Nine tips for scaffolding multi-step calculations

Principles to help students sequence longer maths tasks

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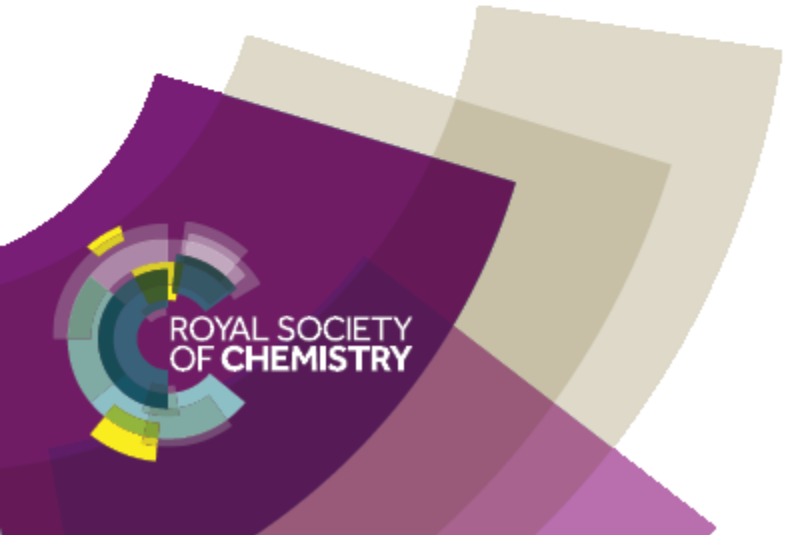
Build up the basics

Ensure you have secured the following maths skills before applying them to a multi-step problem



1. Units

Include units throughout a calculation.

- This makes it easier to see if you need to convert units.
  For example, if a concentration is given in g dm^{-3} but a volume is given in cm^3, the volume should be converted to dm^3 before substituting into the formula.
- It's also a useful way of checking for errors. If you end up with the units for concentration as $dm^3\ g^{-1}$, you know you've made a mistake.

Additionally, you will become more familiar with which units are used for each type of measurement (eg dm^3 for volume, g for mass), and recognise that something measured in dm^3 relates to a volume.

2. Making sense of formulas

Understanding that concentration is how much solute is present in a certain volume of liquid helps to make sense of the formula, because the formula represents, in words, the amount per volume.

For example, something concentrated has a large amount in a relatively small volume.

$$concentration = \frac{amount}{volume}$$

Also understand that, for example, the molar mass is the mass per mole of a substance. So, a very large atom or molecule will have a large molar mass because each atom or molecule is bigger.

3. Speaking the language

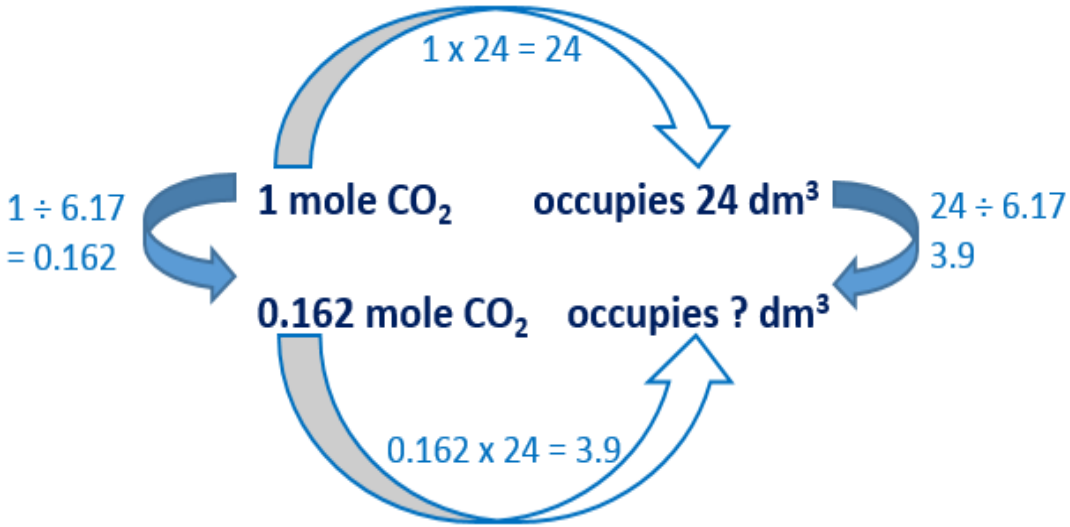
Talk through what you're doing in a calculation – this will help you learn the appropriate language.

For example, it helps to make the link between 'per' and 'divide'.

4. Using ratio and proportion

Clearly set out the answers to questions involving ratio and proportion.

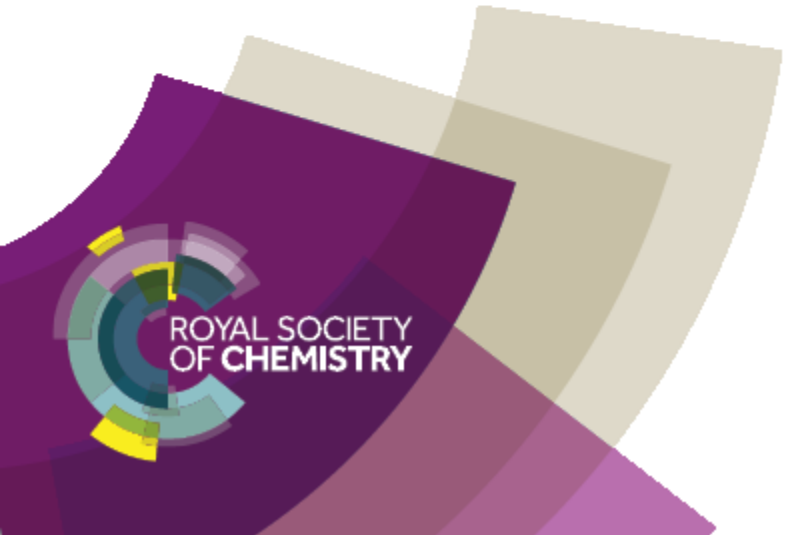
For example, if we know that 1 mole of CO_2 gas occupies 24 dm^3, what volume would 0.162 mole of CO_2 gas occupy?



Think through this calculation carefully. We have a ratio of 1 mole CO_2 to 24 dm^3 volume. To get from 1 to 24 we multiply by 24. So to work out the volume for 0.162 mole CO_2, we multiply 0.162 by 24 to get 3.9 dm^3.

Scaffold the process

Once you're comfortable with calculation basics, build up the process for solving a multi-step calculation.



5. Narrative

Describe what the question tells you and what it asks you to do.

Make 20.0 g of copper chloride from copper carbonate and dilute acid. The equation for the reaction is: $CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$

Relative atomic masses, Ar: H = 1; C = 12; O = 16; Cl = 35.5; Cu = 63.5

Calculate the mass of copper carbonate you should react with dilute hydrochloric acid to make 20.0 g of copper chloride.

For this example, you might say, 'The balanced chemical equation tells me one mole of copper carbonate gives me one mole of copper chloride. Moles are our currency in chemistry. I know the mass of copper chloride. So, I first have to work out the number of moles that corresponds to. Once I know this, I can say how many moles of copper carbonate would be required, and then I can convert that into grams to get the answer.'

6. Signposts

Write signposts that describe what is done at each step.

7. Colour code

Colour helps you make connections between the different parts of the chemical equation and the calculations.

8. Put equations before numbers

Write the equation needed before substituting numbers to do the calculation.

9. Format carefully

Setting out working in plenty of white space.

Set fractions out visually, for example:

$$\frac{a}{b}$$

not inline as a / b.

Make 20.0 g of copper chloride from copper carbonate and dilute acid. The equation for the reaction is:

$$CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$$

Relative atomic masses, A_r: H = 1; C = 12; O = 16; Cl = 35.5; Cu = 63.5

Calculate the mass of copper carbonate you should react with dilute hydrochloric acid to make 20.0 g of copper chloride.

The balanced chemical equation tells us how many moles of each reactant and product are involved in the reaction. We are given the mass of $CuCl_2$ so we need to convert from g to moles.

$CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$

20 g

formula mass $CuCl_2 = 63.5 + 2 \times 35.5 = 134.5$

Convert g to moles.

$$\textit{number of moles} = \frac{\textit{mass}}{\textit{formula mass}}$$

$$\textit{number of moles} = \frac{20\text{ g}}{134.5\text{ g mol}^{-1}} = 0.149\text{ mol}$$

From the balanced chemical equation we know that 0.149 mole of $CuCl_2$ is made from 0.149 mole of $CuCO_3$.

1 mole $CuCO_3 \rightarrow$ 1 mole $CuCl_2$

0.149 mole $CuCO_3 \rightarrow$ 0.149 mole $CuCl_2$

We are asked for the mass of copper carbonate so convert moles to g.

mass = number of moles x formula mass

formula mass

$CuCO_3 = 63.5 + 12 + 3 \times 16 = 123.5$

mass $CuCO_3 = 0.149\text{ mol} \times 123.5\text{ g mol}^{-1} = 18.4\text{ g}$

You need 18.4 g copper carbonate to react with dilute hydrochloric acid to make 20.0 g copper chloride.

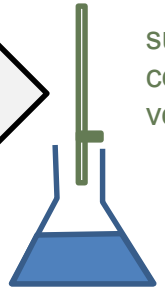
A student used a pipette to add 25.0 cm^3 of sodium hydroxide of unknown concentration to a conical flask. The student carried out a titration to find out the volume of 0.100 mol/dm^3 sulfuric acid needed to neutralise the sodium hydroxide. The student carried out five titrations with the results shown in the table.

Concordant results are within 0.10 cm^3 of each other. Use the student's concordant results to work out the mean volume of 0.100 mol/dm^3 sulfuric acid added.

Calculate the concentration of the sodium hydroxide. Give your answer to three significant figures

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Volume of 0.100 mol dm^{-3} sulfuric acid in cm^3	27.40	28.15	27.05	27.15	27.15

calculate moles of sulfuric acid from concentration and volume



sulfuric acid
conc = 0.100 mol dm^{-3}
volume = 27.1 cm^3

amount in moles = 0.100 mol dm^{-3} x 27.1 cm^3
= 0.100 mol dm^{-3} x $\frac{27.1}{1000}$ dm^3
amount in moles = 0.00271 mol

sodium hydroxide
volume = 25.0 cm^3
concentration = ?

write balanced equation

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

use equation to calculate moles in flask

2 moles NaOH reacts with 1 mole H_2SO_4
2 x 0.00271 mol NaOH reacts with 0.00271 mol H_2SO_4
0.00542 mol NaOH reacts with 0.00271 mol H_2SO_4

use moles and volume to get concentration

sodium hydroxide
amount = 0.00542 mol, volume = 25.0 cm^3
concentration = $\frac{0.00542 \text{ mol}}{0.025 \text{ dm}^3}$ = 0.217 mol dm^{-3}

The concentration of the sodium hydroxide is 0.217 mol dm^{-3}