HWA CHONG INSTITUTION
2024 C2 H2 CHEMISTRY PRELIMINARY EXAMINATION
SUGGESTED SOLUTIONS

Paper 4

1 **(a)** **(i)** Test 2

Obs 1.	white/ off-white ppt formed (*with 1cm^3 NaOH(aq)*)
Obs 2.	brown ppt formed/ brown ppt observed on the wall of the boiling tube/ white ppt turned brown
Obs 3.	(white) ppt partially soluble / insoluble in excess NaOH
Obs 4.	brown residue (*on filtering*)
Obs 5.	colourless filtrate (*on filtering*)
Obs 6.	white ppt formed (when dilute H_2SO_4 is added to the filtrate)
Obs 7.	(white) ppt soluble in excess dilute H_2SO_4

Test 3

Obs 8.	white ppt (*with dropwise addition of NH_3(aq)*)
Obs 9.	brown ppt/ some white ppt turns brown/ brown ppt observed on the wall of the test-tube
Obs 10.	ppt insoluble in excess aq. ammonia

Test 4

Obs 11.	white ppt (*with aq. barium nitrate)*
Obs 12.	(white ppt) insoluble in dilute HNO_3

There are 12 Obs. They are scaled to **6** marks as follows.

11 – 12 = **[6]**
9 – 10 = **[5]**
7 – 8 = **[4]**
5 – 6 = **[3]**
3 – 4 = **[2]**
1 – 2 = **[1]**
0 = **[0]**

1 **(a)** **(ii)** Al^{3+}: Based on test 2, white ppt forms in the filtrate when dilute H_2SO_4 is added to it. **[1]**

Mn^{2+}: Based on test 2 (&/or 3), white ppt rapidly turns brown. **[1]**

SO_4^{2-}: Based on test 4, white ppt insoluble in dilute HNO_3 **[1]**

1 (a) (iii) Effervescence of CO_2 is due to the acid-base reaction between CO_3^{2-} and the H^+(aq) produced from the hydrolysis/ionisation of $[Al(H_2O)_6]^{3+}$. **[1]**

The white ppt observed is due to the precipitation of insoluble $MnCO_3$ and $Al(OH)_3$. **[1]**

1 (b) (i)

Obs 1.	pale brown / colourless filtrate (after dilute HNO_3 is added)
Obs 2.	solution decolourises / remains colourless (when **FA 2** is added)
Obs 3.	brown ppt/solution observed when NaOH(aq) is first added
Obs 4.	brown ppt dissolves/ brown solution decolorises shortly after appearing
Obs 5.	this is followed by effervescence of colourless, odourless gas
Obs 6.	that relights a glowing splint
Obs 7.	gas evolved is oxygen
Obs 8.	brown ppt formed dissolves more slowly (with excess NaOH(aq)) / brown ppt remains eventually. (effervescence ceases)

There are 8 Obs. They are scaled to **3** marks as follows.

6 – 8 = **[3]**
4 – 5 = **[2]**
2 – 3 = **[1]**
0 – 1 = **[0]**

1 (b) (ii) The brown intermediate formed on adding NaOH(aq) increases the rate of decomposition of H_2O_2. **[1]**

OR

Since O_2 evolved when NaOH(aq) is added, H_2O_2 is being oxidised in an alkaline medium. This implies that H_2O_2 is a stronger reducing agent in an alkaline medium.

OR

H_2O_2 decomposes more rapidly in alkaline medium as compared to in acidic medium.

2 (a)

Headers and units for transfer time and t Transfer time in min & s, to nearest s. t correctly calculated to 1 d.p.	**[1]**
Headers and units for burette readings and volume of FA 5 Correct calculation of volume of FA5 added All burette readings and volumes of FA5 to 2 d.p. (0.05 cm^3).	**[1]**
5 sets of data, 1st and 2nd aliquot within 1st and 2nd min of expt (accept up to 1.9 and 2.9 min), last aliquot not exceeding 10 min	**[1]**

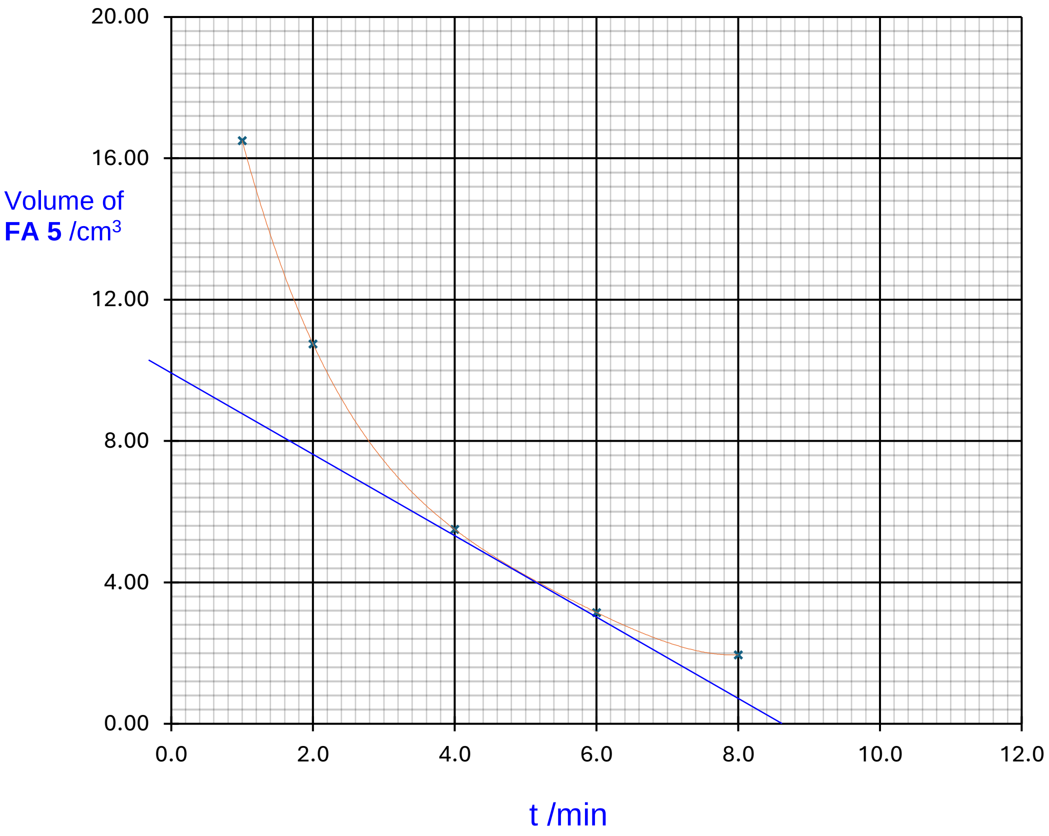
Example

Transfer time		t /min	Final burette reading /cm^3	Initial burette reading /cm^3	Volume added /cm^3
min	s				
1	01	1.0	16.50	0.00	16.50
2	00	2.0	27.25	16.50	10.75
4	00	4.0	32.75	27.25	5.50
6	00	6.0	35.90	32.75	3.15
8	00	8.0	37.85	35.90	1.95

2 (b)

Label axes & units, suitable scale (not odd, plots occupy at least half the grid in x and y directions).	**[1]**
All points correctly plotted within ±½ small square.	**[1]**
Suitable best-fit curve ignoring anomalous points.	**[1]**

Example



$t_{½}$ values: 1.7 min (16.0 cm^3 to 8.0 cm^3); 1.9 min (12.0 cm^3 to 6.0 cm^3);
2.4 min (8.0 cm^3 to 4.0 cm^3)

2 (c) Show working for at least two half-lives. **[1]**

Conclude the order of reaction based on whether $t_{½}$ is (approximately) constant. **[1]**

E.g. Since volume of FA 5 (V_{FA5}) is directly proportional to concentration of MnO_4^- in the reaction mixture, for V_{FA5} to decrease from 16.0 cm^3 to 8.0 cm^3, the half-life is 1.7 min. For V_{FA5} to decrease from 12.0 cm^3 to 6.0 cm^3, the half-life is 1.9 min.

Since the two half-lives are almost identical, I agree that the order with respect to MnO_4^- is one.

2 (d) (i) Draws tangent at t = 5.0 min, tangent line must touch the curve at t = 5.0 min **[1]**

An example is drawn on the graph in **2(b)**.

(ii) Gradient of tangent = (7.6 – 0.0) / (2.0 – 8.6)
= –1.15 cm^3 min^{-1} (answer must be negative) **[1]**

(iii) rate of change in amount of $S_2O_3^{2-}$ ions = $-1.152 \times 10^{-3} \times 0.0050$
= -5.76×10^{-6} mol min^{-1} **[1]**

2 (d) (iv) rate of change in amount of MnO_4^- ions in 10 cm^3 = $-5.76 \times 10^{-6} \times 1/2 \times 2/5$
= -1.15×10^{-6} mol min^{-1}
[1]

(v) rate of change of the concentration of MnO_4^- ions
= $(-1.15 \times 10^{-6}) / 0.010$
= -1.15×10^{-4} mol dm^{-3} min^{-1} **[1]**

2 (e) (i) Sigmoidal, showing the gradient becoming more negative (or increase in magnitude) before the point of inflexion and then becoming less negative (or decrease in magnitude) after that. **[1]**

Reaction starts slowly at the beginning, then speeds up, then slows down at the end. **[1]**

(ii) Without adding **FA 1**, the reaction is slow initially (*as both MnO_4^- and $C_2O_4^{2-}$ are negative ions. This leads to a high activation barrier*); the Mn^{2+} produced (auto)catalyses the reaction explaining the increase in reaction rate/ increase in magnitude of gradient of the curve after some time. **[1]**

For the graph in **2(b)**, **FA 1** is added in step **3**.

FA 1 contains the catalyst Mn^{2+} and the reaction proceeds via the alternative catalysed pathway, causing reaction rate to be high right from the start of the reaction. **[1]**

3 (a) (i) Correct calculations of each titre value. Mark lost if initial and final readings are swapped. **[1]**

Correct recording of titration values to nearest 0.05 cm^3 **[1]**

At least 2 titration results consistent to within 0.10 cm^3 **[1]**

(ii) Correctly picks 2 values for calculation of average titre value based on the hierarchy:
- 2 identical values
- average of titre values within 0.05 cm^3
- average of titre values within 0.10 cm^3

Correct calculation for average titre value to 2 d.p. **[1]**

Accuracy
Teachers' value: 18.80 cm^3
18.70 – 18.90 cm^3 = **[2]**
18.60 – 19.00 cm^3 = **[1]**

3 **(b)** **(i)** $Na_2CO_3 + H_2SO4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ **[1]**

(ii) Calculation of amount of carbonate in 25.0 cm^3 **[1]**
Calculation of percentage purity by mass **[1]**

<u>Example:</u>
Average titre value = 19.00 cm^3
Amount of acid use = 19.00/1000 × 1.00 = 0.0190 mol
Amount of carbonate in 25.0 cm^3 = 0.0190 mol
*ecf from balanced equation in **1(b)(i)***

Amount of carbonate in 1 dm^3 = 0.0190 / 25 x 1000 = 0.760 mol
Mass of sodium carbonate = 0.760 × 106 = 80.56 g
Percentage purity by mass = 80.56/90 × 100 = 89.51 %
(ecf from wrong value for amount of carbonate in 25.0 cm^3)

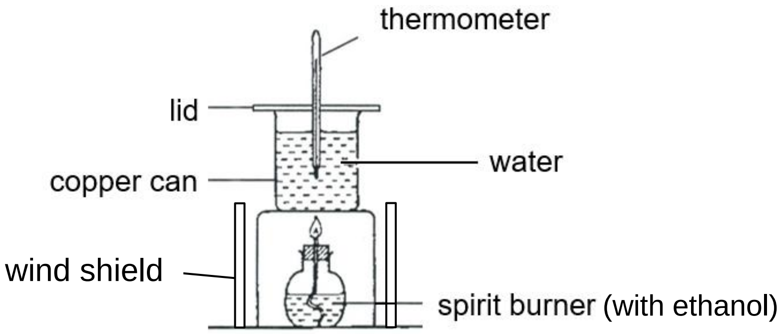
Correct significant figures for all final answers in calculation questions for whole paper
Correct units in final answer for Q3. **[1]**

Show working for all calculation questions attempted for the whole paper. No penalty for questions left blank. **[1]**

4 **(a)** Heat lost by hot water = $mc\Delta T$ = 75 x 4.18 x (60.4 – 25.6) = 10909.8 J [1]
Heat gained by cold water = $mc\Delta T$ = 75 x 4.18 x (25.6 – 8.9) = 5235.45 J [1]

Difference in value of heat = 10909.8 – 5235.45 = 5674 J
Heat capacity of copper can = (5674) ÷ (25.6 – 8.9) = 340 J K^{-1} [1]

4 **(b)** Labelled diagram:



Sample procedure:

1. Weigh the spirit burner with ethanol using an electronic balance. Record its mass, M1.
2. Using a measuring cylinder, measure 150 cm^3 of water and pour into the copper can.
3. Record the initial temperature of the water, T1, with a thermometer.
4. Set up the apparatus as shown in the diagram.
5. Using a lighter, light up the spirit burner to heat up the water. Stir the water carefully and gently using the thermometer.
6. Extinguish the flame when the temperature of the water has risen by about 10 °C. Record the maximum temperature reached, T2.
7. Cool the spirit burner to room temperature. Re-weigh the spirit burner and the remaining ethanol. Record its mass, M2.

Mark Scheme

Diagram [2] - to obtain full credit, apparatus drawn must be suitable for the experiment described in the question.

- Labelling of thermometer, copper can and spirit burner [1]
- A suitable method to minimise heat loss to the surroundings must be shown and clearly labelled in the diagram (e.g. a lid or wind shield) [1]

Procedure [4] - to obtain full credit, sequence of steps must be logical and suitable for the aim of the experiment.

- Weighing of initial mass of spirit burner and ethanol with electronic balance before experiment starts and re-weighing of spirit burner with remaining ethanol after the experiment. [1]
- Transferring of deionised water to copper can with reasonable volume of water (50 - 180 cm^3) using suitable apparatus to measure volume of water (measuring cylinder burette if 50 cm^3) [1]
- Light up spirit burner and extinguish flame when temperature rise of around 10 °C, before the final temperature is taken. [1]
- Recording of initial temperature of water in copper can and final temperature after extinguishing flame. [1]

4 **(c)** maximum temperature rise = (T2 – T1) = ΔT °C
mass of water used = 150 g
q = (150 x 4.18 x ΔT) + (340 x ΔT) J [1] *ecf from value of C found in (a)*

mass of ethanol combusted = (M1 – M2) g
n = no. of moles of ethanol combusted = (M1 – M2) /46 mol
enthalpy change of combustion $\Delta H = -q / n$ J mol^{-1} [1]

Assumption: There is no heat loss to the surroundings / all heat from the combustion of ethanol was transferred to the copper can and water. [1]