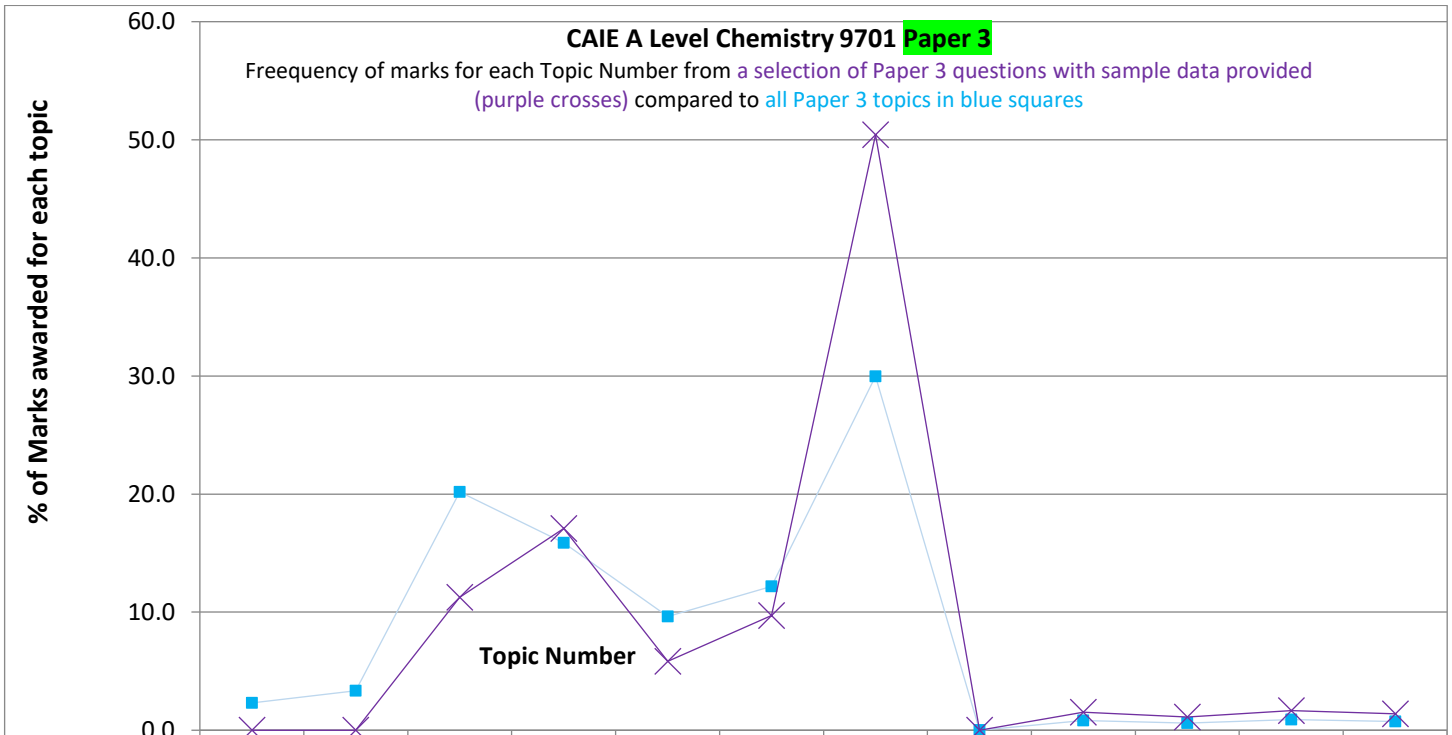
Name: Class: Date:

ALvl Chem 2 EQ P3 22w to 09s Paper 3 Atoms, molecules and stoichiometry 31marks

- 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 2 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)	31		10	3	8	12	16	23	31
Time @180/mark (minutes)	93	0	31	9	23	37	47	70	93

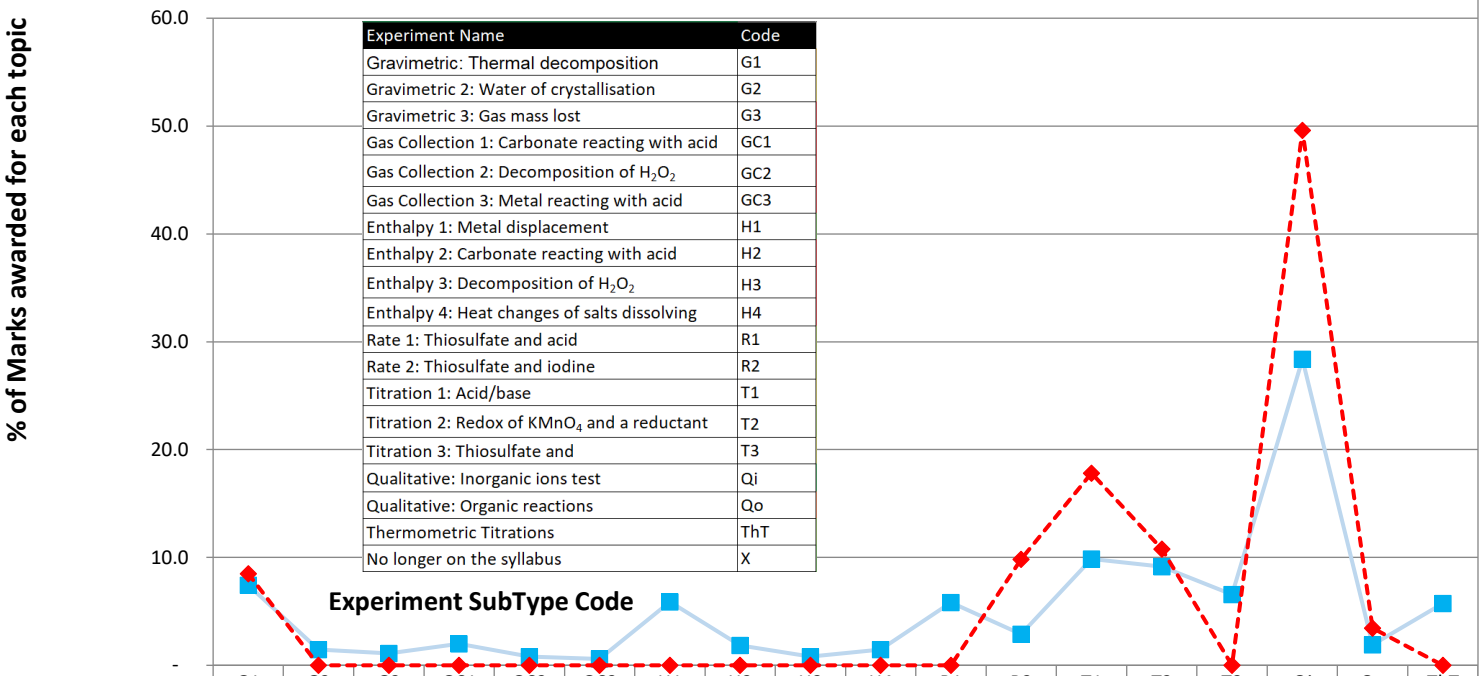


	2	5	6	7	8	10	12	14	15	16	17	18
P3 09s-22m	2.3	3.3	20.2	15.9	9.6	12.2	30.0	0.0	0.8	0.6	0.9	0.7
P3 09-22 SD	0.0	0.0	11.3	17.1	5.8	9.7	50.4	0.0	1.5	1.1	1.7	1.4

[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 In **Question 1** you used a titration method to determine the value of *x* in a hydrated salt. In **Question 2** you will use a gravimetric method. In this method a sample of solid is heated to remove the water of crystallisation.

You will carry out this method on a different hydrated compound, **FA 4**, with formula $MZ{\bullet}yH_2O$. In **FA 4** the value of *y* is an integer.

$$MZ{\bullet}yH_2O(s) \rightarrow MZ(s) + yH_2O(g)$$

FA 4 is a hydrated compound, $MZ{\bullet}yH_2O$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Place between 2.40 g and 2.60 g of **FA 4** in the crucible and record its appearance below.
- Weigh the crucible, its lid and contents and record the mass.
- Without the lid, place the crucible on the pipe-clay triangle and heat gently for approximately one minute and record your observations.
- Then heat more strongly for approximately four minutes.
- Place the lid on the crucible and leave it to cool.

You may wish to start Question 3 while you are waiting for the crucible to cool.

- Weigh the crucible, its lid and contents and record the mass.
- Calculate and record the mass of **FA 4**, the mass of residue after heating and the mass of water lost.

Keep FA 4 for use in Question 3.

Results

appearance of **FA 4** .....

observations during heating for the first minute .....

.....

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the number of moles of water lost when your sample of $MZ \cdot yH_2O$ was heated.

moles of water = ... mol

The relative formula mass of the anhydrous compound MZ is 120.4.

Calculate the number of moles of MZ present in the residue.

moles of MZ = ... mol
[1]

(ii) Use your answers from **(b)(i)** to calculate the value of *y* in **FA 4**, $MZ \cdot yH_2O$.
Show your working.

y = ... [1]

(iii) State an assumption you made when calculating the value of *y* in the hydrated compound.

..... [1]

(c) A student suggested that the experiment would be more accurate if the crucible had been heated with the lid on for the first minute.

State and explain whether you agree with the student.

.....

..... [1]

[Total: 8]

1 The concentration of hydrogen peroxide may be given in mol dm^{-3} or as 'volume strength'. You will determine the concentration of hydrogen peroxide in mol dm^{-3} and in 'volume strength' by a gas collection method.
Hydrogen peroxide decomposes to form water and oxygen. The reaction is much faster in the presence of a catalyst such as manganese(IV) oxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

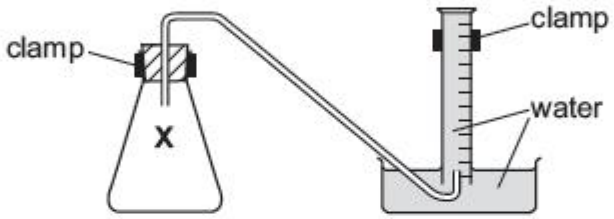
'Volume strength' is defined as the volume of oxygen in cm^3 produced from the decomposition of 1.0 cm^3 of hydrogen peroxide at room temperature and pressure. For example, 1.0 cm^3 of '100 volume' hydrogen peroxide will produce 100 cm^3 of oxygen.

FA 1 is a solution of hydrogen peroxide, H_2O_2.
FA 2 is manganese(IV) oxide, MnO_2.

(a) Method

Read the whole method before starting any practical work.

The diagram below may help you in setting up your apparatus.



- Fill the tub with water to a depth of about 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so that the open end is in the water just above the base of the tub.
- Rinse the 50 cm^3 measuring cylinder with a little **FA 1** then use it to transfer 150 cm^3 of **FA 1** into the reaction flask labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip **FA 2** into the hydrogen peroxide and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is given off. Replace the flask in the clamp.
- Measure and record the final volume of gas in the measuring cylinder in the space below.

Keep FA 1 for use in Question 2.

Result

[2]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use the information on page 2 to calculate the 'volume strength' of **FA 1**.

'volume strength' of **FA 1** = ...

(ii) Calculate the number of moles of oxygen collected in the measuring cylinder.
[Assume 1 mole of gas occupies 24.0 dm^3 under these conditions.]

moles of O_2 = ... mol

(iii) Using your answer to **(ii)** calculate the number of moles of hydrogen peroxide in the volume of **FA 1** added to flask **X**.

moles of H_2O_2 = ... mol

(iv) Calculate the concentration of hydrogen peroxide, **FA 1**, in mol dm^{-3}.

concentration of H_2O_2, **FA 1** = ... mol dm^{-3}
[4]

(c) (i) A source of error in this experiment is that some oxygen escapes before the bung can be inserted.

Suggest a change to the practical procedure given in **(a)** to reduce this source of error. You may draw a diagram as part of your answer.

.....

.....

(ii) The error in reading a 50 cm^3 measuring cylinder is ±0.5 cm^3.

Calculate the maximum percentage error in the volume of hydrogen peroxide added to flask **X** in **(a)**.

maximum percentage error in volume of H_2O_2 = ... %

(iii) Explain why the presence of 20 cm^3 of air in the 250 cm^3 measuring cylinder before the start of the experiment would decrease the accuracy of the results obtained in **(a)**.

.....

.....

.....

[4]

(d) If you repeated the method described using half the mass of **FA 2**, what volume of gas would you expect to collect? Explain your answer.

.....

..... [1]

[Total: 11]

For Examiner's Use

2 In this experiment you are to determine the formula of hydrated barium chloride, **FA 5**, by heating to remove the water of crystallisation. You will heat **two** separate samples. The anhydrous barium chloride does not decompose when heated.

FA 5 is hydrated barium chloride, $BaCl_2.xH_2O$

(a) Method

Record **all** weighings, in an appropriate form, in the space below.

- Record the mass of the empty crucible **without** its lid.
- Add between 2.0 and 2.4 g of **FA 5** into the crucible. Record the mass of the crucible and its contents.
- Use a pipe-clay triangle to support the crucible and contents on a tripod.
- Heat the crucible and its contents gently for about **one** minute with the lid off. Then heat strongly for a further **four** minutes.
- Put the lid on the crucible and leave to cool for approximately 10 minutes.

While you are waiting for the crucible to cool, start work on Question 3.

- When the crucible is cool, **remove the lid**, and weigh the crucible with the residue.
- Record the mass of anhydrous barium chloride remaining in the crucible after heating and the mass of water lost.

- To prepare for the second experiment, use a spatula to remove the residue from the crucible into the beaker labelled **waste**.
- Reweigh the empty crucible **without** its lid.
- Carry out the experiment again. This time use between 1.5 and 1.9 g of **FA 5**.

[6]

I	
II	
III	
IV	
V	
VI	

(b) Calculation

Show your working in **each** step.

(i) Calculate the **mean** number of moles of water removed from the hydrated salt in the experiments.
(A_r: H, 1.0; O, 16.0)

moles of H_2O = ... mol

(ii) Calculate the **mean** number of moles of anhydrous barium chloride produced in the experiments.
(A_r: Ba, 137; C*l*, 35.5)

moles of $BaCl_2$ = ... mol

(iii) Calculate the value of **x** in the formula of hydrated barium chloride, $BaCl_2.xH_2O$.

x = ...
[3]

(c) (i) Suggest how the experimental procedure could be modified to ensure that **all** of the water of crystallisation had been removed by heating hydrated **FA 5**.

.....

.....

.....

(ii) Do you think that the results from your two experiments are consistent with each other?
Justify your answer by carrying out appropriate calculations.

[3]

[Total: 12]

Q# 1/ ALvl Chemistry/2021/s/TZ 1/Paper 3/Q# :o) www.SmashingScience.org

2(a)	I **Appearance** **FA 4**: white / colourless **and** crystals /solid **AND** obs during heating: swelling / steam / (some) solid melts / dissolves / white powder forms around the edges *Allow evaporation of water* *Allow bubbling / bubbles of water* *Ignore fizzing / effervescence*	1
	II **Unambiguous headings and units in list / table of data:** • (Mass of) crucible and lid *(not 'weight' in any reading)* • (Mass of) crucible, lid and **FA 4** (or 'contents before heating') • (Mass of) crucible, lid and residue / contents after heating • (Mass of) **FA 4** (used) • (Mass of) residue • (Mass of) water (lost) *Ignore mention of 1st heating if reheated* *Do not allow 'mass of **FA 4** after heating' in third weighing.* *Use of lid must be consistent.* *Unit must be given correctly in each case.*	1
	III **Three weighings recorded and all listed subtractions (minimum one) correct** • All weighings to the same number of dp • Mass of **FA 4** used between 2.40 and 2.60 g *If 4 weighings shown then all must be to the same number of dp*	1
	IV **Accuracy mark** Award if ratio between 1.80–2.10	1
2(b)(i)	**Correctly calculates** $n(H_2O)$ = mass loss in **(a)** / 18 and answer to 2 or more sf **AND** n(MZ) = mass of residue in **(a)** / 120.4 and answer to 2 or more sf *If masses are not shown in **(a)** then values used must be correct*	1
2(b)(ii)	**Shows use of** ratio n(MZ) : $n(H_2O)$ **AND** *y* is an integer *Other correct methods are available.*	1
2(b)(iii)	**One of the following** • All water (of crystallisation) was lost / dehydration was complete • No MZ decomposed on heating	1
2(c)	**One of the following** • student incorrect **and** because there was no spitting (and therefore lid not required) • student correct **and** to catch any spitting (check observations for spitting or swelling) • student incorrect **and** because putting the lid on makes no difference to water (vapour) escaping	1

Q# 2/ ALvl Chemistry/2017/m/TZ 3/Paper 3/Q# :o) www.SmashingScience.org

1(a)	**M1** unambiguous recording of volume of oxygen gas with unit	1
	M2 volume of gas within 10% of the supervisor's value	1
1(b)(i)	correctly calculates **V(a)** ÷ 150 to 2–4 sig. fig.	1
1(b)(ii)	correctly calculates $\frac{V(a)}{24.0 \times 1000}$ to 2–4 sig. fig.	1
1(b)(iii)	correctly uses **(ii)** × 2 **AND** answer to 2–4 sig. fig.	1
1(b)(iv)	shows working $\frac{(iii) \times 1000}{150}$ **AND** answer to 2–4 sig. fig.	1
1(c)(i)	MnO_2 in (ignition) tube / floating in weighing boat **OR** use a dropping funnel / syringe for H_2O_2 **AND** subtract the liquid volume	1
1(c)(ii)	**M1** $\frac{0.5 \times 100}{50}$ = 1.0%	1

	M2 × 3 = 3.0% (3.0 with no working shown scores [2].)	1
1(c)(iii)	(agree as) two readings to find volume of gas evolved are needed so there is twice the percentage error in the gas volume reading	1
1(d)	no change because MnO_2 / **FA 2** / solid is a catalyst	1

Q# 3/ ALvl Chemistry/2013/w/TZ 1/ Paper 3/Q# 2/ :o) www.SmashingScience.org

2 (a)	MMO Collection	**I** The masses of **FA 5** used by the candidate were between 2.0–2.4 g (expt 1) and 1.5–1.9 g (expt 2).	1	
	PDO Display	**II** Suitable headings for a table or list, shown completely for at least one experiment carried out. If 2 experiments, all headings must be correct. • (mass of) empty crucible • (mass of) crucible + **FA 5** • (mass of) crucible + residue / **FA 5** after heating • (mass of) residue *(owtte)* • mass lost **or** (mass of) water lost. **and** unit was given "covering" every weighing; *Unit: /g **or** (g) **or** in grams **or** g following **each** weighing*	1	
	PDO Recording	**III** Records **all** weighings **consistently** to at least 1 dp. *A minimum of **three** weighings are needed.*	1	
	Accuracy (Q) marks for gravimetric experiment – 3 marks available Examiner checks working for mass of residue **and** mass of water and expresses the ratio $^{\text{mass of hydrated solid}}/_{\text{mass of water}}$ to 2 dp for **each** experiment. The expected ratio = $^{244}/_{36}$ = 6.78.			
(a) (cont)	MMO Quality	Award **IV** if the ratio in expt **1** is between 6.30 and 7.25. Award **V** If the ratio in expt **2** is between 6.30 and 7.25. Award **VI** If the ratio in **both** of experiments **1** and **2** is between 5.90 and 7.65, inclusive.	1 1 1	[6]
(b) (i)	MMO Display	Correct expression for the number of moles of water lost (from mass as recorded) **or** correct answer.	1	
(ii)	ACE Interpretation	Correct expression for the number of moles of residue with **correct** masses of anhydrous salt **and** 208 **and** answer expressed to 2–4 sf **or** correct answer **and** 2–4 sf If only **one** expt carried out then **correct calculation** for number of moles of residue expressed to 2–4 sig fig.	1	
(iii)	ACE Interpretation	Correct calculation of **(i)** ÷ **(ii)** to give answer as an integer. (should be **x** = 2)	1	[3]
(c) (i)	ACE Improvements	Heat to constant **mass** (owtte)	1	
(ii)	ACE Interpretation	An **attempt** to "**scale**" mass loss to the mass of **FA 5** used **or** to calculate **x** separately for the two experiments.	1	
	ACE Conclusion	Uses calculated values to comment sensibly on the consistency the results.	1	[3]