4-3 Quantitative chemistry – Chemistry

1.0 This question is about carbonates.

1.1 Sodium carbonate, Na_2CO_3, is used as a water softener.
Give the number of atoms of each type in sodium carbonate.

[3 marks]

Sodium (Na) atom(s): _____

Carbon (C) atom(s): _____

Oxygen (O) atom(s): _____

1.2 Calculate the relative formula mass (M_r) of sodium carbonate, Na_2CO_3

Relative atomic masses (A_r): Na = 23; C = 12; O = 16.

[2 marks]

Relative formula mass (M_r) of sodium carbonate =_____

1.3 A student heated a sample of calcium carbonate.
The equation for the reaction is:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

This is an example of thermal decomposition.
What is meant by 'thermal decomposition'?

[2 marks]

_____

_____

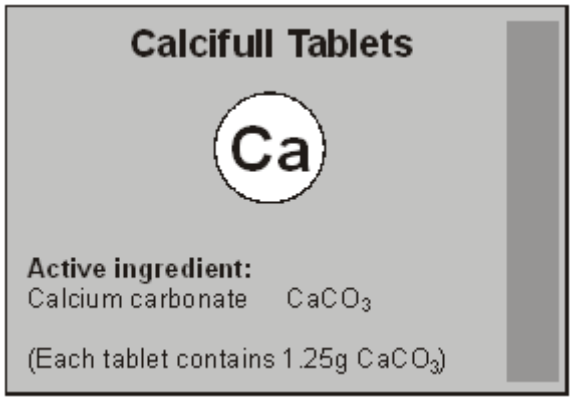
1.4 Both calcium carbonate and calcium oxide are white solids.
The student weighed the white solid before and after heating.
Explain why a decrease in mass was observed.
Use the equation in **part 1.3** to help you answer the question.

[2 marks]

_____

_____

1.5 Calcium carbonate tablets are used to treat people with calcium deficiency.



Each tablet contains 1.25 g of calcium carbonate.
The percentage of calcium in calcium carbonate is 40 %.
Calculate the mass of calcium in each tablet.

[2 marks]

Mass of calcium = _____ g

1.6 A side effect of these tablets is that it can cause the patient to have 'wind' (too much gas in the intestine).
A reaction takes place between the tablet and stomach acid (hydrochloric acid).
The equation for the reaction is:

$$CaCO_3\ (s) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$$

Suggest why the patient may suffer from 'wind'.
Use the equation to help you answer the question.

[2 marks]

_____

_____

1.7 One type of copper ore is mainly copper carbonate. When producing copper, the ore reacts with carbon.

copper carbonate	+ carbon	→	copper	+ carbon dioxide
____ tonnes	24 tonnes		254 tonnes	264 tonnes

Calculate the mass of copper carbonate needed to produce 254 tonnes of copper.

[2 marks]

Mass = _____ tonnes

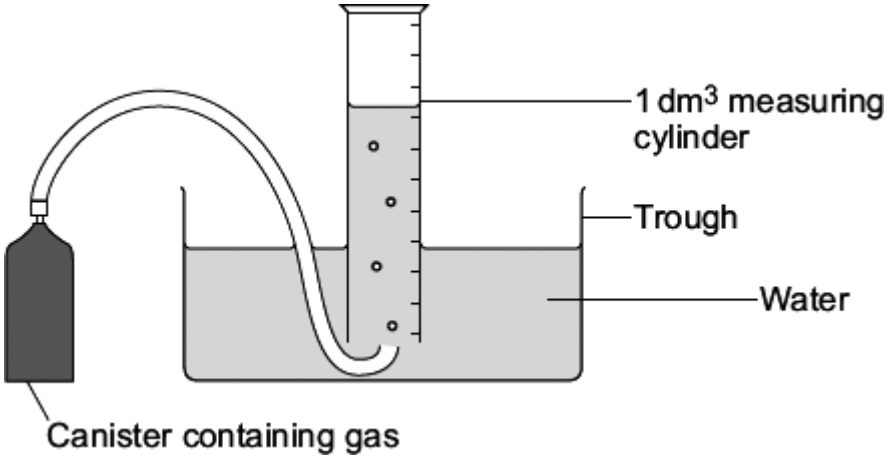
1.8 Suggest **one** reason why it is important for the company to calculate the mass of reactants needed to produce 127 tonnes of copper.

[1 mark]

_____

2.0 A student did an experiment to find the relative formula mass (M_r) of a gas.
The equipment used is shown in **Figure 1**

Figure 1



The student:

- measured the mass of the canister of gas
- filled the measuring cylinder with 1 dm^3 of the gas from the canister
- measured the mass of the canister of gas again
- measured the temperature of the laboratory
- measured the air pressure in the laboratory
- repeated the experiment.

2.1 The results for one of the experiments are shown in **Table 1**.

Table 1

Mass of the canister of gas after filling the measuring cylinder	50.62 g
Mass of 1 dm^3 of gas in the measuring cylinder	1.86 g

Calculate the mass of the canister of gas before filling the measuring cylinder.

[1 mark]

Mass = _____ g

2.2 Suggest how the results could be made more accurate.

[1 mark]

_____

2.3 The student calculated values for the relative formula mass (M_r) of the gas.
The results are shown in the table below.

Experiment	**1**	**2**	**3**	**4**
Relative formula mass (M_r)	45.4	51.5	46.3	45.8

Calculate the mean value for these results.
Give your answer to 3 significant figures.

[2 marks]

Mean = _____

2.4 The experiments gave different results for the relative formula mass of the gas. This was caused by experimental error.

Suggest **two** experimental errors that the student may have made.

[2 marks]

_____

_____

2.5 Give **two** reasons why it is important to repeat the experiment.

[2 marks]

_____

_____

3.0 A student investigated the thermal decomposition of calcium carbonate.
The equation for the reaction is:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

The relative formula masses (M_r) are: $CaCO_3 = 100$; $CaO = 56$; $CO_2 = 44$

Describe how this experiment could be used to provide evidence for the law of conservation of mass.
Include in your answer:

- The method
- Which measurements should be taken
- How the student could show evidence for conservation of mass

[6 marks]

4.0 A student made some copper sulfate crystals, $CuSO_4$.
The student used 7.95g of copper oxide and 100 cm^3 of a 2.00 mol/dm^3 solution of sulfuric acid.
The equation for the reaction is:

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

4.1 Calculate the number of moles of copper oxide in 7.95 g copper oxide.
Relative atomic masses A_r: O = 16; Cu = 63.5

[2 marks]

Answer = _____ moles

4.2 Calculate the number of moles of sulfuric acid in 100 cm^3 of 2.00 mol/dm^3 sulfuric acid.

[2 marks]

Answer = _____ moles

4.3 It is common to use an excess of one reactant.

Explain why a reactant is used in excess.

[2 marks]

_____

_____

4.4 Another student made copper sulfate using 0.250 moles of copper oxide and 0.500 moles of sulfuric acid.

Calculate the **maximum** mass of copper sulfate which could be produced.
Give your answer to 3 significant figures.
Relative formula mass (M_r) $CuSO_4$ = 159.5

[4 marks]

Maximum mass of copper sulfate = _____ g

5.0 Chlorine, Cl_2, is more chemically reactive than bromine, Br_2.
Chlorine will react with potassium bromide, KBr, to produce bromine and potassium chloride (KCl).

5.1 Write a balanced symbol equation for this reaction.

[2 marks]

_____

5.2 A teacher demonstrated the reaction.
The teacher reacted a solution containing 10 g of potassium bromide with excess chlorine.
The teacher's demonstration produced 6.12 g of bromine.
The theoretical yield of bromine was 6.72 g.

Calculate the percentage yield.
Give your answer to 1 decimal place.

[2 marks]

Percentage yield = _____ %

5.3 Suggest **one** reason why the calculated yield of bromine might not be obtained.

[1 mark]

_____

MARK SCHEME

Qu No.		Extra Information	Marks
1.1	2 1 3	In this order	1 1 1
1.2	(2 x 23) + 12 + (3 x 16) **or** 46 + 12 + 48 106	An answer of 106 without any working shown gains **2** marks	1 1
1.3	Breaking down Using heat		1 1
1.4	Carbon dioxide is produced which goes into the atmosphere	Allow a gas is produced	1 1
1.5	$1.25 \times \frac{40}{100}$ 0.5 (g)	An answer of 0.5 (g) without any working shown gains **2** marks	1 1
1.6	Carbon dioxide is produced which is a gas		1 1
1.7	(254 + 264) − 24 **or** 518 – 24 494 (tonnes)	An answer of 494 (tonnes) without any working shown gains **2** marks	1 1
1.8	Any **one** from: • So no reactant is wasted / left unreacted • So they know how much product they will make • So they can work out their carbon footprint		1

Qu No.		Extra Information	Marks
2.1	52.48 g		1
2.2	Use a balance which weighs to more decimal places	Allow use a measuring cylinder with smaller (scale) divisions / intervals	1
2.3	(45.4 + 46.3 + 45.8) ÷ 3 45.8	Allow 46 or 45.83(33…) Allow 47.3 Allow **2** marks for an answer of 45.8 without working	1 1
2.4	Any **two** from: • Loss of gas or leak • Error in measurement of volume of gas • Error in weighing the canister / gas at start • Error in weighing the canister / gas at end • Change in temperature • Change in pressure	Error in weighing the canister / gas = **1** mark Allow incorrect measurement of temperature Allow incorrect measurement of pressure If no other mark awarded allow error in weighing for **1** mark	2
2.5	To check for anomalous results To find the mean	 Allow to find the average	1 1

Qu No.		Extra Information	Marks
3.0			
Level 3:	A coherent method is described and explained with relevant detail, which demonstrates a broad understanding of the relevant scientific techniques and procedures. The steps in the method are logically ordered and would lead to the production of valid results. An explanation of the expected results is provided.		5–6
Level 2:	The bulk of a method is described with mostly relevant detail, which demonstrates a reasonable understanding of the relevant scientific techniques and procedures. The method may not be in a completely logical sequence and may be missing some detail. An attempted explanation of the expected results is given.		3–4
Level 1:	Simple statements are made which demonstrate some understanding of some of the relevant scientific techniques and procedures. The response may lack a logical structure and would not lead to the production of valid results.		1–2
Level 0:	No relevant content		0
Indicative content			
Method • Measure mass of suitable container eg boiling tube • Mass measured using balance • Place calcium carbonate in boiling tube • Measure mass of boiling tube and calcium carbonate • Heat boiling tube and calcium carbonate • Allow to cool • Reweigh tube and contents • Repeat heating, cooling and weighing until constant mass is obtained Conservation of mass • Identifies the conservation of mass • Carbon dioxide produced as a gas • Carbon dioxide escapes to the surroundings • So mass will decrease during the reaction • Suggests initial mass to be heated • Use the initial mass to suggest final mass in boiling tube • Use suggested masses to confirm law of conservation of mass			

Qu No.		Extra Information	Marks
4.1	$\frac{7.95}{16+63.5}$ or $\frac{7.95}{79.5}$ 0.1 (moles)	 Allow **2** marks for an answer of 0.1 (moles) without working	1 1
4.2	$\frac{100}{1000} \times 2$ 0.2 (moles)	 Allow **2** marks for an answer of 0.2 (moles) without working	1 1
4.3	(So that) the other reactant is completely used up		1 1
4.4	Evidence of sulfuric acid in excess or Copper oxide limiting reagent Moles of copper sulfate = moles of copper oxide = 0.250 (Mass of copper sulfate =) 0.25 x 159.5 39.9 (g)	 Allow ecf for steps 2/3/4 Allow **4** marks for an answer of 0.2 (moles) without working	1 1 1 1

Qu No.		Extra Information	Marks
5.1	Cl_2 +2KBr → 2KCl + Br_2	 Allow **1** mark for correct formulae on correct sides of equation	2
5.2	$\frac{6.12}{6.72}$ 91.1 (%)	 Allow **2** marks for an answer of 91.1 (%) without working	1 1
5.3	Any **one** from: • The reaction is incomplete • Some lost / escaped / released (when separated) • Impure reactant(s)	Ignore measurement and calculation errors	1