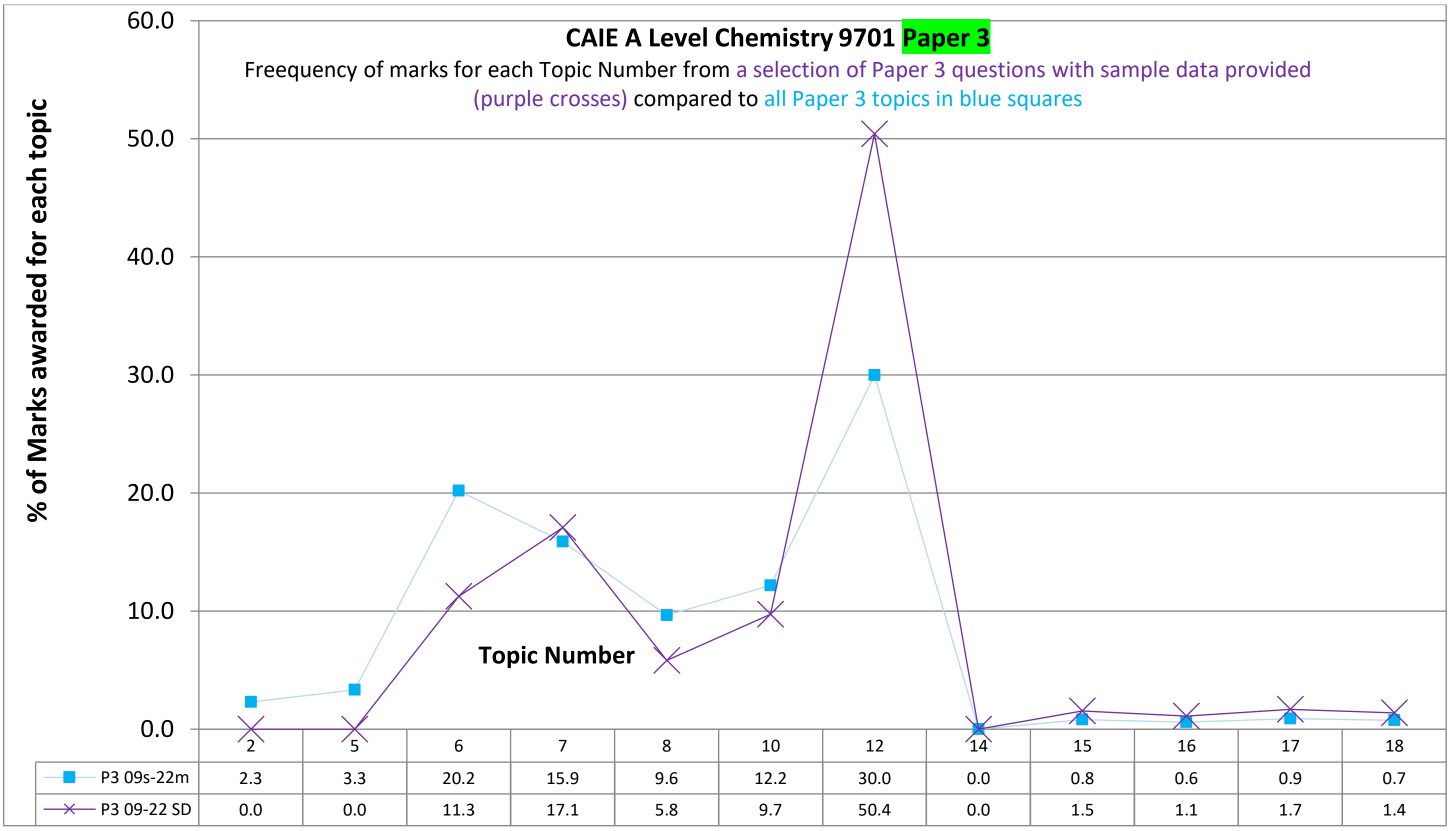
Name: Class: Date:

ALvl Chem 5 EQ P3 22w to 09s Paper 3 Chemical energetics 45marks

- This **booklet cannot replace lab experience** as the best way to prepare for Paper 3, but it can help with understanding some of the theory aspects.
- This booklet does not include sample data, though such booklets do exist for most experiment types on www.SmashingScience.org
- It is usually better to revise Paper 3 by looking at specific experiment types, rather than by topic. But these booklets may be helpful when learning each topic for the first time.
- Successful work on these questions without doing the experiments is much harder to do, but you can use them to investigate the kinds of experiments that each topic has, and as a starting point to learn about that experiment in a way that would allow you to understand the question and deliver correct answers.
- The average time in Paper 3 for each mark is 180 seconds, or 3minutes. The marks that result from a successful experiment relate to work that will require more time than this average. Most, if not all, of the theory marks will require a good student far less time than 180 seconds of work to achieve. The biggest challenge in Paper 3 tends to be effective time management, so thinking carefully and analytically about the time required for the different parts of the exam is a critical Paper 3 skill.

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper3 Topic 5 **Checklist** Tick each task off as you go along	RANK:	P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	**P1[1] Winner**	**P1 Hero**	**P1 Legend**
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	45		11	5	11	18	23	34	45
Time @180/mark (minutes)	135		34	14	34	54	68	101	135



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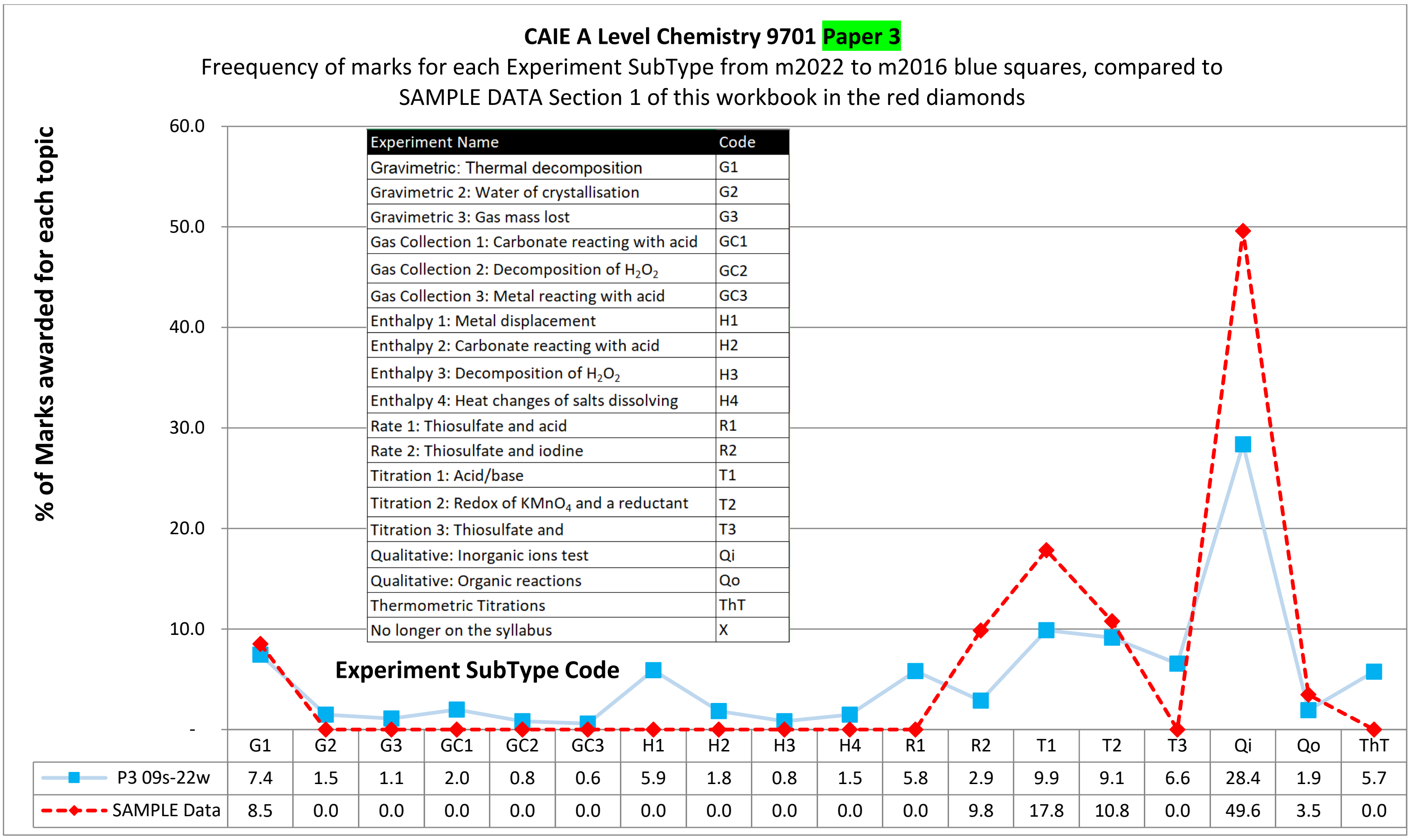
[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Gold**" (40%) in the same topic in both **Paper 1** and **Paper 2**, which is **MOST (77%)** of your **AS grade**



CAIE A Level Chemistry 9701 Paper 3

Freequency of marks for each Experiment SubType from m2022 to m2016 blue squares, compared to SAMPLE DATA Section 1 of this workbook in the red diamonds

Experiment Name	Code
Gravimetric: Thermal decomposition	G1
Gravimetric 2: Water of crystallisation	G2
Gravimetric 3: Gas mass lost	G3
Gas Collection 1: Carbonate reacting with acid	GC1
Gas Collection 2: Decomposition of H_2O_2	GC2
Gas Collection 3: Metal reacting with acid	GC3
Enthalpy 1: Metal displacement	H1
Enthalpy 2: Carbonate reacting with acid	H2
Enthalpy 3: Decomposition of H_2O_2	H3
Enthalpy 4: Heat changes of salts dissolving	H4
Rate 1: Thiosulfate and acid	R1
Rate 2: Thiosulfate and iodine	R2
Titration 1: Acid/base	T1
Titration 2: Redox of $KMnO_4$ and a reductant	T2
Titration 3: Thiosulfate and	T3
Qualitative: Inorganic ions test	Qi
Qualitative: Organic reactions	Qo
Thermometric Titrations	ThT
No longer on the syllabus	X

	G1	G2	G3	GC1	GC2	GC3	H1	H2	H3	H4	R1	R2	T1	T2	T3	Qi	Qo	ThT
P3 09s-22w	7.4	1.5	1.1	2.0	0.8	0.6	5.9	1.8	0.8	1.5	5.8	2.9	9.9	9.1	6.6	28.4	1.9	5.7
SAMPLE Data	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	17.8	10.8	0.0	49.6	3.5	0.0

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. Paper 3 can sometimes cause a good student at a higher-grade boundary to gain or lose that higher grade, but generally tends to have less impact than the 2 theory papers. However, success in Paper 3 is unusually strongly linked to good preparation.
5. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

2 Hydrated copper(II) sulfate, $CuSO_4{\cdot}5H_2O$, can lose its water of crystallisation to form anhydrous copper(II) sulfate.

The enthalpy change for the dehydration of hydrated copper(II) sulfate is shown in the equation.

$$CuSO_4{\cdot}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

You will carry out experiments to determine the enthalpy changes for the solution of hydrated and anhydrous copper(II) sulfate and then use Hess's law to determine the enthalpy change of dehydration.

FA 4 is hydrated copper(II) sulfate, $CuSO_4{\cdot}5H_2O$.
FA 5 is anhydrous copper(II) sulfate, $CuSO_4$.

(a) Determination of the enthalpy change of solution of hydrated copper(II) sulfate.

Method

- Weigh the container with **FA 4**. Record the mass.
- Support the cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 25.0 cm³ of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 4** into the water and stir until the solid dissolves.
- Measure and record the lowest temperature reached.
- Rinse and dry the cup ready for the next experiment.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 4** used.

Results

[2]

(b) Calculations

(i) Calculate the energy change during this reaction.

energy change = ... J [1]

(ii) Calculate the amount, in mol, of hydrated copper(II) sulfate, **FA 4**, used in the experiment. Show your working.

amount of $CuSO_4{\cdot}5H_2O$ = ... mol [1]

(iii) Calculate the enthalpy change, in kJ mol^{-1}, when 1.00 mol of hydrated copper(II) sulfate dissolves in water. This is the enthalpy of solution.

enthalpy change of solution = ... kJ mol^{-1} [1]

sign *value*

(c) Determination of the enthalpy change of solution of anhydrous copper(II) sulfate.

Method

- Weigh the container with **FA 5**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 5** into the water and stir until the solid dissolves.
- Measure and record the highest temperature reached.
- Weigh the container with any residual **FA 5**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 5** used.

Results

[1]

(d) Calculations

(i) Calculate the enthalpy change, in kJ mol^{-1}, for the enthalpy change of solution of anhydrous copper(II) sulfate.

enthalpy change = ... kJ mol^{-1} [2]
sign *value*

(ii) Use the enthalpy changes calculated in **(b)(iii)** and **(d)(i)** to calculate the enthalpy change of dehydration of hydrated copper(II) sulfate.

$$CuSO_4{\bullet}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Show clearly how you obtained your answer.

enthalpy change = ... kJ mol^{-1} [1]
sign *value*

(e) In the experiments in **(a)** and **(c)** you used the same method to determine the enthalpy change of solution of two solids.

Tick the box to indicate which statement is correct.
Ignore the effect of differences in mass used.

The percentage error in **(b)(iii)** is less than the percentage error in **(d)(i)**.	
The percentage errors in **(b)(iii)** and **(d)(i)** are equal.	
The percentage error in **(b)(iii)** is greater than the percentage error in **(d)(i)**.	

Explain your choice.

....

.... [1]

2 In this experiment you will determine the enthalpy change of solution for anhydrous sodium carbonate.

FA 5 is anhydrous sodium carbonate, Na_2CO_3. (You are given approximately 11 g.)

(a) Method

Experiment 1

- Weigh a cup. Record the mass.
- Transfer 4.0–4.2 g of **FA 5** from the container into the cup.
- Reweigh and record the mass of the cup with **FA 5**.
- Calculate and record the mass of **FA 5** used.
- Support the cup in the 250 cm^3 beaker.
- Pour 30 cm^3 of distilled water into the 50 cm^3 measuring cylinder.
- Measure and record the temperature of the distilled water in the measuring cylinder.
- Add the 30 cm^3 of distilled water to the **FA 5** in the cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Calculate and record the temperature rise.

Experiment 2

- Repeat **Experiment 1** but this time use 5.0–5.2 g of **FA 5** and the other cup.
- Record all data from **both** experiments in one table.

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the energy produced during **Experiment 1**.
(Assume that 4.2 J change the temperature of 1.0 cm^3 of solution by 1.0 °C.)

energy produced = ... J [1]

(ii) Calculate the number of moles of Na_2CO_3 used in **Experiment 1**.

moles of Na_2CO_3 = ... mol [1]

(iii) Use your answers to **(b)(i)** and **(b)(ii)** to calculate the enthalpy change, in kJ mol^{-1}, for the reaction below.
Show your working.

$$Na_2CO_3(s) + aq \rightarrow Na_2CO_3(aq)$$

enthalpy change = ... kJ mol^{-1}
sign *value* [1]

(c) **(i)** A student suggested that by using the same thermometer, quantities of **FA 5**, and water, a more accurate value for the temperature rise could be calculated.

Suggest how the student could obtain a more accurate measurement.

....

....

.... [1]

(ii) State the maximum error in a single thermometer reading in your experiment in **(a)**.

maximum error = ...

Hence calculate the maximum percentage error in the measurement of the temperature rise in **Experiment 2**.

% error = ...
[2]

[Total: 10]

2 In this experiment you will determine the enthalpy change, ΔH, for the catalytic decomposition of hydrogen peroxide into water and oxygen.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

FA 3 is aqueous hydrogen peroxide, H_2O_2.
FA 5 is manganese(IV) oxide, MnO_2.

(a) Method

Experiment 1

- Support one of the plastic cups inside the 250 cm³ beaker.
- Use the 50 cm³ measuring cylinder to add 30 cm³ of **FA 3** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the plastic cup.
- Stir constantly until the maximum temperature is reached and record this temperature.
- Calculate and record the temperature rise.
- Rinse and dry the thermometer.

Experiment 2

- Support the second plastic cup inside the 250 cm³ beaker.
- Use the 50 cm³ measuring cylinder to add 40 cm³ of **FA 3** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the plastic cup.
- Stir constantly until the maximum temperature is reached and record this temperature.
- Calculate and record the temperature rise.

I	
II	
III	
IV	
V	

[5]

(b) Calculation

(i) Calculate the energy released in **Experiment 1**.
[Assume that 4.2 J changes the temperature of 1.0 cm^3 of solution by 1.0 °C.]

energy released = ... J [1]

(ii) Use your answer to **1(c)(iv)** to calculate the number of moles of hydrogen peroxide used in **Experiment 1**.
(If you were unable to calculate the concentration of H_2O_2 in **FA 3**, assume that it is 1.02 mol dm^{-3}. This may **not** be the correct value.)

moles of H_2O_2 = ... mol [1]

(iii) Calculate the enthalpy change, in kJ mol^{-1}, for the decomposition of 1 mole of hydrogen peroxide into water and oxygen.

enthalpy change = ... kJ mol^{-1} [1]
sign *value*

(c) (i) A student suggested that the experiment would be more accurate if the same mass of **FA 5**, manganese(IV) oxide, had been weighed out for each experiment.

State and explain whether you agree with the student's suggestion.

....

....

....

.... [2]

(ii) The student also suggested that **Experiments 1** and **2** should give the same temperature rise, even though a greater volume of **FA 3** was used in **Experiment 2**.

State and explain whether you agree with the student's suggestion.

....

....

.... [1]

[Total: 11]

2 You will determine, using Hess' Law, the enthalpy change, ΔH_1, for the reaction of magnesium with oxygen to form magnesium oxide.

For Examiner's Use

$$Mg(s) + \tfrac{1}{2}O_2(g) \rightarrow MgO(s)$$

(a) Reaction of magnesium with sulfuric acid

Method

FA 4 is 0.64 mol dm^{-3} sulfuric acid.
FA 5 is magnesium turnings. This is supplied in two containers.

You will carry out the experiment **twice**.

- Support the plastic cup in a 250 cm^3 beaker.
- Using a measuring cylinder, transfer 25 cm^3 of **FA 4** into the plastic cup.
- Tilt the beaker so that the bulb of the thermometer is covered by the solution. Measure and record the initial temperature of the solution.
- **Carefully**, add all the **FA 5** from one of the containers into the plastic cup.
- Stir the mixture constantly with the thermometer.
- Record the highest temperature obtained.
- Empty and rinse the plastic cup and dry it with a paper towel.
- Repeat the experiment using the second portion of **FA 5**.

In the space below, record all your readings in an appropriate form.
Calculate the mean temperature rise.

I	
II	
III	
IV	
V	

mean temperature rise = ... °C [5]

Calculation

Show your working and express your answers to **three** significant figures.

(i) Using the mean temperature rise above, calculate the mean heat energy produced in the reaction.
(You may assume that 4.3 J are required to raise the temperature of 1.0 cm^3 of any solution by 1.0 °C.)

heat energy produced = ...
value *unit*

(ii) Calculate the enthalpy change, ΔH_2, in kJ mol^{-1}, for the following reaction.

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

You should assume that the magnesium in your reaction is in excess.

ΔH_2 = ... kJ mol^{-1} [2]
sign *value*

(b) Reaction of magnesium oxide with sulfuric acid

Method

FA 4 is 0.64 mol dm^{-3} sulfuric acid.
FA 6 is magnesium oxide.

- Using a measuring cylinder, transfer 50 cm^3 of **FA 4** into a 250 cm^3 beaker.
- Place the beaker on a tripod and gauze, and heat gently until the temperature of the acid reaches 45 °C–60 °C.
- Support a plastic cup in a 250 cm^3 beaker.
- Transfer all the solution of hot **FA 4** into the plastic cup.
- Stir and record the temperature of hot **FA 4**.
- **Immediately** add all the **FA 6** to the **FA 4** in the plastic cup.
- Stir the mixture constantly with the thermometer.
- Record the highest temperature obtained.

In the space below, record all your readings in an appropriate form.

[3]

Calculation

Show your working and express your answers to **three** significant figures.

(i) Calculate the heat energy produced in the reaction.
(You may assume that 4.3 J are required to raise the temperature of 1.0 cm^3 of any solution by 1.0 °C.)

heat energy produced = ...
value *unit*

(ii) Calculate the enthalpy change, ΔH_3, in $kJ\,mol^{-1}$, for the following reaction.

$$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$$

You should assume that the magnesium oxide in your reaction is in excess.

ΔH_3 = ... $kJ\,mol^{-1}$
sign *value*

(iii) The enthalpy change for the following reaction is $-286\,kJ\,mol^{-1}$.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H = -286\,kJ\,mol^{-1}$$

Use the Hess' Law cycle given below to calculate ΔH_1, the enthalpy change for the reaction of magnesium with oxygen.

$$\begin{tikzcd}
Mg(s) + H_2SO_4(aq) + \tfrac{1}{2}O_2(g) \arrow[r, "\Delta H_1"] \arrow[d, "\Delta H_2"'] & MgO(s) + H_2SO_4(aq) \arrow[d, "\Delta H_3"] \\
MgSO_4(aq) + H_2(g) + \tfrac{1}{2}O_2(g) \arrow[r, "-286\,kJ\,mol^{-1}"] & MgSO_4(aq) + H_2O(l)
\end{tikzcd}$$

ΔH_1 = ... $kJ\,mol^{-1}$ [3]
sign *value*

(c) Suggest **one** improvement to the method by which heat losses from your apparatus could have been reduced.

....

....[1]

[Total: 14]

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2(a)	**M1: table of readings with unambiguous headings and correctly displayed units for all entries in the space for Results** • (mass of) container + FA 4 • (mass of) container (+ residue) • first / start / initial temperature / temperature of water • lowest / final temperature	2
	M2: **readings in 2(a)** • both thermometer readings shown to 0.0 °C or 0.5 °C • balance readings shown consistently to either 2 dp or to 3 dp • mass and temperature rise in (a) subtracted correctly and shown in the space for results	
2(b)(i)	**correctly calculates energy change** energy change = 25 × 4.18 × *T* fall (J) **and** answer to 2–4 sf	1
2(b)(ii)	**correctly calculates amount of FA 4** amount = $\frac{\text{mass FA 4}}{249.6}$ (mol) and answer to 2–4 sf	1
2(b)(iii)	**correctly uses** $\frac{\text{(b)(i)}}{\text{(b)(ii)}}$ enthalpy change = $\frac{\text{(b)(ii)}}{\text{(b)(ii)} \times 1000}$ (kJ mol^{-1}) and + sign and answer to 2–4 sf	1
2(c)	**readings** mass of FA 5 and temperature rise are correctly calculated two thermometer readings are both above 10 °C temperature rise is greater than *T* fall in (a)	1
2(d)(i)	**correct expressions shown for enthalpy change** • energy change = 25 × 4.18 × *T* change (J) • amount used = $\frac{\text{mass of FA 5 used}}{159.6}$ (mol) • $\Delta H = \frac{\text{energy change}}{\text{number of moles} \times 1000}$ (kJ mol^{-1}) • negative sign in answer	2
2(d)(ii)	**Hess's cycle calculation** correct calculation of Δ*H* = **(b)(iii)** – **(d)(i)** (kJ mol^{-1}) **and** some working shown e.g., equation as shown and 2 downward arrows with labelling / correct values from **(b)(iii)** and **(d)(i)** with correct signs	1
2(e)	**explanation for answer selected** box 1 ticked: Δ*T* is larger for **(b)(iii)** (ora) box 2 ticked: Δ*T* is the same for both experiments box 3 ticked: Δ*T* is larger for **(d)(i)** (ora)	1

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2(a)	**I Unambiguous table of data** • Mass of cup • Mass of cup + **FA 5** • Mass of **FA 5** used • Initial temperature or temperature of water / °C • Final / maximum temperature / °C • Temperature rise / °C • Both experiments must be attempted	1
	II Readings recorded appropriately • All four thermometer readings recorded to .0 or .5. • All four subtractions correct (two masses and two temp rises). • No thermometer reading is less than 10 °C • Mass of **FA** 5 used for first experiment is 4.0–4.2 g • Mass of **FA** 5 used for second experiment is 5.0–5.2 g	1
	III + IV Accuracy marks Check and correct temp subtractions for candidate and supervisor. Round each measured temperature to 0.5 °C if necessary Compare the temperature rises for the two experiments.	
	Award **III** if candidate's rise is within 1.0 °C of supervisor in **Expt 1**.	1

	Award IV if candidate's rise within 1.0 °C of supervisor in Expt 2.	1
2(b)(i)	**Correct calculation of energy change (2, 3 or 4 sf)** Energy change = 30 × 4.2 × temp rise (J)	1
2(b)(ii)	**Correct calculation of no of moles of Na_2CO_3 used (2–4 sf)** n = $^{\text{mass claimed}}/_{106}$	1
2(b)(iii)	**Correct use of (i) and (ii) to calculate enthalpy change (2–4 sf)** Enthalpy change = – $^{\text{energy}}/_{1000 \times \text{moles}}$	1

2(c)(i)	**Accuracy improvement** Plot graph to obtain better (estimate of) temp rise or plot a cooling curve	1
2(c)(ii)	Error = 0.5	1
	Correct calculation of % error to 2 or more sig fig % error = $^{2 \times 0.5}/_{\text{temp rise (expt 2)}} \times 100$	1

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2(a)	I Table (or two lists) showing unambiguous headings and data for both experiments in the space provided: • two initial thermometer readings + values • two final / highest thermometer readings + values • two temperature rises / changes + values	1
	II Recording of data • correct units 'covering' all thermometer readings • all four readings recorded to .0 or .5 °C • both rises in temperature correctly calculated	1
	III Award this mark based on the table below	1
	IV Award this mark based on the table below	1

ΔT_{sup} (°C)	$\Delta T \geqslant 15.0$	$15 > \Delta T \geqslant 10.0$	$10 > \Delta T \geqslant 5.0$	$\Delta T < 5.0$
δ	2.0	1.5	1.0	0.5

	V Award mark if both the candidate's corrected temperature rises are within 1.0 °C of each other	1
2(b)(i)	Correctly calculates heat produced = 30 × 4.2 × temp rise for expt 1 **AND** answer given to 2–4 sf	1
2(b)(ii)	Correctly uses number of moles H_2O_2 = 0.03 × answer to **1**(c)(iv) **AND** answer given to 2–4 sf Answer for default value = 0.0306 / 0.031 mol	1
2(b)(iii)	Correct expression for enthalpy change • Enthalpy change = $\frac{\text{ans (i)}}{\text{ans (ii)}} \times \frac{1}{1000}$ • Negative sign must be shown • Answer is shown to 2–4 sf	1

2(c)(i)	(FA 5 / MnO_2 is a) catalyst	1
	(Student is wrong:) the mass of MnO_2 used does not alter the heat produced / enthalpy change / temperature change (for decomposition of H_2O_2)	1
2(c)(ii)	Student is correct: energy / heat released is greater because more / greater (moles / molecules of) hydrogen peroxide / FA 3 is used in Experiment 2 **AND** more moles / molecules / greater amount of water / solution / FA 3 / hydrogen peroxide heated is greater (in the same proportion)	1

Q# 7/ Chem 5 ALvl Chemistry/2011/s/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 **(a)**	MMO Collection	**I**	Two pairs of temperature values recorded as instructed in **(a)**, with units for all readings in **(a)** and **(b)** – minimum of 3 readings. *Acceptable units are /°C, (°C), temperature in degrees Celsius, temperature in °C.*	1	

	PDO Recording	**II** **All** thermometer readings recorded to 0.0 °C or 0.5 °C. (check readings in sections **2(a)** ***and*** **2(b)** – minimum of 4 readings).	1	
	ACE Interpretation	**III** Correct subtractions to give temperature rises **and** the correct mean value in **2(a)**. *Mean value may be rounded to 0.5 °C* ***or*** *to one d.p* ***or*** *to 0.05 °C and from 0.025 and 0.075 or these may be rounded up or down to nearest 0.1.*	1	
Supervisor script: check subtractions and calculate mean ΔT *Marks are awarded for comparing the “true” means: check working of candidate and Supervisor.* *Show Supervisor’s mean (corrected* ***if*** *necessary) on the script in a ring.*				
	MMO Quality	Award **IV** and **V** if candidate’s mean temp rise is within 2.0 °C of Supervisor’s (incl) Award **IV** if the difference is between 2.0 °C and 3.0 °C.	1 1	[5]
	PDO Display	Heat produced (J) = 25 × 4.3 × temp rise *(method mark).* *Unit is needed in the quoted answer (kJ if divided by 1000).* Correctly evaluates enthalpy change = $^{\text{heat produced}}/_{0.016}$. *Division by 1000 is not required if candidate did this in the previous step.* *Answer must be negative and to 3 sig figs.*	1 1	[2]
Examiner to calculate 20% and 40% of supervisor’s ΔT and convert to nearest 0.5°C.				
(b)	ACE Interpretation MMO Quality	**I** Both temperature measurements clearly shown. Award **II** and **III** if candidate’s temp rise is within 20% of Supervisor’s. Award **II** if candidate’s temp rise is within 40% of Supervisor’s.	1 1 1	[3]
	ACE Interpretation PDO Display ACE Conclusions	**IV** Calculates 0.032 for moles in **(ii)** or 0.016 for moles in **(a)(ii)**. **V** Enthalpy change correctly calculated (= – $^{\text{heat change}}/_{0.032}$). *Answer* ***must*** *show negative sign (unless already penalised) and be given to 3 sig figs. (unless already penalised).* **VI** Correct calculation of enthalpy change $\Delta H_1 = \Delta H_2 - \Delta H_3 - 286$	1 1 1	[3]
(c)	ACE Improvements	Extra/thicker lagging ***or*** use a lid ***or*** use a vacuum flask	1	[1]
				[Total: 14]