Hwa Chong Institution
2025 C2 H2 Chemistry Prelim Exam
Paper 4 Mark Scheme

Qn **Mark Scheme**

1(a)

test	observations	
To 1 cm depth of FA 1, add 1 cm depth of dilute H_2SO_4.	No effervescence	**M1**
To 1 cm depth of FA 1, add aqueous barium nitrate (dropwise).	White ppt	**M2**
To 1 cm depth of FA 1, add 1 (or 2) drops of aqueous silver nitrate. followed by aqueous NH_3, until there is no further change	Pale cream/ cream/ cream-yellow/ pale yellow ppt ppt partially soluble/ insoluble in NH_3(aq)	**M3** **M4**

[1] for each test and correct observation

anion: **SO_4^{2-} [1]** and **Br^- [1]** **M5** **M6**

1(b)(i)

test	observations
Transfer all of the solid sample of **FA 4** into a boiling tube. Add all of **FA 3** to this boiling tube. Gently warm the boiling tube. Turn off the Bunsen flame.	White solid <u>dissolves</u> to give a colourless solution. **[½]** **(–½ overall if "effervescence/ gas/ gas bubbles" is written here)**
Handle the hot boiling tube with care. Add **FA 2** to the mixture in three separate portions using a spatula, shaking after each separate addition. Add all the remaining **FA 2** to the mixture. Using the ***glass filter funnel***, filter the mixture into a test tube and leave the filtrate to stand. The filtrate contains compound **X**. Retain this filtrate for use in **(b)(ii)**.	Effervescence **[½]** Gas gives white ppt in limewater **[½]** Gas is CO_2 **[½]** Colourless/ pale pink/ reddish-pink/ red/ purple-red filtrate **[½]** Black residue **[½]**

M7 **M8** **M9**

1(b)(ii)

test	**FA 5**	filtrate from **(b)(i)**
To 1cm depth of **FA 5** in a test tube, add aqueous ammonia dropwise, until in excess. Repeat using filtrate from **(b)(i)**.	<u>off-white ppt</u> **[½]** <u>insoluble in excess</u> **[½]** <u>turns brown on standing/ on contact with air</u> **[1]**	<u>light brown / brown ppt</u> **[½]** <u>insoluble in excess</u> **[½]** turns darker brown on standing/ on contact with air

M10 **M11** **M12**

1(b)(iii) Ion present is: Mn^{2+} **[½]** **M13**
Explanation: <u>off-white ppt</u> formed with aqueous NH_3, ppt <u>insoluble in excess</u> aqueous NH_3 and <u>turns brown</u> on standing/ on contact with air **[½]**

1(b)(iv) Identity of ion: Mn^{3+} **[½]** **M14**
(Incomplete) reduction of MnO_2 (ZO_2) (FA 2) to Mn^{3+} / some of the MnO_2 were reduced (in **(b)(i)**) to Mn^{3+} only. Mn^{3+} formed the brown ppt when aqueous NH_3 was added. **[½]**

1(ci)

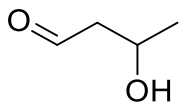
	test	Observations
1	Add 2 cm depth of aqueous silver nitrate to a clean boiling tube. Add 1 cm depth of aqueous sodium hydroxide slowly to the same tube.	brown/black ppt formed
	Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You may use a clean glass rod to help dissolve the precipitate.	brown ppt dissolved to form a <u>colourless</u> solution
	Add 2 cm depth of **FA 6** to this mixture and shake the boiling tube. Place the boiling tube in the test-tube rack and leave it for 3 minutes.	silver mirror formed
2	Add about 1 cm depth of **FA 6** in a test-tube. To this test-tube add 8 drops of sodium hydroxide solution followed by iodine solution, dropwise until no further change is seen.	yellow ppt formed

M15
M16
M17

4 correct observations: **3m**
3 correct observations: **2m**
1 or 2 correct observations: **1m**

1(c)(ii) The reagent undergoes <u>reduction</u> **[½]** from $[Ag(NH_3)_2]^+$ to Ag since <u>oxidation state of Ag decreases from +1 to 0.</u> **[½]** **M18**

1(c)(iii) **M19**



Qn **Mark Scheme**

2(a)

	actual time		*t* /min	initial burette reading /cm^3	final burette reading /cm^3	volume of **FA 11** added /cm^3
	min	s				
1	4	1	4.0	0.60	17.60	17.00
2	8	1	8.0	17.60	32.50	14.90
3	12	30	12.5	3.95	16.80	12.85
4	16	1	16.0	16.80	28.00	11.20
5	20	1	20.0	28.00	37.70	9.70

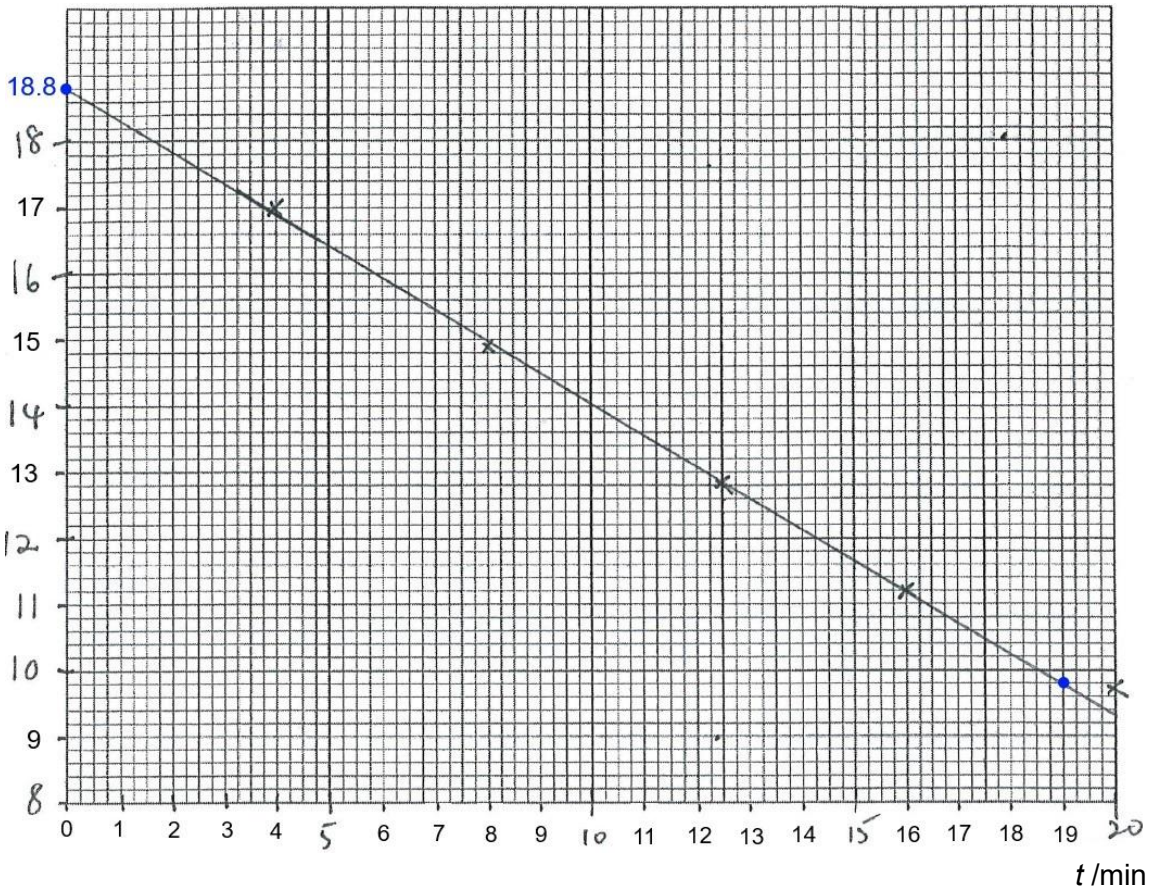
1. **[1]** Headers and units (Reject “sec” / “minutes” / “seconds” as the units) **M20**
   This mark is lost if t (the decimal time) is recorded in s. The question stated that t is to be recorded in min.

2. **[1]** Records all burette readings and volume of **FA 11** to 0.05 cm^3 **M21**
   AND actual times to min and s (whole numbers)
   This mark is lost if final burette reading < initial burette reading / inverted.
   This mark is lost if final burette reading > 50.00 cm^3.

3. **[1]** Correctly calculates *t* /min to 1 d.p. **M22**
   This mark is lost if t (the decimal time) is calculated in s.
   This mark is lost if the actual time in min and s is not recorded. This is because the marker is then unable to check whether the student has correctly calculated t

4. **[1]** 5 sets of titration results **M23**
   AND first aliquot taken at 3.5–4.5 min
   AND student chooses well-spaced values of chosen times (minimum 3 min intervals)
   AND longest time is at most 20.4 min
   This mark is lost if any titres remain the same or rise as t increases.
   *This mark is lost if there is any error in calculating the volume of **FA 11**.*

2(b)(i) Volume of $Na_2S_2O_3$ /cm^3



1. **[1]** Axes correct way round **M24**
   AND correct axes labels including units

2. **[1]** Scale is chosen such that the plotted points occupy at least half the graph grid in the x direction AND in the y direction. **M25**

3. **[1]** Plots all points correctly (give ±½ small square allowance). **M26**

4. **[1]** Draws best-fit straight line. Judge best-fit by scatter of points about the candidate's line, there must be a fair scatter of points on either side of the line **M27**
   AND allow only 1 point to be >1 small square diagonally away from the best-fit straight line.
   This mark is lost if the graph line is not straight.

2(b)(ii) The order with respect to $[I_2]$ is zero as graph line is straight, so no change in rate (or rate remains constant) as $[I_2]$ decreases. **M28**
This mark is lost if the graph line is not straight.

2(b)(iii) Clear indication of correct coordinates from graph (give ±½ small square allowance) **M29**
AND gradient correctly calculated.
e.g. gradient = $\frac{18.8-9.8}{0-19}$ = –0.474 cm^3 min^{-1}
This mark is lost if the graph line is not straight.

2(b)(iv) 1. **[1]** Line correctly extrapolated to meet y-axis. **M30**
AND V_{max} correctly read (give ±½ small square allowance)
This mark is lost if the x-axis does not start at t = 0 min.
This mark is lost if the y-intercept (V_{max}) is not within the grid.
Reject use of "y = mx + c" method to calculate V_{max} because the question stated that the V_{max} is to be *read* at the y-intercept.

2. **[1]** Accuracy Mark: 1m if student's V_{max} is 17.80 – 18.80 cm^3 **M31**
(If the student's x-axis does not start at t = 0 min or student draws a curve for the graph, excel was used to determine the student's V_{max} value, using the student's data table. Accuracy Mark was then awarded accordingly.)

3. **[½]** $n(S_2O_3^{2-}) = V_{max} \div 1000 \times 0.0100$ **M32**
[½] $n(I_2)$ in 10 cm^3 aliquot = $n(S_2O_3^{2-}) \times ½$
e.g. $n(S_2O_3^{2-}) = \frac{18.8}{1000} \times 0.0100 = 1.88 \times 10^{-4}$ mol
$n(I_2)$ in 10 cm^3 aliquot = $1.88 \times 10^{-4} \times ½ = 9.40 \times 10^{-5}$ mol

4. **[½]** $n(I_2)$ in 100 cm^3 reaction mixture (or in 50 cm^3 **FA 8**) **M33**
= $n(I_2)$ in 10 cm^3 aliquot × 100/10
[½] $[I_2]$ in **FA 8** = $n(I_2)$ in 50 cm^3 **FA 8** ÷ (50/1000)
e.g. $n(I_2)$ in 100 $cm^3 = 9.40 \times 10^{-5} \times 10 = 9.40 \times 10^{-4}$ mol
$[I_2]$ in **FA 8** = $\frac{9.40 \times 10^{-4}}{50/1000} = 0.0188$ mol dm^{-3}

2(b)(v) Correct calculation of $t_{max} = V_{max} / |$ gradient $|$ **M34**
e.g. $t_{max} = \frac{18.8}{0.474} = 39.7$ min

2(c) rate = $k[CH_3COCH_3][H^+]$ or rate = k[propanone]$[H^+]$ **M35**

2(d) If the concentration of iodine is very much lower than that of propanone (and that of acid), very little propanone (and acid) is/are removed from the reaction mixture. So the <u>concentration(s) of propanone (and acid) remain effectively constant</u>. **M36**

2(e) The excess $NaHCO_3$ neutralises / removes the acid (H^+ or H_2SO_4) catalyst. **M37**
So reaction 1 stops / drops to very slow rate and can be considered stopped.

2(f) **[½]** The yellow ppt is iodoform / CHI_3. **M38**
[½] Propanone undergoes oxidation.

Qn **Mark Scheme**

3(a)

mass of capped container and **FA 12** / g	7.24
mass of capped container and residual **FA 12** / g	5.74
mass of **FA 12** used / g	1.50 (1.40 ≤ x ≤ 1.60)

M39

- Mass readings recorded to 2 d.p.
- Deduct mark if mass of **FA 12** is outside range due to the missing cap
- Deduct mark if units are given again

	temperature / °C
$T_{initial}$	29.6
T_{max}	35.9

M40

- Temperature readings recorded to 0.1°C
- Deduct mark if T_{max} is unbelievably high, likely due to wrong reading of thermometer
- Deduct mark if units are given again

3(b)(i) $\Delta T = 35.9°C - 29.6°C = 6.3°C$ **M41**

- Calculated value, allow 3 s.f.

3(b)(ii) $q = mc\Delta T = 20 \times 4.2 \times 6.3 = 529.2$ J (allow ecf) **M42**

3(b)(iii) $n_{H2SO4} = \frac{20}{1000} \times 1 = 0.0200$ mol **[½]**

$n_{Na2CO3} = \frac{1.50}{23\times2 + 12 + 16\times3} = \frac{1.50}{106} = 0.01415$ mol **[½]** **M43**

$\therefore$ Na_2CO_3 is the limiting reactant

$\Delta H_r = -\frac{529.2}{0.014151} = -37.396$ kJ mol^{-1} = –37.4 kJ mol^{-1} (3 s.f.) **M44**

[1] correct sign and value for ΔH_r
–½m if the sign is missing
ecf *only for wrong calculation of n(Na_2CO_3)*

3 or 4 s.f. for all calculations in **2(b)(iii), (iv), (v)**; **2b(v)** accepts 1 d.p. or 3/4 s.f.
AND correct units and 3 or 4 s.f for all calculations in **3(b)(i), (ii), (iii)** **M45**
AND measurement precision in 3(a)

3(c)(i)

1. Fill a burette with NaOH.
2. Use a second burette to add 20.00 cm^3 of wastewater sample into a clean and dry polystyrene cup, stacked in another polystyrene cup and then supported in a 250 cm^3 beaker.
3. Place a 0.2 °C interval thermometer in the polystyrene cup and cover the cup with a lid.
4. Stir the wastewater sample gently with the thermometer. Record its initial temperature to 0.1 °C.

5. From the burette, add 2.00 cm^3 of NaOH into the polystyrene cup. Stir the mixture using the thermometer and record the highest temperature reached ($T_{mixture}$) and the total volume of NaOH added up to that point (V_{NaOH}).
6. Repeat step 5 until a total of 50.00 cm^3 of NaOH has been added.
7. Plot a graph of $T_{mixture}$ against V_{NaOH} added.

(optional table)

Total volume of NaOH added / cm^3	Temperature of mixture / °C
0.00 2.00 4.00 … … 24.00 26.00 … … 50.00	

Quantities to use	• Volume of wastewater: 10.00 cm^3 to 20.00 cm^3 • Suitable NaOH additions: best is 2.00 cm^3 • Minimum of 5 additions of NaOH before and after equivalence point • Final total volume of NaOH added from the burette cannot exceed 50.00 cm^3 (burette capacity)	**[2]**	**M46** **M47**
Apparatus to use	• Burette for NaOH • Burette or 10 cm^3 pipette for wastewater sample • Polystyrene cup as calorimeter • (0.2°C interval) Thermometer	**[1]**	**M48**
Procedure to follow and Measurements to take	Logical flow **[2]** • NaOH in burette, wastewater sample in polystyrene cup + lid • Add NaOH, stir • Measure $T_{initial}$, highest $T_{mixture}$ after each addition • Record total V_{NaOH} added **[1]** Repeat, stating a clear end to the experiment.	**[3]**	**M49** **M50** **M51**

3(c)(ii) The point of intersection of the 2 best fit lines gives the volume of NaOH required at the equivalence point. Using the concentration of NaOH, the no. of moles of OH^- can be found by multiplying V_{NaOH} (in dm^3) by 1.5. **M52**

Mole ratio of NaOH to H_2SO_4 is 2:1, hence the no. of moles of NaOH divided by 2 will give the no. of moles of H_2SO_4. The no. of moles of H_2SO_4 divided by volume of acid used will give us the concentration of acid in the waste water sample. **M53**

Or via mathematical expressions
e.g.

Student marks out $V_{equivalence}$ on the given Fig 3.1 (the intersection point between the two curves)

n(NaOH) = $1.5 \times \frac{V_{equivalence}}{1000}$ mol **[½]**

n(H_2SO_4) = $\frac{1}{2} \times 1.5 \times \frac{V_{equivalence}}{1000}$ mol **[½]**

[H_2SO_4] = $\frac{n(H_2SO_4)}{20/1000}$ mol dm^{-3} **[1]**

(if 20 cm^3 is the chosen volume of wastewater sample used)

3(c)(iii) Before equivalence point

- The reaction is <u>exothermic</u> and releases heat energy to cause <u>$T_{mixture}$ to rise</u>.
- Each addition of <u>NaOH releases the same amount of heat but it is spread over a larger volume of mixture</u>, thus resulting in a <u>smaller temperature rise</u>.

M54

After equivalence point

- After the equivalence point, <u>no more heat is released</u> as the reaction has completed. Addition of the <u>cooler NaOH helps to decrease the temperature of the mixture</u>.
- <u>As the temperature difference between the mixture (in the polystyrene cup) and the NaOH (from the burette) becomes smaller, each temperature fall is smaller than the previous</u>.

M55