3

CHEMICAL REACTIONS

We know that substances can change. We can freeze water to form ice, and we can melt that ice to form water again. This is a physical change. If you place some sodium metal (Na) in water (H_2O), the hydrogen from the water is released as a gas. This change is different; a chemical reaction has occurred. During chemical reactions, substances interact to form different substances. How are new substances produced from existing materials? What is happening at an atomic level, that we cannot see?

3.1 CHANGING MATTER WITH CHEMICAL REACTIONS

A chemical change is defined by the creation of a new substance, but that new substance is created from the existing atoms available in the reactants. No atoms are destroyed or created in a chemical reaction. Chemical formulas are used to explain the composition of substances, while word and chemical equations demonstrate the changes in arrangement of atoms during a chemical reaction.

Students:

» recall that matter is composed of atoms which have mass

» identify the names and chemical formulas of some common compounds

» construct word equations to describe chemical reactions

» deduce that atoms of reactant substances are rearranged during chemical reactions to produce new substances

» balance chemical equations (additional content)

3.2 CLASSIFYING CHEMICAL REACTIONS

When one or more substances interact to produce one or more new substances, a chemical reaction is said to have occurred. The types of reactants and products, or the manner in which the reactants interact, enable chemists to classify chemical reactions and predict the outcome of similar reactions.

Students:

» classify compounds based on common chemical properties

» investigate the characteristics of the main types of chemical reactions including combustion, reactions between acids and metals and carbonates, corrosion, precipitation, neutralisation and decomposition

3.3 CHEMICAL REACTIONS IN LIFE

Chemical reactions are not just activities within scientific laboratories, they happen naturally in both living and non-living systems. Photosynthesis and respiration are spontaneous chemical reactions that are key fuels for life on the Earth. But humans also use chemical reactions to extract, refine and use other fuels for heat and electricity.

Students:

» identify the importance of the chemical reactions involved in photosynthesis, respiration and digestion

3.1 CHANGING MATTER WITH CHEMICAL REACTIONS

For several thousand years, until the 17th century, alchemists tried to produce valuable substances, such as gold, from less valuable ones, such as lead. The word 'alchemy' comes from an Arabic word meaning 'value'. Without knowledge of what happens to atoms during a chemical reaction, early alchemists were attempting the impossible. Modern chemists still use some of the language and equipment of alchemy, but they can now consider what is really happening to the 'invisible' particles in chemical reactions.

CHEMICAL REACTIONS AND CHEMICAL FORMULAS

All matter is made up of atoms. Some of these atoms join together to form molecules or three-dimensional lattice structures. Sometimes different types of atoms or elements join together to form compounds. The different ways in which atoms join together form all the different substances on the planet.

Every atom is made up of protons and neutrons in the nucleus, which are surrounded by layers of orbiting electrons in electron shells. The number and arrangement of the subatomic particles determines the element and the properties of that element.

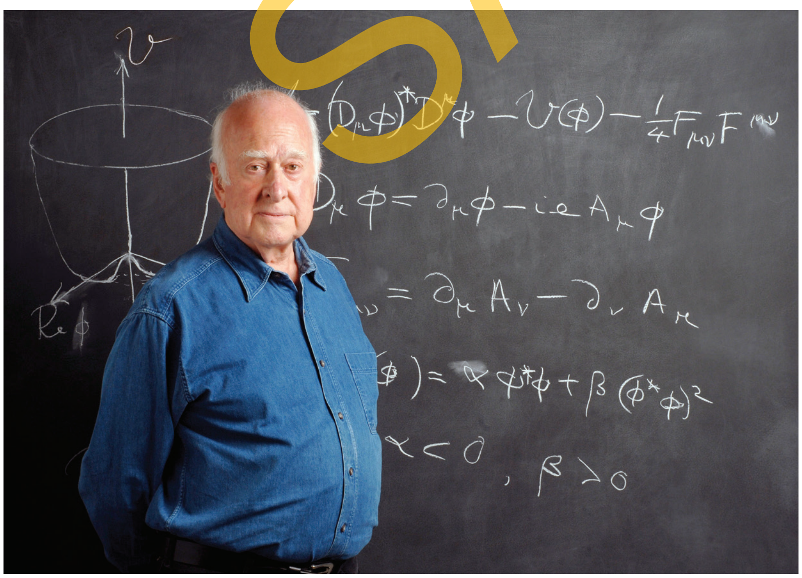


Figure 3.1 British theoretical physicist Peter Higgs predicted the existence of an additional subatomic particle in 1964 and called it the Higgs boson. The Higgs boson was finally discovered in 2012.

In July 2012, the physics world was in a state of excitement. A new type of subatomic particle had been confirmed by CERN, the European Organization for Nuclear Research.

The Standard Model, which describes the particles, forces and interactions of the universe, is supported by the existence of a subatomic particle called the Higgs boson. Until July 2012, that particle was predicted but undiscovered. Discovery of the Higgs boson is proof of a force that gives particles their mass. If particles had no mass, they would travel through the universe without attracting each other and so would never form into bodies such as planets and stars.

CERN's observations are important in areas other than physics. You will find out in this chapter just how vital the idea of mass is to chemical reactions.

Chemical reactions

Chemical change is defined as the production of a new substance from existing substances. All chemical reactions start with one or more reactants (ingredients) and result in one or more new products. The products are formed using the atoms of the reactants. No atoms are destroyed and no new atoms are created by the reaction. It is simply a rearrangement of the atoms that are already there.

ACTIVITY 3.1.1: THE ALCHEMIST'S DESIRE

Imagine that you and your friends are approached by an alchemist claiming to be able to change lead into gold. You know that the claims are an attempt to trick you, but your friends are tempted to believe the alchemist, because they think they could become incredibly wealthy.

Your task is to convince your friends that the alchemist is a fraud and that alchemy simply doesn't work. You have the following pieces of evidence.

- Elements always behave predictably in chemical reactions.
- All elements have physical properties that appear to be consistent.
- When chemicals react with each other, the total amount of mass of the chemicals does not change.
- Pure metals don't change in terms of physical properties unless they're mixed with other metals or form compounds.

1 Do you think any of these pieces of evidence would be useful in persuading your friends to ignore the alchemists? If so, why?

2 Choose three of the points and explain why you think you could use them as evidence to support your opinion that alchemy is more of a trick than a scientific endeavour.

Figure 3.2 Alchemists did not have an understanding of the structure of atoms or the nature of chemical reactions and were never successful in converting lead into gold.

Atoms can be thought of like Lego blocks that can be clicked together and taken apart, over and over, in many different ways, to form different things.

Describing chemical reactions

Figure 3.3 shows sodium metal reacting with water. Perhaps you have seen this reaction at school or on the Internet.

There are different ways to describe this reaction.

- Describing observed changes: The sodium metal dissolves in the water; heat is produced; fizzing is caused by the production of hydrogen gas; if there is enough heat, the hydrogen gas catches fire above the sodium metal.
- Using a word equation: The reactants are sodium and water and they interact to form the products, which are hydrogen gas and sodium hydroxide. A **word equation** summarises the changes in words:

  sodium + water → sodium hydroxide + hydrogen

- Using a chemical equation: This includes the formulas of all the substances involved and the ratio in which they react. The ratio in which they react, and the formulas and states of each substance are described by a balanced **chemical equation**:

  $$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

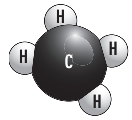
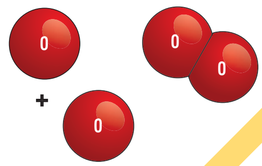
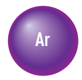
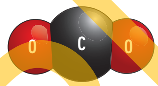
Each representation tells us something different about the changes occurring in the chemical reaction.

Figure 3.3 Sodium metal reacts spectacularly with water.

ACTIVITY 3.1.2: REPRESENTING CHEMICALS

Table 3.1 represents four chemicals in different ways.

Table 3.1 Representations of four chemicals

Chemical name	Formula/symbol	Diagram
Methane	CH_4	
Oxygen	O_2	
Argon	Ar	
Carbon dioxide	CO_2	

1 Identify:
   a an element composed of molecules
   b a compound composed of molecules
   c an element composed of atoms
2 Which representation tells us the most about the chemicals: the formula or the diagram? Explain your reasoning or discuss your answer with others.
3 Which of these substances will burn in air and produce heat energy?

Did you remember these key facts about chemicals?

- Elements are made up of one type of atom.
- Compounds are combinations of different atoms.
- Molecules are atoms bonded together.

ACTIVITY 3.1.3: OBSERVING A CHEMICAL REACTION

What you need: candle, matches, range of measuring devices such as a stopwatch, thermometer, etc.

1 A burning candle is an example of a common chemical reaction. Light a candle and spend 5 minutes listing as many observations about what happens as you can. Remember that you can use observational tools other than your eyes. Share your list of observations with a partner.
2 Imagine that you were asked to say what type of chemical reaction this is. Would any of your observations help to classify the reaction? Use your observations to answer the following questions.
   - Was energy released in the reaction?
   - If so, what forms of energy? How do you know?
   - Was it a fast reaction?
   - What was used up in the reaction? What was produced?
   - Did the reaction start on its own? (Was it spontaneous?)

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Chemical formula

To be able to understand the atoms contained in a substance and involved in chemical reactions, scientists use **chemical formula**. The letters are element symbols and tell us which elements are present. The subscript numbers tell us how many atoms of that element are present in each molecule, or in the case of lattice structure, the ratio of atoms of each element.

You were introduced to ionic and covalent compounds in Oxford Insight Science 9.

Ionic compounds

Ionic compounds contain both metal and non-metal elements. The metal atoms donate their valence electrons to the non-metal atoms, causing the metal atoms to form positively charged cations. Accepting the extra electrons causes the non-metal atoms to form negatively charged anions. The difference in charge forms ionic bonds between ions. Ionic bonds are relatively weak and often break when the compound is dissolved in water. The number of electrons donated or accepted determines the charge of the ion, which in turn influences the ratio of atoms in the compound.

Ionic compounds list the metal element first in the name, followed by the non-metal element name. However, the non-metal name is altered slightly so that it always ends in 'ide'. For example, oxygen becomes oxide; chlorine becomes chloride; sulfur become sulfide; and so on. Polyatomic ions (ions made up of a combination of more than one atom and usually more than one element) take on their own specific name, which may not necessarily end in 'ide'.

Ionic compounds usually form hard and brittle crystal lattices. The chemical formula of ionic compounds is an indication of the ratio of different elements in the compound.

Molecular compounds

Molecular compounds contain two or more different non-metal elements. The different atoms share electrons in their valence shells and form strong covalent bonds. The number of electrons required to make the valence shell of each atom stable determines the number of electrons shared and the ratio of elements involved in the compound.

Molecular compounds form discrete molecules, so the numbers in the chemical formula indicate the exact number of atoms required for each molecule.

Molecular compounds are named according to the number of each element in the compound. There are a number of rules involved in naming molecular compounds.

- The element listed first is found further left on the periodic table than the other element. For example, carbon is to the left of oxygen on the periodic table, and so would be listed first in any compound containing carbon and oxygen.
- The second element name is change to end in 'ide'.
- Each element is given a numerical prefix to indicate the number of atoms of that element (see Table 3.2).
- If there is only one atom of the first listed element, the prefix 'mono' is dropped.

Some everyday molecular compounds have

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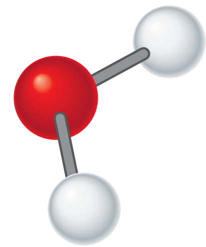


Figure 3.5 Covalent bonds are formed when valence electrons are shared between two atoms.

Table 3.2 Some common molecular compounds

Chemical formula	Scientific name	Common name
H_2O	Dihydrogen monoxide	Water
NH_3	Nitrogen trihydride	Ammonia
CH_4	Carbon tetrahydride	Methane
H_2O_2	Dihydrogen dioxide	Hydrogen peroxide
HCl	Hydrogen monochloride	Hydrochloric acid

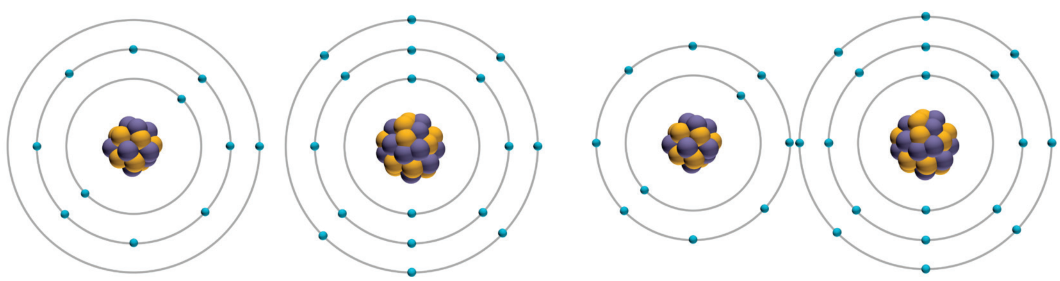


Figure 3.4 Sodium chloride (NaCl) forms a 3D lattice made up of one positively charged sodium cation for every negatively charge chlorine anion.

SCIENCE SKILLS

Naming compounds and writing chemical formulas

Part A: Ionic compounds

Ionic compounds are always written and named with the metal element before the non-metal element, which always ends in 'ide'. The ratio of cations and anions must result in a substance without charge. That is, the positive charges must cancel out the negative charges. Table 3.3 lists some common ions.

Table 3.3 Some common ions

Cations		Anions	
Element	**Formula**	**Element**	**Formula**
Lithium	Li^+	Fluorine	F^-
Sodium	Na^+	Chlorine	Cl^-
Potassium	K^+	Bromine	Br^-
Magnesium	Mg^{2+}	Iodine	I^-
Calcium	Ca^{2+}	Oxygen	O^{2-}
Zinc	Zn^{2+}	Sulfur	S^{2-}
Aluminium	Al^{3+}	Nitrogen	N^{3-}

Example

1 What is the name and formula for the compound of zinc and sulfur?
- The ions are Zn^{2+} and S^{2-}.
- Because the charges 2+ and 2- are equal, the ions need to be in the ratio of 1:1.
- Therefore the formula is ZnS.
- The compound is called zinc sulfide.

2 What is the name and formula for the compound of aluminium and oxygen?
- The ions are Al^{3+} and O^{2-}.
- Because the charges 3+ and 2- are unequal, the ions need to be in the ratio of 2:3 (2 × 3 = 6, 3 × 2 = 6).
- Therefore the formula is Al_2O_3.
- The compound is called aluminium oxide.

Your turn

1 Write the chemical formula and the name for the compounds of:
- **a** calcium and bromine
- **b** sodium and nitrogen.

Part B: Molecular compounds

Molecular compounds are named using numerical prefixes to identify the number of atoms for each element involved. The second element always ends in 'ide'. Table 3.4 lists the numerical prefixes.

Example

1 Identify the name of the compound, NF_3.
- Identify the element symbols: N = nitrogen, F = fluorine.
- Because nitrogen does not have a subscript number, it doesn't require a prefix.
- Fluorine has the subscript number 3, so needs the prefix 'tri' and must end in 'ide'.
- The compound is called nitrogen trifluoride.

2 Identify the formula of the compound, phosphorus pentachloride.

- Identify the element symbols: phosphorus = P, chlorine = Cl.
- Because phosphorus doesn't have a prefix, there must only be one atom, and so no subscript number is needed.
- Chlorine has the prefix 'penta', so must have the subscript number 5.
- The chemical formula of the compound is written as PCl_5.

Your turn

1 Name the compound S_2F_{10}.

2 Write the chemical formula for sulfur hexafluoride.

Table 3.4 Numerical prefixes for name molecular compounds

Number of atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

QUESTIONS 3.1.1: CHEMICAL REACTIONS AND CHEMICAL FORMULA

Remember

1 Definite the terms 'reactant' and 'product' in terms of chemical reactions.

2 Identify which way of describing a chemical reaction tells us most about what is happening to the atoms.

3 Recall the differences between ionic and molecular compounds. You may like to use a table or graphic organiser.

Apply

4 Identify what you think the '(s)', '(l)', '(g)' and '(aq)' stand for in the chemical equation for the reaction of sodium metal with water (see p. XX).

5 Name the following compounds.

a N_2H_4

b Na_2O

6 Identify whether the compounds in question 5 are ionic or molecular. Justify your decisions.

7 Write the chemical formula for dinitrogen tetraoxide.

Analyse

8 Suggest an advantage of using chemical formula over compound names.

CONSERVATION OF MASS

While a chemical reaction creates a new substance, only the atoms present in the reactants are used. Chemical bonds between atoms may be broken and reformed between different atoms, but no atoms are destroyed or created in the process. This means that all the atoms that were present at the start of the reaction are still present at the end. They have simply been rearranged into something new.

The **law of conservation of mass** explains this phenomenon by stating that the total mass of the reactants must be equal to the total mass of the products of a chemical reaction.

EXPERIMENT 3.1.1: COMPARING MASS BEFORE AND AFTER A CHEMICAL REACTION

Aim

To determine if mass is conserved in a chemical reaction.

Hypothesis

Predict whether you think the mass of the products of this reaction will be the same as the mass of the reactants consumed in this reaction. Rewrite your prediction as a hypothesis using an 'If … then …' statement.

Materials

- Balance
- Measuring cylinder
- 2 conical flasks
- Sodium bicarbonate
- Watch glass
- Vinegar
- Gas jar and cover
- Limewater
- Spatula
- Balloon
- Thermometer

WARNING

> Make sure that you have discussed any possible risks to yourself or others with your teacher and members of your investigation team. Identify how you could minimise or eliminate any anticipated risks.

Part A

Method

Figure 3.6 Add the sodium bicarbonate to the vinegar.

1. Copy the results table below for part A to record your results.
2. Weigh 2.0 g of sodium bicarbonate onto a watch glass.
3. Add 20 mL of vinegar to a flask.
4. Use a thermometer to measure the temperature of the vinegar.
5. Ensure the balance is reading zero. Weigh the vinegar and flask. Record this mass (M_1).
6. Predict whether the mass of the flask and vinegar after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.
7. Add 2.0 g of sodium bicarbonate (M_2) to the flask containing the vinegar and swirl the solution until the bubbling stops.
8. Measure the temperature of the solution in the flask.
9. Weigh the flask after the reaction has stopped. Record the final mass (M_3).

Results

Mass of flask and vinegar (M1)	Mass of sodium bicarbonate (M2)	Total mass before reaction (M1 + M2)	Mass after reaction (M3)

Part B

Method

1 Copy the results table below for part B to record your results.
2 Weigh 2.0 g of sodium bicarbonate onto a watch glass.
3 Add 20 mL of vinegar to the clean flask.
4 Ensure the balance is reading zero. Weigh the vinegar, flask and a balloon. Record this mass (M_1).
5 Predict whether the mass of the flask, vinegar and balloon after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.
6 Add 2.0 g of sodium bicarbonate (M_2) to the balloon then stretch it over the neck of the flask to collect any gas produced in a reaction.
7 Invert the balloon so its contents empty into the flask and vinegar.
8 Weigh the flask after any reaction ceases, with the balloon still attached. Record the final mass (M_3).
9 Pour limewater into a gas jar to a depth of around 2 cm.
10 Pinch the balloon and remove it from the flask, then pour the gas inside into the gas jar and limewater. Put the gas jar lid on immediately and gently swirl the limewater in the jar, noting what happens. If the limewater turns milky it suggests that the gas carbon dioxide was produced in the reaction of vinegar and sodium bicarbonate. This gas has then reacted with the limewater to produce white calcium carbonate.

Figure 3.7 Quickly stretch the balloon over the flask to collect any gases produced.

Results

Mass of flask, vinegar and balloon (M1)	Mass of sodium bicarbonate (M2)	Total mass before reaction (M1 + M2)	Mass after reaction (M3)

Discussion

1 Compare the initial and final masses for each part of the experiment. Is this what you expected? Explain why or why not.
2 Did you identify that a gas was produced in the reaction between sodium bicarbonate and vinegar? How did you know?
3 Describe whether the temperature of the vinegar liquid was the same, lower or higher after the reaction with sodium bicarbonate.
4 Identify the gas produced.
5 Identify the purpose of the balloon.
6 Was the gas carbon dioxide produced in the reaction? Describe how you know this.
7 Explain how the design of this experiment could be improved. Include a suggestion of how the reliability of your results could be improved.

Conclusion

- Describe the evidence you observed that tells you that a chemical reaction did occur.
- Describe the evidence you have that indicates mass was conserved in this chemical reaction.
- Was your hypothesis supported or not supported by your observations?

Chemical reactions and mass

What happens to the mass of chemicals during chemical reactions? To find out, we can gather some evidence by experimenting. Consider the reaction of acid in vinegar with sodium bicarbonate. This reaction produces carbon dioxide gas, and it can be represented as:

acetic acid (in vinegar) + sodium bicarbonate → sodium acetate + carbon dioxide + water

If you did Experiment 3.1.1, you found out that when the products of a chemical reaction are not allowed to escape, the mass of the products after the observed reaction is the same as the mass of the reactants that you started with. This is a very important observation. It shows that the total mass of the chemicals is not changed in a chemical reaction and supports the law of conservation of mass.

Atoms in a chemical reaction

Methane gas (CH_4) is the main gaseous compound present in natural gas, which is used in the home for cooking and heating. When it burns, it combines with oxygen (O_2) in the air to form carbon dioxide (CO_2) and water (H_2O), which can be represented as:

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

Figure 3.8 shows what is happening to the atoms during this reaction. Different atoms are represented by different colours. One methane molecule combines with two oxygen molecules to produce one carbon dioxide molecule and two water molecules.

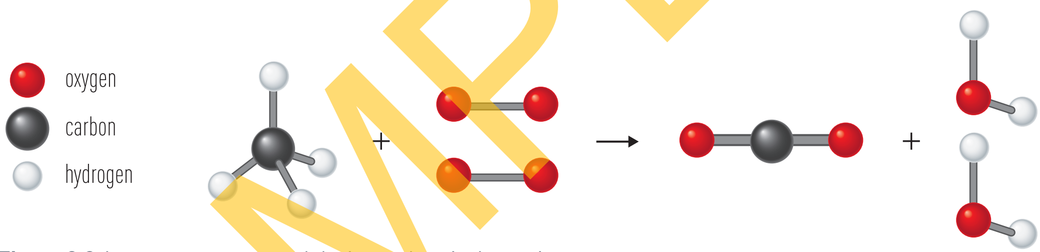


Figure 3.8 Atoms are rearranged during a chemical reaction.

When the methane gas is burning, this reaction is happening between millions of molecules, but for each and every reaction between methane and oxygen, the atoms always rearrange in this way, if there is plenty of oxygen.

Writing chemical equations

Hydrogen can combine with oxygen to produce water. The equation can be written using the following steps.

1 Write the word equation for the reaction.

hydrogen + oxygen → water

2 Write a chemical equation using the formulas of the substances involved.

$$H_2 + O_2 \rightarrow H_2O$$

3 Work out the numbers of each type of atom in the reactants (left-hand side) and in the products (right-hand side) by looking at the subscript numbers.

4 Compare the number of each type of atom in the reactants with the number in the products. In this case, the number of atoms in the products of the reaction (2 + 1 = 3) is different to the number of atoms in the reactants (2 + 2 = 4). This doesn't fit the law of conservation of mass. We can't have 'lost' an oxygen atom.

5 The equation needs to show that the numbers of each atom in the products are the same as they were in the reactants, according to the law of conservation of matter. We do this by including whole numbers (called coefficients) in front of the formulas of the elements or molecules, where necessary. The coefficient is a multiplier and applies to each different type of atom within a molecule. Coefficients are added to the chemical formulas until the equation is balanced; the number of reactant atoms equals the number of product atoms for each element.

6 To balance the equation for the reaction between hydrogen and oxygen molecules, the hydrogen molecule in the reactants and the water molecule in the products each have a coefficient of 2. The oxygen molecule has a coefficient of 1, but a coefficient of 1 doesn't need to be shown.

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

	Reactants		→	Products	
Type of atom	H	O	→	H	O
Number of atoms	2	2	→	2	1

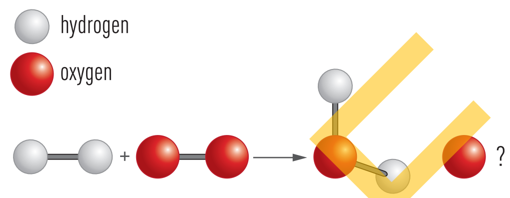


Figure 3.9 An atom of oxygen can't have 'magically' disappeared. This reaction is not yet balanced.

	Reactants		→	Products	
Type of atom	H	O	→	H	O
Number of atoms	2 × 2 = 4	2	→	2 × 2 = 4	2 × 1 = 2

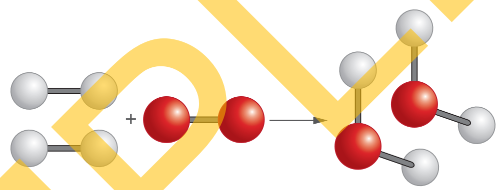


Figure 3.10 The law of conservation of mass means that two molecules of hydrogen must react with one molecule of water to produce two molecules of water.

SCIENCE SKILLS

Balancing chemical equations (additional content)

When an airbag from an older car activates, the atoms in a chemical called sodium azide (NaN_3) split up to form sodium metal and nitrogen. The sodium metal then reacts with potassium nitrate or silica to form stable compounds that are not reactive.

Your turn

Follow these steps to write and balance the equation for airbag activation.

1 Write the word equation for the reaction.

2 Write the word equation as a chemical equation using the formulas of the substances involved.

3 Work out the numbers of each type of atom in the reactants (left-hand side) and in the products (right-hand side).

4 Compare the number of each type of atom in the reactants with the number of products and use coefficients to balance the number of atoms on both sides.

QUESTIONS 3.1.2: CONSERVATION OF MASS

Remember

1 Recall the key feature of a chemical change, compared to a physical change.

2 If no mass is lost or gained in a chemical reaction, outline what this tells you about the atoms involved in the reaction.

3 Recall what the following numbers in a chemical formula tell you.

  a Subscript numbers

  b Coefficient numbers

Apply

4 Explain why the products have properties very different to those of the reactants, even though the total mass remains the same.

5 Explain why chemical reactions that are not 'balanced' are always incorrect.

Analyse

6 Balance the following equations by adding numbers as required:

  a $Na + \_\_ H_2O \rightarrow \_\_ NaOH + \_\_ H_2$

  b $H_2 + \_\_ O_2 \rightarrow \_\_ H_2O$

  c $CH_4 + \_\_ O_2 \rightarrow \_\_ CO_2 + \_\_ H_2O$

  d $Mg + \_\_ HCl \rightarrow \_\_ H_2 + \_\_ MgCl_2$

  e $NaOH + \_\_ HCl \rightarrow \_\_ NaCl + \_\_ H_2O$

7 Rewrite all of the equations in question 6 as word equations. Identify the common names for NaCl and H_2O.

CHANGING MATTER WITH CHEMICAL REACTIONS

3.1

CHECKPOINT

Remember and understand

1 Describe what all substances are made from. [1 mark]

2 State the law of conservation of mass. [2 marks]

3 Describe what happens to atoms during a chemical reaction. [2 marks]

4 Identify how many atoms of each element in total are present in:

a a molecule of citric acid ($C_6H_8O_7$). [3 marks]

b water molecules ($6H_2O$). [3 marks]

Apply

5 Identify three things you could observe that would indicate a chemical reaction has taken place when chemicals are mixed or burned. [3 marks]

6 In the car airbag described in the Science Skills: Balancing chemical equations (see p. XX), other chemicals are present in the bag to react with the sodium metal after it is produced. Apply your knowledge of sodium to explain why you think that this is necessary. [2 marks]

Analyse and evaluate

7 Outline the advantages and disadvantages of using a balanced chemical equation to describe a chemical reaction. [2 marks]

Critical and creative thinking

8 Think back to the work of the early alchemists. Outline why they thought they could create new materials from old ones. Use your knowledge from this unit to explain why their efforts to produce gold from other substances were futile. [2 marks]

9 The law of conservation of mass states that the total mass of substances is the same before and after a chemical reaction. Explain why the following observations do not contradict (go against) the law of conservation of mass.

a An iron nail becomes heavier as it rusts. [2 marks]

b When a piece of magnesium is mixed with acid in a beaker to produce hydrogen gas, the combined mass of the beaker and its contents decreases. [2 marks]

Making connections

10 The main idea that you have been considering in this section is that when substances interact and change, atoms within the substances are rearranged. LPG (liquefied petroleum gas), which is used in barbecues, contains propane (C_3H_8). When propane gas burns in air, it reacts with oxygen to produce carbon dioxide and water.

The reaction can be represented by a chemical equation:

propane + oxygen → carbon dioxide + water vapour

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

The molecules involved in the reaction can be represented as shown in Figure 3.11.

a Describe what happens to a carbon atom (black) during this reaction. [2 marks]

b Explain why three molecules of carbon dioxide are produced for each molecule of propane reacted. [2 marks]

c Use this reaction to explain the law of conservation of mass in a chemical reaction. [2 marks]

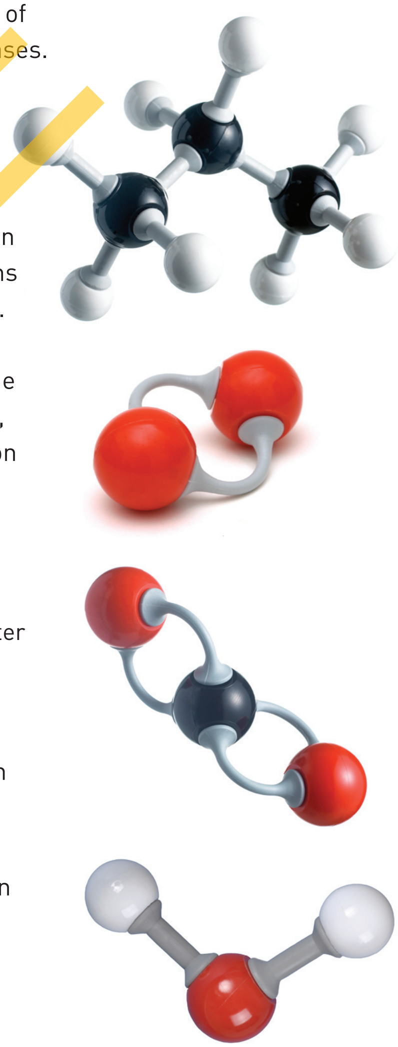


Figure 3.11 (a) Propane (C_3H_8), (b) oxygen (O_2), (c) carbon dioxide (CO_2) and (d) water (H_2O).

TOTAL MARKS
[/30]

3.2 CLASSIFYING CHEMICAL REACTIONS

All chemical reactions begin with reactants and result in products. However, reactions can be classified according to particular interactions between reactants and the products they produce. Descriptions of reactions may focus on observation, for example the production of gas or heat. Alternatively, they may involve naming the chemicals involved, writing word equations or chemical equations with symbols and formulas to demonstrate the rearrangement of atoms during the reaction.

REACTIONS INVOLVING ACIDS AND BASES

Acids are commonly found around us. Unripe fruits taste sour because of the presence of acid. Weak acids in fruit include citric acid in oranges and lemons, tartaric acid in grapes, malic acid in green apples and oxalic acid in rhubarb. Vitamin C is ascorbic acid. Sour milk and yoghurt contain lactic acid. Vinegar is acetic acid. Fizzy soft drinks contain carbonic acid.

Acids are a group of chemical compounds, all with similar properties. As well as tasting sour, all acids produce a prickling or burning sensation if they contact skin. All acids contain at least one hydrogen atom. They tend to react with many metals.

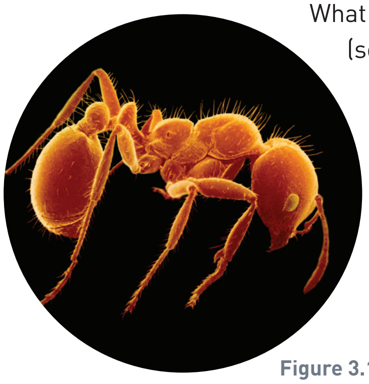
Some acids are strong and some are weak. Strong acids are dangerous because they can react continuously and can 'eat' their way through objects. Very strong acids such as concentrated sulfuric acid can dehydrate (remove water from) carbohydrates such as sugar to leave behind carbon. This gives an appearance of burning. Weak acids are much safer and we can eat and drink some of them. In fact most, of us enjoy the sour taste of weak acids in foods or condiments such as vinegar or in citrus fruits.

Bases can be described as the chemical opposites of acids. They are bitter and feel slippery or soapy to touch. A base that dissolves in water is called an **alkali** and solutions that are formed by these soluble bases are described as **alkaline** solutions.

Both acids and bases can be very dangerous. It is important to remember not to taste or touch any chemicals in a laboratory!

DEEPER UNDERSTANDING

Treating the sting of ant bites



What happens when an ant bites you? Most ants release a toxin that includes methanoic acid (sometimes called formic acid), which is released into the skin when they bite. Methanoic acid is what causes the stinging sensation. A preparation that contains baking soda works quite well to reduce the stinging sensation. This is because baking soda is a base, so it neutralises the acid in the toxin, thus taking away the sting.

Not all insect stings are acidic. Fire ants release an alkaline compound. Treating fire ant stings with a base like baking soda will not ease the pain because one base will not neutralise another base. What do you think would neutralise the effect of a sting from a fire ant?

Figure 3.12 An SEM image of a fire ant. Unlike many ant species, fire ants release a strong base when they bite.

Identifying acids and bases

Acids and bases can be identified by taste, touch and smell, but it's often not safe to do so. A safer alternative is to use an indicator.

An **indicator** is a substance that changes colour in the presence of an acid or a base. Some plants naturally contain pigments that are examples of these substances.

The coloured chemicals in many flowers and fruits can be extracted with hot water and then used as an indicator for acids and bases. Red cabbage contains a water-soluble pigment called flavin, which is also found in plums, poppies, grapes and apple skin. Very acidic solutions will become red when flavin is added, and neutral solutions become a purplish colour. Alkaline solutions appear greenish yellow if flavin is added to them.

Figure 3.13 Some vegetables, such as red cabbage, can be used to make pH indicators.

In the laboratory, scientists commonly use **litmus paper** and **universal indicator** as indicators. Litmus paper is the most commonly used indicator for quickly testing whether a substance is an acid or a base. Litmus paper becomes red in acidic solutions and blue in basic solutions.

Universal indicator is a mixture of different indicators. It is more accurate than litmus paper, because it also indicates the strength of the acidic or the basic solution that is being tested.

Figure 3.15 Universal indicator paper will turn a range of different colours depending on the strength of the acid or base. Reds and oranges are typically acids, blues and purples are bases, while neutral is usually green.

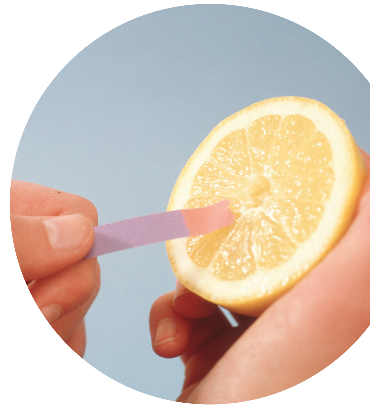


Figure 3.14 Blue litmus paper turns red to indicate the presence of acid.

The pH scale

The **pH scale** describes the relative acidity or alkalinity of a solution. If a solution is **neutral** – that is, it is neither an acid nor a base – it has a pH of 7. Pure water has a pH of 7 because it is neutral.

Acidic solutions have pH values of less than 7. The higher the acidity of a solution, the lower the pH of the solution. A pH of 1 or less indicates a very acidic solution.

Bases have pH values greater than 7. Strong bases, such as caustic soda (sodium hydroxide), can form solutions with a pH of up to 14.

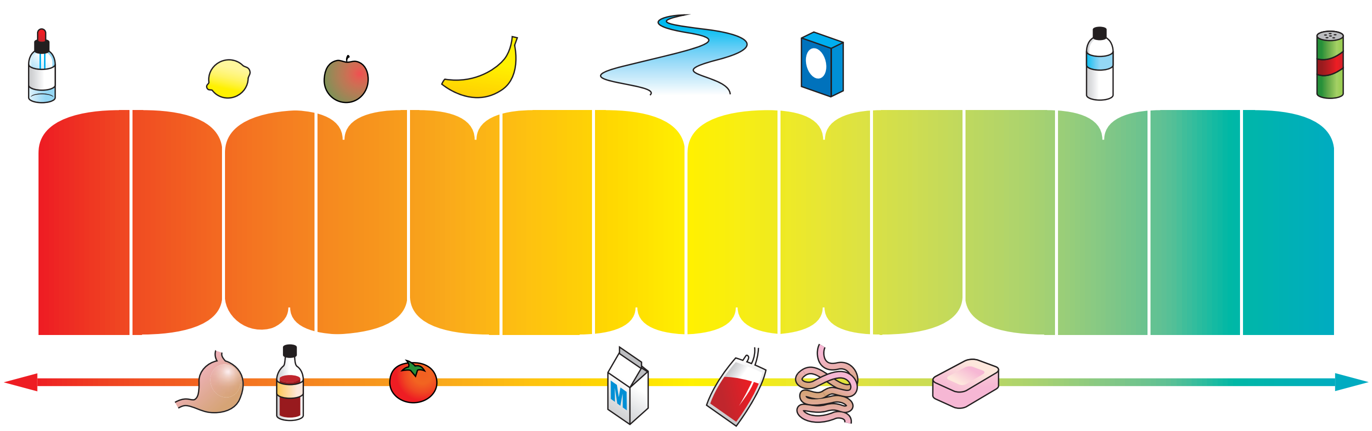


Figure 3.16 The pH scale and the relative pH of various substances.

ACTIVITY 3.2.1: TESTING WITH PH PAPER

What you need: pH paper and pH colour chart, white tile, variety of laboratory acids and bases, vinegar, milk, toothpaste, lemon juice

1. Tear off about 1 cm of pH paper and place it on a white tile.
2. Place a drop of a laboratory acid on the paper.
3. Compare the colour of the wet spot on the pH paper with the pH colour chart.
4. Repeat for the laboratory bases and the other substances.
5. For each substance, record the pH colour and number and note whether the substance is an acid, a base or neutral.
6. Dilute some of the substances in water and measure the pH of the diluted solutions with more indicator paper.
   - Which was the most acidic solution that you tested (lowest pH)?
   - Which was the most basic solution that you tested (highest pH)?
   - What happens to the pH of an acid when the acid is diluted in water? Is it more or less acidic?
   - Using your answer to the previous question, suggest a way of treating a burn caused by acid.

EXPERIMENT 3.2.1: CREATING AN INDICATOR WITH RED CABBAGE

Aim

To make an indicator from red cabbage and demonstrate how it can be used to identify acids and bases.

Materials

- 2 leaves from a fresh red cabbage (shredded)
- Stirring rod
- Water
- Beaker (250 mL)
- Strainer
- Hotplate or Bunsen burner, tripod and gauze mat
- Test tubes and test-tube rack
- Hydrochloric acid (0.1 M)
- Sodium hydroxide (0.1 M)

Method

1. To make the indicator:
   - **a** Cut a few red cabbage leaves into smaller pieces and place in a beaker.
   - **b** Cover the cabbage leaves with water and boil the mixture until the water is purple.
   - **c** Cool the liquid and then strain it, discarding the cabbage leaves.
2. To test the indicator:
   - Add a small amount of hydrochloric acid to a test tube and then add a few drops of red cabbage indicator. Record any colour change in a results table.
   - Add a small amount of water (neutral solution) to a test tube and then add a few drops of red cabbage indicator. Record any colour change in your table.
   - Add a small amount of sodium hydroxide (basic solution) to a test tube and then add a few drops of red cabbage indicator. Record any colour change in your table.
   - Add a few drops of red cabbage indicator solution to a variety of products, such as shampoo, vinegar and baking soda. Record the colour changes and determine which products are acids and which are bases.

Results

Include your table of observations here.

Discussion

1 What colour is the extract from red cabbage?

2 What colour does the extract become in:
  a an acid? b a base? c water?

Conclusion

Identify whether the red cabbage solution is a suitable acid–base indicator.

Extension

Plan an investigation to discover what other plants, flowers or fruits could be used to create an indicator to test for the presence of an acid or a base.

Reactions involving acids

Some reactions are common to all acids. A general reaction for an acid is a word equation that summarises a reaction, without naming the particular acid. General reactions help you to learn the common reactions involving acids. You can also use them to predict the products of a reaction if you know the reactants being used.

Acids reacting with bases

When an acid and a base react, they neutralise each other to form a **salt**. Water is also produced in this reaction. This type of reaction is called a **neutralisation** reaction.

acid + base → salt + water

Different acids will produce different salts in neutralisation reactions. For example, sulfuric acid will produce salts called sulfates.

When hydrochloric acid reacts with sodium hydroxide, the salt sodium chloride (common table salt) and water are produced.

sodium hydroxide + hydrochloric acid → sodium chloride + water

The chemical equation is: $NaOH + HCl \rightarrow NaCl + H_2O$

Acids reacting with metals

When an acid reacts with a metal, hydrogen gas is produced, as well as a salt.

metal + acid → salt + hydrogen

Some metals, such as magnesium, react rapidly with acids. Magnesium reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas.

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The chemical equation is: $Mg + 2HCl \rightarrow MgCl_2 + H_2$

Less reactive metals, such as lead, need to be heated to get them to react with acids such as hydrochloric acid. Other metals, such as gold, will not react with typical acids found in school science labs.

Acids reacting with metal carbonates or bicarbonates

When an acidic solution reacts with a metal carbonate or bicarbonate a salt, carbon dioxide and water are produced. The general reaction is:

metal carbonate + acid → salt + carbon dioxide + water

overmatter

The reaction of citric acid ($C_6H_8O_7$) with sodium bicarbonate ($NaHCO_3$) is used in sherbet to produce the fizzy sensation in your mouth.

EXPERIMENT 3.2.2: NEUTRALISATION REACTIONS

Aim

To investigate neutralisation reactions.

Materials

- Hydrochloric acid (1 M)
- Sodium hydroxide (1 M)
- Test tubes and test-tube rack
- Dropping pipettes
- 10 mL measuring cylinder
- Universal indicator solution
- 100 mL beaker
- Petri dish
- Microscope or magnifying glass

WARNING

> Ensure that you wear safety goggles at all times during this experiment and avoid skin contact with the hydrochloric acid and the sodium hydroxide solutions.

Method

1 Using the measuring cylinder, transfer 5.0 mL of hydrochloric acid into the beaker and then rinse out the measuring cylinder with water.

2 Add 2 drops of universal indicator solution to the acid.

3 Pour 10 mL of the sodium hydroxide into the measuring cylinder.

4 Using the dropping pipette, add the sodium hydroxide from the measuring cylinder to the acid in the beaker.

5 Stop adding the sodium hydroxide when the acid has been neutralised. (The indicator will turn green.)

6 Record how much sodium hydroxide you needed to add.

7 Carefully empty and rinse out your glassware and repeat the experiment. This time, do not add any universal indicator but use the same amount of sodium hydroxide as you did before.

8 Pour the solution into a Petri dish until full and leave open in a safe warm place in the laboratory for a few days. As the solution evaporates, record your observations.

Results

Present your results in a table.

Discussion

1 Why was it essential to rinse the measuring cylinder with water after it was used?

2 Outline why the experiment was repeated without the indicator.

3 Outline how you could produce the solid salt more quickly in the last step of the method.

4 Should you taste the product of this reaction to check whether salt has been produced? Explain your reasoning.

Figure 3.17 Compare the colour of the solution to the universal indicator pH scale to determine when it is neutral.

5 Describe what you notice about the shape of the salt crystals produced. What can you infer about the arrangement of the particles inside the salt crystals?

Conclusion

What have you observed about neutralisation reactions?

EXPERIMENT 3.2.3: REACTION BETWEEN AN ACID AND A METAL AT DIFFERENT TEMPERATURES

Aim
To investigate the rate of a metal reacting with an acid at different temperatures.

Hypothesis
Predict the effect of an increased or a decreased temperature on the reaction between magnesium and hydrochloric acid. Write this prediction as a hypothesis using an 'If … then …' statement.

Materials
- Hydrochloric acid (1 M)
- 3 test tubes and test-tube rack
- 3 beakers
- Ice slurry
- 3 pieces of magnesium ribbon of identical length
- Stop watch with lap timer capacity

Method
1 Add 5 mL of hydrochloric acid to each test tube.

2 Place one test tube in a beaker of ice water, one in water at room temperature and one in hot water. Leave the acid to reach the same temperature as the beaker in which it is sitting (5–10 minutes). This is called equilibrating.

3 Add a strip of magnesium to each test tube and commence timing the reaction in each test tube.

4 Record the time at which the reaction is no longer observed, that is, when all magnesium is reacted.

Results
Present your results in a table.

Conclusion
Identify which reaction occurred fastest and which was slowest. What does this suggest about the effect of increased temperature on the rate of this reaction? How accurate was your hypothesis?

ACTIVITY 3.2.3: MAKING SHERBET

What you need: small zip-lock sandwich bag, 1 tablespoon icing sugar, 1/4 teaspoon sodium bicarbonate (baking soda), 1/4 teaspoon citric acid, 1 teaspoon flavoured jelly crystals

WARNING
> Do this activity in a food preparation area using food preparation implements so that the sherbet is safe to eat. Remind your teacher if you have food allergies or diabetes – you may not be able to taste the sherbet.

1 Make sure the utensils are clean and dry.

2 Mix all the ingredients in the sandwich bag.

3 Dip a clean spoon into the mixture and put a small amount on your tongue.
- What happened to the sherbet when it mixed with the saliva in your mouth?
- What three substances were formed?
- How did the sherbet feel on your tongue? What differences in tastes did you observe?
- Do you think that carbonates and bicarbonates should be described as bases? Explain your answer, carrying out research if required.

Figure 3.18 Sherbet fizzes in a chemical reaction involving saliva.

ACTIVITY 3.2.2: METALS AND ACIDS

What you need: hydrochloric acid (1 M), test tubes and test-tube rack, small pieces of metals (e.g. aluminium, copper, iron, magnesium, tin and zinc) to fit into test tubes

WARNING

> Wear safety goggles at all times and avoid skin contact with the acid.

1 Add a small piece of one metal to a test tube and pour in enough acid to cover it.

2 Observe what happens (e.g. bubbling, metal dissolving, colour change, test tube warming) and record your observations in a table.

3 Repeat steps 1 and 2 for each metal.

4 If one of the test tubes bubbles vigorously, collect some of the gas from the bubbles by holding an empty inverted larger test tube over the top of the reaction test tube. Test to see if that gas is hydrogen by, while keeping the collection test tube inverted, holding a lighted match near the mouth of the test tube. If the gas is hydrogen you will hear a popping sound.

- What observations did you make about how the metals reacted with the acid?
- Which metal was the most reactive with the acid?
- Which metal was the least reactive with the acid?

QUESTIONS 3.2.1: REACTIONS INVOLVING ACIDS AND BASES

Remember

1 List the main properties of acids and bases. You could use a table or graphic organiser to help you.

2 Identify what pH would indicate a strong base. What about a strong acid?

3 Identify the nature of a substance with a pH of 7.

4 Describe the colour of litmus paper in a solution of:

a an acid

b a base.

5 Identify the general terms to describe the two products of a neutralisation reaction between an acid and a base.

6 Identify the gas produced when an acid and a carbonate react.

Apply

7 Leo spilt some acid on his laboratory coat. What should he do? Explain your answer.

8 Write the word and chemical equations for two of the reactions you have investigated in this section.

Analyse

9 Count the number of each type of atom on both sides of the equations you wrote in question 8. Describe what you notice about the numbers of atoms. Are the equations balanced? What does this tell you about what is happening to atoms in these reactions?

REACTIONS INVOLVING OXYGEN

When you see something burn, you are witnessing a substance reacting with oxygen in a chemical reaction. The amount of energy released can be huge. It is in the form of heat energy and light energy, which we see as a flame, and sometimes sound energy. Chemists classify these as **combustion** reactions.

Not every substance reacts with oxygen in this way. For example, iron reacts with oxygen quite slowly at room temperature. There are no flames, just gradual corrosion of the metal. This type of reaction with oxygen is not classified as combustion.

Figure 3.19 Oxygen is a key reactant in all combustion reactions.

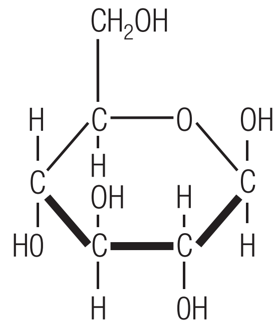


Figure 3.20 Glucose ($C_6H_{12}O_6$) reacts with oxygen in living systems.

Metals reacting with oxygen

When metal elements react with oxygen, a metal oxide is formed.

metal + oxygen → metal oxide

In the case of very reactive metals, this reaction is rapid and produces a lot of heat. For example, if magnesium metal is briefly exposed to a flame or is heated, it will start to react with the oxygen in the air, producing a brilliant white light. This reaction should never be watched directly because the light can damage your eyes.

The word equation for this reaction is:

magnesium + oxygen → magnesium oxide

The chemical equation is:

$$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$$

For moderately reactive metals like iron, the reaction still produces heat but it is slow.

Figure 3.21 Burning magnesium produces a dangerously intense white light.

Corrosion

Corrosion reactions are most commonly seen as metals reacting with the oxygen and moisture in their surroundings to produce metal oxides.

Corrosion costs the Australian economy billions of dollars each year. Metal roofs, cars, metal pipelines, metal bridges such as the Sydney Harbour Bridge and steel ships all corrode, at great expense. Maintenance is constant and expensive.

Corrosion is generally associated with a metal reacting with oxygen and water. The corrosion you will be most familiar with is the corrosion of iron or steel known specifically as rusting.

The word equation for this reaction is:

iron + water + oxygen → rust

The chemical equation is:

$$4Fe_{(s)} + 6H_2O_{(l)} + 3O_{2(g)} \rightarrow 4Fe(OH)_{3(s)}$$

The rate of corrosion is different for different metals. For example, zinc corrodes much more quickly than iron, while gold corrodes much more slowly. The rate of corrosion of a metal will also change depending on the conditions. Understanding corrosion means that we can come up with methods to prevent it or reduce the harm it can cause to structures.

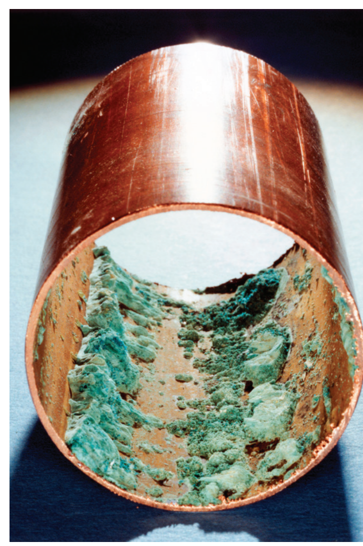


Figure 3.22 All metals corrode, but only iron forms rust. The corrosion of this copper pipe produced copper oxide, which then reacted further with carbon dioxide to form green copper carbonate.

ACTIVITY 3.2.4: RUSTING AWAY

When iron 'rusts away', it is undergoing a corrosion reaction. But is it actually losing mass?

What you need: balance, pair of similar clean iron nails, pair of test tubes, test-tube rack

1 Predict whether a corroded nail will weigh more or less than the same nail when not corroded. Write your prediction as a hypothesis.
2 Accurately weigh both nails and record their mass.
3 Add water to one test tube and place both test tubes in the test-tube rack.
4 Add a nail to each test tube, noting the weight of each nail in each test tube.
5 Leave the nails for a week.
6 Take both nails out of their test tubes and leave them in a dry environment for 24 hours. Note any difference in appearance in the nails.
7 Reweigh both nails. Compare the mass of both nails with that of 8 days before.
   - Has the corroded nail decreased in mass, increased in mass or stayed the same?
   - Has the law of conservation of mass been compromised? Explain based on your observations.
   - Was your hypothesis supported or not supported? What evidence did you use to decide this?
   - Corrosion occurs in many metals. Outline why in some situations, such as the corrosion of a metal boat, the corroded metal seems to have disappeared.

STUDENT DESIGN TASK

Investigating corrosion prevention

Challenge

To investigate the conditions required for the corrosion of iron and to determine the best conditions to prevent corrosion. You may like to refer back to the results of the Rusty Nails Experiment you did in *Oxford Insight Science 8*.

Questioning and predicting

- Choose one variable to focus your investigation on (e.g. oxygen availability, salt concentration, temperature, surface covering, etc).
- Make predictions about which condition will best prevent corrosion and write this prediction as an 'If … then …' statement.

Figure 3.23 Some possible conditions you may like to test.

Planning and conducting

- State the aim of your experiment. During your planning, refer to your aim continually to ensure your method is valid.
- Identify which variables will need to be kept constant and explain why this is the case.
- Describe a logical method for your experiment, making sure to specifically identify equipment needed.
- Identify how you will take your measurements and specific the units to be used.

- Assess any risks associated with your method and determine how to minimise them.
- Show you teacher your method before carrying it out.

Processing data and problem solving

- Collect, collate, summarise and present your data appropriately.
- Apply numerical procedures as appropriate (e.g. finding the average of data sets).
- Identify the data which supports or disproves your hypothesis.
- Describe ways to improve your method and your data.
- Describe relationships between variables.
- Determine the reliability and validity of your data.
- Based on your results, suggest a method of preventing corrosion of iron.

Communicating

Present your findings as scientific evidence to support your proposal for corrosion prevention.

Non-metals reacting with oxygen

Some non-metal elements do react with oxygen, which is also a non-metal. The result is generally a molecular compound. Consider the following reactions.

hydrogen + oxygen → water

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

carbon + oxygen → carbon dioxide

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$$

Both of these reactions give out a lot of heat energy. The first reaction can cause explosions and the second is what happens when coal burns. The products of these reactions are described as non-metal oxides.

Carbon dioxide, like the oxides of most non-metals, is an acidic substance. When non-metal oxides dissolve in water, they form acidic solutions, so they are called **acidic oxides**. Other examples of acidic oxides are sulfur dioxide (SO_2) and nitrogen dioxide (NO_2).

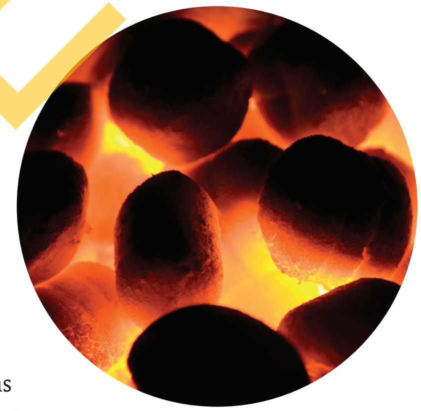


Figure 3.24 Burning charcoal coal heat beads produces carbon dioxide.

DEEPER UNDERSTANDING

Acid rain

One problem caused by carbon dioxide and certain other gases in the atmosphere is acid rain.

As rainwater condenses from water vapour in the air and falls to the ground, it can dissolve carbon dioxide from the atmosphere. A product of this reaction is a weak acid called carbonic acid (H_2CO_3). As a result, fresh rainwater usually has a pH of 5 to 6.

Cars, other vehicles, factories and power plants all give off pollutants that enter the atmosphere. These pollutants include sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), which may also dissolve to produce much stronger acids like sulfuric (H_2SO_4) and nitric acids (HNO_3). The result is known as acid rain. Acid rain can have a pH as low as 3.

Acid rain is corrosive to building materials, marble and limestone, and much corrosion has been found on buildings and statues due to acid rain. It kills wildlife in lakes and rivers and has destroyed vast areas of forest throughout the world.

One way to prevent acid rain is to treat waste gases so that acid-causing pollutants are reduced in the atmosphere. Another way is to reduce the use of fuels containing carbon and sulfur.

Figure 3.25 This stone lion has been heavily corroded by acid rain.

Combustion of fuels

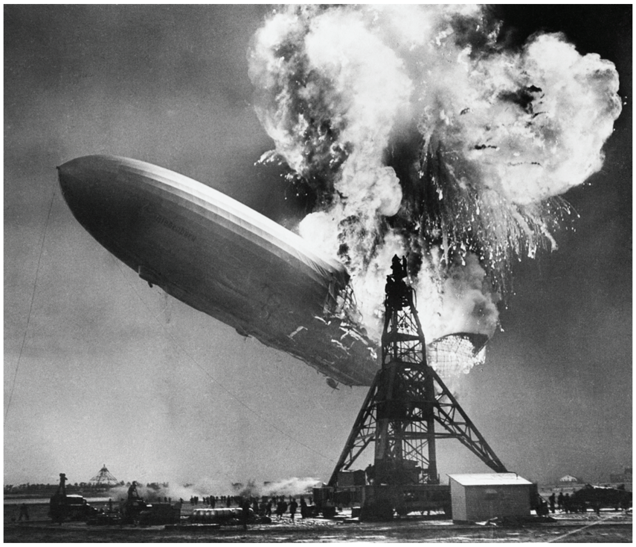


Figure 3.26 The reaction of hydrogen with oxygen caused the *Hindenburg* airship to explode and burn.

When hydrogen gas burns in oxygen, large amounts of heat energy are produced. If this reaction happens in uncontrolled conditions it is very dangerous. It caused the destruction of the *Hindenburg* airship in 1937 when a spark set a huge amount of hydrogen gas ablaze. Thirty-five of the passengers died. Under controlled conditions, hydrogen can be used safely as a fuel.

In science, a **fuel** is a substance that will undergo a chemical reaction in which a large amount of useful energy is produced at a fast but controllable rate. Fuels are the substances we use to produce heat and/or electricity, and to run engines and motors.

Many fuels consist of compounds of carbon and hydrogen, which are known as **hydrocarbons**. When hydrocarbons burn in unlimited air, carbon dioxide and water are produced. When the air supply is more limited, which occurs when the combustion happens in a confined space, carbon monoxide can be produced.

hydrocarbon + excess oxygen → carbon dioxide + water

hydrocarbon + limited oxygen → carbon monoxide + water

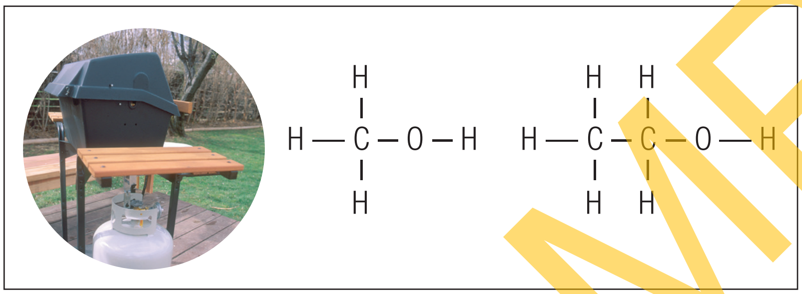


Figure 3.28 (a) Household barbecues use LPG, which is mainly (b) propane (C_3H_8).

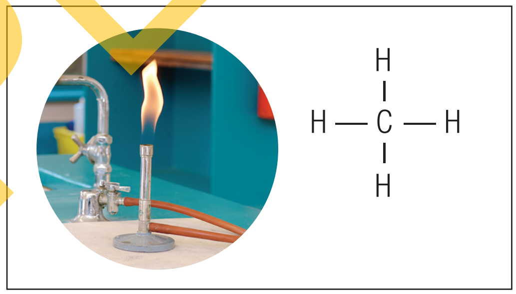


Figure 3.27 (a) Bunsen burners use natural gas, which is mainly (b) methane (CH_4).

The combustion of fuels is the most important chemical reaction to produce energy for industry and transport in modern societies. You will cover more about combustion in chapter 4.

Figure 3.29 Oil and gas are hydrocarbon fuels that can be found under the sea floor, and are extracted at offshore rigs.

QUESTIONS 3.2.2: REACTIONS INVOLVING OXYGEN

Remember

1 Identify the gas essential for combustion reactions.

2 Identify the two elements always present in hydrocarbons.

3 Identify the other two reactants (i.e. besides a metal) that are vital for corrosion reactions.

Apply

4 Carbon dioxide (CO_2) and sulfur dioxide (SO_2) are both acidic oxides produced during combustion of carbon- or sulfur-containing compounds. Discuss what you think the 'di' in their names relates to.

5 When carbon dioxide reacts with water, the product is carbonic acid (H_2CO_3), which is a weak acid.

- a Write a word equation for this reaction.
- b Write the chemical equation for the reaction.
- c Estimate the pH of a solution of carbonic acid.
- d Carbonic acid reacts with metals to produce carbonates. Identify the carbonate that would be produced when zinc from galvanised iron reacts with carbonic acid in rain.

Analyse

6 When sulfur dioxide reacts with water vapour, it produces an acidic solution. Would you expect this to accelerate metal corrosion? Explain your answer.

7 The following combustion equations are not balanced. Rewrite the following equations correctly.

- a $C_4H_8 + 6O_2 \rightarrow 4CO_2 + 3H_2O$
- b $C_5H_{12} + 5O_2 \rightarrow 5CO_2 + 6H_2$

8 Ethene gas, C_2H_4, is the gas from which polyethene (a type of plastic sometimes called polyethylene) is produced. The trouble is that it is highly flammable. Set out the steps for writing a balanced equation for the combustion of ethene in excess air.

9 People sometimes describe corrosion as 'rusting away to nothing'. From a scientific perspective, discuss the correctness of this statement.

10 The fuels used in cars, trucks and buses are generally liquefied petroleum gas (LPG), petrol or diesel. These fuels are mainly hydrocarbons.

- a Predict the main two substances present in vehicle exhaust gases.
- b Explain why scientists are warning that excessive use of these vehicles is contributing to the enhanced greenhouse effect.

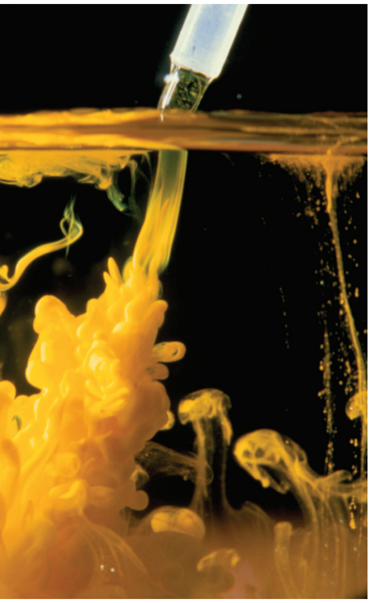


Figure 3.30 A solution of lead nitrate mixed with a solution of potassium iodide produces a yellow precipitate of lead iodide.

DISPLACEMENT AND DECOMPOSITION REACTIONS

Some reactions are classified, not according to their specific reactants, but the ways in which the reactants interact.

Displacement and precipitation reactions

When salts dissolve in water, the chemical bonds between the metal and non-metal parts of the salt break to form charged particles called ions. Sometimes, when separate solutions of two soluble salts are mixed, swapping of ion pairings occurs and one or more insoluble salts are produced. This swapping of ions in the compounds is called **displacement** and can be generalised as:

$$AB + CD \rightarrow AD + CB$$

Sometimes one of the new salts formed is insoluble. Insoluble salts that are heavier than their solution 'fall out' of solution; fine particles appear and settle at the bottom of the solution. This is called **precipitation**, the solid particles that form are called the **precipitate** and the reaction that made the insoluble salt is a precipitation reaction.

Lead salts are toxic. If a water supply contains lead, this is a big problem. A simple test for lead in the water supply is a precipitation reaction test (see Figure 3.30).

EXPERIMENT 3.2.4: PRECIPITATION AND CONSERVATION OF MASS

Aim

To observe a precipitation reaction and determine whether the law of conservation of mass describes it.

Hypothesis

Read the aim and method, and write a hypothesis for this experiment as an 'If … then …' statement.

Materials

- Balance
- 2 small beakers (150 mL)
- Sodium iodide solution
- Lead nitrate solution

WARNING

> The chemicals involved in the experiment are dangerous so gloves and safety glasses should be worn at all times. If any spills occur, clean up immediately and notify your teacher.

Method

1 Add sodium iodide to one beaker and add lead nitrate solution to the other beaker to a depth of around 2 cm.

2 Measure the temperature of each solution and record it.

3 Accurately weigh each beaker with solution and record its mass.

4 Add the contents of the sodium iodide solution to the lead nitrate solution, taking care not to spill any liquid. If a spill occurs, clean it up with paper towel and dispose of the paper towel immediately.

5 Note any change that occurs in the mixed solution.

6 Measure and record the temperature of the combined solutions.
7 Reweigh the empty beaker accurately.
8 Add the mass of both beakers and solutions before reaction and compare the total mass to that of both beakers and the solutions after reaction.

Results

Record your observations in an appropriate format.

Discussion

1 What observations did you make that suggested a chemical reaction had taken place?
2 Was the temperature of the solutions before reaction the same as the temperature of the reactions immediately after reaction? Was it higher or lower? If the temperature of the solution increases, energy is released by the reaction. If the temperature falls then energy is absorbed during the reaction. This energy change is the result of breaking or forming new bonds between particles.

Conclusion

Was your hypothesis supported or not supported? Was the law of conservation supported by this reaction? Was energy produced or absorbed?

Decomposition reactions

In **decomposition**, the atoms of a compound are separated to form two or more products. The reaction follows this general reaction:

$AB \rightarrow A + B$

Decomposition reactions are important in the industrial smelting of metal sulfide ores and ores that are metal oxides. For example, copper sulfide, when roasted at high temperatures, will produce copper metal and release sulfur dioxide gas as the sulfur reacts with oxygen from the atmosphere.

When water undergoes electrolysis (the breaking of chemical bonds using an electric current) it will produce hydrogen gas and oxygen gas. Similarly, when aluminium oxide undergoes electrolysis, it produces aluminium metal and oxygen.

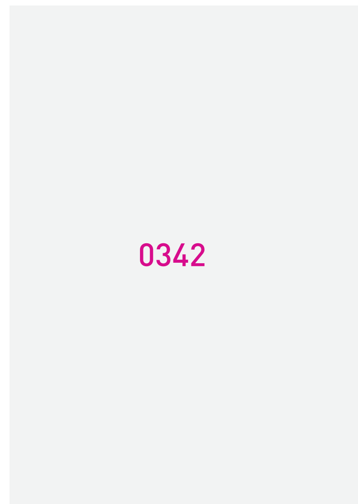


Figure 3.31 Copper sulfide decomposes when it is heated strongly.

EXPERIMENT 3.2.5: DECOMPOSITION AND CONSERVATION OF MASS

Aim

To observe a decomposition reaction and determine whether the law of conservation of mass has been obeyed in the reaction.

Hypothesis

Write a hypothesis about what you think will happen as an 'If … then …' statement.

WARNING

> This experiment involves strong heating. Read through the method carefully, considering any foreseeable risks. Take steps for their prevention.

Materials

- Balance
- Large test tube
- Test-tube holder
- Copper carbonate
- Limewater
- Bunsen burner
- Balloon

Method

1 Weigh a test tube and record its mass. Add about 2 g of copper carbonate to the test tube and record its mass. Calculate the mass of copper carbonate added by difference.

2 Collapse a balloon and fit it over the neck of the test tube.
3 Accurately weigh the test tube, balloon and copper carbonate. This is the system mass before decomposition.
4 Heat the copper carbonate in the test tube. Take care not to get the opening of the test tube so hot that the balloon bursts, melts or catches on fire. Note any changes in colour of the copper carbonate you observe. If it turns black, you have produced copper oxide. Note what happens to the balloon.
5 Accurately weigh the test tube with the products and the balloon, then record their masses. This is the system mass after the decomposition reaction.
6 Compare the system mass before decomposition and after decomposition.
7 Pour limewater into a gas jar to a depth of about 2 cm.
8 Pinch the balloon and remove it from the test tube, then pour the gas inside into your gas jar and limewater. Immediately put the gas jar lid on and gently swirl the limewater in the jar, noting what happens. If the limewater turns milky, it suggests that carbon dioxide gas was produced in the reaction.

Results

Record your observations in an appropriate format.

Discussion

1 Identify the reactant in this experiment.
2 Identify the products of this decomposition reaction.
3 Write a word equation for the decomposition reaction you observed.
4 Was mass conserved in this experiment? How can you tell?

Conclusion

- Was your hypothesis supported or not supported by your observations? Justify your answer based on the results of this experiment.
- Identify whether the law of conservation of mass was obeyed.
- Outline how this experiment might be improved.

QUESTIONS 3.2.3: DISPLACEMENT AND DECOMPOSITION REACTIONS

Remember

1 Identify the most important property that determines whether or not a precipitate will form from the mixing of two soluble solutions.
2 Describe the characteristic features of a displacement reaction.
3 Describe the characteristic features of a decomposition reaction.

Apply

4 Some ores of zinc are carbonates. Outline one way to extract the zinc from these ores.

CLASSIFYING CHEMICAL REACTIONS

3.2 CHECKPOINT

Remember and understand

1 Identify whether the following statements are true or false. Rewrite the false statements to make them true. [4 marks]

- a Reactants are made in chemical reactions.
- b Oxygen is a fuel.
- c Hydrocarbons require oxygen to burn.
- d Sulfur dioxide will dissolve in water to form an alkali.

2 Identify the products when methane burns in an excess supply of oxygen. [2 marks]

3 Write down the chemical formula of:

- a carbon dioxide [1 mark]
- b carbon monoxide [1 mark]
- c sulfur trioxide. [1 mark]

4 Identify whether the chemicals in question 3 are acidic or basic substances. Explain how you know. [4 marks]

Apply

5 Consider the following equation:

potassium hydroxide + sulfuric acid → potassium sulfate + water

- a Identify the reactants and the products in this reaction. [2 marks]
- b Identify the type of reaction. [1 mark]
- c Identify what you could add to the reaction mixture to show whether all of the acid has been used up in the reaction. [1 mark]

6 You should never drink orange juice because it contains acid. Evaluate the accuracy of this statement. [2 marks]

7 Consider the following chemical reactions:

- a Carbon in brown coal reacts with oxygen in the air to form carbon dioxide.
- b Carbon dioxide dissolves in water (containing universal indicator) to form a solution of carbonic acid (H_2CO_3).

For each reaction:

- i Describe the expected observation of the reaction. [3 marks]
- ii Write the word equation. [2 marks]
- iii Write a balanced chemical equation. [2 marks]

Critical and creative thinking

8 Some insect stings are acidic and some alkaline; however, it might not always be possible to know what insect caused the bite. Imagine you are asked to design a treatment that would reduce the pain of all insect stings. Identify the chemicals it would need to contain. Suggest a short descriptive name for your product that identifies how the product works. Present your ideas in the form of an information pamphlet or an advertisement for your 'anti-sting' treatment. [4 marks]

Research

9 Research ways that are used to restore or prevent the corrosion of objects. [5 marks]

10 Investigate the activity series of metals. What is it? What does the order of the metals mean? Which metals are high on the list? Which are low? Compare this list to the Galvanic series of metals. [5 marks]

TOTAL MARKS
[/40]

3.3 CHEMICAL REACTIONS IN LIFE

Chemical reactions are happening all around us, all the time. They affect living and non-living systems, and involve acids and bases, metals and gases – all sorts of substances. Some chemical reactions improve our lives, keeping our bodies healthy, homes clean and food tasting good, while others can harm us. Understanding these chemical reactions allows us to control some of them, start others, or use them to our advantage.

USING ACIDS AND BASES

A lot of chemical reactions that take place naturally and spontaneously involve acids and bases. Acids and bases are important in our everyday lives; they are found within our bodies, in foodstuffs, in cleaning products and in a range of industrial applications.

Acids

You have seen that acids are a group of chemicals with similar properties. Strong acids are dangerous because they are corrosive and can cause severe burns, even when they have been diluted. Weak acids are much less reactive and many are in the foods we eat and in drinks, even lemonade. Even so, many of them are corrosive and can cause bad burns when in concentrated form.

We use acids for many purposes. For example, sulfuric acid is used extensively in industry and to make other acids. It is used in car batteries and to clean oxide layers off metals before they are plated with other metals. Nitric acid is used to manufacture fertilisers, plastics, dyes and explosives. Hydrochloric acid is used to clean metals, bricks and tiles.

Phosphoric acid (H_3PO_4) is an ingredient of some cola drinks, but its main industrial use is in the production of fertilisers. It is also used as a rust remover or rust converter. Only a very small amount of phosphoric acid is added to cola drinks, so the concentration of the acid in these drinks is very low. Small amounts of phosphoric acid are enough to give the drinks a distinctive tangy taste. The acid also acts as a preservative by preventing the growth of microorganisms.

Figure 3.32 (a) Strong acids are dangerous and corrosive.,(b) Weak acids are often found in the foods we eat.

Bases

Bases have many uses. They react with fats and oils to produce soaps. Some bases, such as ammonia solution, are used in cleaning agents. One that is very effective is household cloudy ammonia. Sodium hydroxide is used in the manufacture of soap and paper. It is also used in drain cleaner and oven cleaner. Calcium hydroxide is used to make plaster and mortar.

Figure 3.33 Many cleaning products are alkaline solutions (bases).

Figure 3.34 Sodium hydroxide, a base, is used to make soap.

Table 3.5 Examples of common acids and bases

Strong acids		Strong bases	
Hydrochloric acid	HCl	Sodium hydroxide	NaOH
Nitric acid	HNO_3	Potassium hydroxide	KOH
Sulfuric acid	H_2SO_4	Barium hydroxide	$Ba(OH)_2$
Weak acids		**Weak bases**	
Ethanoic acid	CH_3COOH	Ammonia	NH_3
Carbonic acid	H_2CO_3	Sodium carbonate	Na_2CO_3
Phosphoric acid	H_3PO_4	Calcium carbonate	$CaCO_3$

Acids and bases in digestion

Have you ever had heartburn? Has somebody in your family complained of having indigestion? One of the causes of that burning feeling is gastric reflux, a failure of the ring muscle at the top of the stomach to keep gastric acids where they belong, in the stomach.

Gastric acid is mostly hydrochloric acid (HCl), potassium chloride (KCl) and sodium chloride (NaCl). It has a pH of 1.4 to 3.5. The hydrochloric acid has several important jobs, including reducing the number of bacteria that we eat with food, and dissolving leftover nutrients.

The main role of the stomach is to digest proteins. In the acidic environment produced by gastric acid, a substance called pepsin digests most of them. After spending some time in the stomach, food is mixed by muscle contractions and the gastric juices, turning it into chyme. Muscle contractions lower in the stomach push chyme into the small intestine where the hydrochloric acid is neutralised. The next stage of digestion, the breakdown of fats, happens in a basic environment.

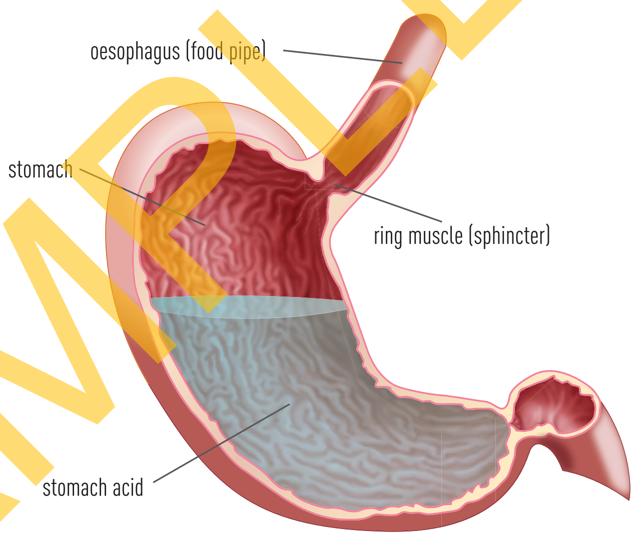


Figure 3.35 The ring muscle at the top of the stomach works to keep gastric acid in the stomach. A burning feeling in the chest can result when the muscle doesn't work as it should.

ACTIVITY 3.3.1: INVESTIGATING ACIDS

1. Choose one strong acid and one weak acid from Table 3.5.
2. Find out about some of the key uses of the two acids and describe examples of their use, if possible using situations that affect your own life.
3. Explain how the strength of the acids influence what they are used for, and how they need to be handled by the people using them.
4. Find out the difference between the strength of an acid or a base and its concentration. Draw a diagram to explain your findings.
5. Present your information as an informative pamphlet, a comparative graphic organiser or some other appropriate format.

DEEPER UNDERSTANDING

Acidic oceans

Figure 3.36 Coral reefs are made of the weak base calcium carbonate, which dissolves in acid.

Rising carbon dioxide levels in the atmosphere have caused the oceans to become acidic. Our oceans are a major carbon 'sink' and absorb much of the carbon dioxide (CO_2) in the atmosphere. When carbon dioxide dissolves in water, it forms carbonic acid (H_2CO_3). Before the Industrial Revolution, the oceans were in equilibrium with the atmosphere, absorbing as much carbon dioxide as they released.

Since the beginning of the Industrial Revolution, carbon dioxide levels have increased in our atmosphere due to large-scale burning of fossil fuels and industrial processes in which carbon dioxide is produced (e.g. the production of steel, aluminium and cement).

The oceans have responded by absorbing more carbon dioxide, thus increasing their acidity. Scientists estimate that the oceans now absorb 30 million tonnes of carbon dioxide every day.

As the oceans become increasingly acidic, the effect on marine ecosystems is devastating.

Coral reef ecosystems rival rainforests in terms of the huge diversity of species present. They also help protect coastlines from erosion. But coral reefs across the world are now struggling. One problem is that the coral itself is built up from calcium carbonate ($CaCO_3$), which is a weak base. This reacts with the weakly acidic seawater, causing the calcium carbonate to slowly dissolve and crumble.

The ability of molluscs, such as sea snails, to produce adequate protective shells, which are also made from calcium carbonate, is also greatly affected. The lower pH of the water affects many species of marine organisms that reproduce by ejecting their sperm and eggs into the water. If the number of successfully fertilised eggs decreases and some of these species die out, this will affect the entire food chain and hence the diversity of species that can survive.

QUESTIONS 3.3.1: USING ACIDS AND BASES

Remember

1. Describe the difference between an acid and a base.
2. Identify which acid and/or base you would be likely to find in:
   - a cleaning products
   - b alcoholic drinks
   - c insect stings.
3. Identify the major cause of the increase in acidity of the oceans.
4. Describe how pH changes as the acidity of the oceans increases.

Apply

5. Outline why acids used in foods are always weak acids.
6. Part of the human digestive system in the mouth treats food with saliva, which is basic. The stomach then produces acids, including the strong acid, hydrochloric acid, to mix with the food. The small intestine adds basic chemicals to the chyme it receives from the stomach. At both ends of the stomach, a biological valve called a sphincter stops excessive amounts of liquids travelling back along the digestive tract. Outline how these changes in the type of chemicals are important for health and well being.
7. Plants growing in soils that are too acidic have difficulty in taking up nutrients. Adding a small amount of lime to the soil is one suggested solution. Describe the nature of lime and identify why it probably works.

CELLULAR REACTIONS

Two chemical reactions essential to life are **respiration** and **photosynthesis**. The interdependence of these reactions maintains a balance of carbon dioxide and oxygen in ecosystems.

Chemistry of respiration

During respiration, energy stored in the chemical bonds of fuel molecules is changed to a usable form of energy. The fuel is usually a carbohydrate such as glucose ($C_6H_{12}O_6$), however, fats and proteins can also be used. The fuel molecule is converted in a series of steps into a chemical called adenosine triphosphate (ATP), which is essential for cell function. This molecule is the biological energy-storage molecule. This molecule then undergoes other reactions that release energy as required.

When enough oxygen is present, **aerobic** respiration occurs in plant and animal cells. The word and chemical equations are:

glucose + oxygen → carbon dioxide + water + ENERGY (stored in an ATP molecule)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

When you exercise strenuously, your muscle cells don't have enough oxygen for aerobic respiration. The cells quickly produce energy anaerobically (without oxygen) and make lactic acid ($C_3H_6O_3$) as a waste product. The build-up of lactic acid is thought to make your muscles feel sore and causes you to breathe very heavily. The word and chemical equations for the overall reaction are:

glucose → lactic acid + ENERGY

$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + \text{ENERGY}$

In plants, **anaerobic** respiration, known as fermentation, produces alcohol. The word and chemical equations are:

glucose → ethanol + carbon dioxide + ENERGY

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2\ CO_2 + \text{ENERGY}$

Some living things, such as certain types of bacteria, survive on anaerobic respiration alone.

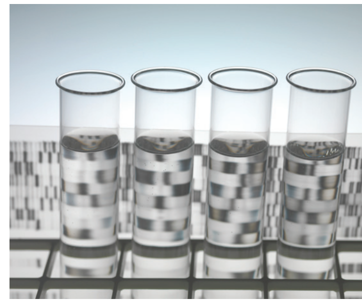


Figure 3.37 Glucose is the most common source of energy in aerobic respiration.

Figure 3.38 The fermentation of yeast is what causes bread to rise and produces the alcohol in beer.

ACTIVITY 3.3.2: TESTING FOR CARBON DIOXIDE

Limewater is a saturated solution of calcium hydroxide ($Ca(OH)_2$).

What you need: limewater, large test tube, straw

1 Pour approximately 10 mL of limewater into a large test tube.

2 Gently blow into the limewater through the straw, making sure that you do not suck the limewater through the straw. Observe the changes in the appearance of the limewater.

- Write word and chemical equations for the reaction of limewater with carbon dioxide.
- Explain the change to the limewater, in terms of producing a new substance.

Figure 3.39 Limewater can be used to test for the presence of carbon dioxide.

EXPERIMENT 3.3.1: THE PRODUCTS OF CELLULAR RESPIRATION

Aim
To determine what is produced in cellular respiration.

Hypothesis
Construct a hypothesis to describe what you think will be produced during respiration in this experiment. Remember to write your hypothesis as an 'If ... then ...' statement.

Materials
- 3 test tubes
- Test-tube rack
- Yeast
- Sugar
- Stirring rod
- Incubator (set at 37°C)
- Single-hole rubber stopper with glass connection to flexible tubing about 20 cm long
- Distilled water and bromothymol blue indicator

Method
1. To a test tube add half a large spatula each of yeast and sugar, and 20 mL of warm (not hot) distilled water. Stir gently.
2. To the second test tube add 20 mL of distilled water and a few drops of bromothymol blue indicator.
3. Set up the apparatus by connecting the rubber stopper and tubing to the yeast mix (ensure no leaks) and connecting the outlet hose so that it is under the level of distilled water and bromothymol blue indicator.
4. Set up a third test tube of distilled water and bromothymol blue indicator that is not connected to the yeast.
5. Leave the apparatus set up in a warm place overnight. An incubator set at 37°C can be used. If an incubator is used, put test-tube racks in a tray because the yeast may leak out of the test tube.

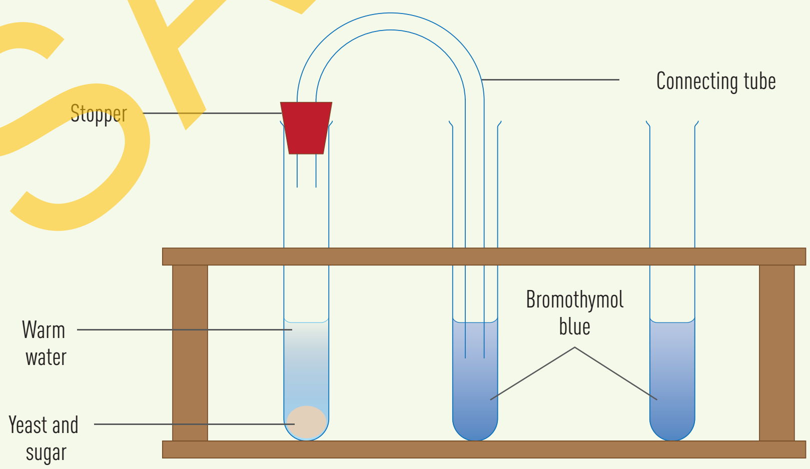


Figure 3.40 Experimental set-up.

Results
Record your observations. Distilled water and bromothymol blue indicator is blue in colour and is slightly alkaline (base). Carbon dioxide gas is slightly acidic. Bromothymol blue indicator will change to either green or yellow in the presence of an acid.

Discussion

Compare and contrast your observations between the test tube of bromothymol blue indicator and distilled water connected to the yeast and the unconnected bromothymol blue indicator and distilled water. Draw on your understanding of the reactants and products of respiration and limewater. Cover the following in your discussion.

- Identify the purpose of the third test tube that was not connected to the yeast.
- Describe what happened to the test tube containing bromothymol blue indicator and distilled water that was connected to the yeast.
- Identify why bromothymol blue indicator was used.
- Describe the evidence of water being produced. Explain.
- Identify the process that was happening in the yeast cells. Write an equation for this process.
- Identify how this experiment could be modified to test respiration in plants.

Conclusion

Was your hypothesis supported or not supported? Justify your answer using the evidence of your data.

Chemistry of photosynthesis

Living things need energy to grow, to move around and to reproduce. Plants, some algae and some bacteria are able to produce this energy by photosynthesis. In this process, glucose, a chemical with a high level of stored energy, is made from water and carbon dioxide. Oxygen is also produced as a by-product.

Photosynthesis occurs within plant cells in organelles called chloroplasts. Chloroplasts are mainly found in the leaf cells of plants, and in some algae and some bacteria. One plant leaf, on average, has tens of thousands of cells, and a single cell may contain about 40–50 chloroplasts.

The overall word and chemical equations for photosynthesis are:

carbon dioxide + water → glucose + oxygen

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Energy from sunlight is transformed into chemical energy, stored in the chemical bonds of the glucose product. ATP, the energy-storage molecule in biological organisms, is also involved in the process.

Figure 3.41 Sunlight is essential to photosynthesis.

QUESTIONS 3.3.2: CELLULAR REACTIONS

Remember

1. Recall where photosynthesis occurs in plants.
2. Outline why plants require energy from the Sun in the form of light for photosynthesis to occur.
3. Identify the source of energy for cellular respiration.
4. Write the general word equation for cellular respiration.

Apply

5. Explain why cellular respiration constantly happens in cells.
6. Identify the raw materials needed for photosynthesis. How do they enter the plant?
7. Draw a flow diagram showing the inputs and outputs of respiration.

3.3
CHECKPOINT

CHEMICAL REACTIONS IN LIFE

Remember and understand

1 Identify the products when methane burns in an excess supply of oxygen. [2 marks]

2 Identify and give the formulas of two gases that contribute to the formation of acid rain. [2 marks]

3 Outline how the cells of animals get their energy. Consider an oxygen-rich and an oxygen-poor environment. [4 marks]

Apply

4 Carbon dioxide (CO_2) is produced when hydrocarbons burn in oxygen. Outline why carbon monoxide (CO) can be produced when the supply of oxygen to the fuel is reduced. [2 marks]

5 Advertisements claim that antacids act fast to relieve heartburn and acid reflux. Describe how antacids work. [3 marks]

6 In the photosynthesis reaction that occurs in plants, glucose ($C_6H_{12}O_6$) and oxygen (O_2) are produced from carbon dioxide (CO_2) and water (H_2O).

a Write a chemical equation for this reaction. [1 mark]

b Identify how many molecules are required to produce each molecule of glucose. [1 mark]

c Outline why this reaction is important to most life on Earth. [2 marks]

Analyse and evaluate

7 Conduct a PNI ('positive', 'negative', 'interesting') analysis on the effect of acids on our lives. [5 marks]

8 If the carbon dioxide levels in our atmosphere stopped increasing and became stable, predict whether acidity levels in the oceans would change back to the levels they were at before the Industrial Revolution. Explain your answer. [4 marks]

Critical and creative thinking

9 Describe the similarities and differences between respiration and photosynthesis in a table. [4 marks]

Making connections

10 Imagine all the chemical interactions and changes that occur during the baking of a loaf of bread in an oven fuelled by LPG gas. Describe, in less than 100 words, the chemical changes that will occur in this process. Include the processes that produce the heat for the oven and the chemical processes within the food itself. You may need to carry out some additional research. [5 marks]

TOTAL MARKS
[/35]

3

CHAPTER REVIEW

1 Fill in the gaps, using the words in the Word Bank below:

Chemical reactions rearrange the atoms in the _______________ to form new substances called _______________. The law of _______________ of mass states that the total mass of the reactants must equal the total mass of the products because no atoms are _______________ or created during the reaction.

Chemical _______________ outline the arrangement of atoms in each reactant and product, while word and chemical _______________ outline the interaction between the reactants and the production of new substances.

Chemical _______________ can be classified into distinct types depending on key reactants or key products. For example, _______________ reactions involve a _______________, oxygen and water; whereas a reaction between an acid and a _______________ salt will always produce carbon dioxide and water.

While many chemical reactions happen _______________ in nature, we can use controlled chemical reactions to produce useful substances like _______________ and other resources.

WORD BANK:

Carbonate	Equations	Reactants
Conservation	Formulas	Reactions
Corrosion	Fuels	Spontaneously
Destroyed	Metal	Products

Recall that matter is composed of atoms which have mass

2 Outline the nature of matter. [3 marks]

3 Corrosion of iron increases the mass of the substance. Explain how this is possible. [3 marks]

Identify the names and chemical formulas of some common compounds

4 Write the chemical formula and name the following ionic compounds.

a Potassium bonds with iodine. [2 marks]

b Calcium bonds with nitrogen. [2 marks]

5 Identify the chemical formula for the following molecular compounds.

a Trioxide. [2 marks]

b Nitrogen trihiydride. [2 marks]

Construct word equations to describe chemical reactions

6 Recall the word equations for respiration and photosynthesis. [2 marks]

7 Describe the production of water and carbon dioxide from the interaction between methane and oxygen using a word equation. [1 mark]

Deduce that atoms of reactant substances are rearranged during chemical reactions to produce new substances

8 A neighbour says that she is going to get rid of a large pile of combustible rubbish by burning it. Describe whether the rubbish has really disappeared after burning. Explain any scientific principle that supports your answer. [2 marks]

9 Describe how you know that a chemical reaction has occurred. [1 mark]

Classify compounds based on common chemical properties

10 Identify two key differences between ionic and molecular compounds. [2 marks]

11 Compare the nature and properties of acids and bases. [2 marks]

3 CHAPTER REVIEW

12 A student, when asked about antacids to stop indigestion and acid reflux, suggested that the best way to improve the action and reaction time of the antacids is to use a concentrated base. Explain why this would not be a practical solution. [2 marks]

Identify the importance of the chemical reactions involved in photosynthesis, respiration and digestion

13 A man with indigestion takes two indigestion tablets. He then belches a large burp. Describe why this probably happened and what the nature of the gas probably was. [2 marks]

14 Explain why digestion is mostly about chemical reactions that produce small molecules such as glucose, to provide cells with energy through respiration. [2 marks]

15 Plants through the photosynthesis reaction take up carbon dioxide and release oxygen. Animals and plants through respiration consume oxygen and produce carbon dioxide. Carbon dioxide is much lower in concentration at less than 0.04% of the atmosphere than oxygen at 21%. Predict what would happen to these concentrations if the amount of photosynthesis occurring was significantly reduced. [2 marks]

Investigate the characteristics of the main types of chemical reactions including combustion, reactions between acids and metals and carbonates, corrosion, precipitation, neutralisation and decomposition

16 Neutralisation reactions always produce water. Explain why. [2 marks]

17 Identify a key feature that would enable you to classify a reaction as being a:

a combustion reaction [1 mark]

b precipitation reaction [1 mark]

c decomposition reaction [1 mark]

d acid and metal reaction. [1 mark]

Balance chemical equations (additional content)

18 Balance the following chemical reactions:

a ___Zn + ___ HCl → ___ $ZnCl_2$ + ___ H_2 [2 marks]

b ___ $C_{10}H_8$ + ___ O_2 → ___ CO_2 + ___ H_2O [2 marks]

TOTAL MARKS
[/42]

RESEARCH

Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

Phosphoric acid

Phosphoric acid has a wide variety of uses – as a fertiliser, rust remover and food additive. It is even an ingredient of cola drinks. Describe how it is produced and identify more about its uses.

pH of blood

Identify the name given to the conditions in which the pH of blood becomes too low or too high, and the effects on people who have these conditions.

Explosives

The history of the development of explosives is fascinating. Identify who discovered them. When were explosives first used? How do they work? Describe the main chemicals used and their types. Outline the part Alfred Nobel played.

Reflect

Me

1 What new science laboratory skills have you learned in this chapter?

2 What was the most surprising thing that you found out about chemical reactions?

3 What were the most difficult aspects of this topic, and why?

My world

4 Why is it important to know about chemical reactions?

5 What changes have the products of chemical reactions made to how we live?

6 What are the risks of using some chemicals?

My future

7 How are chemists trying to minimise the negative effect of some chemicals on the natural environment?

8 What more can be done to ensure the sustainable use of certain chemicals?

Key words

acidic oxide
acid
aerobic
alkaline
alkali
anaerobic
base
chemical equation
chemical formula
combustion
corrosion
decomposition
displacement
fuel
hydrocarbon
indicator
law of conservation of mass
litmus paper
neutral
neutralisation
respiration
pH scale
precipitate
precipitation
photosynthesis
salt
universal indicator
word equation

3

MAKING CONNECTIONS

Iron and steel

Steel, which is an alloy of iron, is produced in vast quantities from iron ore. Australia is the second biggest producer of iron ore in the world. Steelworks such as the Port Kembla steelworks in New South Wales generate huge amounts of steel from this ore, although Australia exports most of its supplies of iron ore. The origin of iron dates back to the beginning of the Earth.

When it was a molten ball hurtling through space, the early Earth contained vast amounts of molten iron, as well as oxygen. The atoms of these elements rearranged in spontaneous reactions and produced oxides of iron such as ferric oxide (or iron(III) oxide, Fe_2O_3). The reaction to form iron(III) oxide is:

iron + oxygen → iron oxide

$4Fe_{(l)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$

As the crust cooled, the minerals such as iron oxide were embedded in rocks in various crystalline arrangements. Iron oxide is not soluble and, in some areas, including vast regions of Australia, these minerals became concentrated in the rocks.

The first metals used by humans that were not simply dug out of the ground, included alloys of copper and iron. No doubt their discovery was accidental. As people sat around their fires at night, in some places they noticed molten metal trickling out of the rocks. Some thought the rocks were 'bleeding'. The metal was extracted from certain minerals present in the rocks by exposing them to high temperatures and hot charcoal. Before long, when people realised the metals were very useful materials, they started to build furnaces to obtain more metal.

When European settlers in Australia brought their knowledge of how to extract iron from rocks, and when iron-rich rocks with their red–brown colour were discovered, our iron and steel industry was born.

The extraction of iron from its oxide involves separating the iron and oxygen atoms from one another, reversing the reactions that formed the iron oxides in the first place.

Generally, iron is extracted from its oxides in a huge furnace known as a blast furnace. Given that we are trying to remove oxygen from iron, not oxidise it, why do we need all this hot air?

Consider four chemical reactions that occur in the blast furnace. One of the raw materials added to the blast furnace, along with crushed iron oxide (Fe_2O_3), is coke, which is mostly carbon (C). The coke undergoes a combustion reaction with the hot air.

Reaction 1

carbon + oxygen → carbon dioxide

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

This is a highly exothermic (produces lots of heat) reaction. It produces enough heat to help break down the iron ore.

Another raw material added to the furnace is limestone, which is mostly calcium carbonate ($CaCO_3$). As it gets very hot, it breaks down.

Reaction 2

calcium carbonate → calcium oxide + carbon dioxide

$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

This is a decomposition reaction. The calcium oxide produced in this process helps to remove some of the other materials contained in the iron ore by reacting with them. The carbon dioxide reacts with some of the coke to produce carbon monoxide (CO).

Figure 3.42 Iron ore.

Figure 3.43 Steel is produced in huge blast furnaces.

Reaction 3

carbon + carbon dioxide → carbon monoxide

$C_{(s)} + CO_{2(g)} \rightarrow 2CO_{(g)}$

The carbon monoxide then reacts with the iron ore and takes the oxygen.

Reaction 4

carbon monoxide + iron oxide → iron + carbon dioxide

$$3CO_{(g)} + Fe_2O_{3(s)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

Objects made from steel will often rust as the iron reacts with oxygen in the air to form iron(III) oxide. This reaction occurs more quickly in the presence of water because the water helps the oxygen atoms (which dissolves into the water) and the atoms of iron to be in contact so that there is a greater chance of a reaction occurring.

There are a number of ways that we can prevent items made from iron or steel from corroding and forming rust. Tin cans are, in fact, tin-plated steel. Being a less reactive metal than iron, the tin coating is like paint, helping protect the iron from corrosion. So that the tin sticks properly to it, the steel used must be very clean. If a can is dropped and dented, the tin coating may crack and expose the iron inside to corrosion.

Figure 3.44 Tin cans are steel cans plated with tin to help protect the steel from corroding.

The problem is that when hot steel is produced, it reacts with the air and produces a surface coating of iron(III) oxide, or rust. This is insoluble in water, so it can't be simply washed off. But it is a basic oxide, so it will react with acid. The reaction is:

iron(III) oxide + sulfuric acid → iron(III) sulfate + water

$$Fe_2O_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2O$$

So, the steel sheeting is dipped into a tank of sulfuric acid on its way to the cell in which it is plated with tin.

Your turn

Create a poster, animation, video or other presentation format that explains one or more aspects of the above information about iron and steel. Consider using graphic representations of the atoms and reactions and including labels and other notes. You may need to do some further research. Remember to cite all your resources, including any images you may use, in a bibliography.

Overmatter from pg 111

a common name as well as a scientific name (see Table 3.2).