00} \times 100\% = 1.00\%$
 - (ii) Burette

Note: Measuring cylinder is not considered as **FA 3** is added in excess.

2 (a)

Expt	V _{FA 6} /cm ³	V _{H20} /cm ³	Reaction time, t /s	Ig(V _{FA 6})	lg (rate)
1	20.00	0.00	17.8	1.30	1.75
2	10.00	10.00	63.9	1.00	1.19
3	13.00	7.00	39.1	1.11	1.41
4	17.00	3.00	24.6	1.23	1.61

(b)

(c)

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gradient =1.87.....

m =2.....

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(ii) From graph, when lg(12.30) = 1.09,

$$lg(\frac{1000}{\text{reaction time}}) = 1.36$$

reaction time = $\frac{1000}{10^{1.36}} = 43.7$ s

reaction time =43.7 s.....

(d) (i)

expt	volume of FA 5 /cm ³	volume of FA 6 /cm ³	volume of FA 7 /cm ³	volume of water /cm ³	reaction time /s
2	10	10	20	10	t_2
5	5	10	20	15	t ₅

(ii) <u>Halving the concentration (or volume) of Fe³⁺</u> will cause the <u>rate to be halved</u>. Since rate is inversely proportional to reaction time, time taken for experiment 5 will be double that of experiment 2, i.e. $t_5 = 2t_2$.

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

(iv) K_c for step 1 = $\frac{[FeI^{2+}]}{[Fe^{3+}][I^-]}$

Since FeI^{2+} is an intermediate, <u>rate = $k[FeI^{2+}][I^{-}] = kK_c[Fe^{3+}][I^{-}]^2 = k'[Fe^{3+}][I^{-}]^2$ </u>.

This matches the rate equation for the reaction, hence the proposed mechanism is consistent with the observed kinetics data.

(e) <u>Disagree</u> with student. The reaction time should be <u>shorter</u> since <u>less/ smaller amount of</u> <u>thiosulfate ions is present to react with iodine</u>.

3

Tests		Observations			
1.	Test the FA 9 solution using Universal Indicator paper.	FA 9 is an (dark) orange solution. $[\checkmark]$ UI paper turns orange. $[\checkmark]$ FA 9 has a pH of 2/3. $[\checkmark]$			
2.	To a 2 cm depth of FA 9 in a test tube, add a 2 cm depth of FA 10 and shake the mixture thoroughly. Observe the mixture until there is no further change.	Effervescence observed. $[\checkmark]$ Colourless and odourless gas evolved. Gas evolved rekindled a glowing splint. $[\checkmark]$ O ₂ (g) evolved. $[\checkmark]$ Test tube felt warm to touch. $[\checkmark]$			
3.	To a 2 cm depth of FA 9 in a boiling tube, add aqueous sodium hydroxide until there is no further change.	Red-brown ppt formed. Ppt was insoluble in exces NaOH(aq). [✓]			
	Warm the mixture obtained.	Colourless, pungent gas evolved. Gas evolved turned moist red litmus blue. [✓] NH ₃ (g) evolved. [✓]			
4.	To a 2 cm depth of FA 9 in a test tube, add aqueous sodium carbonate.	 (Red-/ orange-) brown ppt formed. [√] Bubbles of gas/ effervescence observed. [√] Colourless, odourless gas evolved. Gas evolved formed white ppt with limewater. [√] CO₂(g) evolved. [√] 			
5.	To a 2 cm depth of FA 9 in a test tube, add aqueous potassium thiocyanate, KSCN(aq).	Blood red/ deep red/ dark red colouration observed. [✓]			
6.	To a 2 cm depth of FA 9 in a test tube, add aqueous barium nitrate. Leave the mixture to stand for 5 minutes and discard the liquid. To the remaining solid, add dilute nitric acid.	White ppt formed. Ppt was insoluble in dilute nitric acid. [✓]			

(b) Fe³⁺.

 Fe^{3+} undergoes <u>hydrolysis</u> and forms <u>H₃O⁺</u>, resulting in an acidic solution.

(c)	Identity of ions	Supporting evidence
	NH4 ⁺	In test 3 , colourless and pungent $NH_3(g)$ evolved that turned moist red litmus blue.
	SO4 ²⁻	In test 6 , white ppt BaSO ₄ (s) formed that was insoluble in dilute nitric acid.

- (d) Ligand exchange reaction
- (e) Test: To 2 cm depth of FA 10 in a test tube, add acidified KMnO₄(aq).

Observations: Purple KMnO₄(aq) decolourises. Colourless, odourless gas evolved that rekindled a glowing splint.

Explanation: $E_{cell} = +1.52 - (+0.68) = +0.84 \text{ V} > 0$, hence reaction between MnO₄⁻ and H₂O₂ is spontaneous.

OR

Test: To 2 cm depth of FA 10 in a test tube, add acidified KI(aq).

Observations: Colourless KI(aq) turns brown/ black deposits formed.

Explanation: $E_{cell} = +1.77 - (+0.54) = +1.23 \text{ V} > 0$, hence reaction between H₂O₂ and KI is spontaneous.

OR

Test: To 2 cm depth of FA 10 in a test tube, add dilute HCl.

Observations: Greenish-yellow, pungent gas evolved that turned moist blue litmus red then bleached.

Explanation: $E_{cell} = +1.77 - (+1.36) = +0.41 \text{ V} > 0$, hence reaction between H_2O_2 and HCl is spontaneous.

4 (a)
NaOH(aq) +
$$\frac{1}{x}$$
 H_xA(aq) $\rightarrow \frac{1}{x}$ Na_xA(aq) + H₂O(I)

(b) Since varying volumes of **FA 11** and **FA 12** should be used for the series of experiments, the following combination of volumes can be chosen for the experiments:

Experiment	1	2	3	4	5	6
V _{FA 11} / cm ³	10	20	25	30	40	50
V _{FA 12} / cm ³	50	40	35	30	20	10

The total volume of the mixture should be kept constant for all experiments.

M45: suitability of volumes

- minimum 6 experiments
- total volume of mixture kept constant
- do not award if student fixes volume of either FA 11 or FA 12

Procedure:

- 1. Using a <u>50 cm³ measuring cylinder/ burette</u>, measure 10.0 cm³ of **FA 11** into a styrofoam cup supported in a 250 cm³ beaker.
- 2. Using a thermometer, measure and record the initial temperature of FA 11, T_{FA11}.
- 3. Using another <u>50 cm³ measuring cylinder</u>, measure 50 cm³ of **FA 12**.
- 4. Measure and record the <u>initial temperature of FA 12</u>, T_{FA12} .
- 5. Calculate the <u>average initial temperature</u>, T_{average} .
- 6. Add **FA 12** from the measuring cylinder into the styrofoam cup, <u>cover with the lid</u> and <u>stir</u> the mixture using the thermometer.
- 7. Measure and record the <u>maximum temperature</u> reached, T_{max} .
- 8. Calculate $\Delta T = T_{max} T_{average}$ for each experiment.
- 9. <u>Wash</u> and <u>dry</u> the styrofoam cup.
- 10. <u>Repeat</u> steps 1-8 for <u>five</u> further volumes of **FA 11** and record all volumes and temperatures in a table. The <u>total volume of the mixture should be kept constant</u>.
- 11. Plot a graph of ΔT against V_{FA 12}.

M46: apparatus

- 50 cm³ / 100 cm³ measuring cylinder/ burette for solution in styrofoam cup
- 50 cm³ / 100 cm³ measuring cylinder for solution to be added (no direct addition; accept burette into beaker)
- Thermometer (can be presented in diagram)
- Styrofoam cup with lid (can be presented in diagram)

M47: measurements

- Initial *T* of **FA 11** and **FA 12**
- T_{average} and T_{max}
- Show $\Delta T = T_{max} T_{average}$

M48: experimental details

- stir
- use of clean and dry styrofoam cup
- repeat procedure

Graph:



M49: graphs

- 2 clearly labelled graphs with higher ΔT for dibasic acid
- straight line passing through origin
- graph lines should not extend beyond intersection point (unless in dotted lines)
- both graphs should meet at the same highest V_{FA 12}
- do not award if student fixes volume of either FA 11 or FA 12

M50: V_{eq}

- V_{eq} (dibasic) = $\frac{Vtotal}{3}$
- V_{eq} (monobasic) = $\frac{Vtotal}{2}$
- do not award if student fixes volume of either FA 11 or FA 12

Explanation:

Before the equivalence point, FA 12 is limiting.

After the equivalence point, **FA 11** is <u>limiting</u>.

At equivalence point, NaOH and HA react in stoichiometric amounts, the largest amount of H₂O is formed, and the <u>largest amount of energy is evolved</u>, giving rise to maximum ΔT .

M51: explanation

- (c) Amount of H₂O formed will be doubled. <u>Heat evolved</u> will also be <u>doubled</u> as <u>total volume</u> is doubled. Hence, ΔT will be the <u>same</u>.
- (d) Repeat one of the experiments from procedure in (b), replacing HA with HC/.

If ΔT for HC*l*-NaOH reaction is <u>equal/similar</u> to that for HA-NaOH reaction, HA is a <u>strong</u> acid.

If ΔT for HC*l*-NaOH reaction is <u>higher</u> than that for HA-NaOH reaction, HA is a <u>weak</u> acid as some <u>energy evolved</u> (from neutralisation) is absorbed to bring about complete <u>dissociation of HA</u>.

(e) $\frac{1}{2}$ H₂SO₄(aq) + NaOH(aq) $\rightarrow \frac{1}{2}$ Na₂SO₄(aq) + H₂O(I)

Amount of $H_2SO_4 = \frac{25.0}{1000} \times 1.00 = 0.0250$ mol

Amount of NaOH =
$$\frac{25.0}{1000} \times 1.00 = 0.0250$$
 mol

NaOH is limiting.

Amount of $H_2O = 0.0250$ mol

Heat evolved = (25.0 + 25.0)(4.2)(6.8) = 1428 J = 1.428 kJ

 $\Delta H_{\rm neut} = -\frac{1.428}{0.0250} = -57.1 \text{ kJ mol}^{-1}$