Stage 1

Algebra and equations

ROYAL SOCIETY OF CHEMISTRY

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Introduction

Today, you will use the same estimation and checking skills you have already practised in maths but will apply them to real chemical situations. You will learn to predict missing results of reactions, write those reactions using words and symbols, and understand that mass never simply disappears, even when substances change completely (which might seem surprising at first).

Learning objectives

1. Make estimates of the results of simple calculations.
2. Recognise mass is conserved during a chemical reaction.
3. Understand some common symbols used in word and symbol equations.

Lesson question

During this session we will cover the mathematics skills needed to answer the following question.

Iron reacts with sulfur when it is heated to form a compound called iron sulfide.

A learner carries out an experiment and records the following results:

Substance	Mass (g)
Iron (before the reaction)	5.6
Sulfur (before the reaction)	3.2
Iron sulfide (after the reaction)	8.8

Lesson question

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a) Write a word equation for this reaction.
b) Do the results show that mass was conserved? Show your working and explain your answer.

This is the symbol equation for the reaction:

$$Fe + S \rightarrow FeS$$

c) State whether the equation is balanced and give a reason for your answer.
d) Estimate the relative formula mass of iron sulfide. Iron has a relative atomic mass of 56 and sulfur is 32.
e) Calculate the relative formula mass for iron sulfide.

Making estimates in maths

In maths, **estimating** usually means **rounding** numbers to **one significant figure** before calculating an answer. This makes the numbers easier to use. It gives us a rough idea of what the answer might be.

- **Estimate** the result of 38×52

  The numbers are rounded to $40 \times 50 = 2000$

- **Calculate** $38 \times 52 = 1976$

We can see that the actual value is close to the estimated value, so the answer is likely to be correct.

Find the estimated value of 6.7×4.2.

Making estimates in chemistry

In maths, we estimate to check our answers are roughly correct. In chemistry, the numbers we start with are often approximate.

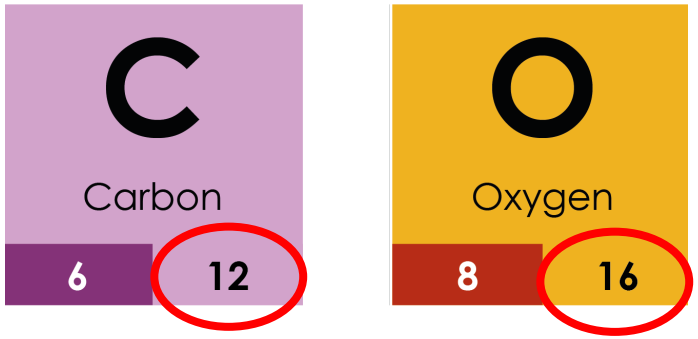
If we measure out **approximately** 2 g of a substance, then any answer we calculate using that figure must be an **estimate** too.



Making estimates in chemistry: example

Calculate the relative formula mass of carbon dioxide (CO_2).

A student uses a periodic table to find the relative atomic mass of carbon and oxygen.



Answer: $12 + 16 + 16 = 44$

In chemistry, we use rounded values on most periodic tables.

The more precise value for carbon is 12.011 and for oxygen is 15.999. So, the answer above is an estimate. The more precise calculation gives a relative atomic mass of 44.009, so the student's answer is a good estimate.

Which answer is correct?

Activity

A pebble has a mass of 93 g and a volume of 31 cm^3.

Use the formula provided to calculate the density of the pebble:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Four learners calculated different answers. **Which answer is correct?**

A. 0.33 g/cm^3

B. 3.0 g/cm^3

C. 124 g/cm^3

D. 2.883 g/cm^3

What mistake did the other learners make?

Which answer is correct? Answer

Correct answer:

A. 0.33 g/cm^3

B. 3.0 g/cm^3 ✓

C. 124 g/cm^3

D. 2.883 g/cm^3

What mistake did the other three learners make?

- A is dividing the wrong way round.
- C is adding instead of dividing.
- D is multiplying instead of dividing.

Answer

Making estimates using a table of results

In chemistry, we often need to use the information provided to suggest or estimate a sensible number or value for missing readings.

A learner carries out an experiment to measure the temperature of a liquid as it cools every minute. Estimate the missing temperature of the liquid at 4 minutes. Use the following steps.

Time (minutes)	Temperature (°C)
0	90
2	85
4	
6	75
8	70

Step 1: look at the range.

Step 2: look for a pattern.

Step 3: use the trend to estimate.

Step 4: check it makes sense.

Conservation of mass

The word **conservation** comes from the Latin word *conservare*, which means ‘to keep together’.

In a chemical reaction, **no atoms are created or destroyed**. They are rearranged to form new substances.

If we have 10 bricks and rearrange them in a different way, we still have 10 bricks. This is the same with atoms in a chemical reaction.

Conservation of mass means that the **total mass of the reactants** before a chemical reaction always equals the **total mass of products** after it.



Conservation of mass in a chemical reaction

Activity

When magnesium burns in oxygen, the product is magnesium oxide.

In chemistry, we often summarise sentences in a **word equation**:

$$\text{magnesium} + \text{oxygen} \rightarrow \text{magnesium oxide}$$

A scientist measured:

- the mass of magnesium at the start = 2.4 g
- the mass of oxygen used up = 1.6 g
- the mass of magnesium oxide produced = 4.0 g

Is the law of conservation of mass true for these experimental results?

Conservation of mass in a chemical reaction – answer

Answer

Step 1: identify the reactants and their masses.

What are we starting with? Magnesium and oxygen.

What are their masses? 2.4 g and 1.6 g.

Step 2: add the masses of the reactants on.

Total mass before the reaction = $2.4 + 1.6 = 4.0\ \text{g}$

Step 3: identify the product and its mass.

What is produced? Magnesium oxide. What is its mass? 4.0 g

Step 4: compare. Mass before = 4.0 g. Mass after = 4.0 g.

Conservation of mass when a gas is produced

Activity

Calcium carbonate reacts with hydrochloric acid to produce calcium chloride, water and carbon dioxide.

a) Summarise this chemical reaction using a word equation.

A learner carries out the experiment and measures the mass at the start and at the end.

Mass at the start: 50.0 g Mass at the end: 47.8 g

b) What has happened to the mass?

Carbon dioxide gas was produced and escaped into the air. Mass is still conserved but some of the mass has just moved into the air.

c) If the experiment had been carried out in a sealed container, what would you expect to happen?

Conservation of mass when a gas is produced – answers

Answers

Calcium carbonate reacts with hydrochloric acid to produce calcium chloride, water and carbon dioxide.

a) $\text{calcium carbonate} + \text{hydrochloric acid} \rightarrow \text{calcium chloride} + \text{water} + \text{carbon dioxide}$

b) The mass has remained the same. The mass of the carbon dioxide produced was 2.2 g.

c) If no gas could escape, all the products would stay inside the container. The total mass of everything inside would still be 50.0 g because no atoms have left.

Activity

From words to symbols

Word equations are useful because they tell us the names of the substances involved in a chemical reaction.

Chemists all over the world speak different languages, so it is useful to write chemical reactions in a way that everyone can understand.

This is why we use symbol equations. Instead of writing the name of each substance, we use the correct chemical symbols. These are the same in every country.

Do you know the chemical symbols for these elements?

Element	Symbol
Carbon	
Calcium	
Cobalt	
Chlorine	

From words to symbols – answer

Answer

Do you know the chemical symbols for these elements?

Element	Symbol
Carbon	C
Calcium	Ca
Cobalt	Co
Chlorine	Cl

The first letter of a symbol is always a capital. Any second letter is always lower case.

Remember: Co and CO are very different.

From symbols to formulas

Individual symbols represent single elements. Mg represents the element magnesium.

In chemistry, many substances are made of two or more different elements joined together. We call these **compounds** and we write them using a **chemical formula**.

A **subscript** number to the right of a symbol tells us how many atoms (or ions) of that element have formed the substance.

Compound	Formula	Meaning
Magnesium oxide	MgO	1 magnesium joined to 1 oxygen
Carbon dioxide	CO_2	1 carbon joined to 2 oxygen
Water	H_2O	2 hydrogen joined to 1 oxygen

Reading a symbol equation

Here is the word equation for magnesium burning in oxygen:

$$\text{magnesium} + \text{oxygen} \rightarrow \text{magnesium oxide}$$

Here is the same reaction written as a symbol equation:

$$Mg + O_2 \rightarrow MgO$$

Oxygen atoms are found naturally in pairs. O_2 means 2 oxygen atoms joined together. Count the number on each side of the arrow.

On the left side of the equation	On the right side of the equation
$Mg = 1$	$Mg = 1$
$O = 2$	$O = 1$

The magnesium is balanced on both sides of the equation.

The oxygen is not. **Where has the other oxygen atom gone?**

Balancing a symbol equation

In a chemical reaction, **no atoms are created or destroyed**. This means the number of atoms on the left of the arrow must equal the number of atoms on the right. When this is the case, we say the equation is **balanced**.

Looking back at our equation: $\mathrm{Mg} + \mathrm{O_2} \rightarrow \mathrm{MgO}$

There are 2 oxygens on the left but only 1 on the right.

The equation is **not balanced**.

To fix this we add a large number in front of a formula. This is called a **coefficient**. We never change the subscript numbers inside a formula because doing so would change the substance entirely.

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

Is it balanced?

Activity

The number of atoms (or ions) of each element must be the same on both sides of a chemical equation. This is what it means for an equation to be balanced.

$$\mathbf{2}\mathrm{Mg} + \mathrm{O}_2 \rightarrow \mathbf{2}\mathrm{MgO}$$

On the left side of the equation	On the right side of the equation
$\mathrm{Mg} = 2$	$\mathrm{Mg} = 2$
$\mathrm{O} = 2$	$\mathrm{O} = 2$

- Does the equation show that the law of conservation of mass has been upheld?
- How do you know?

Returning to the lesson question

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e) Calculate the relative formula mass for iron sulfide.

Returning to the lesson question – answers

Answers

a) $\text{iron} + \text{sulfur} \rightarrow \text{iron sulfide}$

b) $5.6 + 3.2 = 8.8\,\text{g}$ is the total mass of the reactants. Mass is conserved because the total mass of the reactants (8.8.g) equals the total mass of the product (8.8g).

c) The equation is balanced because the number of each type of atom is equal on both sides of the arrow.

Atoms on the left side of the equation	Atoms on the right side of the equation
$\text{Fe} = 1$	$\text{Fe} = 1$
$\text{S} = 1$	$\text{S} = 1$

d) Estimate: 56 is rounded to 60 and 32 is rounded to 30. The relative formula mass of iron sulfide is 90.

e) Calculate: $56 + 32 = 88$

Acknowledgements

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