Reactions

Metals and non-metals *and* Acids and alkalis

Ideas you have met before

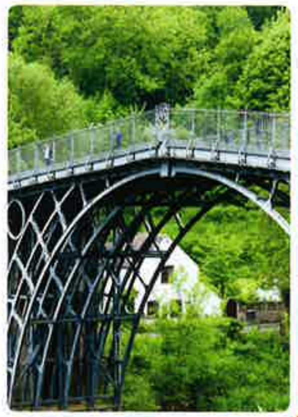
Metals

Materials can be grouped based on their properties such as hardness, solubility, conductivity and response to magnets.

Many useful materials, including plastics, wood and metals, have uses that exploit their properties.

Metals are shiny solids that we use for many applications, such as making cars, computers, bridges and so on.

Metals are good electrical conductors, which is why we use them to make wires for circuits.



Chemical changes

Changes can occur when materials are mixed. Some of these changes are non-reversible – these are called chemical changes, or chemical reactions.

Mixing bicarbonate of soda with vinegar or making toast are chemical changes – you cannot get the original materials back.

The new materials made in chemical changes can be useful.

Burning

Burning materials (such as wood, wax and gas) produces new materials.

Burning is a chemical change. Burning is also known as combustion.

In this chapter you will find out

Properties of metals and non-metals

- Most metals are solid and strong. Alloys often have different properties from their component metals, giving them different uses.
- Many non-metals are unreactive gases at room temperature.
- Some metals and non-metals have unusual properties, for example mercury and bromine.

Types of reactions

- We can represent reactions using equations and particle diagrams.
- Many metals react with acids to produce a salt plus hydrogen gas.
- Oxidation is a reaction with oxygen to form an oxide compound. Combustion and rusting are examples of oxidation.
- More reactive elements will remove less reactive elements from their compounds. This is known as displacement. We can use displacement reactions to predict a reactivity series.
- The reactivity series is a list of elements (mainly metals) arranged in order of their reactivity.

Acids, alkalis and indicators

- We use acids in our everyday lives, for example in food and batteries.
- We use alkalis in our everyday lives, for example in cleaning products and medicines.
- Some acids and alkalis are hazardous.
- We can make and use indicators to show how acidic or alkaline a substance is.
- The pH scale is an important measure of the level of acidity and alkalinity of a substance.

Reactions of acids and alkalis

- Acids react with metals and with alkalis.
- In these reactions the particles are rearranged – we can show this using diagrams, equations and other models.
- A neutral substance is one with pH 7. It is made when an acid and an alkali exactly neutralise one another.
- Neutralisation reactions can be useful for our health.

Using metals and non-metals

We are learning how to:

- Recognise the properties and uses of metals and non-metals.
- Explain the uses of metals and non-metals based on their properties.

Some **metals** have similar properties, such as being strong and shiny. These properties help us in different uses. **Non-metals** are neither strong nor shiny, and some are gases at room temperature. However, some **metals and non-metals** are more unusual, for example, three metals are magnetic and one metal is a liquid at room temperature.

FIGURE 1.6.1a: Cars rely on different properties of metals.

Metals and their properties

We use metals for building because they are strong and for making jewellery because they are shiny and attractive. *Strong* and *shiny* are two properties of metals.

We use metals in electrical circuits because they all **conduct** electricity and are **ductile**, which means they can be stretched into wires. Metals are also **malleable**, meaning that they can be bent, rolled into sheets and shaped without them breaking. Most metals make a ringing noise when hit – we say that they are **sonorous**. They also conduct heat very well and most have high melting points.

1. List the properties common to most metals.
2. Which properties of metals are most important for making:

   a) saucepans? **b)** water pipes? **c)** drinks cans?

Did you know...?

Mobile phones contain more than 10 different metals including some of the rarest. The battery contains copper, cobalt, zinc and nickel. The circuit board and touchscreen may contain copper, gold, arsenic, cadmium, lead, nickel, silver, zinc, mercury, indium and tantalum.

Metals and their alloys

Iron is a very strong, grey metal which makes it useful as a structural material. Copper is an orange-coloured metal that is more malleable and ductile than iron. It is used in electrical circuits, wires and water pipes. Water pipes were made of lead until it was found to be harmful to living things. Unlike iron, copper does not corrode.

Iron, cobalt and nickel are unusual because they are the only **magnetic** metals. Magnetic materials have many uses, such as in toys, on cupboard doors and in credit cards. Other metals have unusual properties, for example, mercury is a liquid at room temperature and sodium is soft and is very reactive.

FIGURE 1.6.1b: Stainless steel is an alloy of iron that doesn't rust.

Metals can be mixed together to form **alloys**. Alloys have different properties compared with the metals that they are made from, which sometimes makes them more useful. Stainless steel is an alloy of iron – adding different metals, like chromium, to the iron makes it stronger, shinier and less likely to rust.

3. List three metals in everyday use and state their uses. Explain how their properties make them useful.
4. Suggest why copper is not used in credit card strips and why sodium is not used in building.
5. What is an alloy and why are alloys often used instead of pure metals?

FIGURE 1.6.1c: Credit cards contain a magnetic strip which encodes information about its owner.

Properties of non-metals

Non-metals have lower densities than metals, are often **dull** and are poor conductors of both heat and electricity. Around half are unreactive gases at room temperature. They have different uses to metals.

One non-metal, bromine, is unusual because it is a liquid at room temperature. It is harmful if its vapour is breathed in but it can be used to treat swimming pool water and in pesticides.

FIGURE 1.6.1d: Both bromine and chlorine can be used to treat water in swimming pools.

Sulfur is a bright yellow solid. It has uses in making rubber car tyres and gunpowder.

Neon can be used in glowing lights and helium is used to fill balloons.

6. Describe the differences in properties of metals and non-metals.
7. Describe what is unusual about bromine. Suggest why it is used in swimming pools.
8. Identify the property of helium that makes it useful in balloons.

Know this vocabulary

metal
non-metal
metals and non-metals
conduct
ductile
malleable
sonorous
magnetic
alloy
dull

Exploring the reactions of metals with acids

We are learning how to:

- Describe the reaction between acids and metals using word equations and particle diagrams.
- Explain the reaction between acids and metals.
- Compare the reactivities of different metals.

Most metals react with acids. The way that a metal reacts varies, depending on its reactivity. Some metals are so reactive that we would never add acid to them in the laboratory.

FIGURE 1.6.2a: Some metals are so reactive that they are stored under oil.

Reacting acids with metals

A **chemical reaction** is a change in which new products are made. There are clues that we can look for to spot a chemical reaction. These include:

- bubbles of gas being given off;
- a change in temperature;
- a colour change;
- a change in mass.

When we add an **acid** to most metals, we see bubbles. This is because a gas is produced during the reaction. We may also feel the test tube getting warmer. These observations are both evidence that a chemical reaction has taken place.

FIGURE 1.6.2b: How can you tell that a chemical reaction is taking place between the acid and the magnesium?

1. Describe some of the observations that tell us that a chemical reaction is taking place.
2. Describe two signs that the reaction between an acid and a metal is a chemical reaction.
3. Explain why bubbles are produced during some reactions.

What are the new products?

Acids react with most metals. Particles rearrange and a **salt** and **hydrogen** gas are formed. You can test for hydrogen gas because it burns with a 'pop'. If you put a lighted splint into the top of the test tube in which an acid and a metal are reacting, you will hear a 'pop' sound. This is because the flame ignites the hydrogen and it explodes.

We can summarise the reaction between an acid and a metal using an equation:

acid + metal → salt + hydrogen

The type of salt produced depends on the type of acid and the metal used. For example, if you react nitric acid with zinc metal, zinc nitrate is the salt formed:

nitric acid + zinc → zinc nitrate + hydrogen

We can also show the reaction using a particle diagram:

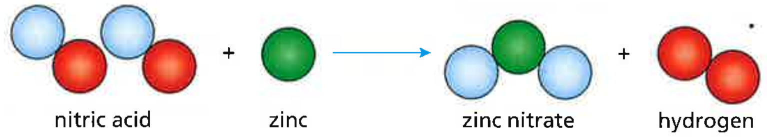


FIGURE 1.6.2d: Particle diagram for the reaction between nitric acid and zinc.

4. Write a word equation for the reaction between hydrochloric acid and magnesium metal.
5. Use the particle diagram in Figure 1.6.2d to explain how hydrogen gas is formed in the reaction between nitric acid and zinc metal.
6. Explain why we should not put a flame near a large amount of hydrogen gas.

Comparing reactivity

A group of students reacted hydrochloric acid with some different metals. They recorded their observations about the **reactivity** of the acid with the metals.

Metal	Observations when acid added
zinc	some bubbles
magnesium	vigorous bubbling
iron	a few bubbles
copper	no bubbles

FIGURE 1.6.2e: Results of the students' experiment showing reactions between hydrochloric acid and some different metals.

7. Order the metals in Figure 1.6.2e in terms of reactivity, going from most reactive to least reactive.
8. The teacher told the students that calcium is more reactive than the metals used in this investigation. Suggest what might be seen if the same acid was added to calcium.
9. Write a word equation for each of the reactions in Figure 1.6.2e.

FIGURE 1.6.2c: Zinc nitrate crystals.

Did you know...?

Precious metals such as gold, silver and platinum do not react with acids. They are so unreactive that they stay as pure metals. This is one reason that they are used to make jewellery.

FIGURE 1.6.2f: Precious metals are unreactive.

Know this vocabulary

chemical reaction
salt
hydrogen
reactivity

Understanding displacement reactions

We are learning how to:

- Represent and explain displacement reactions using equations and particle diagrams.
- Make inferences about reactivity from displacement reactions.

We can use the order of reactivity of substances to make predictions about reactions. Reactive metals can be thought of as 'chemical bullies'. Why might this be so?

Chemical bullies

When a reactive metal reacts with a compound of a less reactive metal, the more reactive metal 'pushes out' or 'displaces' the less reactive metal. The more reactive metal forms a chemical bond with whatever the less reactive metal was bonded to. This can be shown using a particle diagram.

The situation is a bit like a basketball match. Imagine a weak player with the ball. A stronger player takes the ball from him, displacing the weaker player and leaving him on his own. An example of such a **displacement reaction** is when iron is added to a blue copper sulfate solution. Iron is more reactive than copper. A chemical change occurs – iron displaces the copper, bonding with the sulfate to make iron sulfate, which is a pale green solution.

The word equation for the reaction is:

iron + copper sulfate → iron sulfate + copper

1. Describe how you know that a chemical reaction has taken place in Figure 1.6.3b.
2. When magnesium is added to a solution of copper sulfate, the solution changes from blue to colourless much faster than with iron. Which is more reactive, magnesium or iron?

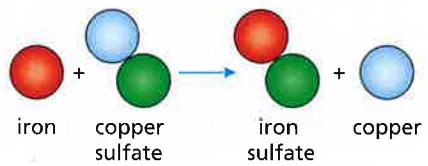


FIGURE 1.6.3a: Particle diagrams for the displacement of copper by iron.

FIGURE 1.6.3b: Iron and copper sulfate solution – before and after the displacement reaction. Over time, the blue copper sulfate solution becomes paler, and the iron nail becomes covered with a brown coating of copper.

Using displacement reactions

We can use displacement reactions to compare the reactivity of metals. We can produce a **reactivity series** (an order of reactivity) for magnesium, copper, iron and zinc, by adding each metal in turn to solutions of salts of each metal, for example, solutions of magnesium sulfate, copper sulfate, iron sulfate and zinc sulfate. Figure 1.6.3d shows the results that some students obtained after carrying out this experiment.

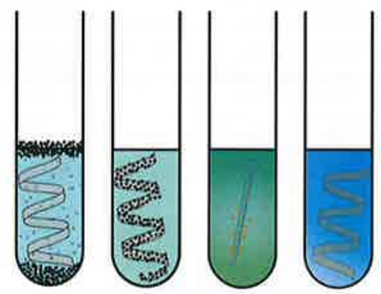


FIGURE 1.6.3c: Working out a reactivity series by reacting metals with copper sulfate solution.

metal \ metal sulfate solution	magnesium sulfate	zinc sulfate	iron sulfate	copper sulfate
zinc	✗		✓	✓
magnesium		✓	✓	✓
iron	✗	✗		✓
copper	✗	✗	✗	

Key: ✓ = reaction observed ✗ = no reaction observed

FIGURE 1.6.3d: Results of students' experiment.

How might these students have decided whether or not there had been a reaction? Is there anything that they could have measured to show that a reaction had taken place?

3. A student couldn't identify one of the metals. It reacted with iron sulfate and copper sulfate but not magnesium sulfate. Which metal was it?
4. Write a word equation for the reaction between zinc and iron sulfate.
5. Using the results (Figure 1.6.3d), suggest a reactivity series (from most reactive to least reactive) for magnesium, copper, iron and zinc.
6. Other students included lead and lead nitrate solution in their investigation. They concluded that lead is more reactive than copper but less reactive than iron. Describe what they would have recorded in their results table for the reactions between:
   a) lead and copper sulfate;
   b) lead and iron sulfate.

Making predictions

The reactivity series is shown in Figure 1.6.3e. The further substances are from each other in the series, the more vigorous the displacement reaction between the more reactive substance and a salt of the less reactive substance.

The reactivity series consists mainly of metals. However, the non-metals carbon and hydrogen are often included because they can be used to extract metals that come below them in the series.

7. Why is no hydrogen produced when copper is added to hydrochloric acid?
8. Deduce a rule about how to use the reactivity series to predict whether a reaction will take place or not.

Did you know…?

Old copper mines often become flooded, and a blue solution of copper sulfate results. By adding cheap scrap iron to this solution, copper metal is produced. This makes extra money for the mine owners.

Most reactive

- K potassium
- Na sodium
- Ca calcium
- Mg magnesium
- Al aluminium
- C carbon
- Zn zinc
- Fe iron
- Sn tin
- Pb lead
- H hydrogen
- Cu copper
- Ag silver
- Au gold
- Pt platinum

Least reactive

FIGURE 1.6.3e: The reactivity series.

Know this vocabulary

displacement reaction
reactivity series

Understanding oxidation reactions

We are learning how to:

- Recall examples of oxidation reactions.
- Describe oxidation using word equations and particle diagrams.
- Investigate changes caused by oxidation.

Oxidation is an important chemical reaction that causes big changes. Some oxidation reactions are fast and others are slow. Oxidation is sometimes useful and at other times it causes problems. Browning of apples, rusting and burning are all oxidation reactions.

Oxidation

Oxidation is the name given to a chemical reaction in which oxygen is added to a substance. When a metal such as copper is heated in air it reacts with oxygen. Black copper oxide is formed:

copper + oxygen → copper oxide

We can also show these reactions using particle diagrams:

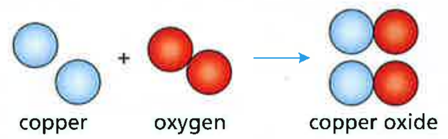


FIGURE 1.6.4a: Particle diagram for the reaction between copper and oxygen.

1. What is an oxidation reaction?
2. Give three everyday examples of oxidation reactions.
3. What changes would you see as copper is heated in the Bunsen burner flame?

Examples of oxidation

Iron and steel (an alloy of iron) undergo rusting. Rusting is an oxidation reaction where the metal reacts with oxygen in the air (when water is also present) to form iron oxide, or 'rust'. Stainless steel is an alloy of iron that doesn't rust. Every year, a huge amount of money is spent on preventing rusting of iron on buildings and structures, for example by painting or otherwise coating the metal.

Did you know...?

In 1986 a huge explosion occurred on the space shuttle *Challenger*, killing all seven astronauts aboard. This was caused by pure oxygen and hydrogen leaking into the shuttle's flames, leading to a powerful, uncontrolled oxidation reaction.

FIGURE 1.6.4b: *Challenger* orbiting the Earth.

There are many examples of useful oxidation reactions. **Combustion** is a special example of oxidation. Fuels contain the element carbon. During combustion, the carbon reacts with oxygen to form carbon dioxide gas. This gas escapes into the atmosphere.

Rockets use an oxidation reaction to fuel them. Hydrogen gas and pure oxygen gas are combined; the hydrogen is oxidised to water and an enormous amount of energy is given out.

Oxidation reactions can be used to make acids and bases (a **base** is any substance that neutralises an acid). Generally, non-metal oxides are acids (for example, sulfur dioxide) whereas metal oxides are bases (for example, sodium oxide).

FIGURE 1.6.4c: What is being oxidised in a combustion reaction?

4. Write a word equation for the formation of rust.
5. How can you tell that a chemical change has taken place during the oxidation reactions of rusting and combustion?

Investigating changes during oxidation

Two students carried out an experiment to investigate the oxidation of magnesium. They measured the mass of magnesium before heating it in a small container called a crucible (see Figure 1.6.4d). They observed a change in the magnesium from a silvery metal to a white powder. After the reaction was complete, the mass of the crucible was measured again.

FIGURE 1.6.4d: Heating magnesium, allowing air in but no magnesium oxide to escape.

The results of the experiment are shown in Table 1.6.4.

TABLE 1.6.4: Experiment results.

	At start	After heating	Change in mass
Mass of crucible and magnesium (g)	17.52	17.82	+0.30

6. Explain the changes that have taken place during the experiment.
7. Write a word equation for the reaction.
8. Using circles to represent the atoms, draw a particle diagram to explain the change in mass.

Know this vocabulary

oxidation
combustion
base

Exploring acids

We are learning how to:

- Describe what an acid is and give examples.
- Identify the hazards that acids pose.

Acids are often thought of as dangerous substances. Indeed, many acids *are* dangerous and we must take precautions when handling them. However, we come across many acids in our daily life that are useful and not dangerous at all.

Useful acids

If you look around your kitchen, you may find some **acids** to eat or drink. Citrus fruits such as lemons and oranges contain citric acid. Vinegar, which is used to pickle foods or to flavour chips, contains ethanoic acid (sometimes called acetic acid). Fizzy drinks contain carbonic acid. Tea contains tannic acid. These acids tend to taste sour.

Acids also have industrial uses. Sulfuric acid is used in car batteries and in making fertilisers. Nitric acid can also be used in making fertilisers and in paints.

1. List some examples of acids that we have in our homes.
2. Describe two acids that may be used to make fertilisers.

FIGURE 1.6.5a: Which acid is found in each of these?

Considering the hazards

Some acids, such as concentrated sulfuric acid, are extremely dangerous. These acids are **corrosive** – this means that the acid can destroy skin and attack metals if spilled.

The types of acid that are used in science lessons are dilute acids – this means that they have fewer acid particles than a concentrated acid solution in the same volume (Figure 1.6.5b). Dilute acids are not as dangerous as concentrated acids. They are not corrosive but may be an **irritant** to the skin. Your skin might become red and blistered if some laboratory acid were spilled on it.

Acids that are found in food and drink, such as in lemons and vinegar, are extremely weak and dilute. This is why they are safe to eat and drink, whereas dilute hydrochloric acid is not. However, they may still sting if they get into a cut.

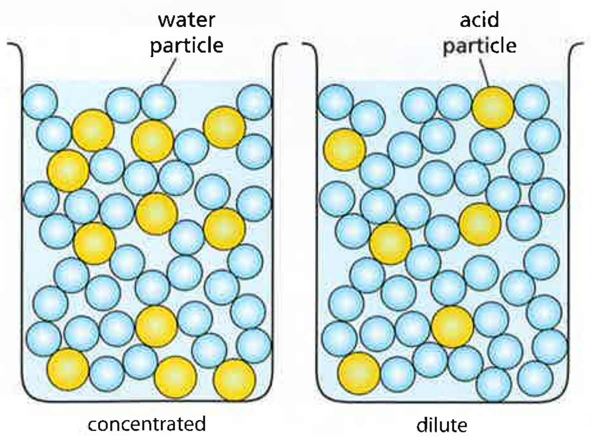


FIGURE 1.6.5b: Concentrated and dilute acids.

3. Explain why it is better to use images on hazard labels, rather than words.
4. Describe the precautions that you should take when working with an acid that displays the 'warning' or 'irritant' hazard symbol.
5. Explain why concentrated acids are more dangerous than dilute acids.

What do acids have in common?

Some acids are weak enough that we can eat or drink them. Acetic acid and citric acid are weak acids. Some acids are strong and could burn your skin even when dilute. Hydrochloric, sulfuric and nitric acid are strong acids. One thing that all acids have in common is that they contain **hydrogen**, but not all compounds containing hydrogen are acids. We can show this by looking at the chemical formulas of acids:

Hydrochloric acid, HCl – this shows that the acid contains hydrogen (H) and chlorine (Cl).

Sulfuric acid, H_2SO_4 – this shows that the acid contains hydrogen (H), sulfur (S) and oxygen (O).

We measure the strength of an acid using a scale called the **pH** scale. The scale ranges from 1 to 6 for acids. The stronger the acid, the lower its pH. We can use strong acids in the laboratory without too much danger if we use them at a low enough **concentration**.

FIGURE 1.6.5e: All of these acids contain hydrogen.

6. The chemical formula for nitric acid is HNO_3. Which elements does nitric acid contain?
7. A sour-tasting substance is found to contain the elements oxygen, sulfur and hydrogen. Suggest whether or not this is an acid and explain your reasoning.

Did you know...?

Your stomach contains hydrochloric acid, which helps to digest food and kill bacteria. You can feel this acid burning your throat slightly when you vomit.

FIGURE 1.6.5c: 'Corrosive' hazard sign.

FIGURE 1.6.5d: Irritant hazard sign, which is used for substances that are not corrosive but are irritants.

Know this vocabulary

acid
corrosive
irritant
hydrogen
pH
concentration

Exploring alkalis

We are learning how to:

- Describe what an alkali is and give examples.
- Identify the hazards that alkalis pose.

Many of the cleaning products that we use have something in common – they all contain an alkali. It is the alkali that gives soap, shampoo and washing powder a soapy feeling. We have alkalis all around us and life would be very different without them.

Useful alkalis

Some **alkalis** are harmful. However, many alkalis are harmless and are very useful.

Many cleaning products – such as bleach, oven cleaner, disinfectant and washing powder – contain alkalis. Toiletries such as soap, shampoo and toothpaste also contain an alkali.

Indigestion remedies contain alkaline substances.

When you bake a cake, you use baking powder to ensure that the cake is light and fluffy. Baking powder contains an alkali called sodium hydrogencarbonate (sodium bicarbonate). Without it, your cakes would be like biscuits!

1. Name some alkaline cleaning products.
2. Name two alkaline substances that are safe to put in your mouth and two that are not.
3. Suggest how your life would change if there were no alkalis.

FIGURE 1.6.6a: Many cleaning products contain an alkali.

Considering the hazards

Many of the alkalis in our homes are dangerous. The most dangerous alkalis include oven cleaners and caustic soda (to unblock drains). These substances are corrosive – they both contain the alkali sodium **hydroxide**.

Other alkalis are classed as an irritant, rather than corrosive. Examples are bleach and disinfectant.

Alkalis are often more dangerous than acids given the same hazard classification. This is because it can be hard to rinse an alkali from the skin because it becomes soapy.

FIGURE 1.6.6b: Which alkali do both of these products contain?

4. Bleach used in homes often has a warning written in Braille on the bottle. Suggest why this is important.
5. Draw the hazard symbol that would be found on a bottle of bleach.
6. Bleach contains sodium hydroxide and another chemical, sodium hypochlorite. Bleach is dangerous, but caustic soda is even more dangerous. Suggest why.

What do alkalis have in common?

Most alkalis feel soapy to touch. Soap forms because the alkali reacts with fats on your skin. However, some alkalis are too harmful to put on your skin. The common feature of all alkalis is that they contain hydroxide particles (chemical symbol OH).

Sodium hydroxide, NaOH, is the alkali used in many cleaning products, such as oven cleaners. Calcium hydroxide, $Ca(OH)_2$, is an alkali used by gardeners when their soil is too acidic. Both of these products would be harmful if you swallowed them. Magnesium hydroxide is the weak alkali found in some indigestion remedies.

We can measure the strength of an alkali using the pH scale. The scale ranges from 8 to 14 for alkalis. The stronger the alkali, the higher its pH.

7. What is the common feature of all alkalis?
8. Which elements are contained in:
   a) calcium hydroxide? **b)** sodium hydroxide?
9. If alkali A has a pH value of 9 and alkali B has a value of 12, which is the stronger alkali? Which is most likely to be used in indigestion remedies?

Did you know…?

In the past, stale urine was used as a source of the alkali ammonium hydroxide. It was used to bleach and clean clothes – it was even used in toothpaste!


FIGURE 1.6.6c: Which alkali does baking powder contain?

Know this vocabulary

alkali
hydroxide

Using indicators

We are learning how to:

- Use indicators to identify acids and alkalis.
- Analyse data from different indicators.
- Compare the effectiveness of different indicators.
- Describe what a pH scale measures.

The traffic indicators on a car tell other vehicles when the car is going to turn. Indicators in science can show us whether a substance is an acid or an alkali. Nature is full of natural indicators and we can make use of these indicators in many ways.

What are indicators?

An **indicator** is a substance that has different colours in an acid and in an alkali. One example of an indicator is **litmus**. Litmus solution turns *red in acid* and *blue in alkali*. If a solution is neither an acid nor an alkali, we say it is **neutral.**

Litmus paper is sometimes easier to use than litmus solution. Blue litmus paper turns red in an acid; red litmus paper turns blue in an alkali.

FIGURE 1.6.7a: What colour is litmus in an acid and in an alkali solution?

1. Describe what an indicator is.
2. Describe the colour changes of litmus solution in an acid and an alkali.
3. Draw a table to show the colours in acid, alkali and neutral of:

   a) red litmus paper; **b)** blue litmus paper.

Using universal indicator

Most chemical indicators just tell us whether a substance is an acid or an alkali. **Universal indicator** turns a range of different colours. The colour depends on whether the substance is an acid or an alkali *and* on how strong or weak it is (Figure 1.6.7b). Each colour is given a **pH** number.

On the pH scale:

- neutral solutions are pH 7;
- acidic solutions are lower than pH 7;
- alkaline solutions are higher than pH 7.

Did you know...?

Baking powder can also be used as an indicator. It does not show any colour change but it does fizz when added to an acid, but not when added to an alkali or to water.

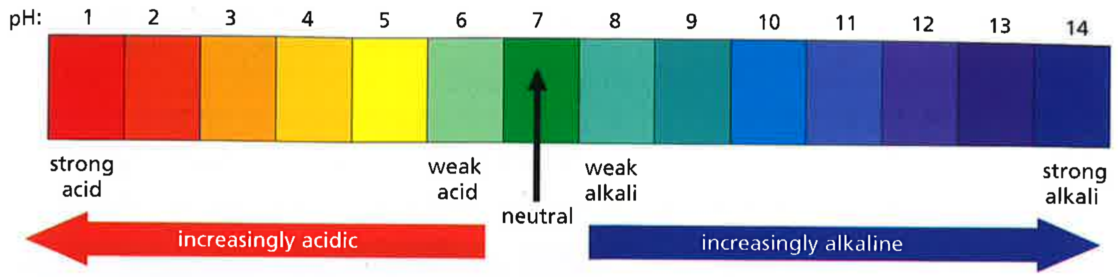


FIGURE 1.6.7b: The colour of universal indicator shows the strength of acids and alkalis. The pH scale ranges from pH 1 to pH 14.

4. Universal indicator is added to a liquid and it changes to yellow. State the pH of the liquid.
5. Describe what happens to the strength of an acid as the pH number decreases.
6. Describe what happens to the strength of an alkali as the pH number increases.

Comparing indicators

Litmus indicator turns red in acid and blue in alkali. Red cabbage indicator turns red in acid and purple in alkali.

Universal indicator is a mixture of several different indicators. This means that it gives a full range of predictable colours, depending on the strength of the acid or alkali.

TABLE 1.6.7: The pH values of different acids and alkalis.

Substance	pH	Acidic or alkaline?
hydrochloric, nitric and sulfuric acids, and car battery acid	0–1	strongly acidic
phosphoric acid	1–2	acidic
citrus fruit, such as lemons and oranges; vinegar	4	acidic
distilled water	7	neutral
egg, hand soap	8	alkaline
ammonia	11	alkaline
oven cleaner	12	alkaline
caustic soda, paint stripper	13–14	strongly alkaline

7. Describe what colour litmus indicator would turn if added to:

   a) hydrochloric acid;

   b) vinegar.
8. Explain the advantages of using universal indicator over litmus or red cabbage indicator.

Know this vocabulary

indicator
litmus
neutral
universal indicator
pH

Exploring neutralisation

We are learning how to:

- Recall and use the neutralisation equation.
- Use indicators to identify chemical reactions.
- Explain colour changes in terms of pH and neutralisation.

The pain of a nettle sting can be eased by rubbing the sting with a dock leaf. Nettles contain a weak acid and dock leaves contain a weak alkali. The alkali 'cancels out' the acid. This is called neutralisation, and there are many other examples around us.

FIGURE 1.6.8a: Why does a dock leaf help with a nettle sting?

Mixing acids and alkalis

As we add an alkali to acid, the particles in the acid and alkali react. The resulting solution becomes less acidic (the pH increases) as we add more alkali. This reaction between acids and alkalis is called **neutralisation**.

If we add just the right amount of alkali, the solution will become exactly neutral.

1. Describe what is meant by 'neutralisation'.
2. Describe what happens to the pH of an acidic solution as an alkali is added. Explain your answer.

Demonstrating neutralisation

We can use indicators to demonstrate neutralisation in action. If universal indicator is added to an alkali, it turns purple. If some acid is then added, the colour changes.

We can use a technique called **titration** to mix acids and alkalis precisely. This allows us to see a whole range of colour changes.

A burette allows an acid to be added to an alkali gradually. If the acid is added slowly enough, the neutral point (pH 7) can be seen. This point is indicated by the solution turning green.

3. Describe the colour changes that would be seen in the conical flask as the solution changed from a strong alkali to neutral.

Did you know...?

Bee stings are acidic and are treated by neutralising the acid with a mild alkali, such as bicarbonate of soda. Wasp stings are slightly alkaline and are treated by neutralising with an acid, such as vinegar. Therefore, it is important to know what has stung you.

4. Suggest what would be seen if more acid were added after the neutral point was reached. Explain your answer.
5. Explain the benefits of using a burette, rather than dropping pipettes, to add the acid.

The neutralisation equation

We can describe neutralisation using an equation:

acid + alkali → salt + water

If hydrochloric acid is neutralised with the alkali sodium hydroxide, the salt produced is sodium chloride.

The first part of the name of the salt comes from the alkali, usually from the metal in the alkali. For example, the alkali sodium hydroxide forms salts that start with 'sodium', whereas magnesium hydroxide forms salts that start with 'magnesium'.

The second part of the name of the salt comes from the acid. Table 1.6.8 summarises the ends of the salt names for each of the common acids.

TABLE 1.6.8: The acid used tells us the end of the salt name.

Acid used in neutralisation	Forms salts that end in...
hydrochloric acid	chloride
sulfuric acid	sulfate
nitric acid	nitrate

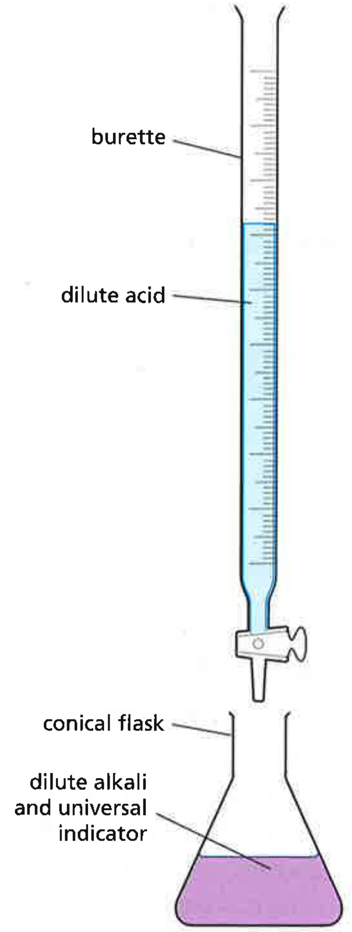


FIGURE 1.6.8b: Titration can be used to carry out a neutralisation reaction precisely.

6. Write the general equation for neutralisation.
7. Name the product of neutralisation that:
   a) is always the same;
   b) depends on the acid and alkali used.
8. a) Write an equation for the reaction between hydrochloric acid and sodium hydroxide.
   b) Describe the two new products that are formed when hydrochloric acid is neutralised with sodium hydroxide.

Know this vocabulary

neutralisation
titration

Investigating neutralisation

We are learning how to:

- Design an investigation to compare the effectiveness of indigestion remedies.
- Analyse data to identify a suitable indigestion remedy and suggest improvements to the investigation.

Heartburn indigestion is caused by acid from the stomach irritating the upper digestive tract. For those who suffer regularly, treatments are available to neutralise this acid. But are some remedies more effective than others?

The need for antacids

The human stomach contains strong hydrochloric acid, with a pH of approximately 1. The acid helps enzymes to digest proteins in the stomach and also prevents some bacteria from surviving in the stomach. Heartburn is a type of indigestion caused when the muscle leading from the osesophagus to the stomach opens, allowing stomach acid to move up the digestive tract. The acid causes a burning sensation in the chest.

Medicines called **antacids** contain substances that can neutralise the acid from the stomach. These substances are bases (remember any substance that neutralises an acid is a **base**, and alkalis are soluble bases). Examples of these bases are calcium carbonate, magnesium hydroxide and sodium hydrogencarbonate (baking soda).

acid + base → salt + water

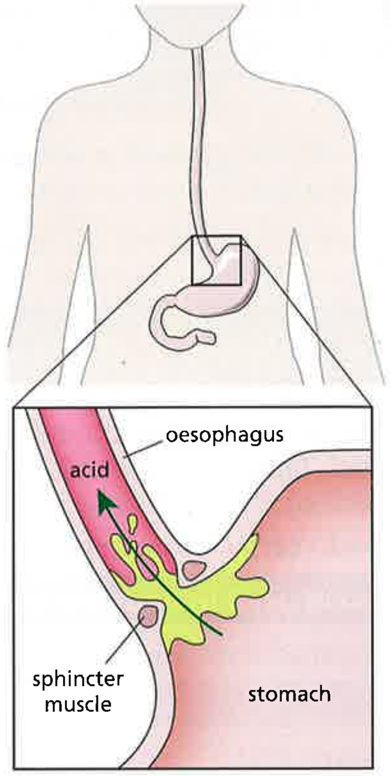


FIGURE 1.6.9a: What causes heartburn?

1. Explain what heartburn is and what causes it.
2. Explain how antacids reduce the acidity of stomach acid.
3. Suggest the effect of antacid remedies on the pH of stomach acid.

Planning an investigation

A group of students wanted to compare the effectiveness of different commercial antacid remedies.

When we plan an investigation, we must consider **variables**. Things we could change are called *independent* variables. Altering these could make a difference to other things, which are called *dependent* variables. Some of the independent variables will be kept the same; these are then called *control* variables. If we alter one independent variable and see how a dependent variable changes we can look for a **correlation**.

FIGURE 1.6.9b: Which bases are found in this remedy?

In this investigation, the students are changing the type of indigestion remedy. They are going to measure the time taken for the pH to change from 1 to 7.

4. Identify the independent variables and the dependent variables in this investigation.
5. Suggest which variables the students should control during this investigation.
6. The students devised a question for their enquiry, 'Which indigestion remedy is best?'. Suggest an improvement on this question using the stem, 'How does…affect…?'

Did you know…?

Even before the chemistry was understood, acid-neutralising remedies were recommended for heartburn. One remedy was to chew limestone rock. We now know that limestone contains the base calcium carbonate.

Considering the data

The students added universal indicator to a beaker of hydrochloric acid at pH 1. They added the recommended dose of indigestion remedy to the acid and measured the time taken for the pH to change from pH 1 to pH 7. They repeated this for each indigestion remedy twice.

Following an investigation, it is important that we consider whether we can be sure that we can trust our data. If the repeat readings are close together, that suggests that our experiment is **repeatable**. If this is the case, we can calculate a **mean** value from our data. If our repeat readings are not close together, we can choose to ignore a reading when calculating a mean or we could repeat that part of the investigation.

Leading from this, we could suggest improvements to our investigations, for example, should we repeat any particular readings, should we have carried out an additional set of readings, or could we have used more accurate measuring equipment?

Antacid remedy	Time taken (s)	
	1	2
Acid-ban	360	388
Acid-ease	175	192
Banish burn	556	544

TABLE 1.6.9: Results of tests on antacid remedies.

7. The students' results are shown in Table 1.6.9. Suggest whether this experiment was repeatable and explain your answer.
8. a) Calculate a mean value of the time taken for each indigestion remedy.
   b) Write a conclusion about which remedy is most effective. Provide scientific explanations for your conclusion.
9. Suggest improvements that these students could make to their method, to improve the accuracy of their results.

Know this vocabulary

antacid
base
variable
correlation
repeatable
mean

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

Identify some common properties of metal elements and non-metal elements and their uses.	Classify metals and non-metals using their properties.	Identify similarities and differences between metals and how these relate to their uses; compare and contrast properties of metals and non-metals.
Identify oxidation reactions.	Explain why oxidation is a reaction.	Use models and word equations to explain changes during oxidation reactions.
Give uses of displacement reactions.	Use models to explain displacement and relate it to the reactivity series.	Write word equations to represent displacement reactions.
Identify some everyday substances that contain acids and alkalis.	Explain what all acids have in common and what all alkalis have in common.	Evaluate the hazards posed by some acids and alkalis and know how these risks may be reduced.
Give an example of an indicator and state why indicators are useful.	Explain what an indicator is and analyse results when using an indicator.	Compare the effectiveness of different indicators.

Describe some examples of neutralisation.	Describe the changes to indicators when acids and alkalis are mixed.	Explain the changes to indicators in terms of pH when acids and alkalis are mixed.
Recognise that water is one product of neutralisation.	Explain the formation of salt and water during neutralisation, giving some examples of common salts.	Predict the reactants or products of different neutralisation reactions.
Describe what indigestion remedies are and explain how they work.	Design an investigation to compare the effectiveness of indigestion remedies.	Analyse data about indigestion remedies to decide which remedy is the most effective.

Questions

KNOW. Questions 1–9

See how well you have understood the ideas in this chapter.

1. What name is given to a reaction in which a chemical combines with oxygen? [1]

a) aeration **b)** oxygenation **c)** oxidation **d)** breathing

2. Write a word equation for the reaction between zinc and hydrochloric acid. [2]

3. Give two examples of the differences between the properties of metals and non-metals. [2]

4. When magnesium is heated, it changes from a silver colour to a white powder. Is this a physical process or a chemical reaction? Explain your answer. [2]

5. All acids contain the element: [1]

a) hydrogen **b)** oxygen **c)** chlorine **d)** hydroxide

6. What is the pH of a neutral solution? [1]

a) 1 **b)** 14 **c)** 7 **d)** 10

7. The reaction between an acid and an alkali is known as: [1]

a) neutralisation **b)** oxidation **c)** burning **d)** combustion

8. Write a word equation for the reaction between an acid and an alkali. [2]

9. Explain why heartburn is treated using a base. [2]

APPLY. Questions 10–14

See how well you can apply the ideas in this chapter to new situations.

10. What product is formed when iron and oxygen react together? [1]

a) oxyiron **b)** iron oxygen **c)** iron oxate **d)** iron oxide

11. Magnesium reacts with oxygen to form magnesium oxide. The mass of the magnesium oxide at the end of the experiment is greater than the mass of magnesium at the start because: [1]

a) it burns with a bright light;
b) it gives off carbon dioxide;
c) magnesium is not very dense;
d) the oxygen has added to the mass of the magnesium.

12. Calcium carbonate can be used to relieve indigestion because: [1]

a) it digests food; **b)** it tastes nice;
c) it increases acidity; **d)** it reduces acidity.

13. A chemical is described as feeling 'soapy'. When tested with indicator, it is shown to have a pH of 9. Explain what type of chemical this is. [2]

14. A student notices that a concentrated acid gave a more vigorous reaction with a metal than a dilute acid with the same metal. Explain why, using the idea of particles. [2]

EXTEND. Questions 15–17

See how well you can understand and explain new ideas and evidence.

15. A student reacts different metals with hydrochloric acid. The observations are recorded in Table 1.6.11a. One of the metals is not labelled.

TABLE 1.6.11a

Metal	Observations
unknown metal	Bubbles seen, test tube became warmer
calcium	Lots of bubbles produced very quickly, test tube became very hot
zinc	Bubbles seen

FIGURE 1.6.11a: Zinc metal reacting with hydrochloric acid.

Compare the reactivity of the unknown metal with that of calcium and zinc. Explain your answer. [2]

16. Brass is a gold-coloured metal – it is an alloy of copper and zinc. It can be cast into different shapes and has a range of uses including musical instruments, electrical switches and door fittings. From this information suggest some of the properties of brass, explaining your answers. [4]

17. A group of students tried to make some indicators from different plant materials. They tested each of the solutions that they made. The results are shown in Table 1.6.11b.

TABLE 1.6.11b

Indicator	Colour in acid	Colour in alkali	Colour in neutral
A	red	blue	blue
B	red	blue	purple
C	yellow	yellow	yellow

Arrange the indicators in the order of most useful to least useful for testing the pH of a variety of different chemicals. Explain your answer. [3]