2021 H2 Chemistry Paper 4 Suggested Solution

<table>
<tr><th>Qn</th><th>Teaching points</th><th>Marks</th></tr>
<tr><td>1(a)</td><td>
<table>
<tr><td>mass of capped bottle and FA 1 / g</td><td>7.378</td></tr>
<tr><td>mass of capped bottle and residual FA 1 / g</td><td>3.488</td></tr>
<tr><td>mass of FA 1 used / g</td><td>3.490</td></tr>
</table>
<table>
<tr><td>initial temperature / °C</td><td>28.8</td></tr>
<tr><td>lowest / minimum temperature reached / °C</td><td>24.8</td></tr>
<tr><td>decrease in temperature / maximum change in temperature / °C</td><td>4.0</td></tr>
</table>
</td><td></td></tr>
<tr><td></td><td>
• May record data in a single table or have one table for mass and one table for temperature; Tabulation may be vertical or horizontal; lines are not essential
• For “temperature drop” allow “temperature change” sign not essential as it will be accounted for later in the sign for the enthalpy change.

[1]: correct headers and units.
[1]: mass readings to 3 d.p. and temperature readings to 1 d.p.
[1]: correctly determined maximum temperature change and mass of FA 1 used
</td><td>[3]</td></tr>
<tr><td></td><td>• Accuracy marks compare student’s and teacher’s $\frac{\Delta T}{m}$</td><td>[2]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(i)</td><td>Calculate heat change using result from 1(a)

Heat change (q_1) = $mc\Delta T$
= (50 x 1.00) x 4.18 x (temp drop)
= ________ J</td><td>[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(ii)</td><td>Determine value of $\Delta H_{sol}(KHCO_3)$ with correct sign

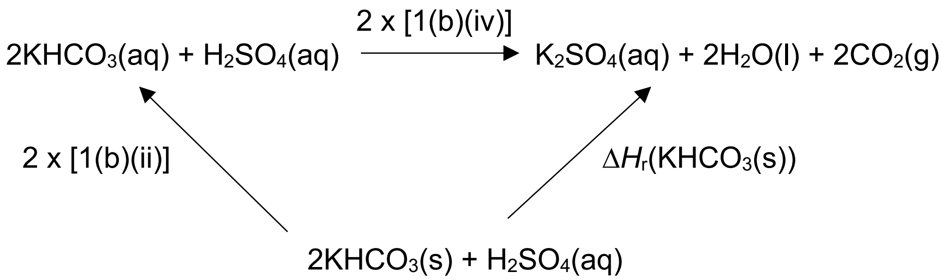
$\Delta H_{sol}(KHCO_3)$ = + (q_1) / n($KHCO_3$)
= + ________ J mol^{-1}</td><td>[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(iii)</td><td>Calculate correctly initial T_{av} = <u>28.6</u> °C</td><td>[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(iv)</td><td>Heat change (q_2) = $mc\Delta T$
= (25+50) x 1.00 x 4.18 x (28.6 – 28.2)
= <u>125.4</u> J

$\Delta H_r(KHCO_3(aq))$ = + (125.4) / (3.450/100.1)
= <u>+3640</u> J mol^{-1}

Final answer to 3 s.f. or 4 s.f. and appropriate units for (b)(i), (b)(ii), (b)(iii) and (b)(iv).</td><td>[1]

[1]

[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

(c)	 2 x [1(b)(ii)] + 2 x [1(b)(iv)] = $\Delta H_r(KHCO_3(s))$ = _________ J mol^{-1} [1]: correct application of Hess' Law [1]: correct answer; awarded only if **(b)(ii)** and **(b)(iv)** are correct and applied correctly (ignore units)	[2]

Qn	Teaching points	Marks
2(a)	**Preliminary Calculations** - Calculate the mass of $MgSO_4$ to use for the experiment. - Assuming that **<u>100 cm³ of water</u>** was used in the experiment and a temperature change of 5 °C is measured and no heat loss to surroundings, n_{salt} x 78.9 x 10^3 = 100 x 4.3 x 5 ⇒ n_{salt} = 0.02724 mol **minimum** mass of $MgSO_4$ to use = 0.02724 x 120.4 = 3.28 g Given the solubility of $MgSO_4$ at 20 °C = 0.292 mol per 100 cm^3 **maximum** mass that can dissolve in 100 cm^3 of water = 0.292 x 120.4 = 35.2 g Hence a mass of about 10 g of $MgSO_4$ can be used for the experiment. *(10 g of $MgSO_4$* is a suitable mass as *it can be easily measure and from the above preliminary calculations, we know that this mass chosen will be able to give a temperature rise of about 5°C and will completely dissolve in 100 cm^3 of water.)* Marking consideration • for min and max temp • for proposed mass	[1] [1]

Expt	Assumed volume of water/cm^3	heat needed/ J	nsalt	Min Mass of solid/g	Max Mass of solid/g
1	50	1075	0.01362	1.6404	17.5784
2	100	2150	0.02725	3.2809	35.1568
3	150	3225	0.04087	4.9213	52.7352
4	200	4300	0.05450	6.5617	70.3136
5	25	537.5	0.00681	0.8202	8.7892
6	75	1612.5	0.02044	2.4606	26.3676
7	125	2687.5	0.03406	4.1011	43.946

<u>No marks</u> will be **<u>deducted</u>** for **<u>wrong/no</u>** determination of **<u>max mass</u>** of $MgSO_4$ used since students will be penalized in (b)

<u>No marks awarded</u> if only the volume of water used is quoted with NO workings to determine mass of solid.

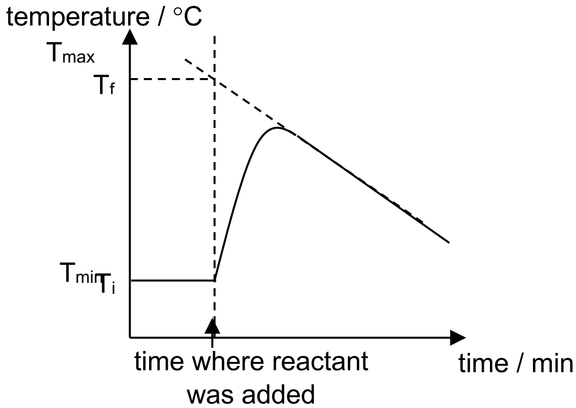
(b) **General outline of experiment**

1. Using an electronic balance, weigh accurately 10.000 g of $MgSO_4$ into a pre-weighed dry weighing bottle.
2. Record the mass of $MgSO_4$ and the bottle in the table.
3. Using a 100 cm^3 measuring cylinder, transfer 100 cm^3 of **water** into a dry Styrofoam cup, placed in a 250 cm^3 beaker.
4. Place the lid on the cup, slip the thermometer through the lid and stir the water gently using the thermometer.
5. Start the stop-watch and record the initial temperature of the water. Record the temperature of the water every 30s for 2.5 min.
6. At exactly 3 min, add the $MgSO_4$ in the weighing bottle to the Styrofoam cup. Cover the cup with a lid and continue to stir the mixture gently with the thermometer and record the temperature every 30s from 3.5 min to 10.0 min.
7. Reweigh the weighing bottle and record the actual mass of $MgSO_4$ that dissolved in water.
8. Plot graph of temperature against time
9. Extrapolate the graph to the third minute when $MgSO_4$ was added to water to obtain the highest temperature reached

Marking consideration:
Correct mention of electronic balance, measuring cylinder, Styrofoam cup, beaker, thermometer
Logical mass of $MgSO_4$ used. (between 3.28 g and 35.2 g)
Starting the stop-watch and measuring the temperature of water for a few minutes before adding $MgSO_4$ into the water
Showing understanding of reweighing the weighing bottle to obtain the accurate mass transferred
Ensuring accurate and reliable value of ΔT_{max} is obtained

Apparatus	Procedure	Graph	Reliability
A1	**P1/ P2**	**G1**	**R1**
1. Electronic/ weighing + balance/ scale/ machine 2. (weighing) bottle (reject: small beaker/ container/ bottle cap) 3. measuring cylinder 4. Styrofoam/ Polystyrene cup (Reject: cup) 5. Thermometer Any 4 will do. *capacity not needed	1. Corresponding mass of $MgSO_4$ used and volume of water from (a) (Mass of solid must be < 50g) (If no mass value determined, accept any value <50g) 2. Starting the stop-watch. 3. Record temperature of water for a few minutes **BEFORE** adding $MgSO_4$ into the water. 4. Add solid (at t = ?) 5. Record temperature of water for a few minutes **AFTER** adding $MgSO_4$ into the water. 6. Reweigh the weighing bottle (All – P2, Only 3 points- P1) P=0 once solid is already in the cup.	1. Plot graph of temperature against time 2. Extrapolate the graph to the third minute (time of addition) when $MgSO_4$ was added to water to obtain the highest temperature reached. (Both)	1. Dry weighing bottle 2. Stir the water 3. Styrofoam cup in beaker 4. Cup covered by lid. Any 2.

Annotation A: apparatus, **P**: procedure **R:** Reliability

(c)	 Correct shape showing graph before and after addition of $MgSO_4$. [1] Correct extrapolation of graph [1] (allow ecf if endo graph is shown) Indicate clearly, minimum temperature, maximum temperature and ΔT on graph [1] (allow ecf if endo graph is shown)

Qn	Teaching points	Marks
3(a)	Table to include with correct headers and units: • Time of transfer (about 1 min, 2 min, 5 min, 8 min, 11 min and 14 min) • Decimal time • Initial and final burette readings • Volume of **FA 3** added Table need not be populated. Table may be horizontal or vertical and lines are not essential but there should be no absence of headers. Appropriate unit for each entry in the table if no units in the header. Can be separate tables.	[1]
	Record **all** • Burette readings and volumes added to 0.05 cm^3 • Transfer times in minutes and seconds (to 1 s) • Correctly calculated values of decimal time • Decimal time to 0.1 min	[1]
	5 sets of result and are transferred within ± 30 seconds of the suggested times.	[1]
(b)(i)	Correct axes, labels and units; scale uses over half the graph paper in both axes. Do not award this mark if an awkward scale (e.g recurring or each big square is 3, 6 etc) is used that makes plotting/reading difficult. Ignore dp of axes (e.g 5, 5.0, 5.00 all ok) Do NOT double penalize if the student has copied the same wrong units from the table.	[1]
	Plotting within ± ½ small square. Check two points – the 2^{nd} and 4^{th} point; put ticks if correct. If less than 5 plotted points – do not award this mark If more than 5 plotted points – can award if 2^{nd} and 4^{th} points are correct Ignore if the plotted points look too big or pencil too blunt. Plotted points are marked separately with shape of curve. Award even if best fit curve not drawn. If student's table does not include decimal time, calculate the decimal time for 2^{nd} and 4^{th} point and award accordingly.	[1]
	Draw a best fit, smooth curve (with correct shape) – accept only auto-catalysis graph. End of graph need not be flatten. Do not accept straight line, 1^{st} order graph (concave or convex) even if points seems to suggest such shapes. Accept if graph touch or did not touch both axes. Do not allow if clearly anomalous points have been included. If the last timing on the X-axes is 6 min or less, allow concave curve.	[1]
(b)(ii)	Describe graph line as downward sloping curve with a gentle gradient at the start, then becoming steep in the middle, then gentle towards the end. Implies reaction begins slowly initially, then proceeds with a faster rate and subsequently slows down towards the end of the reaction.	[1] [1]
(b)(iii)	- Negatively charged MnO_4^- and X^{2-} ions repel each other - Results in **high E_a** for reaction	[1]

	- Electrostatic attraction between Mn^{2+} and the negative ions - Provides alternative pathway with **lower** E_a.	[1]
(c)(i)	Volume of of $KMnO_4$ is directly proportional to the concentration of H_2O_2 First order reaction w.r.t. H_2O_2, constant half-life. Construction line on the graph Indicate at least 2 values of $t_{½}$ on graph Do not accept if values are obtained from extrapolating graph on both ends.	[1] [1]
(c)(ii)	Gradient line touches the curve at the **t** = 15 min point **and** it is a tangent at this point. Do not allow this mark if the line is not tangential, does not touch the curve or covers/crosses part of the curve. Clear indication of **correct** co-ordinates from graph **or** correct values of volume and of time used (measured to ± ½ small square) and gradient correctly calculated	[1] [1]
(c)(iii)	Example using the gradient value of 0.3094 $cm^3\ min^{-1}$ ➔ 0.3094 ÷1000 = $3.094 \times 10^{-4}\ dm^3\ min^{-1}$ Rate of change of the amount of MnO_4^- required = $3.094 \times 10^{-4} \times 0.01$ = 3.094×10^{-6} = 3.09×10^{-6} mol min^{-1} (3s.f) *Student can use the units provided to understand the working based on the manipulation of the units* $\frac{mol}{dm^3} \times \frac{dm^3}{min}$ *where the first term is the concentration while the second term is the gradient* $cm^3\ min^{-1}$ *being converted to* $dm^3\ mol^{-1}$	[1]
(c)(iv)	Rate of depletion of H_2O_2 = $(3.094 \times 10^{-6}) \times \{5/2\}$ = 7.735×10^{-6} = 7.74×10^{-6} mol min^{-1} (3s.f.) Above calculation serve as a guide and should not be automatically used when marking this question. All calculation based on students' gradient value.	[1]
(c)(v)	$(7.735 \times 10^{-6}) \div (10 \times 10^{-3}) = 7.74 \times 10^{-4}$ mol $dm^{-3}\ min^{-1}$	[1] [1]

<table>
<tr><th>Qn</th><th>Teaching points</th><th>Marks</th></tr>
<tr><td>(a)(i)</td><td>Any three observations on heating FA 7:
□ initially pink crystals
□ (on gentle heating) solid turns white / paler (pink)
□ condensation / water droplets / water vapour / misty fumes [1]
□ (gas) turns (damp blue) litmus red
□ melts / liquid formed / dissolves
□ (solid / liquid) turns brown / ochre / yellow-brown [2]
□ residue is dark brown / black solid [3]

[1] Allow steam
[2] Reject red-brown
[3] Reject ppt
Ignore bubbles of gas
Ignore incorrect positive gas tests</td><td>[2]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(a)(ii)</td><td>Off-white ppt, rapidly turn brown on contact with air
Insoluble in excess NaOH(aq)</td><td>[1]
[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(i)</td><td>Selects for halide:
(aqueous) $AgNO_3$ / silver nitrate and (followed by) NH_3 / (aqueous) ammonia
Ignore preliminary use of nitric acid.</td><td>[1]</td></tr>
<tr><td></td><td>Selects for anion containing sulfur:
(aqueous) $BaCl_2$ / $Ba(NO_3)_2$ or names and HCl / HNO_3 or names
Reject if use of sulfuric acid is shown.</td><td>[1]</td></tr>
<tr><td></td><td>If neither mark is awarded, allow 1 mark for:
$AgNO_3$ / silver nitrate – halide
AND $BaCl_2$ / $Ba(NO_3)_2$ (or name) – S-anion
Reject if use of sulfuric acid with Ba^{2+} salt is shown.</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(ii)</td><td>Expected observations:
<table>
<tr><th></th><th>FA7 (aq)</th><th>FA8</th></tr>
<tr><td>+ Ag^+</td><td>white ppt *</td><td>(pale) yellow ppt *</td></tr>
<tr><td>+ NH_3</td><td>(ppt) colour darkens / off-white / buff / beige / pale brown *</td><td>(ppt) insoluble *</td></tr>
<tr><td>+ Ba^{2+}</td><td>no change / no ppt / no reaction / not needed *</td><td>no change / no ppt / no reaction / not needed *</td></tr>
<tr><td>+ H^+</td><td>ignore</td><td>ignore</td></tr>
</table>

Two * = 1 mark (round down).
Allow 1 mark for the following observations with NH_3(aq) if $AgNO_3$(aq) was not selected:
FA 7 (aq): off-white / beige / buff / pale / light brown ppt
AND
FA 8: no reaction</td><td>[3]</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(iii)</td><td>

	FA7	FA8
cation	Mn^{2+}	unknown
anion	Cl^{-}	I^{-}

Ignore K^{+} of FA9
Allow names (manganese (II), chloride, iodide)</td><td>[3]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(iv)</td><td>FA 7 + Cl_2: no reaction / no (visible) change
Allow turns black / dark brown if Mn^{2+} identified.</td><td>[1]</td></tr>
<tr><td></td><td>FA 8 + Cl_2: solution turns yellow / brown or black / dark grey ppt
Allow ecf for bromide for either (not both) FA 7 or FA 8:
solution turns yellow / red-brown / brown.
Allow solution turns orange for either Br^{-} or I^{-}.
Allow no reaction / no (visible) change if SO_3^{2-} / SO_4^{2-} identified.</td><td>[1]</td></tr>
</table>