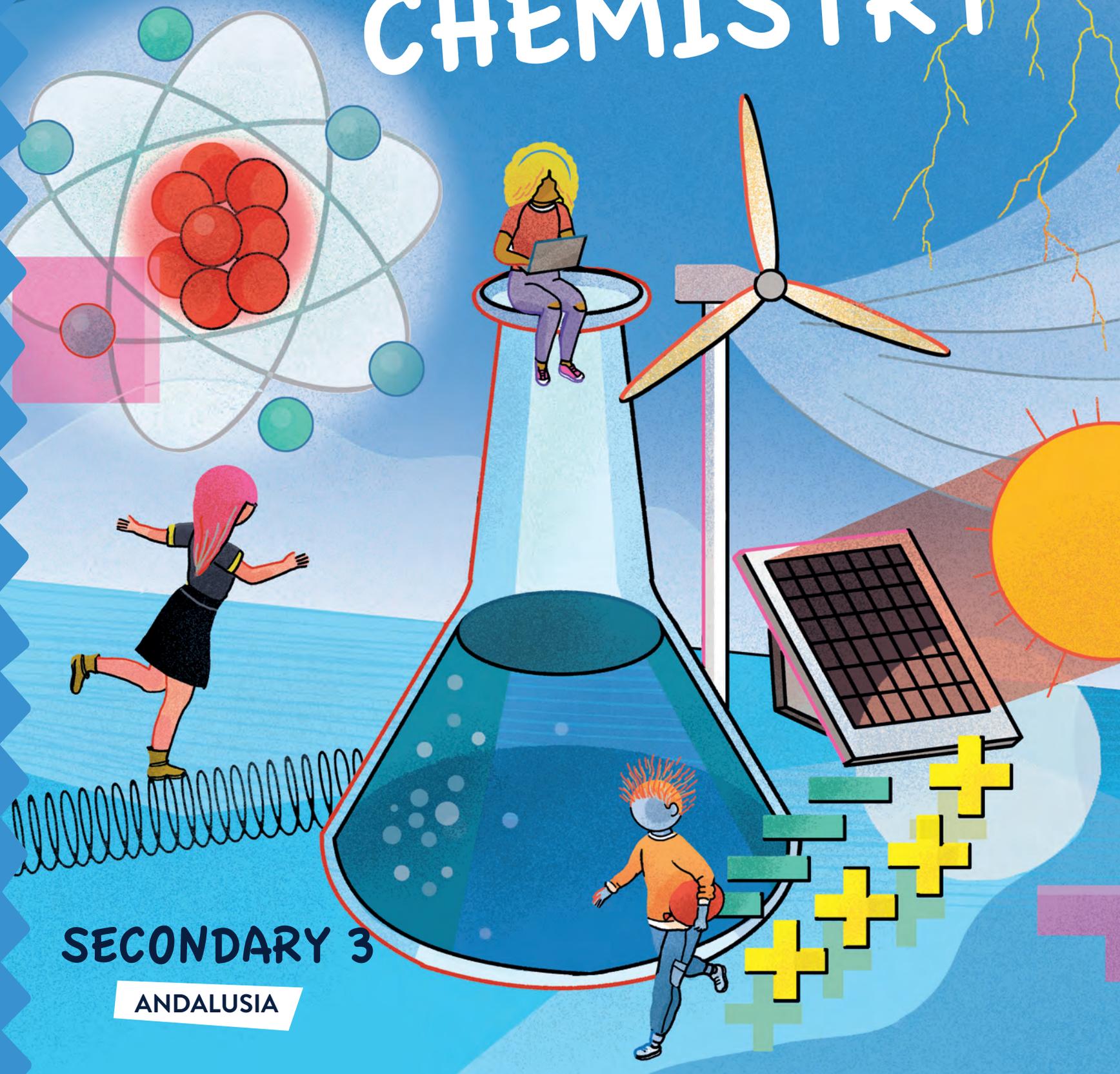




CORE

PHYSICS AND CHEMISTRY



SECONDARY 3

ANDALUSIA

1 Changes in matter: chemical reactions

¹Chemical composition:

arrangement, type and ratio of atoms in molecules of a substance.

²**Chemical bond:** strong force of attraction between ions, atoms or molecules, that enable the formation compounds.

³**Compound:** substance formed by two or more atoms chemically bonded in fixed proportions.



Changes in matter happen around you every day. In a **physical** change, the composition of the initial matter does not change. A **chemical reaction** results in a chemical change. This means the initial substances are transformed into new ones, with a different **chemical composition**¹.

A chemical reaction involves breaking or making bonds between particles (atoms, molecules or ions), which forms a new substance.

Mixture of iron and sulphur

Atoms of iron Atoms of sulphur

Iron sulphide (FeS)

If we mix iron filings (Fe) with sulphur (S), no chemical reaction occurs. The iron and sulphur retain their properties because **chemical bonds**² aren't created between them.

However, if we heat the mixture, each Fe atom binds to an S atom. A new **compound**³, iron sulphide (FeS), is formed with different properties from those of iron and sulphur.

The initial substances are the **reactants** and the new substances that are formed by a chemical reaction are the **products**. The product is the result of the **rearrangement** of atoms, molecules or ions.

We represent chemical reactions using **chemical equations**. A chemical equation includes the initial substances and the final products. We can also indicate the physical state of the substances: solid (s), liquid (l), gas (g) and aqueous solution (aq).

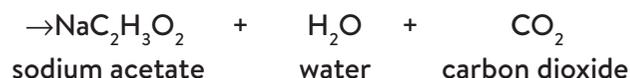
Reactants		Products	
Iron + sulphur	→	Iron sulphide	
Fe + S	→	FeS	

CLIL activities

- 1 🗨️ In your notebook, draw a table with at least three physical and three chemical changes. Then share your table with a classmate.

... is an example of a physical/chemical change because...

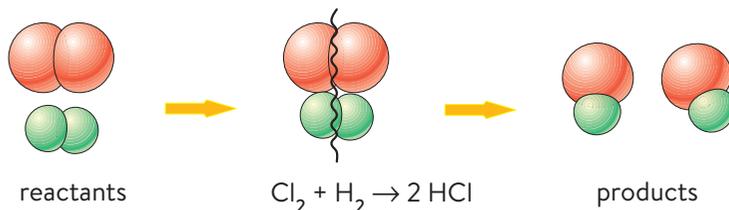
- 2 🧠 Mix baking soda (NaHCO_3) and vinegar (HCH_3COO). Describe the observations that provide evidence that a chemical reaction has taken place?



- 3 🎧 Listen to the scientist talking about two everyday chemical reactions. Take notes about the reactions and identify the reactants and products.

2 The organisation of atoms and collision theory

Look at this diagram. The bonds of the substances that form the **reactants**, Cl_2 and H_2 , are broken and the atoms are rearranged, forming new bonds in a new substance: the **product** is HCl .

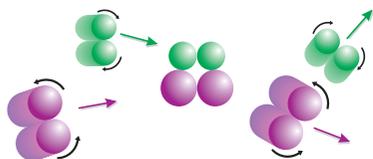


Which chemical bonds have been broken? Which ones have been formed?

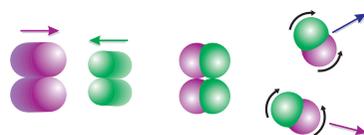
effective collision: collision that results in the formation of a new product.

Collision theory explains how reactions happen and why they happen at different speeds. The theory assumes that for a chemical reaction to occur, reacting particles must **collide** with one another. However, not all collisions produce chemical changes. **Effective collisions**¹ only happen when both of these conditions are met:

- The reactants must have **enough energy**. The minimum amount of energy needed for an effective collision to take place is called **activation energy**.
- The reactants must collide with the **proper orientation** to allow the necessary rearrangement of atoms, molecules or ions for the formation of new substances.



Here, the orientation does not allow contact between the atoms that will become bonded together in the product: no reaction.



Here, the orientation allows contact between the atoms that will become bonded together: chemical reaction.

After an effective collision, a new distribution of the atoms of the reactants takes place, which forms the products of the reaction.

CLIL activities

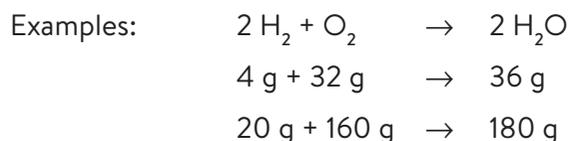
- Copy the sentences in your notebook. Write *true* or *false*. Correct the false sentences.
 - For a chemical reaction to occur, the reactant particles must collide with some energy.
 - For a chemical reaction to occur, the particles can collide in any way.
 - If the particles of the reactants collide effectively, new bonds in the products are formed.
- In pairs, make a one-minute presentation to explain why iron filings and sulphur only react when heated, to form iron sulphide, using collision theory.
- Listen to the description of the reaction $\text{Mg} + 2 \text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$. Then in your own words, describe the electrolysis of water: the decomposition of water into oxygen and hydrogen gas due to an electric current being passed through water: $2 \text{H}_2\text{O}_{(l)} \rightarrow 2 \text{H}_{2(g)} + \text{O}_{2(g)}$. Indicate the bonds that break and the new bonds that are created.

3 The law of the conservation of mass

closed system: system where no reactants or products can escape, only heat can be exchanged freely.

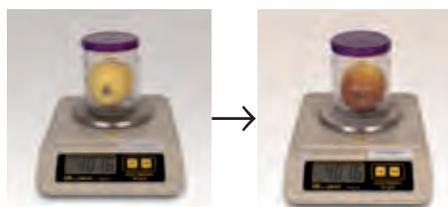
In a **closed system**¹, the sum of the masses of the reactants equals the sum of the masses of the end products. This is known as **law of conservation of mass** or **Lavoisier's Law**.

In a chemical reaction, there is a reorganization of the atoms from the reactants to the products. Neither the type of atoms nor their number change. Therefore, the initial mass is the same as the final mass.



the sum of the reactant masses = the sum of the product masses

We put an apple in a tightly closed jar and weigh it. After a few days, the apple has turned brown. A chemical reaction has taken place.



- Look at the photos. Is the mass the same in both?
- What would happen if we kept the jar open?

The fruit has turned brown because substances in them react with oxygen in the air. Now there is less oxygen and more carbon dioxide and other gases. This reaction is called oxidation.

For years, the French scientist Antoine Lavoisier burned, cut up, melted and boiled every possible substance. He showed that as long as you are very careful about collecting the substances created in a transformation, then the mass of the reactants does not change.

GLIL activities

- 7 Calcium reacts with oxygen in the air to give calcium oxide (quicklime). Copy the table in your notebook and calculate x , y and z applying the law of the conservation of mass.

Experiment	Mass of calcium (g)	Mass of oxygen (g)	Mass of calcium oxide (g)
1	8	3.2	z
2	4	y	5.6
3	x	0.8	2.8

- 8 We weigh a candle before and after lighting it and observe that, after burning, the mass of the candle has decreased.
- Is the law of conservation of mass not fulfilled?
 - We repeat the experience but now in a covered container. On this occasion, the scales indicates the same mass as before combustion. What do you think has happened?
- 9 Listen to this documentary about the French scientist Antoine Lavoisier. Explain the results of the two experiments described by the narrator. Write the chemical equations of the reactions.

4 The law of definite proportions

We cause a reaction between different amounts of sulphur and different amounts of copper, and obtain the following results:



Experiment	Sulphur mass (g)	Copper mass (g)	Copper sulphide mass (g)	Remaining sulphur mass (g)	Remaining copper mass (g)
1	0.25	1.00	1.25	0	0
2	0.25	1.15	1.25	0	0.15
3	0.75	3.00	3.75	0	0

Note that in all three experiments the mass stays the same. But in Experiment 2, there is some remaining copper. What do you think happened? Could it be that substances always react in a certain proportion?

We calculate the ratio of copper mass / sulphur mass of reactants in Experiments 1 and 3, where there is no remaining material. The ratio is constant:

$$\frac{\text{copper mass}}{\text{sulphur mass}} = \frac{1.00}{0.25} = \frac{3.00}{0.75} = 4$$

In Experiment 2, 0.15 g of copper is left over because only 0.25 g of sulphur reacts with 1.00 g of copper.

The reactants in a chemical reaction that produce a given compound will always react in fixed proportions. This is known as **the law of definite proportions**.

CLIL activities

10 In your notebook, write the correct answer to the question.

What is the law of definite proportions?

- The different atoms in a compound are always in the same proportions.
- There are always the same proportions of elements on the earth.
- The proportion of the atoms in the reactant compounds is the same as in the products.

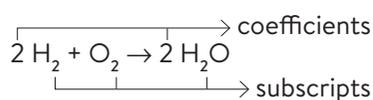
11 When we heat 56 g of iron and 32 g of sulphur, we obtain 88 g of iron sulphide. How much iron sulphide will we obtain if we heat 150 g of iron and 64 g of sulphur?

12  In carbon monoxide (CO), 12 parts by mass of carbon combine with 16 parts by mass of oxygen. Listen to the students describing this reaction and correct the mistakes.

5 Chemical equations

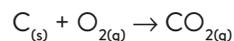
coefficients: necessary numbers in front of the formulas of the substances so that the law of the conservation of mass is fulfilled at atomic scale.

To balance an equation, we can modify the **coefficients**¹, of the formulas, but never the subscripts of the formulas, as it would mean modifying the substances.



Natural gas

Carbon dioxide is obtained in the combustion reaction of carbon with oxygen in the air:

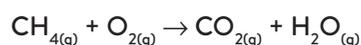


Note that the number of atoms of each class (oxygen and carbon) on both sides of the equation is preserved.

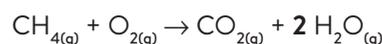
In a **chemical reaction**, atoms are neither destroyed nor created. When we represent a chemical reaction using a **chemical equation**, there must be the same number of atoms of each element on both sides of the equation. When this condition is met, we say that the chemical equation is **balanced**.

Balancing a chemical equation

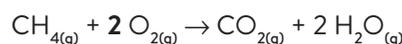
Balance the chemical equation for the combustion of methane (CH₄), the major component of natural gas.



1. C is adjusted: there is one C atom in each side of the equation.
2. There are four H atoms in the reactants and only two in the products: we add a **2** in front of the water formula.



3. Now there are four oxygen atoms on the right and only two on the left; we add a coefficient that equals the O atoms.



4. And finally, we confirm that all the elements have been balanced.

CLIL activities

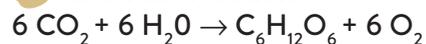
- 13 In your notebook, balance the chemical equations.

- $2 \text{Na}_{(s)} + 2 \text{O}_{2(g)} \rightarrow \text{Na}_2\text{O}_{2(s)}$
- $\text{H}_{2(g)} + 2 \text{Cl}_{2(g)} \rightarrow 2 \text{HCl}_{(g)}$
- $2 \text{Ca}_{(s)} + \text{O}_{2(g)} \rightarrow 2 \text{CaO}_{(s)}$
- $\text{Al}_{(s)} + \text{Br}_{(l)} \rightarrow \text{AlBr}_{3(s)}$

- 14 Listen to a teacher explaining how to balance chemical equations. Copy and complete the sentences.

- To balance a chemical equation, we can change the but never the
- We will have a balanced equation if the total number of of a given element is the same on both sides of the equation.

- 15 Given the reaction:



Discuss with a classmate to find out the following items:

- List the products and reactants.
- What does the arrow represent?
- How many atoms of oxygen are on the product side?
- How many atoms of hydrogen are on the reactant side?
- Is the equation balanced?
- What are the coefficients of the reaction?
- What is the difference between 2 O and O₂? Use this example to explain why subscripts in a formula must not be changed.

6 Stoichiometry: calculating reactants and products in chemical reactions

A balanced equation of a chemical reaction indicates the **proportions** of the substances that participate in the reaction. As we know the masses of the individual atoms, we can calculate the masses of the substances involved in a reaction.

Stoichiometry is the part of chemistry that studies the amounts of substances that are involved in a chemical reaction using balanced chemical equations.

Using stoichiometry, calculate how many grams of NaOH will be required to fully react with 3.10 grams of H_2SO_4 in the (unbalanced!) chemical reaction $\text{NaOH}_{(\text{aq})} + \text{H}_2\text{SO}_{4(\text{aq})} \rightarrow \text{H}_2\text{O} + \text{Na}_2\text{SO}_{4(\text{aq})}$

Molar mass¹ of H_2SO_4 = 98.09 g/mol

Molar mass of NaOH = 40.0 g/mol

1. Reactants and products are identified.	Reactant $\text{Fe}_2\text{O}_3, \text{Al}$	Products $\text{Fe}, \text{Al}_2\text{O}_3$
2. Balance the equation by adding the coefficients.	$2 \text{NaOH}_{(\text{aq})} + \text{H}_2\text{SO}_{4(\text{aq})} \rightarrow 2 \text{H}_2\text{O} + \text{Na}_2\text{SO}_{4(\text{aq})}$	
3. Information provided by this chemical equation.	2 moles ² of NaOH reacts with 1 mol of H_2SO_4 to give 2 moles of H_2O and 1 mole of Na_2SO_4	
4. The proportion between the quantities is established.	$\frac{2 \text{ moles of NaOH} \times 40.0 \text{ g/mol}}{1 \text{ mol of H}_2\text{SO}_4 \times 98.09 \text{ g/mol}} = 0.816$ Every gram of H_2SO_4 reacts with 0.816 g of NaOH	
5. The amount of substance in mol can then be calculated.	3.10 g of H_2SO_4 will react with $3.10 \times 0.816 = 0.58$ g of NaOH	

¹mole: the SI unit of measurement used to measure the number of atoms or molecules.

²molar mass: weight, in grams, of a mole.

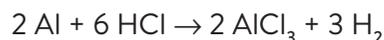
Atomic mass: the mass of an individual atom. It is shown in the periodic table and we can use it to calculate the mass of compounds.



The word **stoichiometry** comes from the Greek words *stoicheion* (meaning 'element') and *metron* (meaning 'measure') and so altogether it means 'measuring elements.'

CLIL activities

- 16** In your notebook, calculate the mass of hydrogen formed when 27 g of aluminium reacts with excess hydrochloric acid (HCl) according to the equation:



Molar masses: Al: 26.98 g/mol; H: 1.01 g/mol;
Cl: 35.45 g/mol)

- 17** Discuss with a classmate why it is important to balance a chemical equation? Use these words in your answer:

reactants products coefficients atoms (or molecules) law of conservation of mass

- 18** Listen to the scientist and answer the questions.
- Why is stoichiometry important?
 - What is the most important unit in chemistry and why?

7 Reaction rates

¹**rust:** red-brown substance that forms when iron reacts with water and oxygen.

²**concentration:** amount of a constituent divided by the total volume of a mixture.

³**catalyst:** substance that speeds up a chemical reaction, but is still present when the reaction has finished. Catalysts aren't reactants because they aren't changed by the reaction.

Catalytic converters in car exhausts use a precious metal, such as platinum, as a catalyst. This enables nitrogen oxide to react with toxic gases, such as carbon monoxide, to form carbon dioxide and nitrogen gases, which are less harmful.

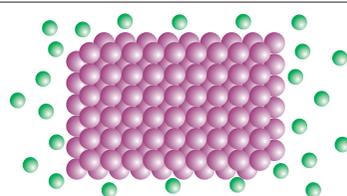
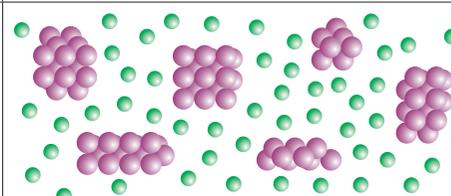
Explosions are chemical reactions that take place very quickly. In contrast, chemical reactions responsible for **rust**¹ on iron are very slow.

The **reaction rate** is a measure of how quickly a chemical reaction occurs. We measure it in units of time by observing the disappearance of a reactant or the appearance of a product.

The rate or speed of a chemical reaction depends on the number and efficiency of the collisions between the reactant particles. These can be affected by several factors:

1. Concentration: The speed of a reaction increases if the **concentration**² of the reactants increases. More reactants, more particles and, therefore, the higher the number of collisions, which will speed up the reaction.

2. Contact surface: The reaction rate increases when the contact surface between the reactants is increased. The greater the surface, the higher the number of collisions.

Magnesium tape Smaller exposed surface	Magnesium powder Greater exposed surface
	
Hydrochloric acid molecules can only collide with the magnesium atoms of the outermost layer of the tape.	Hydrochloric acid molecules can collide with many more powdered magnesium atoms.

3. Temperature: The reaction rate increases at higher temperatures. Heating a substance adds energy to its particles so that they move more rapidly and collide more frequently and more efficiently.

Catalysts³ can also alter the reaction rates. **Enzymes** are proteins in living things that act as catalysts. Enzymes in the human body help to digest the food you eat more quickly. Enzymes in fruit cause oxidation.

CLIL activities

19 Copy the sentences in your notebook. Write *true* or *false*. Correct the false sentences.

- A chemical reaction always takes place at the same speed.
- More collisions always imply higher reaction rate.
- The reaction rate depends on the efficiency of the collisions.
- We can increase the reaction rate by modifying the number and efficiency of collisions.

20 Discuss with a classmate why we refrigerate food; and why we should cover an apple with aluminium foil when we cut it in half.

21 Listen to the group of campers trying to make a campfire. Answer the questions.

- What do they do to make the fire burn faster?
- Which of the factors that influence the reaction rate do they use?

8 The chemical industry

Almost all the products you use every day are made by **chemical reactions**, from cosmetics to concrete, plastics to paper, glass to graphite, stainless steel to shampoo, fibre to food additives, margarine to medicines and many, many more.

The chemical industry is dedicated to transforming **natural materials** into **synthetic materials** that are used to make useful **products** for consumption.

Synthetic materials are made by chemically changing raw materials to create a **material** with different characteristics.



Examples		
Natural Materials	Synthetic Materials	Products
Iron ore	Steel	Machinery, tools...
Petroleum	Plastics, fuels...	Detergents, cosmetics, plastic finished articles, solvents...
Air, water	Ammonia	Fertilizer...

Metals, paper and ceramics have been used for thousands of years. But **plastics**¹ have been around for less than 100 years. Plastics are synthetic (manufactured) materials that can be easily moulded into shape.

Most plastics are the products of chemical reactions with crude oil.

The scientists and engineers who develop new plastics for the spacesuits that allow astronauts to walk in space need a good knowledge of chemistry to create materials that are strong, light and heat resistant.

CLIL activities

22 In your notebook, classify these products according to whether they come from synthetic or natural materials:

- plastic bottle
- table salt
- woollen hat
- petrol
- scissors
- wooden shelf

23 Choose one of the materials below and find out how it is manufactured. Write a report about the chemical reactions used in its production.

- glass
- paper
- nylon
- margarine

24 Listen to the news report and answer the questions.

- Why do we need to manufacture new materials to substitute plastics?
- What is the strongest biomaterial not manufactured by humans?

'plastic': from the Greek word *plastikos* meaning 'able to be shaped.'



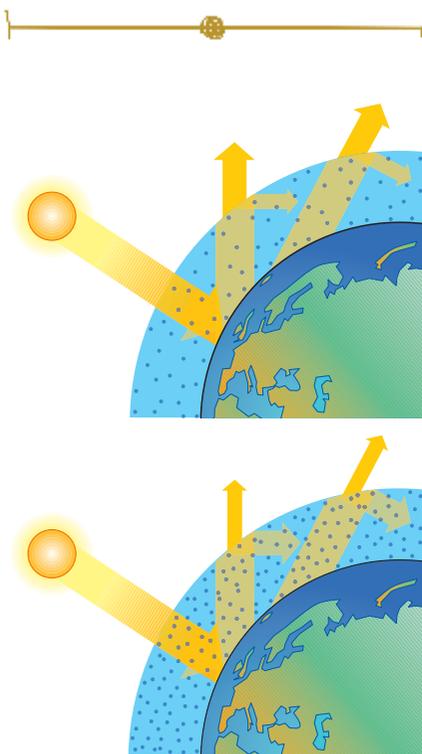
Synthetic chemistry plays an important role in the research and development of medicines.

9 Protecting the environment

¹fossil fuels: natural fuels such as coal or oil, formed over millions of years from the remains of living organisms. In a combustion reaction, they produce heat, carbon dioxide and water vapour.

²CFCs: chlorofluorocarbons, type of gas composed of carbon, fluorine and chlorine that damages the ozone layer.

³corrosive: destroying metal or other materials by a chemical reaction.



The greenhouse effect

	Global warming	Depletion of the ozone layer, O ₃	Acid rain
Cause	Use of fossil fuels ¹ to generate energy.	Use of aerosols and refrigerants.	Use of fossil fuels (transport and power generation).
Substances involved	Greenhouse gases , such as methane, (CH ₄) or carbon dioxide (CO ₂), produced by burning fossil fuels.	CFCs ² , gases present in old aerosols and refrigerants.	Sulphur oxides (SO _x) Nitrogen oxides (NO _x).
Chemical process and consequences	The Greenhouse effect: greenhouse gases, such as methane (CH ₄) or carbon dioxide (CO ₂), collect in the atmosphere and absorb solar radiation from the Earth's surface that would normally escape into space. They trap the heat and the temperature of the Earth rises. The rise in temperatures causes droughts and extreme weather events, changes in rainfall patterns and flooding in coastal areas as sea levels rise.	In the upper atmosphere, CFCs generate chlorine gas, Cl ₂ . This separates into very reactive individual chlorine atoms, which transform ozone molecules into oxygen (O ₂). By losing ozone, ultraviolet rays pass through the atmosphere, which can cause cancer, the destruction of crops and vegetation and decrease life in the oceans.	SO _x and NO _x react with water vapour in the atmosphere and generate sulphuric and nitric acids: $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$ $\text{N}_2\text{O}_5 + \text{H}_2\text{O} \rightarrow 2 \text{HNO}_3$ These substances are extremely corrosive ³ and produce acid rain that destroys forests, crops and harms living things in aquatic environments. It can also cause damage to monuments and buildings.
Preventive measures	Rational use of transport and heating. Reforestation to absorb additional CO ₂ . Change in the energy and transport model.	Eliminate the use of CFCs.	Reduce emissions of sulphur and nitrogen oxides into the atmosphere. Avoid the combustion of fossil fuels.

CLIL activities

25 In your notebook, explain why these actions are affecting the natural greenhouse effect:

- burning coal, oil and gas
- cutting down forests (deforestation)
- using aerosols

26 Work with a classmate. Make a list of four non-renewable and four renewable energy sources and explain how we get energy from them.

27 Listen to the student presentation. Answer the questions.

- Why is the ozone layer important?
- Which substance destroys the ozone layer?
- According to the UN, when will the hole in ozone layer in the Northern Hemisphere close completely?