Stage 2

Ratio and proportion

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Introduction

Today, you will use the same ratio and ratio simplification skills you have already practised in maths but will apply them to real chemical situations.

Learning objectives

1. Use ratios from balanced symbol equations to determine quantities of reactants and products.
2. Calculate and use mole ratios from chemical equations.

Lesson question

During this session we will be covering the mathematics skills needed to answer the following question:

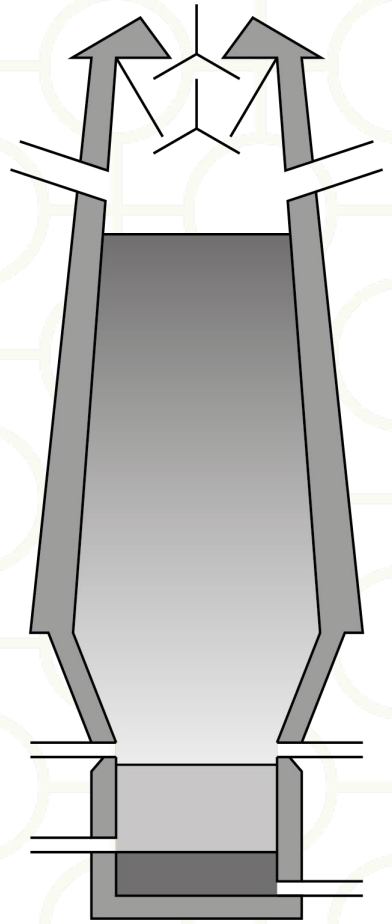
Iron oxide reacts with carbon monoxide to form iron and carbon dioxide:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

A blast furnace uses 480 g of iron oxide, Fe_2O_3.

Calculate the mass of iron produced.

$(M_r: Fe_2O_3 = 160,\ A_r: Fe = 56)$



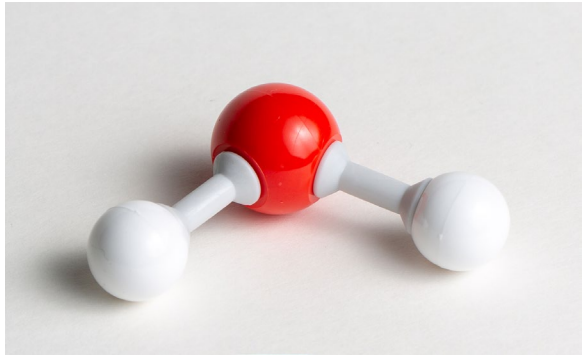
Ratio recap

- **A ratio** – compares the relative sizes of two or more values.
- **To simplify a ratio** – divide all parts by the highest common factor (HCF).
- **Chemical formula** – shows the ratio of atoms, e.g. H_20 has a hydrogen to oxygen ratio of 2:1.
- **Using a ratio** – find the total parts, find one part, then scale to the required amount.

Ratios in chemical formulas

We can use ratios to express how many atoms of an element are present in a compound.

In a water molecule (H_2O) the ratio of hydrogen to oxygen atoms is 2:1.

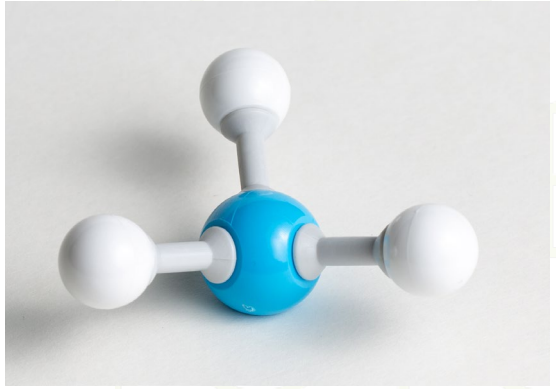


In ratios the order is important.

For example, in a molecule of ammonia (NH_3):

the ratio of **hydrogen** to **nitrogen** atoms is **3**:**1**.

Whereas the ratio of **nitrogen** to **hydrogen** atoms is **1**:**3**.



What is a mole?

A **mole (mol)** is a **unit of measurement**, like metres (m) or grams (g).

It is used to measure the **amount of substance**.

$1\ \text{mole} = 6.02 \times 10^{23}$. This number is known as Avogadro's number.

This means that:

- 1 mole of water contains 6.02×10^{23} water molecules.
- 1 mole of argon gas contains 6.02×10^{23} argon atoms.

What is a mole? – continued

Think of mole like the word '**dozen**'.



1 dozen = 12

So, 1 dozen eggs would be 12 eggs.

2 dozen would be 24 eggs.

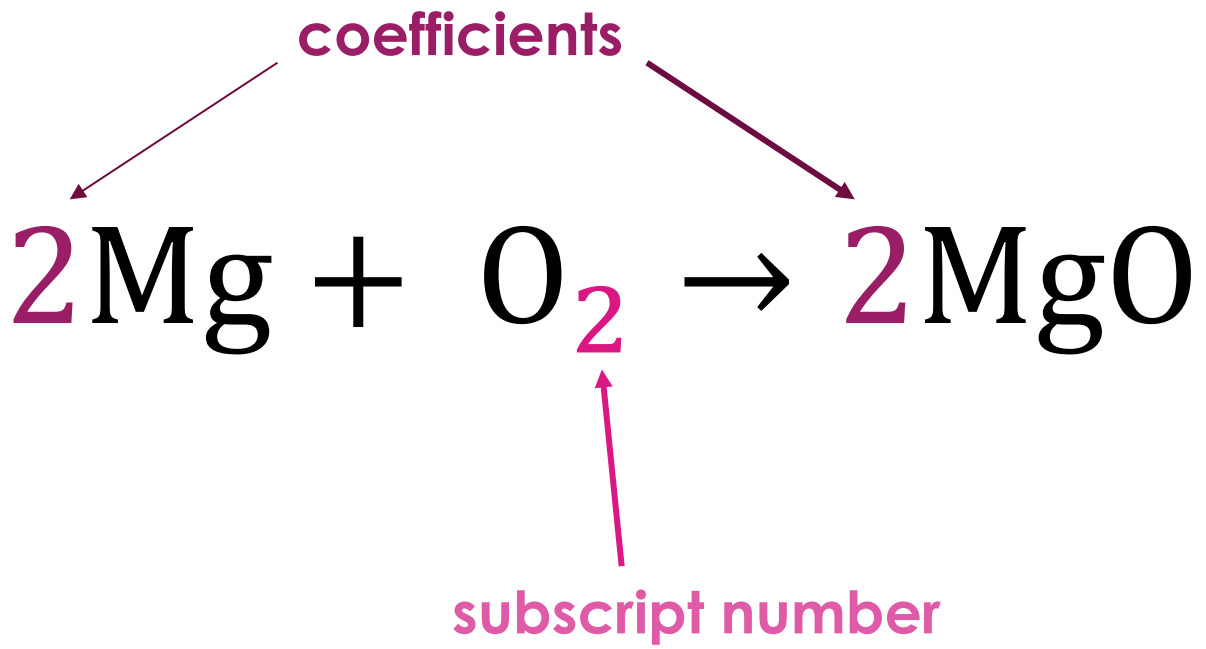
1 mole = 6.02×10^{23}

So, 1 mole of oxygen would be 6.02×10^{23} oxygen molecules.

2 moles would be 12.04×10^{23} or 1.20×10^{24} molecules.

Balanced chemical equations

Chemists read ratios from balanced chemical equations to carry out calculations. Let's look at a balanced chemical equation:



Ratios from balanced chemical equations

$$2\mathrm{Mg} + \mathrm{O_2} \rightarrow 2\mathrm{MgO}$$

2:1:2

- The **coefficients** tell us the ratio of moles of each substance.
- In this equation, 2 moles of magnesium react with 1 mole of oxygen to form 2 moles of magnesium oxide.

Remember: the coefficients tell us the mole ratio **not** the mass ratio.

Reading mole ratios

Use the balanced equations to answer the following questions:

1. How many moles of hydrogen react with 1 mole of nitrogen?

$$N_2 + 3N_2 \rightarrow 2NH_3$$

2. How many moles of water are produced from 1 mole of oxygen?

$$2H_2 + O_2 \rightarrow 2H_2O$$

3. What is the ratio of methane to water?

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

4. What is the ratio of calcium carbonate to calcium oxide?

$$CaCO_3 \rightarrow CaO + CO_2$$

Activity

Reading mole ratios – answers

Answers

1. How many moles of hydrogen react with 1 mole of nitrogen?

$$N_2 + 3N_2 \rightarrow 2NH_3$$

Answer: 3 moles of hydrogen

2. How many moles of water are produced from 1 mole of oxygen?

$$2H_2 + O_2 \rightarrow 2H_2O$$

Answer: 2 moles of water

3. What is the ratio of methane to water?

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Answer: 1:2

4. What is the ratio of calcium carbonate to calcium oxide?

$$CaCO_3 \rightarrow CaO + CO_2$$

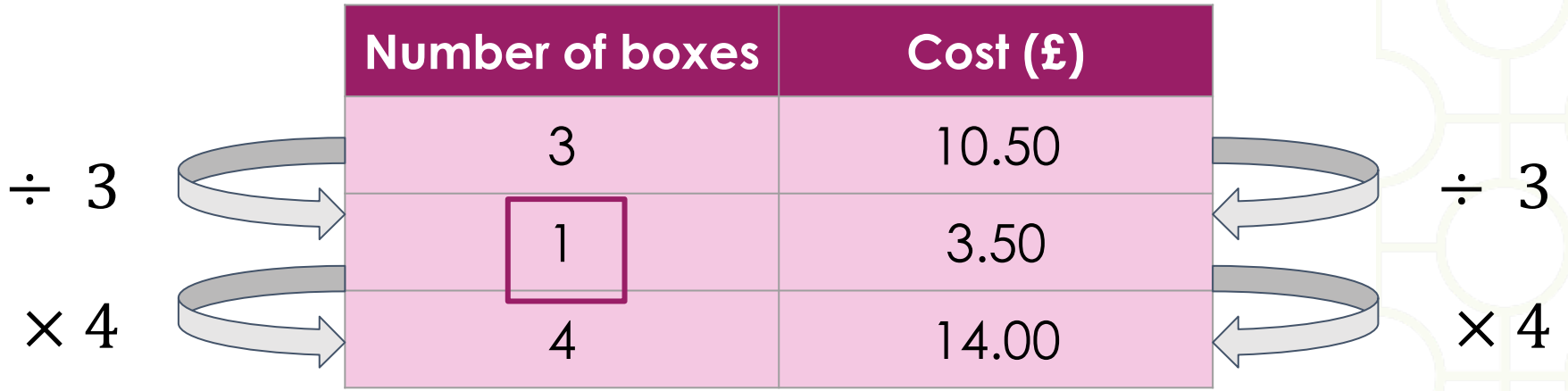
Answer: 1:1

Ratio tables

In maths you may have used ratio tables. Let's look at an example.

If 3 boxes of chocolates cost £10.50, how much would 4 boxes of chocolates cost?

We can use a ratio table to help answer this question.



Worked example

Ratio tables – example 2

If 2 packets of stickers contain 5 sheets, how many sheets would be in 10 packets?

We can use a ratio table to help answer this question. This time we scale up in multiples of the original ratio (2:5).

Packets	Sheets
2	5
4	10
6	15
8	20
10	25

Worked example

Ratio tables in science

Worked example

How many moles of oxygen are needed to react with 6 moles of hydrogen to form water?

$$2H_2 + O_2 \rightarrow 2H_2O$$

H_2	O_2
2	1
4	2
6	3

So, the answer is 3 moles of oxygen.

Using mole ratios to calculate masses

Now we understand how to use the balanced symbol equation to find the mole ratio, let's use the mole ratio to work out the masses of reactants or products.

Step 1: use the balanced equation and **identify** the mole ratio from the coefficients.

Step 2: **calculate** the moles you know:

$$\text{moles} = \frac{\text{mass}}{\text{relative formula mass } (M_r)}$$

Step 3: **use** the ratio to **find** the moles you need. Scale using the mole ratio from the equation.

Step 4: **convert** moles back to mass: $\text{mass} = \text{moles} \times M_r$

Problem pairs

Calculate the mass of magnesium oxide produced when 4.8 g of magnesium reacts with excess oxygen. **Relative masses: $Mg = 24$, $MgO = 40$** $$2Mg + O_2 \rightarrow 2MgO$$	**Calcium carbonate decomposes when heated. A learner heats 25 g of calcium carbonate until it completely decomposes, Calculate the mass of calcium oxide (CaO), produced.** **$M_r\ CaCO_3 = 100$; $CaO = 56$** $$CaCO_3 \rightarrow CaO + CO_2$$
Step 1: identify the mole ratio from the equation. $$Mg: MgO = 2:2 = 1:1$$ **Step 2: calculate** the number of moles of Mg. $$\text{moles} = \frac{\text{mass}}{A_r}$$ $$\text{moles of Mg} = \frac{4.8}{24}$$ $$= 0.2 \text{ mol}$$ **Step 3: use** the ratio to **find** the number of moles of MgO. Ratio = 1:1, so 0.2 mol Mg forms 0.2 mol of MgO. **Step 4: convert** moles to mass. $$\text{mass} = \text{moles} \times M_r$$ $$\text{mass of MgO} = 0.2 \times 40$$ $$= 8.0 \text{ g}$$ **The mass of magnesium oxide produced is 8.0 g.**	**Step 1: identify** the mole ratio from the equation. $$CaCO_3: CaO = 1:1$$ **Step 2: calculate** the number of moles of $CaCO_3$ $$\text{moles} = \frac{\text{mass}}{M_r}$$ $$\text{moles of } CaCO_3 = \frac{25}{100}$$ $$= 0.25 \text{ mol}$$ **Step 3: use** the ratio to **find** the number of moles of CaO. **Step 4: convert** moles to mass. **The mass of calcium oxide produced is**

Problem pairs – answer

Calculate the mass of magnesium oxide produced when 4.8 g of magnesium reacts with excess oxygen.

Relative masses: $Mg = 24$, $MgO = 40$

$$2Mg + O_2 \rightarrow 2MgO$$

Step 1: identify the mole ratio from the equation.

$$Mg : MgO = 2 : 2 = 1 : 1$$

Step 2: calculate the number of moles of Mg.

$$\text{moles} = \frac{\text{mass}}{A_r}$$

$$\text{moles of Mg} = \frac{4.8}{24}$$

$$= 0.2 \text{ mol}$$

Step 3: use the ratio to **find** the number of moles of MgO.

Ratio = 1:1, so 0.2 mol Mg forms 0.2 mol of MgO.

Step 4: convert moles to mass.

$$\text{mass} = \text{moles} \times M_r$$

$$\text{mass of MgO} = 0.2 \times 40$$

$$= 8.0 \text{ g}$$

The mass of magnesium oxide produced is 8.0 g.

Calcium carbonate decomposes when heated. A learner heats 25 g of calcium carbonate until it completely decomposes, Calculate the mass of calcium oxide, CaO, produced.

$M_r\ CaCO_3 = 100$; $CaO = 56$

$$CaCO_3 \rightarrow CaO + CO_2$$

Step 1: identify the mole ratio from the equation.

$$CaCO_3 : CaO = 1 : 1$$

Step 2: calculate the number of moles of $CaCO_3$

$$\text{moles} = \frac{\text{mass}}{M_r}$$

$$\text{moles of } CaCO_3 = \frac{25}{100}$$

$$= 0.25 \text{ mol}$$

Step 3: use the ratio to **find** the number of moles of CaO.

Ratio = 1:1, so 0.25 mol $CaCO_3$ forms 0.2 mol of CaO.

Step 4: convert moles to mass.

$$\text{mass} = \text{moles} \times M_r$$

$$\text{mass of MgO} = 0.25 \times 56$$

$$= 14.0 \text{ g}$$

The mass of calcium oxide produced is 14 g.

Returning to the lesson question

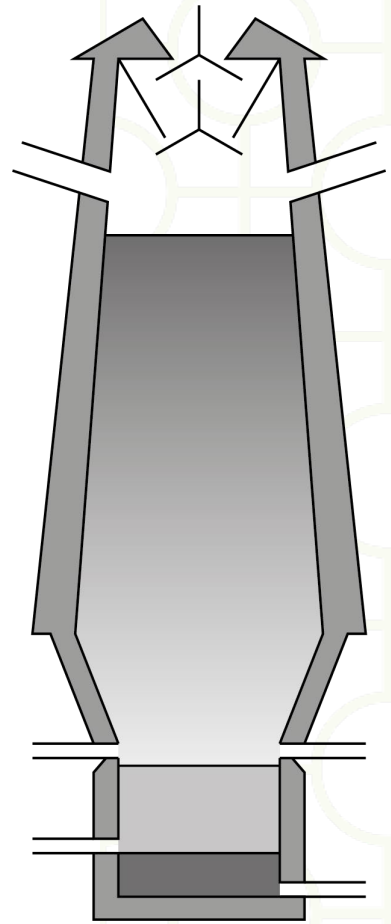
Iron oxide reacts with carbon monoxide to form iron and carbon dioxide:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

A blast furnace uses 480 g of iron oxide, Fe_2O_3.

Calculate the mass of iron produced.

$(M_r: Fe_2O_3 = 160,\ A_r: Fe = 56)$



Returning to the lesson question – answer

Answer

Step 1: **identify** the mole ratio from the equation.

$Fe_2O_3 : Fe = 1:2$. For every 1 mole of iron oxide, 2 moles of iron are produced.

Step 2: **calculate** the number of moles of iron oxide

$$\text{moles} = \frac{\text{mass}}{M_r} \quad \text{Moles of } Fe_2O_3 = \frac{480}{160} = 3 \text{ mol}$$

Step 3: **use** the ratio to **find** the number of moles of iron.

The ratio is 1:2. For every 1 mole of Fe_2O_3, 2 moles of Fe are produced.

So, 3 moles of Fe_2O_3 produces $3 \times 2 = 6$ moles of Fe.

Step 4: **convert** moles to mass.

$\text{Mass} = \text{moles} \times A_r$. Mass of $Fe = 6 \times 56 = 336$ g.

The mass of iron produced is **336 g.**

Acknowledgements

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