# Student Booklet

## C3.2 Introduction to Quantitative Chemistry

Science
**Mastery**

Ark **Curriculum+**

# What will I be learning about?

**Big Idea:** Reactions rearrange matter.

**What does this mean?**

Chemical reactions are the basis of many areas of chemistry and industrial processes. Compounds can be rearranged during reactions to form new substances. Matter cannot be created or destroyed, only rearranged in chemical reactions, so the total number of atoms in a chemical reaction must remain the same.

**What is this unit about?**

Quantitative chemistry is the branch of chemistry in which scientists use calculations to determine how much of a material will react or be produced. In this unit you will be learning about how mass is conserved in reactions and how calculations can be used in chemistry to compare substances and predict the products of reactions. You will learn about the concept of the mole and how it is used in chemistry, as well as learning about concentration.

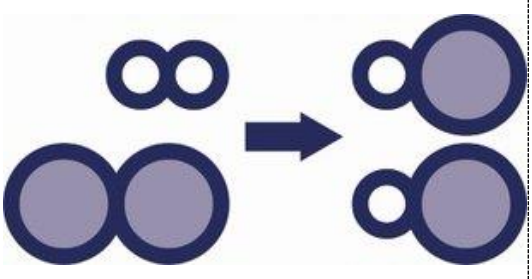
# What should I already know?

- A molecule is two or more (non-metal) atoms chemically joined together – this can be an element (e.g. $H_2$) or a compound (e.g. $H_2O$).
- A compound contains two or more elements chemically joined together in fixed proportions.
- The subscript number after a symbol is the number of atoms of that element are in one molecule.
- A mixture consists of two or more types of atoms or compounds not chemically combined together.
- A pure substance is made of one type of atom or compound.

- A solution is composed of a solute and a solvent.
- A solvent is the substance a solute dissolves in.
- A solute is the substance that dissolves in a solvent.
- A substance is soluble if it will dissolve to form a solution.
- A substance is insoluble if it will not dissolve to form a solution.
- A solute dissolves when the solute particles fill in the spaces between the solvent particles.
- In neutralisation reactions an acid reacts with an alkali to form a salt and water.
- The number and type of atoms do not change in a chemical change and are only rearranged.
- The total overall mass is conserved in a chemical change.
- A chemical change can be identified if there is a change observed by a chemical test.
- The test for hydrogen uses a burning splint held at the open end of a test tube of the gas.
- The test for carbon dioxide uses an aqueous solution of calcium hydroxide (lime water).
- The relative atomic mass of an element is an average value that takes account of the abundance of the isotopes of the element.

## Introduction to Quantitative Chemistry

*How do I know the concentration of a solution? What is the law of conservation of mass? How do you calculate the relative formula mass? How do you make a soluble salt?*



Quantitative chemistry allows us to do calculations to find out about quantities of substances. This is a very important application of chemistry that is used in industry and research. Using the relative formula mass and concentration we can look closely at the amount of reactants and productions in chemical reactions.

This is the **third** unit we are studying as part of the big idea:
**Reactions Rearrange Matter**

In this unit, we will begin by recapping the law of conservation of mass because it means that the mass of products equals the mass of the reactants which is important to remember when doing chemical calculations.

Then we will learn about state symbols and practise using them in symbol equations. Whilst we focus on chemical formulae, we will learn how to calculate the relative formula mass and use this to calculate the mass of reactant or product.

You will have heard the term 'concentration' before and we will learn what the concentration of a substance actually means and then discover how to calculate concentration. Finally, we will carry out a practical with lots of different steps and get the chance to use different types of equipment. The practical is making soluble salts from acids and insoluble substances, such as metal oxides. The end result will be the formation of salt crystals!

TASKS:
What subject will this unit focus on? (circle the correct subject)

BIOLOGY CHEMISTRY PHYSICS

There are lots of keywords underlined above. List these into the two columns:

| Words I know | Words I haven't seen before |
|---|---|
| | |

**To answer before the unit:**

1. What are you most excited to learn about in this topic?

2. What do you already know about this topic?

3. Why do you think it's important to learn how reactions rearrange matter?

4. What knowledge from previous science lessons might help us?

5. What questions do you have about this topic?

**To answer at the end of the unit:**

1. Tick off any words in the 'words I haven't seen before' column that you are now confident with. Circle any you still need more practice to use.
2. What have you most enjoyed about this unit?

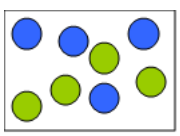
3. What more would you like to learn about particles as part of the big idea: 'Reactions Rearrange Matter'?

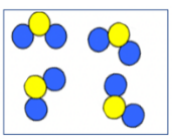
# Pre-Test

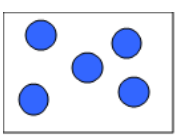
This multiple choice assessment will check that you are ready to start learning about this unit. Take this quiz without any help.

When you've finished, check the answers on the next page and complete any 'fix-it' tasks before moving on to learn the new topic.

1. **Which of these represents a mixture?**

   ☐ A. 

   ☐ B. 

   ☐ C. 

2. **Which of these is a compound <u>and</u> a molecule?**

   ☐ A. Water ($H_2O$)
   ☐ B. Sodium chloride (NaCl)
   ☐ C. Oxygen ($O_2$)

3. **Which of these is <u>not</u> a sign that a chemical reaction has taken place?**

   ☐ A. There was a change in state
   ☐ B. There was a colour change
   ☐ C. A gas was produced

4. **The chemical formula of sodium sulfate is $Na_2SO_4$. How many of each type of atom are present?**

   ☐ A. 1 sodium atom, 2 sulfur atoms and 4 oxygen atoms
   ☐ B. 2 sodium atoms, 4 sulfur atoms and 4 oxygen atoms
   ☐ C. 2 sodium atoms, 1 sulfur atom and 4 oxygen atoms

5. **Which of these correctly states the products that would be formed from a reaction between potassium oxide and hydrochloric acid?**

- ☐ A. Potassium chloride + hydrogen
- ☐ B. Potassium chloride + water
- ☐ C. Potassium chloride + water + carbon dioxide

6. **Which of these equations is balanced?**

- ☐ A. $2\ H_2 + O_2 \rightarrow 2\ H_2O$
- ☐ B. $H_2 + O_2 \rightarrow H_2O$
- ☐ C. $2\ H_2 + 2\ O_2 \rightarrow 2\ H_2O$

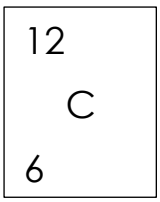
7. **Table salt (sodium chloride) is added to distilled water. Which row correctly identifies the solute, solvent and solution?**

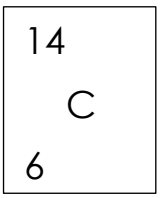
| | Solute | Solvent | Solution |
|---|---|---|---|
| ☐ A. | Sodium chloride | Salt water | Distilled water |
| ☐ B. | Sodium chloride | Distilled water | Salt water |
| ☐ C. | Distilled water | Sodium chloride | Salt water |

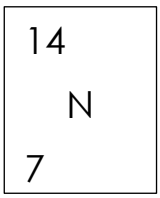
8. **The mass of a beaker including a reaction mixture is 128 g. After a chemical reaction has occurred the mass is 114 g. Which statement gives a possible explanation for this?**

- ☐ A. Mass has been lost because some atoms must have been destroyed in the reaction
- ☐ B. One of the products may have been a gas which escaped from the beaker
- ☐ C. The elements in the products have a smaller mass than the elements in the reactants

**9. Which of these are isotopes of each other?**

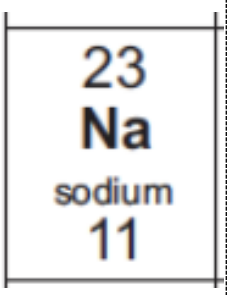
i 


ii 


iii 


- ☐ A. i and ii
- ☐ B. ii and iii
- ☐ C. i and iii

**10. The atomic and mass numbers for sodium are shown (right). Which statement is correct?**




- ☐ A. Sodium has 11 neutrons and 11 protons
- ☐ B. Sodium has 11 protons and 23 neutrons
- ☐ C. Sodium has 11 protons and 12 neutrons

End of Unit Pre-Test. Turn over to see the answers. Give yourself a mark out of 10.

# Pre-Test Answers

| Question | Answer | What to do next (Fix-It task) |
|---|---|---|
| 1 | A | If you answered B or C you need to review the difference between elements, compounds and mixtures. State the definition of each and use particle diagrams to show the difference. |
| 2 | A | If you answered B or C you need to review the meaning of a compound and a molecule. State the definition of each. Explain how a molecule can be an element or a compound and explain why not all compounds are molecules. |
| 3 | A | If you answered B or C you need to review the signs of a chemical reaction. Explain the difference between a chemical and a physical change. Describe the possible observations that would show a chemical reaction has taken place. |
| 4 | C | If you answered A or B you need to review how to read chemical formulae. Determine how many atoms of each element are present in $H_2SO_4$, $HNO_3$ and $H_3PO_4$. |
| 5 | B | If you answered A or C you need to review the reactions of acids with metals and metal compounds. State the general equations for the reactions between an acid and i) a metal; ii) a metal oxide or hydroxide; iii) a metal carbonate. |
| 6 | A | If you answered B or C you need to review how to balance equations. Explain why equations need to be balanced. |
| 7 | B | If you answered A or C you need to review the terms solute, solvent and solution. State the definition of each and identify the solute, solvent and solution when sugar is added to a cup of tea. |
| 8 | B | If you answered A or C you need to review the idea of conservation of mass. Explain what is meant by conservation of mass and suggest why it is difficult to measure the mass of a gas product. |
| 9 | A | If you answered B or C you need to review the meaning of isotopes. State the definition and use it to explain why some elements have a relative atomic mass that is not a whole number. |
| 10 | C | If you answered A or B you need to review the meaning of atomic number and mass number. Describe how to find the number of protons and neutrons in an atom. |

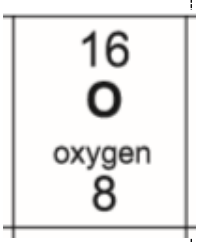
Great job! Now you're ready to start learning about quantitative chemistry!

# Knowledge Organiser

## Chemical reactions

- **Chemical reactions** always involve the formation of one or more new substances.
- Chemical reactions often involve a **temperature change**.
- **Formulae** are used to show the elements bonded together in a compound e.g. $H_2O$ contains 2 hydrogen atoms and one oxygen atom.
- **Compounds** can only be separated into their **elements** by a chemical reaction
  e.g. $2H_2O \rightarrow 2H_2 + O_2$
- In **chemical equations** the three **states of matter** are shown as:
  solid = (s); liquid = (l) and gas = (g)
  **aqueous solutions** are shown as (aq)
  e.g. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
- An aqueous solution is a substance dissolved in water.

## Relative formula mass




- The **relative atomic mass** (**$A_r$**) is the average mass of the atoms of an element compared to the mass of carbon-12.
- The **relative formula mass** (**Mr**) of s substance is the sum of the $A_r$ of all the atoms in the formula.
  e.g. What is the $M_r$ of water ($H_2O$)?
  ($A_r$ H = 1.0; O = 16.0)
  There are 2 x H and 1 x O in the formula
  (2 x 1.0) + (1 x 16.0) = 18.0
- $A_r$ and $M_r$ have **no units** as they are relative masses.
- In a balanced chemical equation:
  **sum $M_r$ reactants = sum $M_r$ products**
  e.g. $2H_2O_2 \rightarrow 2H_2O + O_2$
  Mr reactants = 2 x 34 = 68
  Mr products = (2 x 18) + 32 = 68

- The percentage mass of an element in a compound can be calculated using the relative atomic mass and the relative formula mass.

$$\%\ by\ mass = \frac{A_r\ x\ number\ of\ atoms\ in\ a\ compound}{M_r\ of\ the\ compound} \times 100$$

## Conservation of mass and balancing equations

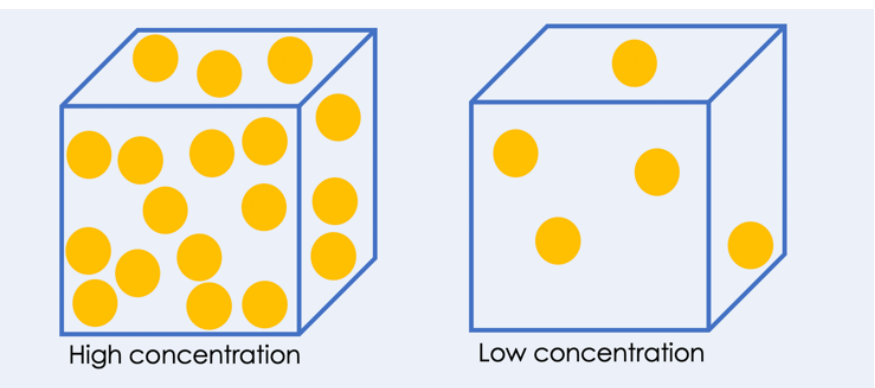
- No atoms are lost or made during a chemical reaction.
- **Mass of products = mass of reactants**
- Chemical reactions can be represented by symbol equations which are **balanced**.
- This means the number of atoms of each element is balanced e.g.
  $2Mg + O_2 \rightarrow 2MgO$
  there are 2 magnesium atoms on each side of the equation.
- Some reactions may appear to involve a change in mass, but this is normally because a reactant or a product is a **gas** e.g.
  $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
  During the reaction hydrogen gas is produced. If the gas is free to leave the reaction container then the measured mass will decrease.

## Uncertainty

- Scientific uncertainty means there is a range of possible values within which the true value of a measurement lies.
- Whenever a measurement is made, there is always some uncertainty about the result obtained.

## Concentration

- Many chemical reactions take place in solutions.




- The more concentrated a solution the more particles it contains in a given volume.

- The concentration of a solution can be measured in mass per given volume of solution e.g. grams per $dm^3$ ($g/dm^3$).
  **mass of solute / volume of solution = concentration**
- Volumes need to be in **$dm^3$**
- 1 $dm^3$ = 1000 $cm^3$

## Making soluble salts

- Soluble substances dissolve in a solvent
- Insoluble substances cannot dissolve in a solvent
- Neutralisation reaction general equation is acid + base → salt + water
- Metal + acid → salt + hydrogen
- Metal oxide + acid → salt + water
- Metal hydroxide + acid → salt + water
- Metal carbonate + acid → salt + water + carbon dioxide
- Soluble salts can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides, or carbonates.
- The solid is added to the acid until no more reacts and the excess solid I filtered off to produce a solution of the salt.
- Salt solutions can be crystallised to produce solid salts.
- Copper oxide reacts with sulphuric acid solution to produce copper sulphate and water
- This reaction can be represented with the equation
  $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H2O(l)$
- Copper sulphate solution is a blue liquid
- Copper sulphate crystals are blue

# Glossary

**$A_r$** This is the symbol for relative atomic mass.

*See **relative atomic mass.***

**Atom** The smallest part of an element that can exist independently.

*The centre of an **atom** is called the nucleus.*

**Atomic number** The number of protons in an atom of an element. This is the smallest number of the two numbers provided beside each element on the periodic table.

*The **atomic number** of magnesium is 12.*

**Boiling point** The temperature at which a substance changes state from liquid to gas. It is also the temperature at which a substance changes from gas to liquid (condenses).

*The **boiling point** of elements in group 1 decrease as you go down the group.*

**Chemical formula** A series of chemical symbols showing the number of atoms of each element in a compound.

*The **chemical formula** for Magnesium Oxide is MgO.*

**Chemical symbol** A letter or series of letters used to represent an element. The first letter is always uppercase (capital).

*C for carbon, Na for sodium.*

**Compound** A substance made up of two or more different elements chemically bonded together.

*Water is a **compound** of hydrogen and oxygen.*

**Concentration** The mass of solute dissolved in a given volume of solvent

*The **concentration** of the copper sulphate solution was 0.1 $g/cm^3$*

**Concentrated** If a solution is concentrated, there is a large mass of solute in a given volume of solvent.

*The salt water solution was **concentrated** because lots of salt was added to a small volume of water.*

**Conservation of Mass** The law of conservation of mass states that the total mass of reactants in any chemical reaction equals the total mass of products

*5 g of iron and sulfur reacted together to make 5 g of iron sulfide. This demonstrates the Law of **Conservation of Mass.***

**Crystallisation** A technique used to produce solid crystals from a solution. This occurs when a solution is warmed and the solvent is evaporated, leaving behind crystals of the solute.

*When copper sulphate solution is warmed slowly, **crystallisation** of blue copper sulphate crystals is observed.*

**Dilute** *To decrease the concentration of a liquid by mixing it with water or another liquid.*

*I plan to **dilute** the acid by adding more water.*

**Element** A substance made of only one type of atom.

*Oxygen is an example of an **element.***

**Evaporation** A separation technique in which a solvent is heated until it vaporises, leaving any dissolved substances behind.

*Water and dissolved salt can be separated by **evaporation**.*

**Filtration** A separation technique which can separate a mixture of a liquid and an insoluble solid, by passing the liquid through filter paper.

*When separating sand and water, **filtration** is used because the sand cannot pass through the filter paper, whereas water can.*

**Formulae** Plural of formula.

*See **chemical formula.***

**Insoluble** A substance is insoluble if it cannot be dissolved in a solvent.

*Wood is **insoluble** in water.*

**Mass number** The total number of protons and neutrons in the nucleus of an atom. It is the larger of the two numbers beside each element in the periodic table.

*Oxygen has a **mass number** of 16.*

**Melting** A change of state that occurs when a solid changes to a liquid.

***Melting** solid ice will form liquid water.*

**Melting point** The temperature at which a substance changes from solid to liquid (melts). It is also the temperature at which a substance changes from liquid to solid (freezes).

*The **melting point** of water is 0° Celsius.*

**Metal** A material which is typically hard, shiny, malleable and ductile, found in the middle and on the left-hand side of the Periodic table.

*Gold is an example of a **metal**.*

**Mixture** A material consisting of two or more different substances that are not chemically combined.

*Air is a **mixture** of gases.*

**Molecule** A small group of non-metal atoms chemically bonded together.

*Oxygen gas is made up of many oxygen **molecules**, each with the chemical formula $O_2$.*

**$M_r$** This is the symbol for relative formula mass.

*See **relative formula mass**.*

**Neutralisation** A chemical reaction in which an acid and a base react with each other.

***Neutralisation** reactions produce a salt and water.*

**Periodic table** A table of all the known elements arranged in order of atomic number so that elements with similar properties are in columns, known as groups.

*All of the elements we know are represented in the **Periodic Table.***

**Relative atomic mass** The relative atomic mass of an element is the relative mass of its atoms compared to the mass of a carbon-12 atom. The relative atomic masses for each element are given in the Periodic Table.

*The **relative atomic mass** of an oxygen atom is 16.*

**Relative formula mass** The relative formula mass of a substance is the sum of the relative atomic masses of its atoms, in the numbers shown in its chemical formula.

*The **relative formula mass** of a molecule of $H_2O$ is 18.*

**Solute** A substance that can be dissolved in a solvent.

*Salt is a **solute** because it can be dissolved in water.*

**Soluble** A substance is soluble if it can be dissolved in a solvent

*Sugar is **soluble** in water.*

**Solution** A mixture of a dissolved solute and a solvent.

*A **solution** of salt and water was used.*

**Solvent** A substance in which a solute can dissolve

*Water is a **solvent** because salt can dissolve in it*

**Subscript** The numbers that come after and below a chemical symbol in a chemical formula, to indicate the number of atoms of that element.

*The **subscript** number two shown in a molecule of $CO_2$ indicates that it contains 2 atoms of oxygen.*

**Transition metal** An element positioned in the central block of the periodic table, between Group 2 and Group 3.

*Iron is an example of a **transition metal.***

New Learning

# Prior Learning Review

**Do Now:**

1. What are the three states of matter?

2. State the chemical symbol for sodium.

3. State the elements that make up $CO_2$.

4. Write the general equation for the reaction between metals and oxygen.

5. Write the general equation for the reaction between metals and acids.

**Foundation:** Explain the difference between a chemical change and a physical change.

**Stretch:** Write a balanced symbol equation for the reaction between magnesium and hydrochloric acid to produce magnesium chloride ($MgCl_2$) and hydrogen.

**Formulae** can be used to show which **elements** are in **compounds** e.g. $H_2O$ contains two hydrogen atoms and one oxygen atom. The **ratio** is 2:1.

Chemical reactions always involve the **formation of one or more new substances**.

**Symbol equations** can be used to show chemical reactions
e.g. $2H_2 + O_2 \rightarrow 2H_2O$

**Compounds** can only be separated into their **elements** by chemical reactions
e.g. $2H_2O \rightarrow 2H_2 + O_2$

## Naming Compounds

**Rule 1** – usually, the metal goes first and the non-metal goes second

**Rule 2** – if a metal and a non-metal react, the name of the non-metal ends in –ide.

**Rule 3** – for some compounds (where the elements are both non-metals), if there are a different number of atoms we add in 'mono' for 1, 'di' for 2 and 'tri' for 3

**Rule 4** – if the compound names ends in –ate then it usually contains three elements, including a non-metal and oxygen

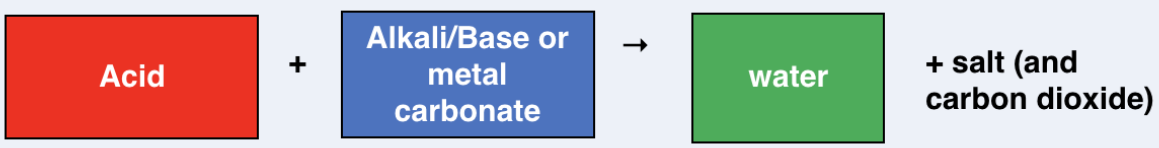
There are some general reactions that you need to know.

**Acid + metal → salt + hydrogen (gas)**

Acids also react with metal compounds in neutralisation reactions:

**Acid + alkali → salt + water**
**Acid + base → salt + water**
**Acid + metal carbonate → salt + water + carbon dioxide.**

These are neutralisation reactions because:




**Limewater** can be used to test for the presence or production of **carbon dioxide**. If limewater turns cloudy/milky then carbon dioxide is present.

The **squeaky pop test** can be used to test for the presence of **hydrogen** gas. If hydrogen gas is present it will burn with a squeaky pop.

# Activities and Practice

1. Determine if the following statements are true or false.
   a. Calcium (Ca) is an element.
   b. Oxygen ($O_2$) is a compound.
   c. Water boiling to form steam is a chemical reaction.
   d. Compounds are made of one element.
   e. $NH_3$ has a fixed ratio of one nitrogen atom to three hydrogen atoms.
   f. $CO_2$ has a fixed ratio of 2 oxygen to 2 carbon atoms.
   g. $Al_2(SO_4)_3$ contains 3 sulfur atoms.
   h. $Al_2(SO_4)_3$ contains 4 oxygen atoms.

2. Write the correct chemical formula for the following substances:
   a. Water
   b. Carbon dioxide
   c. Oxygen gas
   d. Hydrogen gas
   e. Hydrochloric acid

3. Determine how many atoms of each element are present in the following formulae and name each compound. The first has been done for you:
   a. NaCl *(sodium chloride)* contains *1 atom of sodium and 1 atom of chlorine*
   b. MgO _____ contains _____
   c. $SO_2$ _____ contains _____
   d. $Na_2S$ _____ contains _____
   e. $Fe_2O_3$ _____ contains _____
   f. $AgNO_3$ _____ contains _____

4. Determine how many atoms of each element are present in the following compounds:
   a. Sulfuric acid ($H_2SO_4$) contains_____
   b. Barium hydroxide ($Ba(OH)_2$) contains_____
   c. Glucose ($C_6H_{12}O_6$) contains_____
   d. Ethanol ($C_2H_5OH$) contains_____
   e. Nitric acid ($HNO_3$) contains_____
   f. Potassium hydroxide (KOH) contains_____

5. Name the compounds formed when there is chemical reaction between these elements:
   a. zinc + oxygen →
   b. 1 carbon atom + 2 oxygen atoms →
   c. magnesium + oxygen →
   d. lithium + nitrogen + oxygen →
   e. potassium + chlorine →
   f. 1 carbon atom + 3 oxygen atoms →
   g. calcium + fluorine →
   h. nitrogen + silver →
   i. potassium + chlorine + oxygen →
   j. copper + oxygen + sulfur →

6. Complete the following table:

| Chemical name | Chemical Formula |
|---|---|
| Hydrochloric Acid | |
| Nitric Acid | |
| | $H_2SO_4$ |
| | $H_2$ |
| Calcium chloride | $CaCl_2$ |
| Sodium Hydroxide | NaOH |
| | NaCl |
| Copper carbonate | $CuCO_3$ |
| Copper sulfate | $CuSO_4$ |
| | CuO |
| Potassium carbonate | $K_2CO_3$ |
| Potassium nitrate | $KNO_3$ |

7. Complete the general equations to show the products formed in each of the reactions with acids:
   a. Metal + acid →
   b. Metal oxide + acid →
   c. Metal hydroxide + acid →
   d. Metal carbonate + acid →

8. Use the general equations from question 2 to predict the products of these reactions and complete the word equations:
   a. Calcium + hydrochloric acid →

   b. Hydrochloric acid + sodium hydroxide →

c. Sulfuric acid + copper carbonate →

d. Hydrochloric acid + copper oxide →

e. Nitric acid + potassium carbonate →

9. Use the table in Q5 to help you write **balanced** symbol equations for each of the reactions in Q7.
   a.
   b.
   c.
   d.
   e.

10. Use Q8/Q9 to help you answer these questions.
    a. Which reactions would cause a positive result for the squeaky pop test?

    b. Which reactions would cause a positive result for the limewater test?

# Exit Ticket

1. **Ammonia ($NH_3$) contains…**
   - ☐ A. 3 nitrogen atoms and 1 hydrogen atom
   - ☐ B. 3 nitrogen atoms and 3 hydrogen atoms
   - ☐ C. 3 hydrogen atoms and 1 nitrogen atom

2. **How many hydrogen atoms are in the formulae $(NH_4)_2SO_4$?**
   - ☐ A. 4
   - ☐ B. 8
   - ☐ C. 6

3. **Copper carbonate reacted with hydrochloric acid. Which statement is correct?**
   - ☐ A. If a product was bubbled through limewater, limewater would turn milky/cloudy
   - ☐ B. If a product was bubbled through limewater there would be no change
   - ☐ C. A product would burn with a squeaky pop

For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

Subscripts in a chemical formula show the number of atoms of the element directly in front of it. A subscript next to brackets indicates the number of the whole unit inside the bracket. This means that although there are 4 hydrogen atoms within the bracket, the 2 outside the bracket means there are two lots of everything in the bracket. Therefore this formula contains 8 hydrogen atoms.

*Identify how many nitrogen atoms are in the formula $(NH_4)_2SO_4$.*

**If you answered B**

Subscripts in a chemical formula show the number of atoms of the element directly in front of it. A subscript next to brackets indicates the number of the whole unit inside the bracket. This means that although there are 4 hydrogen atoms within the bracket, the 2 outside the bracket means there are two lots of everything in the bracket. Therefore this formula contains 8 hydrogen atoms.

*Suggest how a pupil arrived at answers A or C and describe how you could explain these mistakes.*

**If you answered C**

Subscripts in a chemical formula show the number of atoms of the element directly in front of it. A subscript next to brackets indicates the number of the whole unit inside the bracket. This means that although there are 4 hydrogen atoms within the bracket, the 2 outside the bracket means there are two lots of everything in the bracket, not just that there are two extra hydrogen atoms. Therefore this formula contains 8 hydrogen atoms.

*Identify how many nitrogen atoms are in the formula $(NH_4)_2SO_4$.*

**New Learning**

# Relative Formula Mass

**Do now**

1. State the chemical symbol for potassium.

2. List the elements in $Zn(OH)_2$.

3. Where on the periodic table are non-metals found?

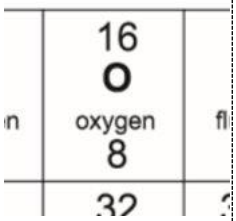
4. List two elements that are found in group 1 of the periodic table.

5. How many atoms are there in $Zn(OH)_2$?

**Foundation:** Explain why when magnesium reacts with hydrochloric acid the mass appears to decrease.

**Stretch:** Write a balanced chemical equation (including state symbols) for the reaction between zinc and oxygen to form solid zinc oxide (ZnO).

Atoms are very small and have very little mass. So instead of using their actual mass in kg (which would be a very tiny decimal) their **relative** masses are used. This is called the **relative atomic mass** and is represented with the symbol $\mathbf{A_r}$.




**Relative atomic mass** ($A_r$) is the average mass of the atoms of an element compared to the mass of carbon-12**.**

The relative atomic mass of an **element** can be found in the **periodic table**. The relative atomic mass of oxygen is 16.

You may notice that some elements (such as chlorine and copper) do not have a whole number for their relative atomic mass. This is because there are different forms of the element that exist (isotopes), which have different numbers of neutrons and therefore a different atomic mass. The relative atomic mass of each element is an **average** value that takes into account how much of each isotope exists. Most elements actually do not have a whole number for their relative atomic mass but they are rounded to help make calculations easier.

## Relative Formula Mass

For compounds (different elements combined together chemically) we can calculate the **relative formula mass** or $\mathbf{M_r}$.

The **relative formula mass** ($M_r$) is the sum of the relative atomic masses of the elements in a formula.

This is calculated by adding up the relative atomic masses of the all the atoms in the **formula.** This means we need to take into account how many atoms of each element are present.

e.g. $CO_2$ contains **1 carbon** atom and **2 oxygen** atoms.

$A_r$: C = 12, O = 16.

$M_r$ of $CO_2$ = 12 + (2 x 16) = 44

## Calculating relative formula mass

### Magnesium nitrate, $Mg(NO_3)_2$

Mg is Magnesium, 24
N is Nitrogen, 14
O is Oxygen, 16

Magnesium: 1
Nitrogen: 2
Oxygen: 6

Magnesium: 24 x 1 = 24
Nitrogen: 14 x 2 = 28
Oxygen: 16 x 6 = 96

24 + 28 + 96 = 148

**Steps:**

1. Write out the **elements** and their **relative atomic masses**
2. Use the formula to write the **number of atoms** of each element
3. Calculate the **mass of the atoms** of each element (Relative atomic mass x number of atoms)
4. **Add up the total mass** of the elements (this is your $M_r$)

## Calculating relative formula mass

### Calcium carbonate, $CaCO_3$

Ca is Calcium, 40
C is Carbon, 12
O is Oxygen, 16

Calcium: 1
Carbon: 1
Oxygen: 3

Calcium: 40 x 1 = 40
Carbon: 12 x 1 = 12
Oxygen: 16 x 3 = 48

40 + 12 + 48 = 100

**Steps:**

1. Write out the **elements** and their **relative atomic masses**
2. Use the formula to write the **number of atoms** of each element
3. Calculate the **mass of the atoms** of each element (Relative atomic mass x number of atoms)
4. **Add up the total mass** of the elements (this is your $M_r$)

# Activities and Practice

**Answer the following questions.**

1. Circle the correct word to complete the sentence.
   a. Relative atomic mass can also be written as **$M_r$ / $A_r$**
   b. Relative formula mass can also be written as **$M_r$ / $A_r$**
   c. The relative atomic mass of an **element / compound** can be found using the Periodic Table
   d. The relative atomic mass can be found next to the chemical symbol, on a Periodic Table, and it is always the **bigger / smaller / top / bottom** number.
2. State the relative atomic mass for the following elements:
   a. Nitrogen
   b. Bromine
   c. Neon
   d. Thallium
   e. Vanadium
   f. Helium
   g. Hydrogen
   h. Oxygen
   i. Carbon
   j. Osmium
   k. Gold
   l. Copper

3. Calculate the relative formula mass of each of the following compounds. Show your working.

   a. $Cl_2$

   b. $H_2$

   c. $H_2O$

   d. $CO_2$

   e. HCl

   f. $CuSO_4$

   g. NaOH

   h. $Al_2O_3$

   i. $Zn(OH)_2$

   j. $Mg(NO_3)_2$

   k. $Ca(HCO_3)_2$

   l. $(NH_4)_2SO_4$

4. Prove that the $M_r$ of products = $M_r$ of reactants using the following equation.

   (Ar: Mg = 24; Cu = 63.5; S = 32; O = 16)

   $Mg + CuSO_4 \rightarrow MgSO_4 + Cu$

5. A metal oxide has the formula MO, where M is the chemical formula for the metal and O is oxygen.

   The relative formula mass for this compound is 40.

   What is the metal?

# Exit Ticket

1. **The relative formula mass for $NH_3$ is… ($A_r$: N=14; H=1)**
   - ☐ A. 17
   - ☐ B. 15
   - ☐ C. 45

2. **The relative formula mass for $Fe_2O_3$ is…($A_r$: Fe=56; O=16)**
   - ☐ A. 384
   - ☐ B. 160
   - ☐ C. 76

3. **Complete the sentence. The relative formula mass is…**
   - ☐ A. The sum of the atomic mass of protons and electrons in a compound
   - ☐ B. The sum of the relative atomic masses of the elements in a formula
   - ☐ C.The sum of the relative atomic masses in an element

For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

The relative formula mass is the sum of the relative atomic masses of the elements in a formula. This means it needs to take into account the relative atomic mass of each element and how many atoms of each element are in the formula. Iron oxide contains 2 iron atoms and 3 oxygen atoms, so to calculate the $M_r$ of iron oxide the calculation would be (2 x 56) + (3 x 16), giving an $M_r$ of 160.

*Calculate the $M_r$ of $Na_2SO_4$.*

**If you answered B**

The relative formula mass is the sum of the relative atomic masses of the elements in a formula. This means it needs to take into account the relative atomic mass of each element and how many atoms of each element are in the formula. Iron oxide contains 2 iron atoms and 3 oxygen atoms, so to calculate the $M_r$ of iron oxide the calculation would be (2 x 56) + (3 x 16), giving an $M_r$ of 160.

*Explain why $M_r$ values are not written with a unit.*

**If you answered C**

The relative formula mass is the sum of the relative atomic masses of the elements in a formula. This means it needs to take into account the relative atomic mass of each element and how many atoms of each element are in the formula. Iron oxide contains 2 iron atoms and 3 oxygen atoms, so to calculate the $M_r$ of iron oxide the calculation would be (2 x 56) + (3 x 16), giving an $M_r$ of 160.

*Calculate the $M_r$ of $Na_2SO_4$.*

**New Learning**

# Percentage by Mass

**Do Now:**

1. State the relative atomic mass of Argon.

2. State the symbol for relative atomic mass.

3. Calculate the relative formula mass of NaCl.

4. State the number of protons, neutrons and electrons in an atom of lithium.

5. What are isotopes?

**Foundation:** Where is most of the mass of an atom located?

**Stretch:** Why are the mass numbers of some elements on the periodic table not whole numbers?

We can calculate the percentage of an element in a compound using the $A_r$ and $M_r$. This is a measure of how much of the substance is made up of each element.

**Percentage by mass** is used to calculate the percentage by mass of an **element** within a **compound**.

$$\% \ by \ mass = \frac{A_r \ x \ number \ of \ atoms \ in \ a \ compound}{M_r \ of \ the \ compound} \times 100$$

e.g. Calculate the percentage of oxygen in water.

1. Calculate the $M_r$ of water = (2 x 1) + 16 = 18
2. Use the calculation:

$$\frac{A_r \text{ of oxygen}}{M_r \text{ of water}} \times 100$$

$$\frac{16}{18} \times 100 = \mathbf{89\ \%}$$

This means that 89 % of a water molecule is actually made up of oxygen. Even though there are two hydrogen atoms present they are both very small compared to oxygen. We could complete this calculation to show the percentage of hydrogen in water

$$\frac{A_r \text{ of hydrogen (in molecule)}}{M_r \text{ of water}} \times 100$$

$$\frac{(1 \times 2)}{18} \times 100 = \mathbf{11\ \%}$$

We can check that our calculations are correct because the total should make 100 %. If there were three elements present we would need to do three calculations to determine the percentage of each element.

# Activities and Practice

$$\%\ by\ mass = \frac{A_r\ x\ number\ of\ atoms\ in\ a\ compound}{M_r\ of\ the\ compound}\ x\ 100$$

**Answer the questions below.**

1. Calculate the percentage by mass of carbon in carbon monoxide, CO.

2. Calculate the percentage by mass of hydrogen in HCl.

3. Calculate the percentage composition of sodium in sodium chloride, NaCl.

4. Calculate the percentage composition of sodium in sodium hydrogen carbonate, $NaHCO_3$.

5. Calculate the percentage of oxygen in sodium hydrogen carbonate, $NaHCO_3$.

6. Calculate the percentage by mass of lithium in lithium hydroxide, LiOH.

7. Calculate the percentage by mass of hydrogen in lithium hydroxide, LiOH.

8. Which makes up the greater percentage by mass in lithium hydroxide (LiOH), oxygen or lithium? Show your working.

9. Calculate the percentage by mass of carbon in calcium carbonate, $CaCO_3$.

10. Calculate the percentage by mass of oxygen in potassium permanganate, $KMnO_4$.

**Stretch:**

11. In a sample of water with a mass of 10 g, what percentage of that mass is made of hydrogen atoms?

12. The percentage by mass of oxygen in a compound is 66.7%. The compound has the formula XO, where X is a metal and O is oxygen. What is the compound?

# Exit Ticket

1. **What is the relative formula mass for $NH_3$?($A_r$: N = 14; H = 1).**
   - ☐ A. 17
   - ☐ B. 15
   - ☐ C. 45

2. **Calculate the percentage by mass of carbon in $C_2H_4$.**
   - ☐ A. 28%
   - ☐ B. 85.7%
   - ☐ C. 42.8%

3. **Calculate the percentage by mass of carbon in carbon monoxide (CO). ($A_r$: C = 12; O = 16).**
   - ☐ A. 18%
   - ☐ B. 43%
   - ☐ C. 50%

For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

Percentage by mass shows how much of a compound's mass is made up of each element. The calculation is $\%\ by\ mass = \frac{Ar\ x\ number\ of\ atoms\ in\ a\ compound}{Mr\ of\ the\ compound}$ x 100. In this case that would be:

% carbon = $\frac{12 \times 2}{28}$ x 100

% by mass of carbon = 85.7 %

*Calculate the percentage by mass of hydrogen in $C_2H_4$.*

**If you answered B**

Percentage by mass shows how much of a compound's mass is made up of each element. The calculation is $\%\ by\ mass = \frac{Ar\ x\ number\ of\ atoms\ in\ a\ compound}{Mr\ of\ the\ compound}$ x 100. In this case that would be:

% carbon = $\frac{12 \times 2}{28}$ x 100

% by mass of carbon = 85.7 %

*Explain what is meant by percentage by mass.*

**If you answered C**

Percentage by mass shows how much of a compound's mass is made up of each element. The calculation is $\%\ by\ mass = \frac{Ar\ x\ number\ of\ atoms\ in\ a\ compound}{Mr\ of\ the\ compound}$ x 100. In this case that would be:

% carbon = $\frac{12 \times 2}{28}$ x 100

% by mass of carbon = 85.7 %

*Calculate the percentage by mass of hydrogen in $C_2H_4$.*

**New Learning**

# Conservation of Mass

**Do Now:**

1. What is the ratio of nitrogen to hydrogen in $NH_3$?

2. What is meant by the law of conservation of mass?

3. Describe the following equation in words (MgO is magnesium oxide):

   *2 Mg + $O_2$ → 2MgO*

4. State the $A_r$ of silicon.

5. Calculate the relative formula mass of LiF (lithium fluoride).

**Foundation:** Turn this word equation into a chemical equation:

*Zinc + oxygen → zinc oxide*

**Stretch:** Turn the following into a balanced chemical equation with state symbols:

*Magnesium reacts with hydrochloric acid to form a salt and hydrogen.*

State symbols give more information about the **state** of reactants and products in a chemical equation.

(s) = solid
(l) = liquid
(g) = gas
(aq) = aqueous (dissolved in water)

State symbols are always written **subscript**

$$HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

An **aqueous** solution forms when a substance dissolves in **water**.

State symbols are useful because they show what a substance is like.

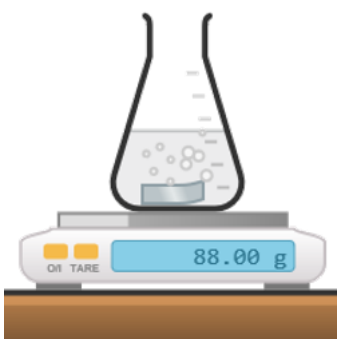
For example:

- $H_2O(l)$ is liquid water but $H_2O(g)$ is steam
- HCl(g) is hydrogen chloride gas but HCl(aq) is hydrochloric acid

The **Law of Conservation of Mass** states that matter cannot be created or destroyed, only transferred from one form to another.

**Does mass change when chemicals react?**

$$HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$




What will happen to the mass on the balance during the reaction?

*The mass on the balance will decrease.*

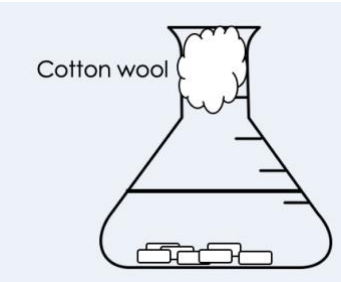
But, **no atoms are lost or made** during a chemical reaction. So why has the mass decreased?

- *Hydrogen gas is being produced.*
- *The hydrogen gas will move out of the flask.*
- *The decrease in mass on the balance will equal the mass of $H_2$ gas.*

# Activities and Practice

**Read the paragraph below.**

**Use the information provided to answer the question.**




Johar decided to observe the reaction between lithium and water in a conical flask with some wool in the neck.

Before the reaction starts, he uses a balance to check the mass of the lithium and the water.

When the lithium is added to the water there is fizzing. After some time there is no more fizzing. Johar then weighed and found the mass of the lithium hydroxide solution. Looking at it he said, "Oh my! Mass just disappeared! The teacher and his law of conservation of mass are nonsense!"

Using the data, picture of the equipment and the equation below, explain why Johar is wrong to doubt the teacher.

**Potassium + Water → Potassium Hydroxide + Hydrogen**

**$2\ Li_{(s)} + H_2O_{(l)} \rightarrow 2\ LiOH_{(aq)} + H_{2(g)}$**

| Masses of substance (g) | | |
|---|---|---|
| **Lithium** | **Water** | **Potassium hydroxide solution** |
| **2g** | **80g** | **81g** |

## Steps for success

**For a great response, you should include answers to the following questions:**

1. What is the law of conservation of mass?
2. What is the total mass of the reactants?
3. What is the mass of the potassium hydroxide solution?
4. What is missing here?
5. Why is the mass 81 on the scales? Use evidence from the symbol equation.
6. Why hasn't the wool stopped this?

7. What will the mass of the hydrogen be?
8. Stretch: What should you use instead if you want to accurately measure the mass of the products?
9. Super stretch: What is the problem with the term weigh?

# Exit Ticket

1. **If 3 g of copper oxide and 2 g of carbon dioxide were produced, how many grams of copper carbonate was broken down?**

$$CuCO_3\ (s) \rightarrow CuO\ (s) + CO_2\ (g)$$

- ☐ A. 1 g
- ☐ B. 6 g
- ☐ C.5 g

2. **When copper carbonate is heated, the mass recorded on a balance decreases. Which of the following is <u>false</u>?**

- ☐ A. The loss in mass is due to a change in state
- ☐ B. The loss in mass is due to a formation of gas
- ☐ C.The mass of products equals the mass of reactants

3. **Complete the sentence. The relative formula mass is…**

- ☐ A. The sum of the atomic mass of protons and electrons in a compound
- ☐ B. The sum of the relative atomic masses of the elements in a formula
- ☐ C.The sum of the relative atomic masses in an element

For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

The law of conservation of mass states that the total mass of products is equal to the total mass of reactants, because atoms are not created or destroyed in chemical reactions, they are simply rearranged. When a gas product is formed and the gas is able to escape, the mass appears to decrease because the gas particles are no longer contributing to the recorded mass. A change in state would not cause a decrease in mass.

*Suggest how the mass of the gas product could be kept in the reaction apparatus and measured.*

**If you answered B**

The law of conservation of mass states that the total mass of products is equal to the total mass of reactants, because atoms are not created or destroyed in chemical reactions, they are simply rearranged. When a gas product is formed and the gas is able to escape, the mass appears to decrease because the gas particles are no longer contributing to the recorded mass. A change in state would not cause a decrease in mass. If 100 g of ice was melted, it would give 100 g of water because the particles themselves are the same, only their spacing has changed.

*Explain the difference between a chemical reaction and a change of state.*

**If you answered C**

The law of conservation of mass states that the total mass of products is equal to the total mass of reactants, because atoms are not created or destroyed in chemical reactions, they are simply rearranged. When a gas product is formed and the gas is able to escape, the mass appears to decrease because the gas particles are no longer contributing to the recorded mass. A change in state would not cause a decrease in mass. If 100 g of ice was melted, it would give 100 g of water because the particles themselves are the same, only their spacing has changed.

*State the law of conservation of mass.*

**New Learning**

# Balancing Equations

**Do Now:**

1. On which side of a chemical equation are reactants found?

2. What does a subscript represent in a chemical formula?

3. Why is mass conserved in chemical reactions?

4. How many of each element are present in $2Fe_2O_3$?

5. Is the following equation balanced? Explain your answer.

$$N_2 + H_2 \rightarrow NH_3$$

**Foundation:** Identify how many of each type of atom are present in $H_3PO_4$.

**Stretch:** Compare the meaning of subscripts and coefficients in chemical equations.

**Conservation of mass and $M_r$**

So we know that **mass of reactants = mass of products**.

In a balanced symbol equation **$M_r$ reactants = $M_r$ products**

We can prove that $M_r$ reactants = $M_r$ products using this equation:

**$2HCl + Mg \rightarrow MgCl_2 + H_2$**
(Ar: Mg = 24; H = 1; Cl = 35.5)

So **total mass of products = total mass of reactants**

This is why chemical reactions are represented by **symbol equations** which are **balanced** in terms of the **number of atoms of each element**.

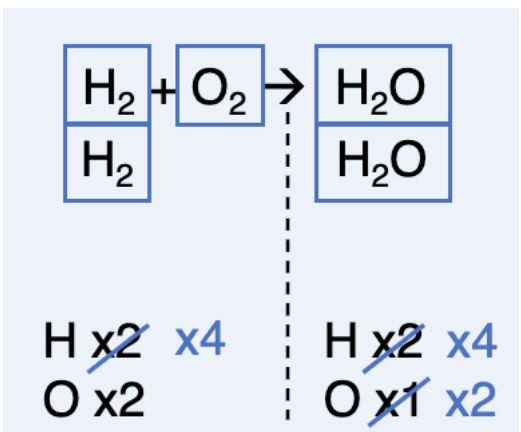
**How do I balance an equation?**

The number of atoms of each element is balanced in a symbol equation e.g. there are 2 oxygen atoms on each side of this equation:

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

Let's balance the following equation:

$H_2 + O_2 \rightarrow H_2O$




1. How many atoms of each element?
2. Box the substances.
3. More oxygen needed – add a box.
4. Now how many atoms of each element?
5. More hydrogen needed – add a box.
6. Now how many atoms of each element?
7. It is now balanced

# Activities and Practice

1. __ $Na$ + __ $Cl_2$ → __ $NaCl$

2. __ $Al$ + __ $O_2$ → __ $Al_2O_3$

3. __ $N_2$ + __ $H_2$ → __ $NH_3$

4. __ $Fe$ + __ $Cl_2$ → __ $FeCl_3$

5. __ $Fe$ + __ $O_2$ → __ $Fe_2O_3$

6. __ $C_4H_6O_3$ + __ $H_2O$ → __ $C_2H_4O_2$

7. __ $C_2H_4$ + __ $O_2$ → __ $CO_2$ + __ $H_2O$

8. __$C_4H_{10}O$+ __ $O_2$ → __ $CO_2$ + __ $H_2O$

9. __ $C_7H_{16}$ + __ $O_2$ → __ $CO_2$ + __ $H_2O$

10. __ $SeCl_6$ + __ $O_2$ → __ $SeO_2$ + __ $Cl_2$

11. __ $CH_4$ + __ $O_2$ → __ $CO_2$ + __ $H_2O$

12. __ AgI + __ $Na_2S$ → __ $Ag_2S$ + __ NaI

13. __ $Na_3PO_4$ + __ HCl → __ NaCl + __ $H_3PO_4$

14. __ $H_2SiCl_2$ + __ $H_2O$ → __ $H_8Si_4O_4$ + __ HCl

15. __ $C_2H_6$ + __ $O_2$ → __ $H_2O$ + __ $CO_2$

16. __ KOH + __ $H_3PO_4$ → __ $K_3PO_4$ + __ $H_2O$

17. __ $SnO_2$ + __ $H_2$ → __ Sn + __ $H_2O$

18. __ $NH_3$ + __ $O_2$ → __ NO + __ $H_2O$

# Exit Ticket

**1. Predict the products of the following equation:**

$Zn + 2\ HCl \rightarrow$

- ☐ A. $ZnCl_2 + H_2$
- ☐ B. $ZnCl + H_2$
- ☐ C. $ZnCl + H$

**2. How many hydrogen atoms make up the products of this reaction?**

$8\ CO + 17\ H_2 \rightarrow C_8H_{18} + 8\ H_2O$

- ☐ A. 28
- ☐ B. 16
- ☐ C. 34

**3. Which equation demonstrates the law of conservation of mass?**

- ☐ A. $CH_4 + 2\ O_2 \rightarrow CO_2 + H_2O$
- ☐ B. $CH_4 + O_2 \rightarrow CO_2 + 2\ H_2O$
- ☐ C. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

For question 3, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

The law of conservation of mass states that the total mass of reactants is equal to the total mass of products in a chemical reaction, because atoms cannot be created or destroyed, only rearranged. For an equation to demonstrate conservation of mass it must be balanced, as that would have the same number of each type of atom in the reactants and products. A is not balanced because there are different numbers of hydrogen and oxygen atoms in the reactants and products.

*Explain why equations must be balanced.*

**If you answered B**

The law of conservation of mass states that the total mass of reactants is equal to the total mass of products in a chemical reaction, because atoms cannot be created or destroyed, only rearranged. For an equation to demonstrate conservation of mass it must be balanced, as that would have the same number of each type of atom in the reactants and products. B is not balanced because there are different numbers of oxygen atoms in the reactants and products.

*Balance equation B so that there are the same number of atoms on each side of the reaction.*

**If you answered C**

The law of conservation of mass states that the total mass of reactants is equal to the total mass of products in a chemical reaction, because atoms cannot be created or destroyed, only rearranged. For an equation to demonstrate conservation of mass it must be balanced, as that would have the same number of each type of atom in the reactants and products. C is a balanced equation because it has the same number of each type of atom on both sides of the reaction.

*Outline the steps taken when balancing a chemical equation.*

**New Learning**

# Uncertainty

**Do Now**

A student measured the volume of hydrogen given off in the reaction between hydrochloric acid and magnesium. Their results are shown in the table.

| Trial | Volume of hydrogen produced |
|---|---|
| 1 | 15.0 |
| 2 | 14.8 |
| 3 | 14.5 |
| 4 | 14.9 |

1. Identify an error in this results table.

2. Calculate the mean of these results.

3. Calculate the range of these results.

4. Write a word equation for the reaction in this investigation.

5. Identify the reactants and products of this reaction.

**Foundation:** Explain the difference between relative atomic mass and relative formula mass.

**Stretch:** Write a balanced symbol equation for the reaction above.

In any science experiment or investigation that requires measurements to be taken, there is always some **uncertainty** in the result obtained. This means that although we can be quite sure our method allowed us to collect valid results, it is difficult to say that our results are completely perfect.

There are different things that can cause uncertainty, and you may be aware of having some doubts in previous investigations as to how accurate or precise your results may have been. One of the most common sources of uncertainty are when measuring the time taken for something to occur (such as for a

reaction to completely finish, or for a physical change of state to finish, or for a solute to dissolve in a solvent).

Another common source of error comes from the **instrument** or measuring apparatus that is being used. For example, if we want to measure a volume of 22 $cm^3$, we will need to use a measuring cylinder that allows us the resolution to do this. We could use a measuring cylinder that has intervals of 1 $cm^3$, but this would still mean that the actual volume we measure could be anywhere between 21.5 and 22.5 $cm^3$.

Scientific uncertainty means that **there is a range of possible values within which the true value of the measurement lies**. A result reported with a small uncertainty means that the experimenter is reasonably confident that the true value falls in between the maximum and minimum (plus and minus) values.

**Example:**

A coach recorded the time taken for an athlete to run 100 metres 4 times, so that they could enter the estimated time for a lane draw in an event. They measured these four times.

| Trial | Time (s) |
|---|---|
| 1 | 10.58 |
| 2 | 10.64 |
| 3 | 10.59 |
| 4 | 10.62 |

We can be fairly confident that the athlete runs 100 metres in about 10.6 seconds, but that is not a very **precise** measurement.

We can use these values to calculate the mean, as well as use the repeated measurements to **estimate** the **uncertainty**. This gives us a numerical way of explaining how confident we are that the true value (how long it actually takes the athlete to run 100 m) falls within our measurements.

We can estimate the uncertainty using the **range**. The uncertainty is taken as **plus or minus (±) half the range.** We can follow the following steps to estimate the uncertainty:

1. Calculate the **mean**.

$$\text{Mean} = \frac{(10.58+10.64+10.59+10.62)}{4}$$

$$\text{Mean} = 10.61 \text{ s}$$

2. Calculate the **range** by subtracting the smallest value from the biggest value.

   **Range = 10.64 - 10.58**

   **Range = 0.06 s**

3. **Divide** the answer for the range **by 2**.

   **Uncertainty = $\frac{0.06}{2}$**

   **Uncertainty = 0.03 s**

4. Write the mean, followed by the uncertainty after the plus or minus symbol.

   **Time = 10.61 s $\pm$ 0.03 s**

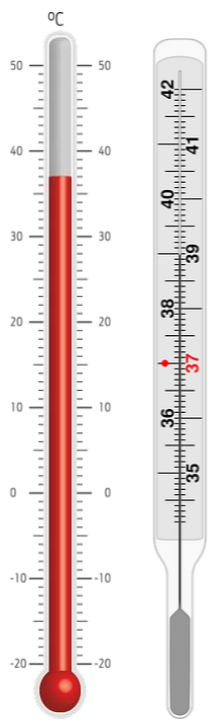
So what does this actually mean?

This means that our calculated mean is 10.61 seconds and our uncertainty is very small. This means that we can be **reasonably confident** that the actual time taken by this runner to run 100 metres falls within 0.03 seconds above or below 10.61 seconds.

We can also estimate uncertainty of measurements from the **resolution** of the **instrument**.

The uncertainty can be estimated as **half** the **smallest interval**.

For a thermometer with resolution of 1 °C, the uncertainty is 0.5 °C.




What this actually means is that a student made a measurement of 37.0 °C using this thermometer, the actual temperature could be as low as 36.5 °C or as high as 37.5 °C. If it was lower than 36.5 °C, the student would read this as 36.0 °C and if it was higher than 37.5 °C, the student would read that as 38 °C. We can call these values (36.5 °C and 37.5 °C) our **minimum** and **maximum** measurements.

For a thermometer with resolution of 0.1 °C, the uncertainty is 0.005 °C.

# Activities and Practice

**Answer the following questions.**

1. A group of students is investigating the reaction between copper hydroxide and sulfuric acid. They are discussing the best volume of acid to use and how they will measure it for this investigation.

   Each student uses a different instrument to measure the volume.

| Volume ($cm^3$) | Uncertainty ($cm^3$) | Minimum volume | Maximum volume |
|---|---|---|---|
| 35 | ± 0.5 | | |
| 32.5 | ± 0.25 | | |
| 30 | ± 1 | | |

   a. Use the uncertainty to determine the maximum and minimum volumes that the students could have measured.

   b. Explain which of the instruments should be used for the investigation.

2. The students investigate how long it takes for copper hydroxide to react fully with different concentrations of sulfuric acid. They recorded their results in the table below.

| | Time taken for reaction to finish (s) | | | | | |
|---|---|---|---|---|---|---|
| Concentration of sulfuric acid ($g/dm^3$) | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Mean | Range |
| 10 | 98 | 99 | 104 | 101 | | |
| 20 | 76 | 78 | 75 | 78 | | |
| 30 | 50 | 52 | 56 | 49 | | |
| 40 | 24 | 25 | 27 | 25 | | |

a. Identify the independent and dependent variables in this investigation.

b. Identify any control variables.

c. Explain why repeat measurements were taken.

d. Calculate the mean and range for each value of the independent variable. Round your answers to 2 decimal places.

e. Calculate the uncertainty for each mean.

f. State the mean for each value with its uncertainty.

g. Suggest reasons for the variation in these measurements.

h. Suggest ways to reduce the uncertainty of the measurements in this investigation.

i. Draw a suitable graph of the results.

# Exit Ticket

**1. What is the best definition of uncertainty?**

- ☐ A. The mean and the range of a data set
- ☐ B. The range of a data set divided by two
- ☐ C. The range of values within which the true value lies

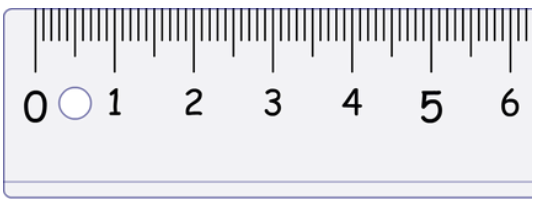
**2. Estimate the uncertainty of this data set.**

- ☐ A. ± 3 g
- ☐ B. ± 6 g
- ☐ C. ± 105 g

| Trial | Mass (g) |
|---|---|
| 1 | 102 |
| 2 | 108 |
| 3 | 105 |

**3. Estimate the uncertainty of this instrument.**

- ☐ A. 1 cm
- ☐ B. 0.1 cm
- ☐ C. 0.05 cm




For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

The uncertainty of a data set is a way of showing the range of values within which the true value of a measurement lies (so a maximum and minimum value). Uncertainty can be estimated using half the range of a set of repeated measurements. In this case, the range is 6 g, so the uncertainty would be half of this, making it ± 3 g.

*Describe the two ways that uncertainty can be estimated.*

**If you answered B**

The uncertainty of a data set is a way of showing the range of values within which the true value of a measurement lies (so a maximum and minimum value). Uncertainty can be estimated using half the range of a set of repeated measurements. In this case, the range is 6 g, so the uncertainty would be half of this, making it ± 3 g.

*Describe the two ways that uncertainty can be estimated.*

**If you answered C**

The uncertainty of a data set is a way of showing the range of values within which the true value of a measurement lies (so a maximum and minimum value). Uncertainty can be estimated using half the range of a set of repeated measurements. In this case, the range is 6 g, so the uncertainty would be half of this, making it ± 3 g.

*Describe the two ways that uncertainty can be estimated.*

**New Learning**

# Introducing Concentration

**Do Now**

Match each term with its description.

| Term | Description |
|---|---|
| A. A saturated solution | 1. Made of one type of atom or compound |
| B. Dissolves | 2. When the solute particles fill in the spaces between the solvent particles |
| C. A pure substance | 3. The substance that dissolves in a solvent. |
| D. Solute | 4. A solution in which no more solute will dissolve |
| E. Insoluble | 5. A substance that will not dissolve to form a solution |

**What is concentration?**

The concentration of a solution tells you how much **solute** is dissolved **in a given volume** of a **solution**.



For example, the bottle on the left is more concentrated than the carton on the right because it has more particles of ribena per unit volume.

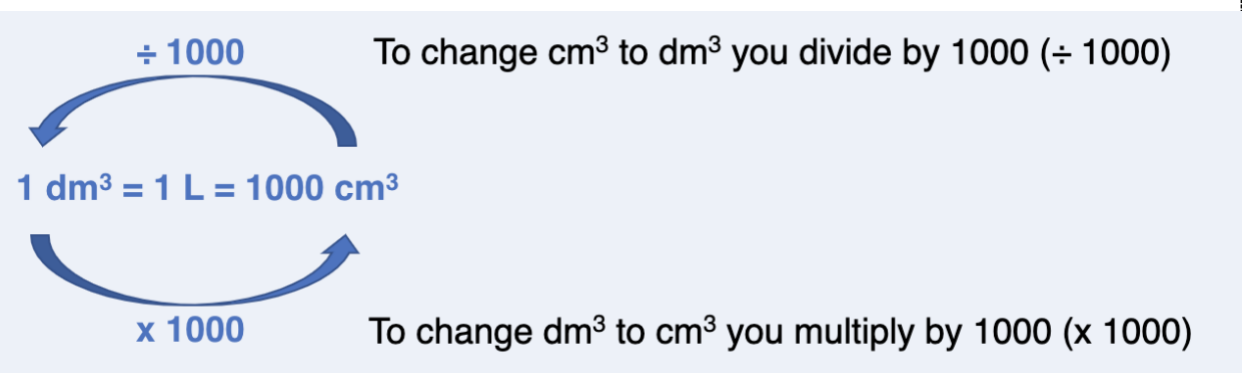
Volume is the **amount of space** that a substance or object takes up.

You may have seen some of the following units for volume:

- **$m^3$** (cubic metres)
- **$cm^3$** (cubic centimetres)
- **L** (Litres)
- **mL** (millilitres)

Scientists use a different unit of volume: **$dm^3$** (cubic decimetres)

**$1\ dm^3 = 1\ L = 1000\ cm^3$**



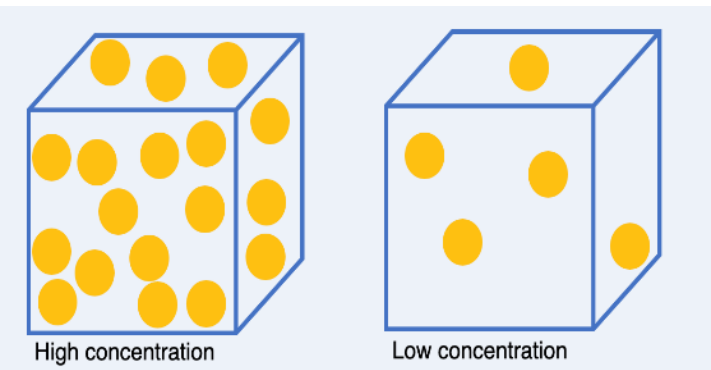

Practice converting these volumes to different units:

| | |
|---|---|
| 1000 $cm^3$ = _____ $dm^3$ | 1 $dm^3$ = _____ $cm^3$ |
| 5000 $cm^3$ = _____ $dm^3$ | 10 $dm^3$ = _____ $cm^3$ |
| 2403 $cm^3$ = _____ $dm^3$ | 179 $dm^3$ = _____ $cm^3$ |
| 145 $cm^3$ = _____ $dm^3$ | 0.2 $dm^3$ = _____ $cm^3$ |

Concentration is the **mass** of a solute in a certain **volume** of solvent.

This means that the unit of concentration is grams per decimetre cubed ($g/dm^3$).

The diagram on the left shows that a substance with a high concentration has more solute particles (a greater mass) dissolved in a given volume than a substance with a low concentration.



# Activities and Practice

1. Complete the following tables by converting the units:

| seconds | minutes | hours |
|---|---|---|
| 3600 | 60 | 1 |
| 60 | | 0.16 |
| | 300 | |
| 2600 | | |
| | | 5 |
| | 540 | |
| 30 | | |

| g | kg |
|---|---|
| 1000 | 1 |
| 5000 | |
| 15000 | |
| | 11 |
| | 0.5 |
| | 0.05 |
| 5 | |

| $cm^3$ | $dm^3$ | L |
|---|---|---|
| 1000 | 1 | 1 |
| 6000 | | |
| | 5 | |
| | | 0.5 |
| | 0.03 | |
| 500 | | |
| 50 | | |

## Volume Practical

**Aim**: To investigate the volume of an irregular object.

**Apparatus**: Displacement can, water, irregular object, measuring cylinder.

**Hypothesis**: I think…

Labelled Diagram:

**Method:**

- Place a displacement can on top of a small step (use a book or other object to place it on), so that the **spout** is above a beaker.
- Fill the displacement can with water and wait until the water stops dripping out. Replace the beaker of water with a measuring cylinder.
- Very carefully lower the object to be measured into the displacement can, making sure it is fully **submerged**.
- Collect all of the water that flows out of the displacement can in the measuring cylinder.
- Note the **volume** of water collected in the measuring cylinder.

**Results:**

Trial 1: Volume of water collected = _____ $cm^3$

Trial 2: Volume of water collected = _____ $cm^3$

Trial 3: Volume of water collected = _____ $cm^3$

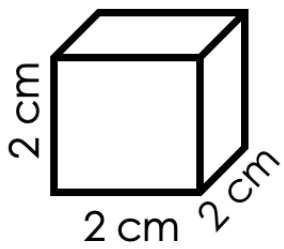
Average volume of water collected = _____ $cm^3$

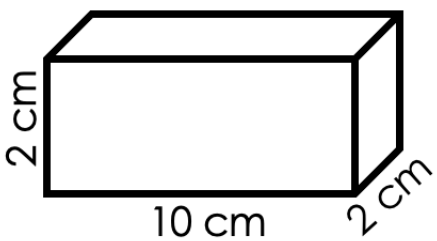
**Follow up questions:**

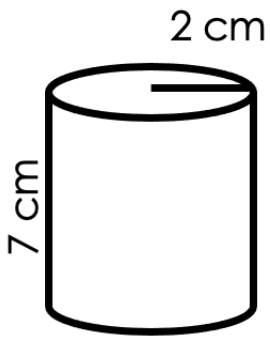
What was the volume of your object in $dm^3$?

Define the words in **bold** in the method.

Calculate the volume of each of the regular shapes below.




Convert the volumes you have calculated from $cm^3$ to $dm^3$.

# Exit Ticket

**1. Salt dissolves in water. Which word describes salt best?**

- ☐ A. Soluble
- ☐ B. Insoluble
- ☐ C. Solvent

**2. 5 g of solute is dissolved in 200 $cm^3$ of solution. Which of these has the same volume as this solution?**

- ☐ A. 0.2 $dm^3$
- ☐ B. 200000 $cm^3$
- ☐ C. 0. 005 kg

**3. Select the answer below which is equal to 0.05 $dm^3$.**

- ☐ A. 500 $cm^3$
- ☐ B. 50 $cm^3$
- ☐ C. 0.00005 $cm^3$

For question 3, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

When measuring volume scientists use the unit $dm^3$. To convert from $dm^3$ to $cm^3$, you need to multiply by 1000. In this case 0.05 $dm^3$ multiplied by 1000 gives 50 $cm^3$.

*Describe how to convert between $dm^3$ and $cm^3$.*

**If you answered B**

When measuring volume scientists use the unit $dm^3$. To convert from $dm^3$ to $cm^3$, you need to multiply by 1000. In this case 0.05 $dm^3$ multiplied by 1000 gives 50 $cm^3$.

*Suggest why it is useful for scientists to all use the same units.*

**If you answered C**

When measuring volume scientists use the unit $dm^3$. To convert from $dm^3$ to $cm^3$, you need to multiply by 1000. In this case 0.05 $dm^3$ multiplied by 1000 gives 50 $cm^3$.

*Describe how to convert between $dm^3$ and $cm^3$.*

**New Learning**

# Concentration Calculations

**Do Now:**

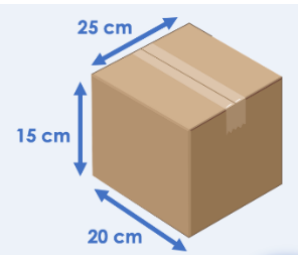
1. How is a solution formed?

2. Convert 3000 $cm^3$ to $dm^3$.

3. Calculate the relative formula mass of $H_2SO_4$.

4. State the unit of concentration.

5. Calculate the volume of the box shown.




**Foundation:** What does the word 'concentration' mean in science?

**Stretch:** Explain the difference between a solvent, a solute and a solution.

## Calculating Concentration

The **mass of solute** found in a solution can be expressed as **g/dm$^3$**.

This is the **mass of solute per dm$^3$ of solution.**

The units, g/dm$^3$, give a clue to how to **calculate** concentration of a solution.


The volume needs to be in dm$^3$.
cm$^3$ ÷ 1000 = dm$^3$

Example:

If 6 g of citric acid is dissolved in water to make up 2000 cm$^3$ of solution, what would the concentration be?

*Concentration = mass ÷ volume*
*= 6 g ÷ 2 dm$^3$*
***= 3 g/ dm$^3$***

2000 cm$^3$ ÷ 1000 = 2 dm$^3$

# Activities and Practice

1. Determine if the following statements are true or false:
   a. To convert $cm^3$ into $dm^3$ you need to multiply by 1000.
   b. 250 $cm^3$ = 0.25 $dm^3$
   c. 250 $cm^3$ of a 4 g/ $dm^3$ solution contains 1 g of solute.
   d. 0.5 $dm^3$ = 5000 $cm^3$
   e. 5.5 g of copper sulfate is dissolved in 500 $cm^3$ to form a 11 g/ $dm^3$ solution.

**Answer the following questions. Show your working**

**Remember: 1 $dm^3$ = 1 000 $cm^3$**

1. State the formula used to calculate concentration using mass and volume.

2. Calculate the concentration (in g/$dm^3$) of:
   a. 40 g solute in 350 $dm^3$
   b. 100 g solute in 77 $dm^3$
   c. 0.08 g solute in 20 $cm^3$
   d. 90 g solute in 780 $cm^3$

3. The mass of $H_2SO_4$ is 32.5 g and the volume of the solution is 0.400 $dm^3$. Calculate the concentration of the solution formed in g/$dm^3$.

4. Explain what would happen to the concentration in question 2 if more water was added to the solution.

5. A 750 $cm^3$ solution of sodium chloride contains 25 g of solute. Calculate the concentration of the solution.

6. What is the concentration of 2 g of copper chloride in 1.5 $dm^3$ of solution?

7. State the formula used to calculate mass using concentration and volume.

8. Calculate the mass of solute in:

   a. 25 $cm^3$ of a 2.3 $g/dm^3$ solution (remember to convert to $dm^3$)

   b. 250 $cm^3$ of a 71 $g/dm^3$ solution

   c. 2.3 $dm^3$ of a 61 $g/dm^3$ solution

9. A solution of sodium chloride has a concentration of 400 $g/dm^3$. Calculate the mass of sodium chloride in 0.8 $dm^3$ of solution.

10. Explain what would happen to the mass of solute in question 6 if more water was added to the solution.

11. A solution of sodium chloride has a concentration of 400 $g/dm^3$. Calculate the mass of sodium chloride in 400 $cm^3$ of solution.

12. A student pours 0.2 $dm^3$ of hydrochloric acid into a beaker. The acid had a concentration of 75 $g/dm^3$. Calculate the mass of hydrochloric acid in the solution.

13. Using 83g of solute, how much water is needed to:

    a. Make a 34 $g/dm^3$ solution?

    b. Make a 0.1 $g/dm^3$ solution?

    c. Make a 83 $g/dm^3$ solution?

    d. Make a 79 $g/dm^3$ solution?

# Exit Ticket

1. **10 g of a solute was used to make a solution with a volume of 25 $dm^3$. What was the concentration of the solution?**

   - ☐ A. 250 $g/dm^3$
   - ☐ B. 0.4 $g/dm^3$
   - ☐ C. 2.5 $g/dm^3$

2. **5 g of solute is dissolved in 200 $cm^3$of solution. The concentration of the solution is…**

   - ☐ A. 25 $g/dm^3$
   - ☐ B. 0.025 $g/dm^3$
   - ☐ C. 0.25 $g/dm^3$

3. **Select the correct formula to calculate the mass of a solute.**

   - ☐ A. Mass = concentration x volume
   - ☐ B. Mass = concentration ÷ volume
   - ☐ C. Concentration = mass ÷ volume

For question 1, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

Concentration is a measure of how much solute there is in a solution and is be measured in $g/dm^3$. It is the mass of the solute in a given volume so to calculate concentration we use the mass divided by the volume, which in this case would be 10 g ÷ 25 $dm^3$, giving 0.4 $g/dm^3$.

*Explain what is meant by the concentration of a solution and describe how to calculate it.*

**If you answered B**

Concentration is a measure of how much solute there is in a solution and is be measured in $g/dm^3$. It is the mass of the solute in a given volume so to calculate concentration we use the mass divided by the volume, which in this case would be 10 g ÷ 25 $dm^3$, giving 0.4 $g/dm^3$.

*Explain what a higher concentration means in terms of particles of a solute compared to a lower concentration.*

**If you answered C**

Concentration is a measure of how much solute there is in a solution and is be measured in $g/dm^3$. It is the mass of the solute in a given volume so to calculate concentration we use the mass divided by the volume, which in this case would be 10 g ÷ 25 $dm^3$, giving 0.4 $g/dm^3$.

*Explain what is meant by the concentration of a solution and describe how to calculate it.*

**New Learning**

# Salts

**Do Now:**

1. Complete this general equation for a neutralisation reaction:
   _____ + alkali → _____+ water
2. Name the products formed when nitric acid reacts with magnesium.

   _____
3. Name the products formed when hydrochloric acid reacts with sodium hydroxide.

   _____
4. What pH range is alkaline?

   _____
5. Link these chemical formulae to the correct names: HCl, $HNO_3$, $H_2SO_4$.

   Nitric acid
   Hydrochloric acid
   Sulfuric acid

   _____

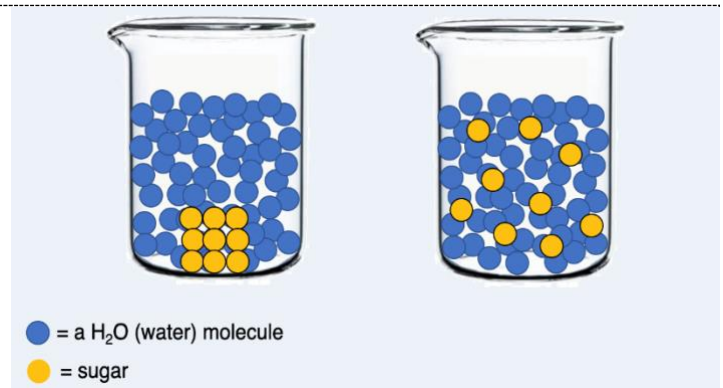
**Foundation:** Write the general word equation for the reaction between an acid and a metal carbonate.

_____

**Stretch:** Write a balanced symbol equation for the reaction between hydrochloric acid and sodium hydroxide.

_____

When a substance dissolves, the **solute** (solid) particles disperse (spread out) throughout the **solvent** (liquid), making a **solution**. As the solute has been added to the solvent, the total mass of the solution will be the mass of the solute plus the mass of the solvent. The solute particles have not disappeared, they have become mixed in with the liquid. If we wanted to get the solute back again, we would simply need to evaporate the solvent.




If a substance is able to dissolve it is **soluble**. If it cannot dissolve it is **insoluble**.

The following table can be used to determine if a salt will be soluble or insoluble.

*Note: you do not need to memorise this table, you just need to be able to use it.*

| Soluble in water | Insoluble in water |
|---|---|
| **All nitrates**<br>*e.g. calcium nitrate* | |
| **Most sulfates**<br>*e.g. magnesium sulfate* | **Lead sulfate, barium sulfate** |
| **Most chlorides, bromides and iodides**<br>*e.g. sodium chloride, sodium bromide, sodium iodide* | **Silver chloride, silver bromide, silver iodide, lead chloride, lead bromide, lead iodide** |
| **Sodium carbonate, potassium carbonate** | **Most other carbonates** |
| **Sodium hydroxide, potassium hydroxide** | **Most other hydroxides** |

Examples:

Using the table we can predict whether or not these salts will be soluble.

- Sodium nitrate – **Soluble** *(all nitrates are soluble, no exceptions)*
- Potassium sulfate – **Soluble** *(most sulfates are soluble, the exceptions are lead sulfate and barium sulfate)*
- Calcium carbonate – **Insoluble** *(most carbonates are insoluble, except sodium carbonate and potassium carbonate)*
- Sodium hydroxide – **Soluble** *(most hydroxides are insoluble, except sodium hydroxide and potassium hydroxide)*

**A soluble salt** can be made from an **insoluble base** in a **neutralisation** reaction.

$$\mathbf{CuO_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}}$$

| |
|---|
| Solid copper oxide + sulfuric acid solution → Copper sulfate (dissolved in water) + water |

# Activities and Practice

1. Complete these word equations.
   a. Copper oxide + hydrochloric acid → copper chloride + water
   b. Magnesium oxide + sulfuric acid → _____+_____
   c. Potassium hydroxide + nitric acid → _____+_____
   d. Calcium oxide + sulfuric acid → _____+_____
   e. _____+_____→ lead chloride + water
   f. _____+_____→ copper sulfate + water + carbon dioxide

2. Write definitions for these key words:
   Soluble _____
   Insoluble_____

3. Fill in the boxes below to describe **how a soluble salt dissolves in water**. You can use written sentences, diagrams, symbols, numbers and key words.

In this box, describe what you can **see**, **observe** and **experience** with your own eyes.

In this box, describe what is happening to the atoms, molecules or particles **that are too small to see** with your own eyes.

In this box, describe the **state symbols** that we can use as scientists to communicate this topic.

5. Use the table below to state whether the following salts a) to j) are soluble or insoluble. Use '**I**' for insoluble and '**S**' for soluble.

| Soluble in water | Insoluble in water |
|---|---|
| All nitrates | |
| Most sulfates | Lead sulfate, barium sulfate |
| Most chlorides, bromides and iodides | Silver chloride, silver bromide, silver iodide, lead chloride, lead bromide, lead iodide |
| Sodium carbonate, potassium carbonate | Most other carbonates |
| Sodium hydroxide, potassium hydroxide | Most other hydroxides |

a) Sodium bromide
b) Sodium hydroxide
c) Lead chloride
d) Calcium sulfate
e) Iron hydroxide
f) Lead iodide
g) Copper chloride
h) Lithium carbonate
i) Silver nitrate
j) Sodium carbonate

6. Complete the general word equations for these reactions:

Metal + acid ⟶ _____ + _____

Metal oxide + acid ⟶ _____ + _____

Metal hydroxide + acid ⟶ _____ + _____

Metal carbonate + acid ⟶ _____ + _____ + _____

7. A chemist needs to make copper chloride and water. Write a word equation to show a reaction that produces copper chloride and water.

8. Complete the symbol equations below. Make sure they are balanced.

   a. $CuO_{(s)} + HCL_{(aq)} \longrightarrow$ _____ + _____

   b. $ZnO_{(aq)} + H_2SO_{4(aq)} \longrightarrow$ _____ + _____

   c. _____ + _____ $\longrightarrow CuSO_{4(aq)} + H_2O_{(l)}$

   d. _____ + _____ $\longrightarrow KNO_{3\ (aq)} + H_2O_{(l)} + CO_{2\ (g)}$

9. A student needs to show that an insoluble base can be used to produce a soluble salt. Using the information in Q4, write a word equation to show an example of this reaction.

   _____

# Exit Ticket

**1. An insoluble salt…**

- ☐ A. dissolves in water to form a solution
- ☐ B. cannot dissolve in water
- ☐ C. is an alkali

**2. Copper sulfate is a salt. Which of the following would not be involved in a reaction to make copper sulfate?**

- ☐ A. hydrochloric acid
- ☐ B. copper oxide
- ☐ C. sulfuric acid

**3. Which is true of an aqueous solution of copper sulfate?**

- ☐ A. It is molten (melted) copper sulfate salt
- ☐ B. It is copper sulfate dissolved in water
- ☐ C. Answers A and B are the same thing

For question 3, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

An aqueous solution is a substance where there is a solute dissolved in water. This does not mean the same as a molten substance. A molten substance would be just the salt in liquid form, whereas an aqueous solution is the salt dissolved or dispersed throughout water.

*Explain the difference between molten copper sulfate and copper sulfate solution.*

**If you answered B**

An aqueous solution is a substance where there is a solute dissolved in water. This does not mean the same as a molten substance. A molten substance would be just the salt in liquid form, whereas an aqueous solution is the salt dissolved or dispersed throughout water.

*Suggest why it is easier for scientists to use copper sulfate solution than molten copper sulfate.*

**If you answered C**

An aqueous solution is a substance where there is a solute dissolved in water. This does not mean the same as a molten substance. A molten substance would be just the salt in liquid form, whereas an aqueous solution is the salt dissolved or dispersed throughout water.

*Explain the difference between molten copper sulfate and copper sulfate solution.*

**New Learning**

# Making Soluble Salts

**Do Now:**

$$CuO_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H2O_{(l)}$$

1. What does the state symbol (s) tell you?

2. Name the reactants in this reaction.

3. Is this symbol equation balanced? If not, balance it.

4. Copper sulfate ($CuSO_4$) is a blue colour. At the end of this reaction would you expect to see a blue liquid or a blue solid?

5. Name the salt produced when hydrochloric acid reacts with copper oxide.

**Foundation:** Write the general word equation for the reaction between an acid and an alkali.

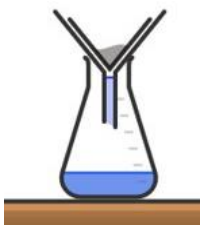
**Stretch:** Write a balanced symbol equation for the reaction between sodium hydroxide and hydrochloric acid.

## Preparing a soluble salt

When preparing a soluble salt, the following steps should be followed:

1. The **solid** (e.g. copper oxide) is added to the acid until **no more reacts**. The acid may be heated gently because a warmer solution will be able to react with the copper oxide faster. Solid copper oxide is added until no more reacts (when the solution has become saturated). This is a neutralisation reaction (acid is reacting with a metal oxide or base).

2. **Excess solid** is **filtered** off to produce a solution of the salt. This removes the copper oxide that has not reacted.



3. The solution is heated to **evaporate** the water to form a more **concentrated solution.**
4. This concentrated salt solution is **crystallised** to produce solid salts. This means it is allowed to cool so that crystals form. It is left in a warm place to evaporate off any remaining water. The salt is patted **dry** between two pieces of filter paper.

It is important to do a risk assessment for every practical experiment.

## Risk Assessment

| Apparatus/Chemical | Hazard | Precaution |
|---|---|---|
| **Hydrochloric acid** | Concentrated acid is corrosive and may cause chemical burns. Dilute acid is an irritant. | Use dilute acid. Ensure beaker is not on the edge of the table. |
| **Bunsen burner and hot apparatus** | Risk of burns or hair/clothing catching fire. | Do not touch apparatus until it cools down. Turn off Bunsen burner when not in use. Tie back hair and stand up. |
| **Glassware** | Cut skin from broken glass. | Hold one item at a time, with care. |

# Activities and Practice

1. Put these steps into the correct order to prepare a soluble salt:
   a. Heat the solution to evaporate the water to form a more concentrated solution.
   b. The solid is added to the acid until no more reacts.
   c. Pat the salt dry between two pieces of filter paper.
   d. This concentrated salt solution is crystallised to produce solid salts.
   e. Filter the excess solid off to produce a solution of the salt.

**Practical activity: Preparation of a pure dry sample of a soluble salt from an insoluble oxide or carbonate**

Follow the practical method to prepare a pure dry sample of a salt.

| **Aim of this activity** |
| --- |
| To prepare a pure, dry sample of a soluble salt from an insoluble oxide or carbonate, using a Bunsen burner to heat dilute acid and a water bath or electric heater to evaporate the solution. |
| **Summary of what you will be doing** |
| You will react dilute hydrochloric acid and an insoluble salt (copper oxide) to prepare an **aqueous solution** of a salt.<br><br>The unreacted solid copper oxide from the reaction will need to be filtered.<br><br>You will evaporate the **filtrate** to leave a **concentrated solution** of the salt, which will crystallise as it cools and **evaporates** further. |

**Before you begin**

1. Explain what is meant by each of the words in **bold** above.

   **Aqueous solution:**

   **Filtrate:**

   **Concentrated solution:**

   **Evaporates:**

2. Summarise briefly the **precautions** you will take to ensure your safety throughout this practical activity.

3. Draw a labelled diagram to show the equipment you will use and how you will set it up.

Read the method on the next page carefully.

**Method**

1. Measure 40 $cm^3$ sulfuric acid into the 100 $cm^3$ beaker. The volume does not need to be very accurate, so you can use the graduations on the beaker.
2. Set up the tripod, gauze and heatproof mat. Heat the acid **gently** using the Bunsen burner until it is almost boiling. Turn off the Bunsen burner.
3. Use the spatula to add **small** amounts of copper (II) oxide powder. Stir with the glass rod.
4. Continue to add copper (II) oxide if it keeps disappearing when stirred. When the copper (II) oxide disappears the solution is clear blue.
5. Stop adding the copper (II) oxide when some of it remains after stirring. Allow the apparatus to cool completely.
6. Set up the filter funnel and paper over the conical flask. Use the clamp stand to hold the funnel.
7. Filter the contents of the beaker from step **3**.
8. When filtration is complete, pour the contents of the conical flask into the evaporating basin.
9. Evaporate this gently using a water bath (250 $cm^3$ beaker with boiling water) on the tripod and gauze. Stop heating once crystals start to form.
10. Transfer the remaining solution to the crystallising dish (evaporating dish). Leave this in a cool place for **at least 24 hours**.
11. Remove the crystals from the concentrated solution with a spatula. **Gently** pat the crystals dry between two pieces of filter paper. These are pure dry crystals of copper (II) sulfate.

Once you have finished, answer the questions below.

1. Name the chemical processes and techniques involved in the preparation.

2. Name the two chemicals required to make the salt.

3. Write a word equation for the reaction.

4. ite a balanced symbol equation for the reaction.

# Exit Ticket

**1. Which of the following is a precaution when preparing a soluble salt?**

- ☐ A. Concentrated acid is corrosive
- ☐ B. Allow hot glassware to cool before touching it
- ☐ C. Concentrated acid can cause chemical burns

**2. After which process/technique are you left with a copper oxide residue?**

- ☐ A. Crystallisation
- ☐ B. Evaporation
- ☐ C. Filtration

**3. Once the copper sulfate solution is prepared, why do we evaporate off some water using the Bunsen burner?**

- ☐ A. To make the solution stronger
- ☐ B. To make the reaction happen faster
- ☐ C. To make the solution more concentrated

For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

There are a number of techniques involved with the preparation of a soluble salt, including crystallisation, evaporation and filtration. The process that would result in a copper oxide (solid) residue would be filtration, where the liquid is separated from the solid. Crystallisation is the process that results in the formation of crystals of the salt.

*Explain what is meant by a soluble salt.*

**If you answered B**

There are a number of techniques involved with the preparation of a soluble salt, including crystallisation, evaporation and filtration. The process that would result in a copper oxide (solid) residue would be filtration, where the liquid is separated from the solid. Evaporation is the process by which water is removed from the solution, leaving the salt ready to be crystallised.

*Describe the processes of evaporation and filtration.*

**If you answered C**

There are a number of techniques involved with the preparation of a soluble salt, including crystallisation, evaporation and filtration. The process that would result in a copper oxide (solid) residue would be filtration, where the liquid is separated from the solid.

*Suggest what would happen if the soluble salt was added to water.*

**New Learning**

# Making Soluble Salts 2

**Do Now:**


Label the above pieces of equipment used in the preparation of soluble salts with their correct names.

**Foundation:** Which pieces of equipment can be used for measuring the volume of a liquid?

**Stretch:** Which of the pieces of equipment that could be used for measuring would be the most precise? Explain your answer.

Let's examine our copper sulfate crystals carefully

Do they look like the ones in this image?

If not, can you explain why they look different?

Large crystals form slowly. Perhaps the water evaporated over a few days.

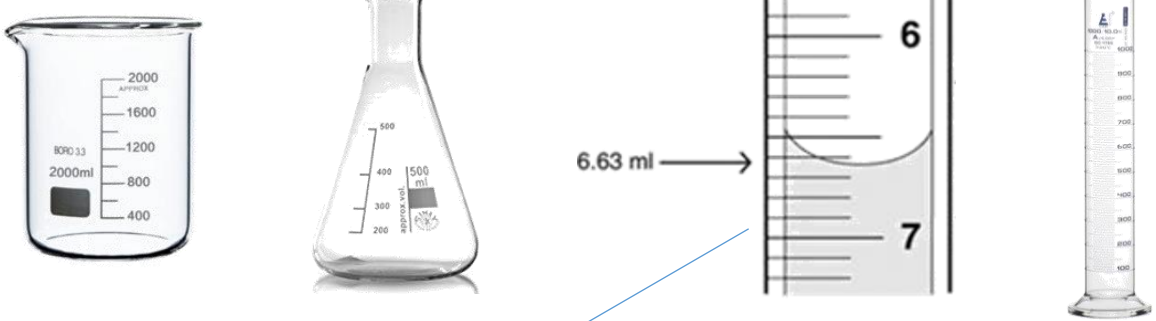
Small crystals form quickly. Perhaps the water was evaporated quickly using a Bunsen burner.

If the crystals aren't clear blue, or if there's some grey or black colouring, it is likely that the black copper oxide powder wasn't all removed by filtration.

## Evaluating a method

1. Measure 40 $cm^3$ sulfuric acid into the 100 $cm^3$ beaker. The volume does not need to be very accurate, so you can use the graduations on the beaker.

   What should we use to measure the volume of liquids if we do want to be very accurate?




Using the graduated measuring cylinder would allow us to take more precise measurements as there is a higher resolution. This means that we can see more intervals between numbers, as you can see in the graduated measuring cylinder where the volume is measured to two decimal places.

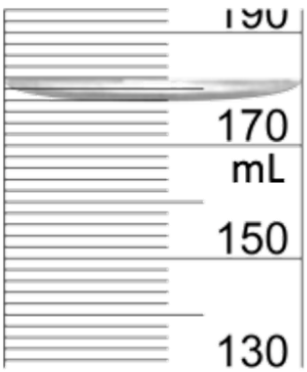
*Note: when measuring volume the reading should be taken from the **bottom** of the **meniscus** (curve at the top of the liquid).*

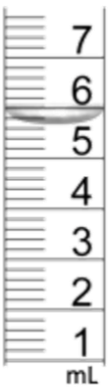
6. Set up the filter funnel and paper over the conical flask. Use the clamp stand to hold the funnel.
7. Filter the contents of the beaker from step **3.**

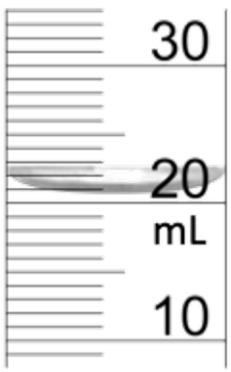
How could we ensure that all of the copper oxide was filtered out of the solution?

- Sprinkle a small amount of water onto the filter paper before filtering so it sticks to the funnel.
- Only pour a small amount of solution into the filter paper at a time.
- Give it time to drip through the filter paper. Don't swirl the funnel or poke with a glass rod!

# Activities and Practice




1. Write down the volume of water in each graduated cylinder.

2. Which graduated cylinder will give us the most precise measurement? Explain your answer.

**Look at this basic method to prepare a soluble salt.**

3. Suggest 3 improvements that could be made to this method.

   Discuss your reason for selecting these improvements.

   a. The solid is added to the acid until no more reacts.

   b. Excess solid is filtered off to produce a solution of the salt.

   c. The solution is heated to evaporate the water to form a more concentrated solution.

   d. This concentrated salt solution is crystallised to produce solid salts.

   e. The salt is patted dry between two pieces of filter paper.

4. Complete the table to explain why each step in the method was used.

| **Practical Method**<br>***What you did*** | **Justification**<br>***Why the steps were important*** |
|---|---|
| 1. Measure 40 $cm^3$ sulfuric acid into the 100 $cm^3$ beaker. The volume does not need to be very accurate, so you can use the graduations on the beaker. | Why did you heat the acid? |
| 2. Set up the tripod, gauze and heatproof mat. Heat the acid **gently** using the Bunsen burner until it is almost boiling. Turn off the Bunsen burner. | |
| 3. Use the spatula to add **small** amounts of copper (II) oxide powder. Stir with the glass rod. | Why did you only add small amounts of copper oxide powder at a time? |
| 4. Continue to add copper (II) oxide if it keeps disappearing when stirred. When the copper (II) oxide disappears the solution is clear blue. | Why did you stir the copper oxide? |
| 5. Stop adding the copper (II) oxide when some of it remains after stirring. Allow the apparatus to cool completely. | Why did you keep adding copper oxide until no more would react? |
| 6. Set up the filter funnel and paper over the conical flask. Use the clamp stand to hold the funnel. | |
| 7. Filter the contents of the beaker from step **3**. | Why did you need to filter the solution? |

| | |
|---|---|
| 8. When filtration is complete, pour the contents of the conical flask into the evaporating basin.<br>9. Evaporate this gently using a water bath (250 $cm^3$ beaker with boiling water) on the tripod and gauze. Stop heating once crystals start to form.<br>10. Transfer the remaining solution to the crystallising dish (evaporating dish). Leave this in a cool place for **at least 24 hours.**<br>11. Remove the crystals from the concentrated solution with a spatula. **Gently** pat the crystals dry between two pieces of filter paper. These are pure dry crystals of copper (II) sulfate. | Why did you leave the solution to cool for at least 24 hours? |

Follow Up Questions

1. A student carrying out this practical measured 40 $cm^3$ sulfuric acid into the 100 $cm^3$ beaker, as suggested in step 1 of the method. Convert these volumes into $dm^3$.

   40 $cm^3$ = _____ $dm^3$

   100 $cm^3$ = _____ $dm^3$

2. Copper oxide has the chemical formula CuO. What is the relative formula mass of copper oxide?

3. What was the concentration of the copper sulfate solution in $g/dm^3$?

4. Would the solution be more or less concentrated if the student had used 0.05 $dm^3$ of acid? Show your workings.

# Exit Ticket

1. **Which piece of equipment would give the most precise measurement of volume?**
   - ☐ A. Graduated cylinder
   - ☐ B. Conical flask
   - ☐ C. Beaker


2. **What volume of water is in the graduated cylinder pictured?**
   - ☐ A. 6.6 mL
   - ☐ B. 7.2 mL
   - ☐ C. 7 mL

3. **Why do we need to heat the acid when preparing a solution of copper sulfate?**
   - ☐ A. So the acid becomes stronger
   - ☐ B. So the reaction happens faster
   - ☐ C. So that bigger crystals form

For question 2, read the guidance below and carry out the 'fix-it' task which has been set for you.

**If you answered A**

Graduated cylinders are useful to measure volume because they have high resolutions, allowing precise measurements to be taken. When measuring a volume, the value should be read from the bottom of the meniscus (curve). In this case each of the smaller lines represents 0.2 mL and the meniscus is closest to the third line between 6 and 7 mL, showing a volume of 6.6 mL.

*Suggest how we could take an even more precise measurement.*

**If you answered B**

Graduated cylinders are useful to measure volume because they have high resolutions, allowing precise measurements to be taken. When measuring a volume, the value should be read from the bottom of the meniscus (curve). In this case each of the smaller lines represents 0.2 mL and the meniscus is closest to the third line between 6 and 7 mL, showing a volume of 6.6 mL.

*Explain why it would not be appropriate to measure small volumes in a beaker.*

**If you answered C**

Graduated cylinders are useful to measure volume because they have high resolutions, allowing precise measurements to be taken. When measuring a volume, the value should be read from the bottom of the meniscus (curve). In this case each of the smaller lines represents 0.2 mL and the meniscus is closest to the third line between 6 and 7 mL, showing a volume of 6.6 mL.

*Explain why using a graduated cylinder is more precise than using a beaker.*

# Scientist in the Spotlight

**Izuchika Nduka**

***Cancer PhD Researcher***

Izuchika Nduka is a Nigerian cancer researcher currently pursuing a PhD at the University of Salford. She studied pharmacy at University for her undergraduate degree, followed by a masters in drug delivery. Pharmacy is the study of the preparation and dispensing of drugs and drug delivery is the study of how best to ensure that drugs target the right parts of the body. This is important for ensuring that drugs have the **desired** effect and are not harmful to the body. This brings together areas of chemistry and biology and chemical calculations in quantitative chemistry are crucial to ensure that dosages are correct. Her current research combines organic chemistry, **nanotechnology** and cell biology. She is passionate about developing new techniques to treat diseases, ever since she lost a loved one to cancer as a young girl.

According to Izuchika, a good scientist should be curious, patient, hard-working and willing to **persevere** through hard times with a "can do" attitude. She believes that the **formative** period of her life in Nigeria had equipped her with a mental **resilience** that is very useful to her in solving problems.

Izuchika is currently working on developing a new drug delivery carrier -- the material that is used to release the drug into a patient's system. This new carrier will be used to treat specific kinds of cancer in children. The development of such materials requires knowledge of many subject areas, which is why her PhD involves the study of so many branches of science. Much of her day is usually spent testing different substances and monitoring their effects, before presenting the results in research papers.

Izuchika is also passionate about diversity in science. She aspires to explore new ways to create opportunities for women from under-represented communities and backgrounds so that they can pursue careers in science too.

This researcher is a bit of a daredevil and the top-most item on her bucket list is skydiving. She also believes that it is very important for PhD researchers to maintain work-life balance.

**Activity**

Use the scientist's profile to answer the following questions:

1. What is the scientist's job?

2. Briefly describe what the scientist does in a typical day.

3. What skills do they need for this job?

4. What do you think is the most interesting part of their job?

5. Describe how this job links with the science you have learned in this unit

6. State the definition of any words in **bold** from the scientist's answers.