

## Reacting masses and gas volumes

This resource is part of the **Structure strips** series of resources, designed to support literacy in science teaching. More resources in this series can be found at: [rsc.li/4aXYgzt](https://rsc.li/4aXYgzt).

### Learning objectives

- 1 Define molar volume and explain how to use this when finding reacting volumes in a gas phase reaction.
- 2 Explain how to find the theoretical and percentage yield of a product in a reaction.
- 3 Combine writing with calculations to give a full explanation of chemical concepts.

### Introduction

Atoms, molecules and formula units have different relative masses, so 10 grams of one substance can contain a very different number of these compared to 10 grams of a different substance. Therefore, in chemistry we use 'amount of substance', measured in moles, to discuss how much of a particular substance we are using, for example in a reaction. By using moles, we can calculate the predicted yield of a product, from a given mass of reactant. Or, if we know how much of our product we need to make, we can work out how much reactant we should start with.

This works well for many substances, but gases are harder to weigh. We usually measure how much gas we have by finding its volume. Therefore, we need to be able to relate the volume of a gas to the number of moles that it contains.

This resource asks learners to demonstrate their thought process, rather than simply using methods they have memorised for carrying out calculations. This will help them to develop deeper understanding. It will also show them how to set out calculations more clearly in exam answers, so that an examiner can follow what they have done, and they can check their own answers more easily.

Usually, learners are introduced to reacting mass calculations using only masses first. Therefore, they often forget that finding reacting volumes in reactions that occur entirely in the gas phase is more straightforward, using Avogadro's law. Both the scaffolded structure strips and the extended answer question juxtapose these two methods to encourage learners to recognise the differences and be ready to apply whichever best suits the context of their calculation.

## How to use structure strips

Structure strips are a type of scaffolding you can use to support learners to retrieve information independently. Use them to take an overview at the start of a topic, to activate prior knowledge, or to summarise learning at the end of a teaching topic. Visit [rsc.li/4f33jAP](https://rsc.li/4f33jAP) for more ideas on how to use structure strips with your learners.

Structure strips have sections containing prompts, sized to suggest the amount that learners must write. Learners glue the strips into the margin of an exercise book and write their answers next to the sections, in full sentences or in bullet points. When they have finished using the structure strip, they will have an A4 page set of notes and examples.

### Scaffolding

Encourage learners to use the suggested key words and phrases in their answers. These words link with our key terms support resources for quantitative chemistry: [rsc.li/3Gi9HHN](https://rsc.li/3Gi9HHN).

To further support learners, you can include additional prompts in the structure strip. If learners are struggling to engage with the task, supply them with sentence starters created from the example answers.

As learners grow in confidence, ask them to attempt the question first and then use the structure strip to improve or self-assess their answer.

### Metacognition

This resource supports learners to develop their metacognitive skills in three key areas.

- **Planning:** the strips provide scaffolding to plan the written response. Learners will decide where to gather information from (textbooks, own notes, revision websites). Ask learners: is the source of information you are using reliable?
- **Monitoring:** learners are prompted by the questions in the structure strip and can check their own answer against the prompts. Ask learners: have you covered all of the prompts in the space provided? Do you need to change anything to complete the task?
- **Evaluation:** learners can self-assess or ask a peer to check their work against the answers. Ask learners: did you achieve what you meant to achieve? What will you do differently another time?

## Example answers

| Structure strip<br>Reacting masses<br>and gas volumes                                                                                                                                                                                                                         | Example answer                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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| Describe at least one method of measuring the volume of gas produced during a chemical reaction.                                                                                                                                                                              | Use either a gas syringe or collect gas in a measuring cylinder over water. The reaction is carried out in a conical flask fitted with a delivery tube. The reaction is started and the bung replaced as quickly as possible. The delivery tube sends gas to: <ul style="list-style-type: none"> <li>a gas syringe, so that the volume can be read from the plunger</li> <li>an upturned measuring cylinder filled with water</li> </ul>                       |
| Explain how to convert a volume of 150 cm <sup>3</sup> into dm <sup>3</sup> .                                                                                                                                                                                                 | 1 dm <sup>3</sup> is the same as 1000 cm <sup>3</sup> . Therefore, to convert a volume in cm <sup>3</sup> to dm <sup>3</sup> you need to divide it by 1000.<br>So, $150 \text{ cm}^3 = \frac{150}{1000} = 0.15 \text{ dm}^3$                                                                                                                                                                                                                                   |
| I have one mole each of methane and carbon dioxide. Explain what volume each will occupy at room temperature and pressure.                                                                                                                                                    | One mole of any gas occupies 24 dm <sup>3</sup> at room temperature and pressure. This is known as the molar volume of a gas. Since there is one mole of both gases, each of them will occupy 24 dm <sup>3</sup> .                                                                                                                                                                                                                                             |
| 100 cm <sup>3</sup> of propane undergoes complete combustion:<br>$\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$<br>Explain how you determine the volume of carbon dioxide that will be produced. | In this reaction all the reactants and products are gases. Therefore, the volumes will be in the same proportions as the moles shown in the balanced symbol equation. Since the ratio of propane to carbon dioxide is 1:3, the ratio of the volumes of these gases will also be 1:3. Hence, combustion of 100 cm <sup>3</sup> of propane should produce 300 cm <sup>3</sup> of carbon dioxide, when the volumes are measured at room temperature and pressure. |
| A chemist reacts 2.4 dm <sup>3</sup> of oxygen with magnesium.<br>$2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$<br>Show how you determine the theoretical yield, in grams, of magnesium oxide.                                                                            | One mole of oxygen would occupy 24 dm <sup>3</sup> , so since there are 2.4 dm <sup>3</sup> , the reaction must use 0.1 moles of oxygen.<br>According to the balanced equation, one mole of oxygen produces two moles of magnesium oxide, so 0.1 moles will produce 0.2 moles MgO.<br>The $M_r$ of magnesium oxide is $20 + 16 = 40$<br>Therefore, the mass of MgO will be $0.2 \times 40 = 8 \text{ g}$                                                       |
| The actual yield of magnesium oxide from the reaction is 6.4 g. Determine the percentage yield.                                                                                                                                                                               | $\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$<br>$= \frac{6.4}{8} \times 100$<br>$= 80\%$                                                                                                                                                                                                                                                                                                                        |

### Extended answer question

Instruct learners to answer the question after they have attempted the structure strip. The structure strip activates the required knowledge, which learners can then apply to the question.

Consider re-framing the context of this question to one that your learners are more familiar with, to empower them to unlock their existing science capital. Read more about science capital here: [rsc.li/40FAMLP](https://rsc.li/40FAMLP).

### Example answers to extended answer question

One mole of any gas occupies the same volume at room temperature and pressure, 24 dm<sup>3</sup> or 24,000 cm<sup>3</sup>. In the reaction between methane and steam, the reactants and products are all gases. Therefore, the volumes of gases used and produced will be in the same ratio as the reactants and products in the balanced symbol equation. The ratio of methane to hydrogen in the equation is 1:4. Therefore the ratio of the volumes of gas will also be 1:4. So, to produce 240 cm<sup>3</sup> of hydrogen we need  $\frac{240}{4} = 60$  cm<sup>3</sup> of methane.

In the second reaction, only the hydrogen is a gas, so we need to convert the volume of gas into moles to be able to compare this with the mass of zinc.

$$\text{moles of hydrogen in 240 cm}^3 = \frac{240}{24000} = 0.01 \text{ moles}$$

According to the balanced equation, one mole of zinc is needed to make one mole of hydrogen. Therefore, the amount of zinc needed is also 0.01 moles.

$$\begin{aligned}\text{mass of zinc} &= \text{moles} \times A_r \\ &= 0.01 \times 65 \\ &= 0.65 \text{ g}\end{aligned}$$