

Chapter 1: Atomic structure

Knowledge organiser

Development of the model of the atom

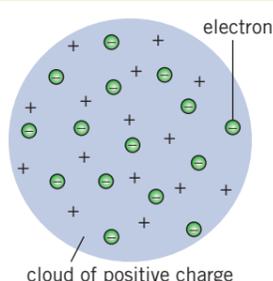
Dalton's model

John Dalton thought of the **atom** as a solid sphere that could not be divided into smaller parts. His model did not include **protons**, **neutrons**, or **electrons**.

The plum pudding model

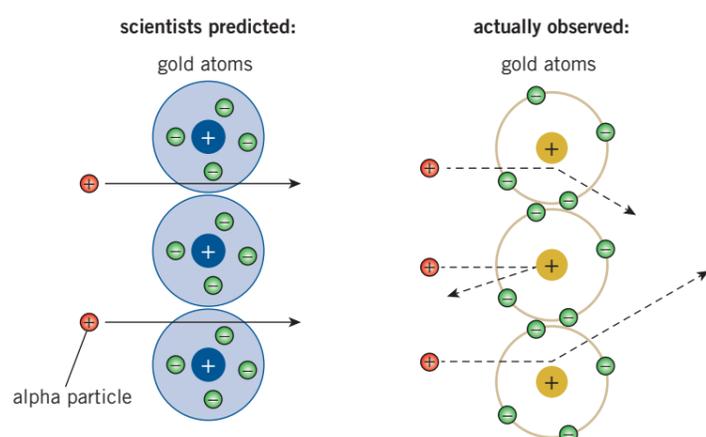
Scientists' experiments resulted in the discovery of sub-atomic charged particles. The first to be discovered were electrons – tiny, negatively charged particles.

The discovery of electrons led to the plum pudding model of the atom – a cloud of positive charge, with negative electrons embedded in it. Protons and neutrons had not yet been discovered.



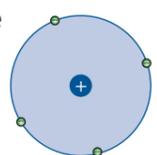
Alpha scattering experiment

- 1 Scientists fired small, positively charged particles (called alpha particles) at a piece of gold foil only a few atoms thick.
- 2 They expected the alpha particles to travel straight through the gold.
- 3 They were surprised that some of the alpha particles bounced back and many were deflected (alpha scattering).
- 4 To explain why the alpha particles were repelled the scientists suggested that the positive charge and mass of an atom must be concentrated in a small space at its centre. They called this space the **nucleus**.



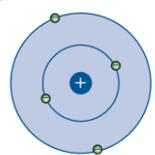
Nuclear model

Scientists replaced the plum pudding model with the nuclear model and suggested that the electrons **orbit** the nucleus, but not at set distances.



Electron shell (Bohr) model

Niels Bohr calculated that electrons must orbit the nucleus at fixed distances. These orbits are called **shells** or **energy levels**.



The proton

Further experiments provided evidence that the nucleus contained smaller particles called protons. A proton has an opposite charge to an electron.

Size

The atom has a radius of 1×10^{-10} m. Nuclei (plural of nucleus) are around 10000 times smaller than atoms and have a radius of around 1×10^{-14} m.

Relative mass

One property of protons, neutrons, and electrons is **relative mass** – their masses compared to each other. Protons and neutrons have the same mass, so are given a relative mass of 1. It takes almost 2000 electrons to equal the mass of a single proton – their relative mass is so small that we can consider it as 0.

The neutron

James Chadwick carried out experiments that gave evidence for a particle with no charge. Scientists called this the neutron and concluded that the protons and neutrons are in the nucleus, and the electrons orbit the nucleus in shells.

Elements and compounds

Elements are substances made of one type of atom. Each atom of an element will have the same number of protons.

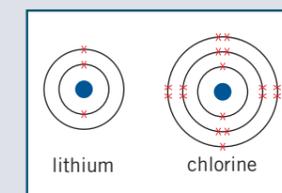
Compounds are made of different types of atoms chemically bonded together. The atoms in a compound have different numbers of protons.

Drawing atoms

Electrons in an atom are placed in fixed shells. You can put

- up to two electrons in the first shell
- eight electrons each in the second and third shells.

You must fill up a shell before moving on to the next one.



Mixtures

- A mixture consists of two or more elements or compounds that are not chemically combined together.
- The substances in a mixture can be separated using physical processes.
- These processes do not use chemical reactions.

Separating mixtures

- filtration – insoluble solids and a liquid
- crystallisation – soluble solid from a solution
- simple distillation – solvent from a solution
- fractional distillation – two liquids with similar boiling points
- paper chromatography – identify substances from a mixture in solution

Atoms and particles

	Relative charge	Relative mass	
Proton	+1	1	= atomic number
Neutron	0	1	= mass number – atomic number
Electron	-1	0 (very small)	= same as the number of protons

All atoms have equal numbers of protons and electrons, meaning they have no overall charge:

$$\text{total negative charge from electrons} = \text{total positive charge from protons}$$

Isotopes

Atoms of the same element can have a different number of neutrons, giving them a different overall mass number. Atoms of the same element with different numbers of neutrons are called **isotopes**.

The **relative atomic mass** is the average mass of all the atoms of an element:

$$\text{relative atomic mass} = \frac{(\text{abundance of isotope 1} \times \text{mass of isotope 1}) + (\text{abundance of isotope 2} \times \text{mass of isotope 2}) \dots}{100}$$

Key terms

Make sure you can write a definition for these key terms.

abundance atom atomic number aqueous compound electron
 element energy level isotope neutron nucleus orbit
 product proton reactant relative atomic mass
 relative charge relative mass shell

Chapter 1: Atomic structure

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C1 questions

Answers

1	What is an atom?	Put paper here	smallest part of an element that can exist
2	What is Dalton's model of the atom?	Put paper here	atoms as solid spheres that could not be divided into smaller parts
3	What is the plum pudding model of the atom?	Put paper here	sphere of positive charge with negative electrons embedded in it
4	What did scientists discover in the alpha scattering experiment?	Put paper here	some alpha particles were deflected by the gold foil – this showed that an atom's mass and positive charge must be concentrated in one small space (the nucleus)
5	Describe the nuclear model of the atom.	Put paper here	dense nucleus with electrons orbiting it
6	What did Niels Bohr discover?	Put paper here	electrons orbit in fixed energy levels (shells)
7	What did James Chadwick discover?	Put paper here	uncharged particle called the neutron
8	Where are protons and neutrons?	Put paper here	in the nucleus
9	What is the relative mass of each sub-atomic particle?	Put paper here	proton: 1, neutron: 1, electron: 0 (very small)
10	What is the relative charge of each sub-atomic particle?	Put paper here	proton: +1, neutron: 0, electron: -1
11	How can you find out the number of protons in an atom?	Put paper here	the atomic number on the Periodic Table
12	How can you calculate the number of neutrons in an atom?	Put paper here	mass number – atomic number
13	Why do atoms have no overall charge?	Put paper here	equal numbers of positive protons and negative electrons
14	How many electrons would you place in the first, second, and third shells?	Put paper here	up to 2 in the first shell and up to 8 in the second and third shells
15	What is an element?	Put paper here	substance made of one type of atom
16	What is a compound?	Put paper here	substance made of more than one type of atom chemically joined together
17	What is a mixture?	Put paper here	two or more substances not chemically combined
18	What are isotopes?	Put paper here	atoms of the same element (same number of protons) with different numbers of neutrons
19	What are the four physical processes that can be used to separate mixtures?	Put paper here	filtration, crystallisation, distillation, fractional distillation, chromatography
20	What is relative mass?	Put paper here	the average mass of all the atoms of an element

Chapter 1: Atomic structure

Knowledge organiser

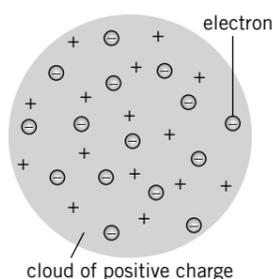
Development of the model of the atom

Dalton's model

John Dalton thought of the _____ as a solid sphere that could not be divided into smaller parts. His model did not include _____, _____, or _____.

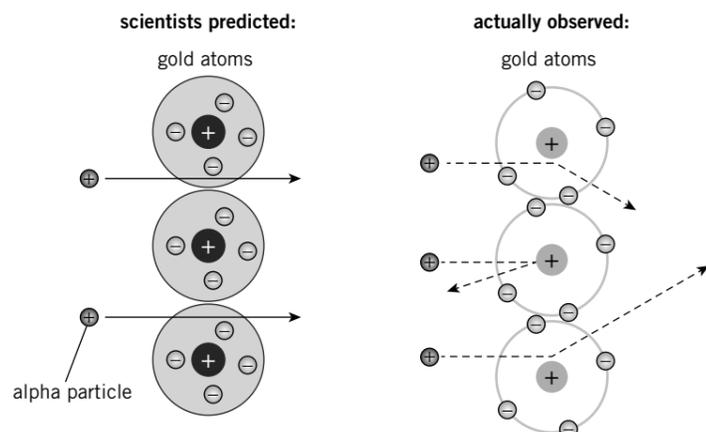
The plum pudding model

Scientists' experiments resulted in the discovery of sub-atomic _____ particles. The first to be discovered were electrons – tiny, _____ charged particles. The discovery of electrons led to the _____ of the atom – a cloud of _____ charge, with negative _____ embedded in it. _____ and _____ had not yet been discovered.



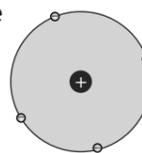
Alpha scattering experiment

- 1 Scientists fired small, _____ charged particles (called _____ particles) at a piece of _____ foil only a few atoms thick.
- 2 They expected the alpha particles to travel _____ through the gold.
- 3 They were surprised that some of the alpha particles _____ back and many were _____ (alpha scattering).
- 4 To explain why the alpha particles were repelled the scientists suggested that the positive charge and mass of an atom must be concentrated in a small space at its centre. They called this space the _____.



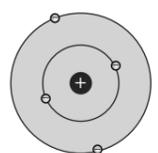
Nuclear model

Scientists replaced the plum pudding model with the nuclear model and suggested that the electrons _____ the nucleus, but not at set _____.



Electron shell (Bohr) model

Niels Bohr calculated that electrons must orbit the nucleus at fixed distances. These orbits are called _____ or _____.



The proton

Further experiments provided evidence that the nucleus contained smaller particles called _____. A proton has an _____ charge to an electron.

Size

The atom has a radius of _____. _____ (plural of nucleus) are around _____ times smaller than atoms and have a radius of around _____.

Relative mass

One property of protons, neutrons, and electrons is _____ – their masses compared to each other. Protons and neutrons have the same mass, so are given a relative mass of _____. It takes almost _____ electrons to equal the mass of a single proton – their relative mass is so small that we can consider it as _____.

The neutron

James Chadwick carried out experiments that gave evidence for a particle with no charge. Scientists called this the _____ and concluded that the _____ and _____ are in the nucleus, and the electrons orbit the nucleus in _____.

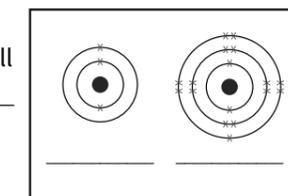
Elements and compounds

Elements are substances made of one type of atom. Each atom of an element will have the same number of _____. _____ are made of different types of atoms chemically _____ together. The atoms in a compound have _____ numbers of protons.

Drawing atoms

Electrons in an atom are placed in fixed shells. You can put _____ up to _____ electrons in the first shell _____ eight electrons each in the _____ and _____ shells. You must fill up a shell before moving on to the next one.

Name the elements



Mixtures

- A mixture consists of _____ elements or compounds that are not _____ combined together.
- The substances in a mixture can be _____ using physical processes.
- These processes do not use _____ reactions.

Separating mixtures

- _____ – insoluble solids and a liquid
- _____ – soluble solid from a solution
- _____ – solvent from a solution
- _____ – two liquids with similar boiling points
- _____ – identify substances from a mixture in solution

Atoms and particles

	Relative charge	Relative mass	
Proton			= _____ number
Neutron			= _____ number – _____ number
Electron			= same as the number of _____

All atoms have _____ numbers of protons and electrons, meaning they have _____ overall charge:
total negative charge from electrons = total positive charge from protons

Isotopes

Atoms of the same element can have a different number of _____, giving them a different overall _____. Atoms of the same element with _____ numbers of neutrons are called **isotopes**.

The **relative atomic mass** is the average _____ of all the atoms of an element:

$$\text{relative atomic mass} = \frac{(\text{abundance of isotope 1} \times \text{mass of isotope 1}) + (\text{abundance of isotope 2} \times \text{mass of isotope 2}) \dots}{100}$$

Key terms

Make sure you can write a definition for these key terms.

abundance atom atomic number aqueous compound electron
 element energy level isotope neutron nucleus orbit
 product proton reactant relative atomic mass
 relative charge relative mass shell

Chapter 1: Atomic structure

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C1 questions

Answers

- | C1 questions | Answers |
|--|---------|
| 1 What is an atom? | |
| 2 What is Dalton's model of the atom? | |
| 3 What is the plum pudding model of the atom? | |
| 4 What did scientists discover in the alpha scattering experiment? | |
| 5 Describe the nuclear model of the atom. | |
| 6 What did Niels Bohr discover? | |
| 7 What did James Chadwick discover? | |
| 8 Where are protons and neutrons? | |
| 9 What is the relative mass of each sub-atomic particle? | |
| 10 What is the relative charge of each sub-atomic particle? | |
| 11 How can you find out the number of protons in an atom? | |
| 12 How can you calculate the number of neutrons in an atom? | |
| 13 Why do atoms have no overall charge? | |
| 14 How many electrons would you place in the first, second, and third shells? | |
| 15 What is an element? | |
| 16 What is a compound? | |
| 17 What is a mixture? | |
| 18 What are isotopes? | |
| 19 What are the four physical processes that can be used to separate mixtures? | |
| 20 What is relative mass? | |

Chapter 2: The Periodic Table

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C2 questions

Answers

1	How is the modern Periodic Table ordered?	Put paper here	by atomic number
2	How were the early lists of elements ordered?	Put paper here	by atomic mass
3	Why did Mendeleev swap the order of some elements?	Put paper here	to group them by their chemical properties
4	Why did Mendeleev leave gaps in his Periodic Table?	Put paper here	leave room for elements that had not yet been discovered
5	Why do elements in a group have similar chemical properties?	Put paper here	have the same number of electrons in their outer shell
6	Where are metals and non-metals located on the Periodic Table?	Put paper here	metals to the left, non-metals to the right
7	What name is given to the Group 1 elements?	Put paper here	alkali metals
8	Why are the alkali metals named this?	Put paper here	they are metals that react with water to form an alkali metal + oxygen → metal oxide
9	Give the general equations for the reactions of alkali metals with oxygen, chlorine, and water.	Put paper here	metal + chlorine → metal chloride metal + water → metal hydroxide + hydrogen
10	How does the reactivity of the alkali metals change down the group?	Put paper here	increases (more reactive)
11	Why does the reactivity of the alkali metals increase down the group?	Put paper here	they are larger atoms, so the outermost electron is further from the nucleus, meaning there are weaker electrostatic forces of attraction and more shielding between the nucleus and outer electron, and it is easier to lose the electron
12	What name is given to the Group 7 elements?	Put paper here	halogens
13	Give the formulae of the first four halogens.	Put paper here	F ₂ , Cl ₂ , Br ₂ , I ₂
14	How do the melting points of the halogens change down the group?	Put paper here	increase (higher melting point)
15	How does the reactivity of the halogens change down the group?	Put paper here	decrease (less reactive)
16	Why does the reactivity of the halogens decrease down the group?	Put paper here	they are larger atoms, so the outermost shell is further from the nucleus, meaning there are weaker electrostatic forces of attraction and more shielding between the nucleus and outer shell, and it is harder to gain an electron
17	What is a displacement reaction?	Put paper here	when a more reactive element takes the place of a less reactive one in a compound
18	What name is given to the Group 0 elements?	Put paper here	noble gases
19	Why are the noble gases inert?	Put paper here	they have full outer shells so do not need to lose or gain electrons
20	How do the melting points of the noble gases change down the group?	Put paper here	increase (higher melting point)

Chapter 2: The Periodic Table

Knowledge organiser

Development of the Periodic Table

The Periodic Table has changed over time as scientists have organised it differently. Mendeleev was able to accurately predict the properties of undiscovered elements based on the gaps in the table.

	First lists of elements	Mendeleev's Periodic Table	Modern Periodic Table
How are elements ordered?			
Are there gaps?			
How are elements grouped?			
Metals and non-metals			
Problems			

Group 1 elements

Group 1 elements react with oxygen, chlorine, and water, for example:

lithium + oxygen \rightarrow _____
 lithium + chlorine \rightarrow _____
 lithium + water \rightarrow _____ + _____

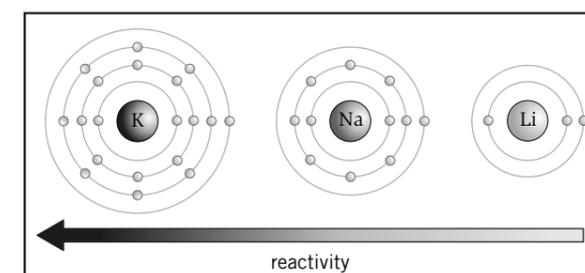
Group 1 elements are called _____ because they react with water to form an alkali (a solution of their metal hydroxide).

Group 1 properties

Group 1 elements all have _____ electron in their outer shell.

Reactivity _____ down Group 1 because as you move down the group:

- the atoms _____ in size
- the outer electron is further away from the nucleus, and there are more shells _____ the outer electron from the nucleus
- the _____ attraction between the nucleus and the outer electron is _____ so it is easier to lose the one _____ electron
- the melting point and boiling point _____ down Group 1.

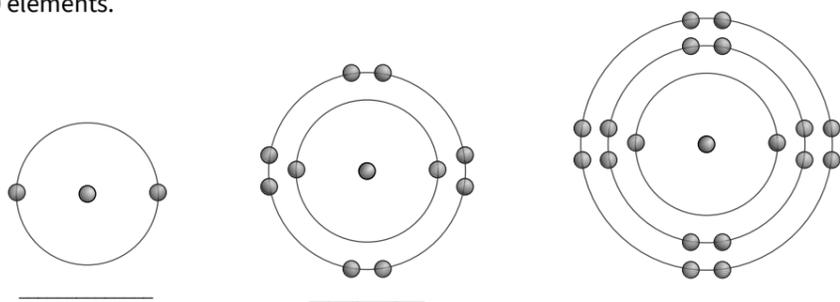


Group 0

Elements in **Group 0** are called the _____. They have the following properties:

- full outer shells with _____ electrons, so do not need to _____ or _____ electrons
- are very _____ so exist as single atoms as they do not bond to form molecules
- boiling points that _____ down the group.

Name the group 0 elements.



Key terms

Make sure you can write a definition for these key terms.

alkali metals chemical properties displacement groups halogens inert isotopes
 noble gas organised Periodic Table reactivity undiscovered unreactive

Group 7 elements

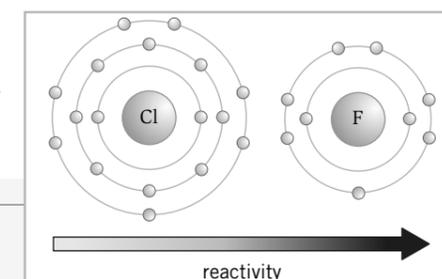
Group 7 elements are called the _____. They are non-metals that exist as molecules made up of _____ of atoms.

Name	Formula	State at room temperature	Melting point and boiling point	Reactivity
fluorine				
chlorine				
bromine				
iodine				

Group 7 reactivity

Reactivity decreases down Group 7 because as you move down the group:

- the atoms _____ in size
- the outer shell is further away from the nucleus, and there are more _____ between the nucleus and the outer shell
- the electrostatic attraction from the nucleus to the outer shell is _____ so it is harder to _____ one electron to fill the outer shell.



Group 7 displacement

More reactive Group 7 elements can take the place of less reactive ones in a compound. This is called _____.

For example, fluorine displaces chlorine as it is more _____:

fluorine + potassium chloride \rightarrow _____ + _____

Chapter 2: The Periodic Table

Retrieval questions

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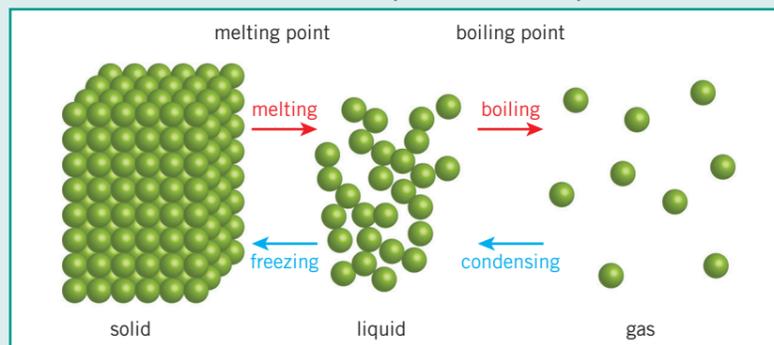
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12 What name is given to the Group 7 elements?	
13 Give the formulae of the first four halogens.	
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16 Why does the reactivity of the halogens decrease down the group?	
17 What is a displacement reaction?	
18 What name is given to the Group 0 elements?	
19 Why are the noble gases inert?	
20 How do the melting points of the noble gases change down the group?	

Chapter 3: Bonding 1

Knowledge organiser

Particle model

The three states of matter can be represented in the particle model.



(HT only) This model assumes that:

- there are no forces between the particles
- that all particles in a substance are spherical
- that the spheres are solid.

The amount of energy needed to change the state of a substance depends on the forces between the particles. The stronger the forces between the particles, the higher the melting or boiling point of the substance.

Covalent bonding

Atoms can share or transfer electrons to form strong chemical bonds.

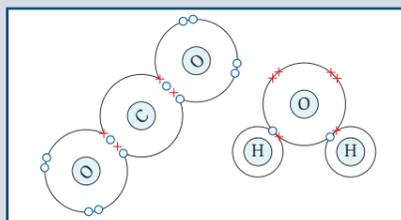
A **covalent bond** is when electrons are *shared* between **non-metal** atoms.

The number of electrons shared depends on how many extra electrons an atom needs to make a full outer shell.

If you include electrons that are shared between atoms, each atom has a full outer shell.

Single bond = each atom shares one pair of electrons.

Double bond = each atom shares two pairs of electrons.



Covalent structures

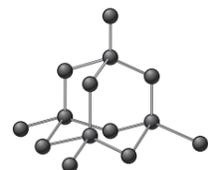
There are three main types of covalent structure:

Structure and bonding

Giant covalent

Many billions of atoms, each one with a strong covalent bond to a number of others.

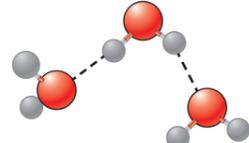
An example of a giant covalent structure is diamond.



Small molecules

Each molecule contains only a few atoms with strong covalent bonds between these atoms. Different molecules are held together by weak **intermolecular forces**.

For example, water is made of small molecules.



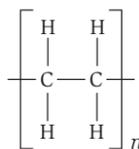
Large molecules

Many repeating units joined by covalent bonds to form a chain.

The small section is bonded to many identical sections to the left and right. The 'n' represents a large number.

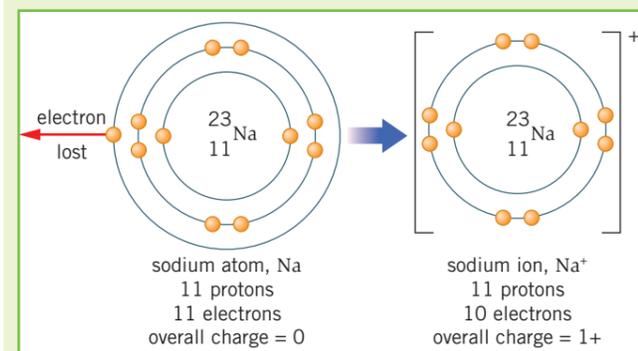
Separate chains are held together by intermolecular forces that are stronger than in small molecules.

Polymers are examples of long molecules.



Ions

Atoms can gain or lose electrons to give them a full outer shell. The number of protons is then different from the number of electrons. The resulting particle has a charge and is called an **ion**.



Conductivity

Solid ionic substances do not conduct electricity because the ions are fixed in position and not free to carry charge.

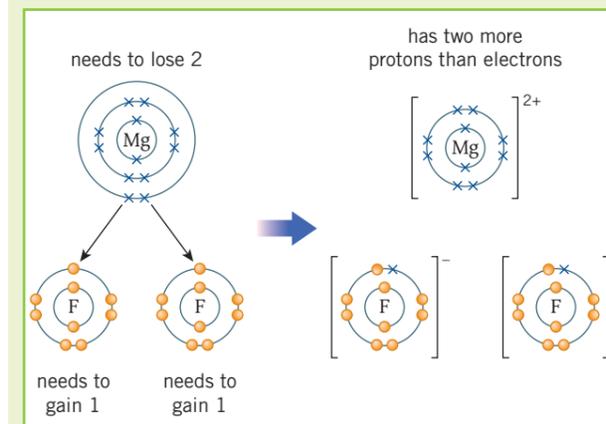
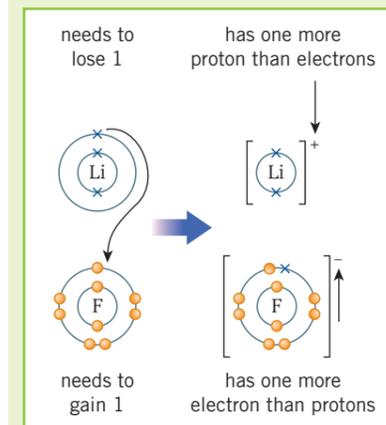
When melted or dissolved in water, ionic substances do conduct electricity because the ions are free to move and carry charge.

Melting points

Ionic substances have high melting points because the electrostatic force of attraction between oppositely charged ions is strong and so requires lots of energy to break.

Ionic bonding

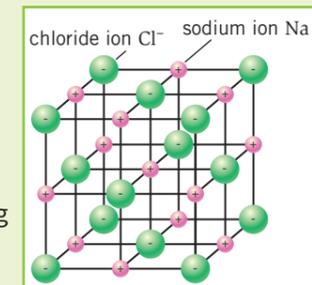
When metal atoms react with non-metal atoms they **transfer** electrons to the non-metal atom.



Metal atoms lose electrons to become positive ions. Non-metal atoms gain electrons to become negative ions.

Giant ionic lattice

When metal atoms transfer electrons to non-metal atoms you end up with positive and negative ions. These are attracted to each other by the strong **electrostatic force of attraction**. This is called ionic bonding.

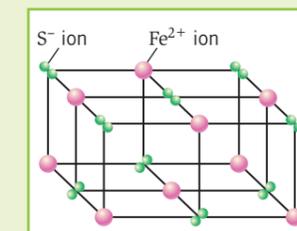


The electrostatic force of attraction works in all directions, so many billions of ions can be bonded together in a 3D structure.

Formulae

The formula of an ionic substance can be worked out

- 1 from its bonding diagram:
for every one magnesium ion there are two fluoride ions – so the formula for magnesium fluoride is MgF_2
- 2 from a lattice diagram:
there are nine Fe^{2+} ions and 18 S^{2-} ions – simplifying this ratio gives a formula of FeS_2



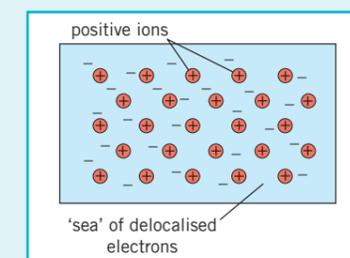
Metals: structure and properties

The atoms that make up metals form layers. The electrons in the outer shells of the atoms are **delocalised** – this means they are free to move through the whole structure.

The positive metal ions are then attracted to these delocalised electrons by the electrostatic force of attraction.

Some important properties of metals are:

- pure metals are **malleable** because the layers can slide over each other
- they are good **conductors** of electricity and of thermal energy because delocalised electrons are free to move through the whole structure
- they have high melting and boiling points because the electrostatic force of attraction between metal ions and delocalised electrons is strong so lots of energy is needed to break it.



Chapter 3: Bonding 2

Knowledge organiser

Properties

High melting and boiling points because the strong covalent bonds between the atoms must be broken to melt or boil the substances.

This requires a lot of energy.
Solid at room temperature.

Low melting and boiling points because only the intermolecular forces need to be overcome to melt or boil the substances, not the bonds between the atoms.

This does not require a lot of energy as the intermolecular forces are weak.

Normally gaseous or liquid at room temperature.

Melting and boiling points are low compared to giant covalent substances but higher than for small molecules.

Large molecules have stronger intermolecular forces than small molecules, which require more energy to overcome.

Normally solid at room temperature.

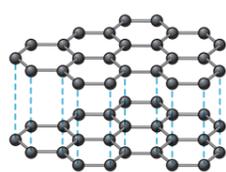
Most covalent structures do not conduct electricity because they do not have **delocalised electrons** or ions that are free to move to carry charge.

Graphite

Graphite is a giant covalent structure, but is different to other giant covalent substances.

Structure

Made only of carbon – each carbon atom bonds to three others, and forms hexagonal rings in layers. Each carbon atom has one spare electron, which is delocalised and therefore free to move around the structure.



Hardness

The layers can slide over each other because they are not covalently bonded. Graphite is therefore softer than diamond, even though both are made only of carbon, as each atom in diamond has four strong covalent bonds.

Conductivity

The delocalised electrons are free to move through graphite, so can carry charges and allow an electrical current to flow. Graphite is therefore a conductor of electricity.

Graphene

Graphene consists of only a single layer of graphite. Its strong covalent bonds make it a strong material that can also conduct electricity. It could be used in composites and high-tech electronics.

Fullerenes

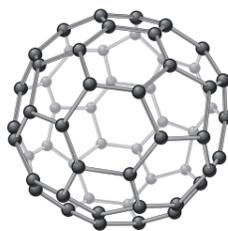
- hollow cages of carbon atoms bonded together in one molecule
- can be arranged as a sphere or a tube (called a **nanotube**)
- molecules held together by weak intermolecular forces, so can slide over each other
- conduct electricity

Spheres

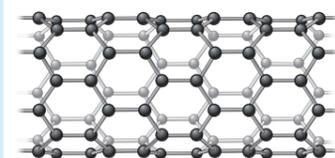
Buckminsterfullerene was the first fullerene to be discovered, and has 60 carbon atoms.

Other fullerenes exist with different numbers of carbon atoms arranged in rings that form hollow shapes.

Fullerenes like this can be used as lubricants and in drug delivery.



Nanotubes



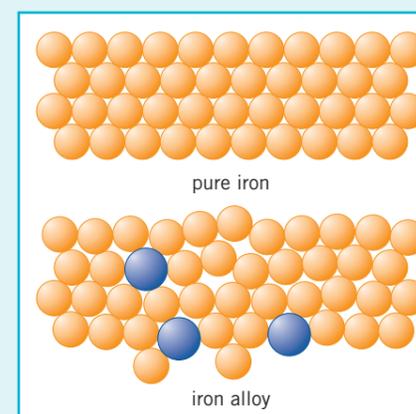
The carbon atoms in nanotubes are arranged in cylindrical tubes.

Their high **tensile strength** (they are difficult to break when pulled) makes them useful in electronics.

Alloys

Pure metals are often too soft to use as they are. Adding atoms of a different element to the pure metal's atoms. This will disturb the regular arrangement of the layers, preventing them from sliding over each other.

The harder mixture is called an **alloy**.



Measuring particles

We use different units and scales to measure the size of particles.

Particle	Particulate matter	Size	Standard form	Full form
grain of sand	N/A	0.1 mm	1×10^{-4} m	0.0001 m
coarse particles (e.g., dust)	PM ₁₀	10 μ m	1×10^{-5} m	0.00001 m
fine particles	PM _{2.5}	100 nm	1×10^{-7} m	0.0000001 m
nanoparticles	< PM _{2.5}	1 to 100 nm	1×10^{-9} to 1×10^{-7} m	0.000000001 m to 0.0000001 m

PM stands for **particulate matter** and is another way of measuring very small particles.

Uses of nanoparticles

Nanoparticles often have very different properties to bulk materials of the same substance, caused by their high surface area-to-volume-ratio.

Nanoparticles have many uses and are an important area of research. They are used in healthcare, electronics, cosmetics, and as catalysts.

However, nanoparticles have the potential to be hazardous to health and to ecosystems, so it is important that they are researched further.

Key terms

Make sure you can write a definition for these key terms.

conductivity conductor delocalised electron electrostatic force of attraction
ion lattice layer malleable nanoparticle particulate matter
surface area to volume ratio transfer

Chapter 3: Bonding

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C3 questions

Answers

1	How are covalent bonds formed?	by atoms sharing electrons
2	Which type of atoms form covalent bonds between them?	non-metals
3	Describe the structure and bonding of a giant covalent substance.	billions of atoms bonded together by strong covalent bonds
4	Describe the structure and bonding of small molecules.	small numbers of atoms group together into molecules with strong covalent bonds between the atoms and weak intermolecular forces between the molecules
5	Describe the structure and bonding of polymers.	many identical molecules joined together by strong covalent bonds in a long chain, with weak intermolecular forces between the chains
6	Why do giant covalent substances have high melting points?	it takes a lot of energy to break the strong covalent bonds between the atoms
7	Why do small molecules have low melting points?	only a small amount of energy is needed to break the weak intermolecular forces
8	Why do large molecules have higher melting and boiling points than small molecules?	the intermolecular forces are stronger in large molecules
9	Why do most covalent substances not conduct electricity?	do not have delocalised electrons or ions
10	Describe the structure and bonding in graphite.	each carbon atom is bonded to three others in hexagonal rings arranged in layers – it has delocalised electrons and weak forces between the layers
11	Why can graphite conduct electricity?	the delocalised electrons can move through the graphite
12	Explain why graphite is soft.	layers are not bonded so can slide over each other
13	What is graphene?	one layer of graphite
14	Give two properties of graphene.	strong, conducts electricity
15	What is a fullerene?	hollow cage of carbon atoms arranged as a sphere or a tube
16	What is a nanotube?	hollow cylinder of carbon atoms
17	Give two properties of nanotubes.	high tensile strength, conduct electricity
18	Give three uses of fullerenes.	lubricants, drug delivery (spheres), high-tech electronics

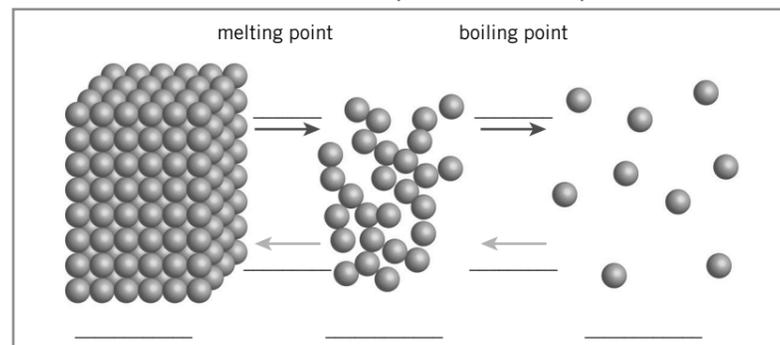
19	What is an ion?	atom that has lost or gained electrons
20	Which kinds of elements form ionic bonds?	metals and non-metals
21	What charges do ions from Groups 1 and 2 form?	Group 1 forms 1+, Group 2 forms 2+
22	What charges do ions from Groups 6 and 7 form?	Group 6 forms 2-, Group 7 forms 1-
23	Name the force that holds oppositely charged ions together.	electrostatic force of attraction
24	Describe the structure of a giant ionic lattice.	regular structure of alternating positive and negative ions, held together by the electrostatic force of attraction
25	Why do ionic substances have high melting points?	electrostatic force of attraction between positive and negative ions is strong and requires lots of energy to break
26	Why don't ionic substances conduct electricity when solid?	ions are fixed in position so cannot move, and there are no delocalised electrons
27	When can ionic substances conduct electricity?	when melted or dissolved
28	Why do ionic substances conduct electricity when melted or dissolved?	ions are free to move and carry charge
29	Describe the structure of a pure metal.	layers of positive metal ions surrounded by delocalised electrons
30	Describe the bonding in a pure metal.	strong electrostatic forces of attraction between metal ions and delocalised electrons
31	What are four properties of pure metals?	malleable, high melting/boiling points, good conductors of electricity, good conductors of thermal energy
32	Explain why pure metals are malleable.	layers can slide over each other easily
33	Explain why metals have high melting and boiling points.	electrostatic force of attraction between positive metal ions and delocalised electrons is strong and requires a lot of energy to break
34	Why are metals good conductors of electricity and of thermal energy?	delocalised electrons are free to move through the metal
35	What is an alloy?	mixture of a metal with atoms of another element
36	Explain why alloys are harder than pure metals.	different sized atoms disturb the layers, preventing them from sliding over each other
37	How big are nanoparticles?	1–100 nm
38	How are nanomaterials different from bulk materials?	nanomaterials have a much higher surface area-to-volume ratio
39	What is the relationship between side length and surface area-to-volume ratio?	as side length decreases by a factor of ten, the surface-area-to-volume ratio increases by a factor of ten
40	What are nanoparticles used for?	used in healthcare, electronics, cosmetics, and catalysts

Chapter 3: Bonding 1

Knowledge organiser

Particle model

The three states of matter can be represented in the particle model.



(HT only) This model assumes that:

-
-
-

The amount of energy needed to change the state of a substance depends on the _____ between the particles. The stronger the _____ between the particles, the _____ the melting or boiling point of the substance.

Covalent bonding

Atoms can _____ or _____ electrons to form strong chemical bonds.

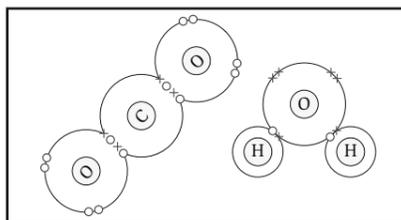
A **covalent bond** is when electrons are _____ between _____ atoms.

The number of electrons shared depends on how many _____ electrons an atom needs to make a full _____.

If you include electrons that are shared between atoms, each atom has a full outer shell.

Single bond = each atom shares _____ pair of electrons.

Double bond = each atom shares _____ pairs of electrons.



Covalent structures

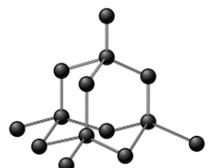
There are three main types of covalent structure:

Structure and bonding

Giant covalent

Many billions of atoms, each one with a _____ covalent bond to a number of others.

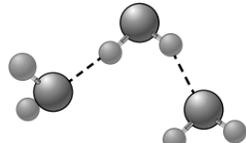
An example of a giant covalent structure is _____.



Small molecules

Each molecule contains only a few atoms with strong covalent bonds between these atoms. Different molecules are held together by weak _____.

For example, _____ is made of small molecules.



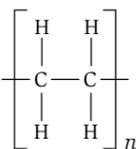
Large molecules

Many repeating units joined by covalent bonds to form a _____.

The small section is bonded to many identical sections to the left and right. The 'n' represents a _____.

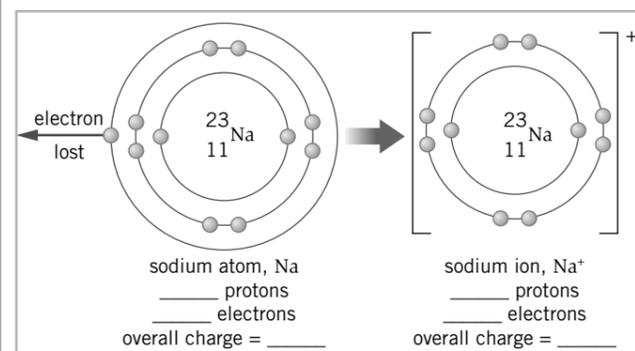
Separate chains are held together by intermolecular forces that are stronger than in _____ molecules.

_____ are examples of long molecules.



Ions

Atoms can _____ or _____ electrons to give them a full outer shell. The number of protons is then different from the number of electrons. The resulting particle has a charge and is called an _____.



Conductivity

Solid ionic substances do not _____ electricity because the ions are fixed in position and not free to carry _____.

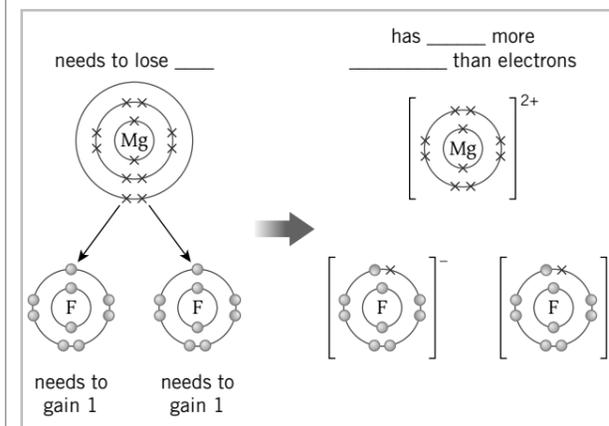
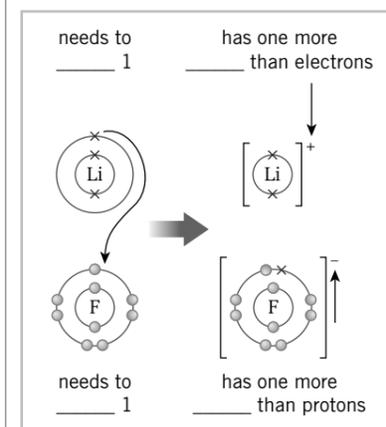
When _____ or _____ in water, ionic substances do _____ electricity because the ions are _____ to move and carry charge.

Melting points

Ionic substances have _____ melting points because the _____ force of attraction between _____ charged ions is strong and so requires lots of _____ to break.

Ionic bonding

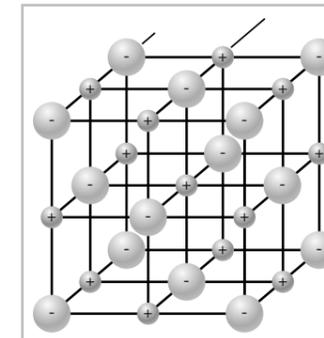
When metal atoms react with non-metal atoms they _____ electrons to the non-metal atom.



Metal atoms _____ electrons to become _____ ions.
Non-metal atoms _____ electrons to become _____ ions.

Giant ionic lattice

When metal atoms _____ electrons to non-metal atoms you end up with _____ and _____ ions. These are attracted to each other by the strong **electrostatic force of attraction**. This is called _____.

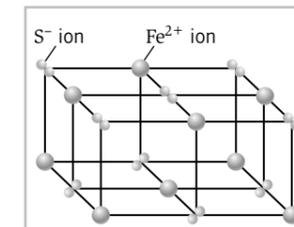


The electrostatic force of attraction works in all _____, so many billions of ions can be bonded together in a _____ structure.

Formulae

The formula of an ionic substance can be worked out

- 1 from its _____:
for every _____ magnesium ion there are _____ fluoride ions – so the formula for magnesium fluoride is MgF₂
- 2 from a _____:
there are nine Fe²⁺ ions and 18 S⁻ ions – simplifying this ratio gives a formula of _____



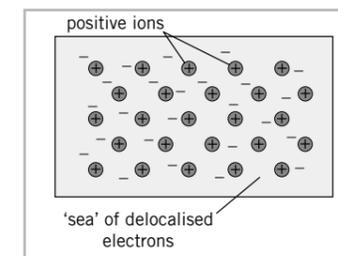
Metals: Structure and properties

The atoms that make up metals form _____. The electrons in the outer shells of the atoms are _____ – this means they are free to move through the _____ structure.

The positive metal ions are then attracted to these delocalised electrons by the _____.

Some important properties of metals are:

-
-
-



Chapter 3: Bonding 2

Knowledge organiser

Properties

High melting and boiling points because the _____ covalent bonds between the atoms must be _____ to melt or boil the substances.

This requires a lot of _____ at room temperature.

_____ melting and boiling points because only the _____ forces need to be overcome to melt or boil the substances, not the _____ between the atoms.

This does not require a lot of energy as the intermolecular forces are _____.

Normally _____ or _____ at room temperature.

Melting and boiling points are _____ compared to giant _____ substances but higher than for small molecules.

Large molecules have _____ intermolecular forces than small molecules, which require more _____ to overcome.

Normally _____ at room temperature.

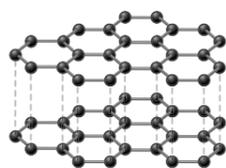
Most covalent structures do not _____ electricity because they do not have _____ or _____ that are free to move to carry charge.

Graphite

Graphite is a giant covalent structure, but is different to other giant covalent substances.

Structure

Made only of _____ - each carbon atom bonds to _____ others, and forms hexagonal rings in _____. Each carbon atom has one _____ electron, which is delocalised and therefore _____ to move around the structure.



Hardness

The layers can _____ over each other because they are not _____ bonded. Graphite is therefore softer than _____, even though both are made only of carbon, as each atom in diamond has _____ strong covalent bonds.

Conductivity

The _____ electrons are free to move through graphite, so can carry charges and allow an electrical current to _____. Graphite is therefore a _____ of electricity.

Graphene

Graphene consists of only a single layer of _____. Its strong covalent bonds make it a _____ material that can also conduct electricity. It could be used in composites and high-tech electronics.

Fullerenes

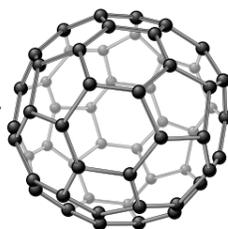
- _____ cages of carbon atoms bonded together in one molecule
- can be arranged as a _____ or a _____ (called a **nanotube**)
- molecules held together by _____ forces, so can slide over each other
- conduct electricity

Spheres

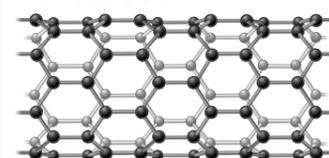
Buckminsterfullerene was the first fullerene to be discovered, and has _____ carbon atoms.

Other fullerenes exist with different numbers of carbon atoms arranged in rings that form hollow shapes.

Fullerenes like this can be used as _____ and in _____.



Nanotubes



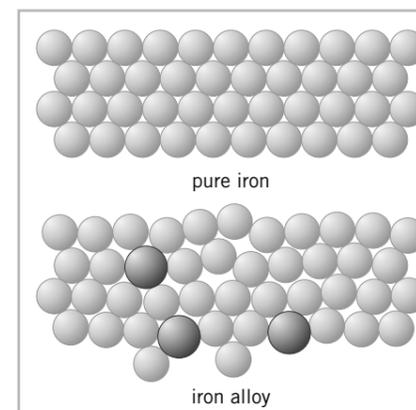
The carbon atoms in nanotubes are arranged in cylindrical tubes.

Their high _____ strength (they are difficult to break when pulled) makes them useful in electronics.

Alloys

Pure metals are often too _____ to use as they are. Adding atoms of a different element can make the resulting mixture _____ because the new atoms will be a different _____ to the pure metal's atoms. This will disturb the _____ arrangement of the layers, preventing them from _____ over each other.

The harder mixture is called an **alloy**.



Measuring particles

We use different units and scales to measure the size of particles.

Particle	Particulate matter	Size	Standard form	Full form
grain of sand	N/A	0.1 mm	1×10^{-4} m	0.0001 m
coarse particles (e.g., dust)	PM ₁₀	10 μ m	1×10^{-5} m	0.00001 m
fine particles	PM _{2.5}	100 nm	1×10^{-7} m	0.0000001 m
nanoparticles	< PM _{2.5}	1 to 100 nm	1×10^{-9} to 1×10^{-7} m	0.000000001 m to 0.0000001 m

PM stands for _____ and is another way of measuring very small particles.

Uses of nanoparticles

Nanoparticles often have very different _____ to bulk materials of the same substance, caused by their high surface area-to-volume-ratio.

Nanoparticles have many uses and are an important area of research. They are used in _____, _____, _____, and as _____.

However, nanoparticles have the potential to be hazardous to health and to _____, so it is important that they are researched further.



Key terms

Make sure you can write a definition for these key terms.

conductivity conductor delocalised electron electrostatic force of attraction
ion lattice layer malleable nanoparticle particulate matter
surface area to volume ratio transfer

Chapter 3: Bonding

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C3 questions

Answers

- 1 How are covalent bonds formed?
- 2 Which type of atoms form covalent bonds between them?
- 3 Describe the structure and bonding of a giant covalent substance.
- 4 Describe the structure and bonding of small molecules.
- 5 Describe the structure and bonding of polymers.
- 6 Why do giant covalent substances have high melting points?
- 7 Why do small molecules have low melting points?
- 8 Why do large molecules have higher melting and boiling points than small molecules?
- 9 Why do most covalent substances not conduct electricity?
- 10 Describe the structure and bonding in graphite.
- 11 Why can graphite conduct electricity?
- 12 Explain why graphite is soft.
- 13 What is graphene?
- 14 Give two properties of graphene.
- 15 What is a fullerene?
- 16 What is a nanotube?
- 17 Give two properties of nanotubes.
- 18 Give three uses of fullerenes.

- 19 What is an ion?
- 20 Which kinds of elements form ionic bonds?
- 21 What charges do ions from Groups 1 and 2 form?
- 22 What charges do ions from Groups 6 and 7 form?
- 23 Name the force that holds oppositely charged ions together.
- 24 Describe the structure of a giant ionic lattice.
- 25 Why do ionic substances have high melting points?
- 26 Why don't ionic substances conduct electricity when solid?
- 27 When can ionic substances conduct electricity?
- 28 Why do ionic substances conduct electricity when melted or dissolved?
- 29 Describe the structure of a pure metal.
- 30 Describe the bonding in a pure metal.
- 31 What are four properties of pure metals?
- 32 Explain why pure metals are malleable.
- 33 Explain why metals have high melting and boiling points.
- 34 Why are metals good conductors of electricity and of thermal energy?
- 35 What is an alloy?
- 36 Explain why alloys are harder than pure metals.
- 37 How big are nanoparticles?
- 38 How are nanomaterials different from bulk materials?
- 39 What is the relationship between side length and surface area-to-volume ratio?
- 40 What are nanoparticles used for?

Chapter 4: Calculations

Knowledge organiser

Formula mass

Every substance has a **formula mass**, M_r .

formula mass $M_r = \text{sum (relative atomic mass of all the atoms in the formula)}$

Avogadro's constant (HT only)

One mole of a substance contains 6.02×10^{23} atoms, ions, or molecules. This is **Avogadro's constant**.

One mole of a substance has the same mass as the M_r of the substance. For example, the M_r (H_2O) = 18, so 18 g of water molecules contains 6.02×10^{23} molecules, and is called one mole of water.

You can write this as: moles = $\frac{\text{mass}}{M_r}$

Theoretical yield

The **theoretical yield** of a chemical reaction is the mass of a product that you expect to be produced.

Even though no atoms are gained or lost during a chemical reaction, it is not always possible to obtain the theoretical yield because

- some of the product can be lost when it is separated from the reaction mixture
- there can be unexpected side reactions between reactants that produce different products
- the reaction may be reversible.

Percentage yield

The **yield** is the amount of product that you actually get in a chemical reaction.

Percentage yield is the actual yield as a proportion of the theoretical yield:

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Atom economy

The **atom economy** of a reaction tells you the proportion of atoms that you started with that are part of *useful* products.

High atom economies are more sustainable, as they mean fewer atoms are being wasted in products that are not useful.

The percentage atom economy is calculated by:

$$\text{atom economy} = \frac{M_r \text{ of useful product}}{M_r \text{ of all products}} \times 100$$

Using balanced equations (HT only)

In a balanced symbol equation the sum of the M_r of the reactants equals the sum of the M_r of the products.

If you are asked what mass of a product will be formed from a given mass of a specific reactant, you can use the steps below to calculate the result.

- 1 balance the symbol equation
- 2 calculate moles of the substance with a known mass using moles = $\frac{\text{mass}}{M_r}$
- 3 using the balanced symbol equation, work out the number of moles of the unknown substance
- 4 calculate the mass of the unknown substance using mass = moles $\times M_r$

If you are asked to balance an equation, you can use the steps below to work out the answer.

- 1 work out M_r of all the substances
- 2 calculate the number of moles of each substance in the reaction using moles = $\frac{\text{mass}}{M_r}$
- 3 convert to a whole number ratio
- 4 balance the symbol equation

Excess and limiting reactants (HT only)

In a chemical reaction between two or more reactants, often one of the reactants will run out before the others. You then have some of the other reactants left over. The reactant that is left over is in **excess**. The reactant that runs out is the **limiting reactant**.

To work out which reactants are in excess and which is the limiting reactant, you need to:

- 1 write the balanced symbol equation for the reaction
- 2 pick one of the reactants and its quantity as given in the question
- 3 use the ratio of the reactants in the balanced equation to see how much of the other reactant you need
- 4 compare this value to the quantity given in the question
- 5 determine which reactant is in excess and which is limiting.

Concentration

Concentration is the amount of solute in a volume of solvent.

The unit of concentration is g/dm^3 .

Concentration can be calculated using:

$$\text{concentration (g/dm}^3\text{)} = \frac{\text{mass (g)}}{\text{volume (dm}^3\text{)}}$$

Sometimes volume is measured in cm^3 :

$$\text{volume (dm}^3\text{)} = \frac{\text{volume (cm}^3\text{)}}{1000}$$

- lots of solute in little solution = high concentration
- little solute in lots of solution = low concentration

Concentration in mol/dm^3

Concentration can also be measured in mol/dm^3 .

$$\text{concentration of solution (mol/dm}^3\text{)} = \frac{\text{number of moles of solute}}{\text{volume of solution (dm}^3\text{)}}$$

You can use this formula and mass = moles $\times M_r$ to calculate the mass of solute dissolved in a solution.

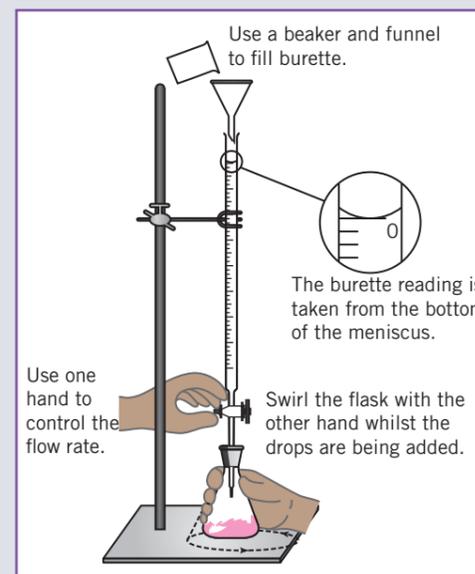
- The greater the mass of solute in solution, the greater the number of moles of solute, and therefore the greater the concentration.
- If the same number moles of solute is dissolved in a smaller volume of solution, the concentration will be greater.

mol is a unit of moles

Titration

Titration is an experimental technique to work out the concentration of an unknown solution in the reaction between an acid and an alkali.

- 1 Use a pipette to extract a known volume of the solution with an unknown concentration. A pipette measures a fixed volume only.
- 2 Add the solution of unknown concentration to a conical flask and put the conical flask on a white tile.
- 3 Add a few drops of a suitable indicator to the conical flask.
- 4 Add the other solution with a known concentration to the burette.
- 5 Carry out a rough titration to find out approximately what volume of solution in the burette needs to be added to the solution in the conical flask. Add the solution from the burette to the solution in the conical flask 1 cm^3 at a time until the end point is reached.
- 6 The end point is when the indicator just changes colour.
- 7 Record the volume of the end point as your rough value.
- 8 Now repeat steps 1–7, but as you approach the end point add the solution from the burette drop-by-drop. Swirl the conical flask in between drops.
- 9 Record the volume of the end point.



Key terms

Make sure you can write a definition for these key terms.

atom economy	burette	concordant	end point
excess reactant	formula mass	limiting reactant	
percentage yield	pipette	room temperature and pressure	
theoretical yield	titration	titre	useful yield

Chapter 4: Calculations

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C4 questions

Answers

1	What is a mole?	mass of a substance that contains 6.02×10^{23} particles
2	Give the value for Avogadro's constant.	6.02×10^{23}
3	Which formula is used to calculate the number of moles from mass and M_r ?	$\text{moles} = \frac{\text{mass}}{M_r}$
4	Which formula is used to calculate the mass of a substance from number of moles and M_r ?	$\text{mass} = \text{moles} \times M_r$
5	What is a limiting reactant?	the reactant that is completely used up in a chemical reaction
6	What is a unit for concentration?	g/dm^3 or mol/dm^3
7	Which formula is used to calculate concentration from mass and volume?	$\text{concentration (g/dm}^3) = \frac{\text{mass (g)}}{\text{volume (dm}^3)}$
8	Which formula is used to calculate volume from concentration and mass?	$\text{volume (dm}^3) = \frac{\text{mass (g)}}{\text{concentration (g/dm}^3)}$
9	Which formula is used to calculate mass from concentration in g/dm^3 and volume?	$\text{mass (g)} = \text{concentration (g/dm}^3) \times \text{volume (dm}^3)$
10	How can you convert a volume reading in cm^3 to dm^3 ?	divide by 1000
11	If the amount of solute in a solution is increased, what happens to its concentration?	increases
12	If the volume of water in a solution is increased, what happens to its concentration?	decreases
13	What is the yield of a reaction?	mass of product obtained from the reaction
14	What is the theoretical yield of a reaction?	maximum mass of the product that could have been produced
15	Why is the actual yield always less than the theoretical yield?	<ul style="list-style-type: none"> reaction may be reversible some of the product can be lost on separation unexpected side reactions between reactants
16	What is the percentage yield?	actual yield as a proportion of theoretical yield
17	How is percentage yield calculated?	$\frac{\text{actual yield}}{\text{theoretical yield}} \times 100$
18	What is atom economy?	measure of how many atoms of the reactants end up as useful products
19	Why is a high atom economy desirable?	results in less waste/is more sustainable
20	How is percentage atom economy calculated?	$\frac{M_r \text{ of useful product}}{M_r \text{ of all products}} \times 100$

21	How can concentration in mol/dm^3 be calculated?	$\frac{\text{moles of solute}}{\text{volume (dm}^3)}$
22	What is a titration?	method used to calculate the concentration of an unknown solution
23	What is the end-point?	the point at which the reaction is complete (when the indicator changes colour) and no substance is in excess
24	How should solution be added from the burette close to the end point?	drop by drop, swirling in between
25	Why is a white tile used in titration?	to see the colour change better
26	What is a titre?	volume of solution added from the burette
27	What volume does one mole of any gas occupy at room temperature and pressure?	24 dm^3 or $24\,000 \text{ cm}^3$

Chapter 4: Calculations

Knowledge organiser

Formula mass

Every substance has a _____, M_r .

$M_r =$ _____

Avogadro's constant (HT only)

One mole of a substance contains _____ atoms, ions, or molecules. This is **Avogadro's constant**.

One mole of a substance has the same _____ as the M_r of the substance. For example, the M_r (H_2O) = _____, so _____ g of water molecules contains _____ molecules, and is called one _____ of water.

You can write this as: moles = _____

Theoretical yield

The **theoretical yield** of a chemical reaction is the mass of a product that you expect to be _____.

Even though no _____ are gained or lost during a chemical reaction, it is not always possible to obtain the theoretical yield because:

-
-
-

Percentage yield

The **yield** is the amount of _____ that you actually get in a chemical reaction.

Percentage yield is the actual yield as a proportion of the theoretical yield:

percentage yield = _____

Atom economy

The **atom economy** of a reaction tells you the _____ of atoms that you started with that are part of _____ products.

High atom economies are more sustainable, as they mean _____ atoms are being wasted in products that are not useful.

The percentage atom economy is calculated by:

atom economy = _____

Using balanced equations (HT only)

In a balanced symbol equation the sum of the M_r of the reactants equals the sum of the M_r of the products.

Write down the steps for how to calculate the mass of a product from a given mass of a specific reactant.

1. _____
2. _____
3. _____
4. _____

Write down the steps for how to balance an equation.

1. _____
2. _____
3. _____
4. _____

Excess and limiting reactants (HT only)

In a chemical reaction between two or more reactants, often one of the reactants will run out before the others. You then have some of the other reactants left over. The reactant that is left over is in _____. The reactant that runs out is the _____.

Write down the steps for working out which reactants are in excess, and which is the limiting reactant.

1. _____
2. _____
3. _____
4. _____
5. _____

Concentration

Concentration is the amount of solute in a _____ of solvent.

The unit of concentration is g/dm^3 . Concentration can be calculated using:

concentration (g/dm^3) = _____

Sometimes volume is measured in cm^3 :

volume (dm^3) = _____

- lots of solute in little solution = _____
- little solute in lots of solution = _____

Concentration in mol/dm^3

Concentration can also be measured in mol/dm^3 .

concentration of solution (mol/dm^3) = _____

You can use this formula and mass = moles $\times M_r$ to calculate _____.

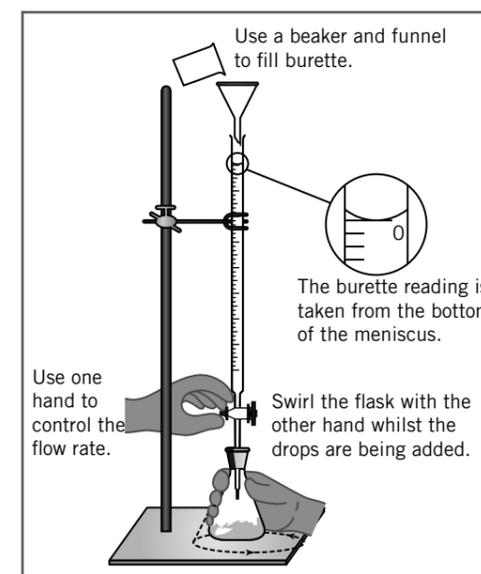
- The greater the mass of solute in solution, the greater the number of _____ of solute, and therefore the greater the _____.
- If the _____ number moles of solute is dissolved in a smaller volume of solution, the concentration will be _____.

mol is a the unit of moles

Titration

Titration is an experimental technique to work out the concentration of an _____ solution in the reaction between an _____ and an _____.

- 1 Use a _____ to extract a known volume of the solution with an unknown concentration. A pipette measures a _____ volume only.
- 2 Add the solution of unknown concentration to a _____ flask and put the conical flask on a white tile.
- 3 Add a few _____ of a suitable indicator to the conical flask.
- 4 Add the other solution with a known concentration to the _____.
- 5 Carry out a rough titration to find out approximately what volume of solution in the burette needs to be added to the solution in the conical flask. Add the solution from the burette to the solution in the conical flask 1 cm^3 at a time until the _____ is reached.
- 6 The _____ is when the indicator just changes _____.
- 7 Record the _____ of the end point as your rough value.
- 8 Now repeat steps 1–7, but as you approach the end point add the solution from the burette drop-by-drop. _____ the conical flask in between drops.
- 9 Record the volume of the end point.



Theoretical yield

The **theoretical yield** of a chemical reaction is the mass of a product that you expect to be _____.

Even though no _____ are gained or lost during a chemical reaction, it is not always possible to obtain the theoretical yield because:

-
-
-

Percentage yield

The **yield** is the amount of _____ that you actually get in a chemical reaction.

Percentage yield is the actual yield as a proportion of the theoretical yield:

percentage yield = _____

Atom economy

The **atom economy** of a reaction tells you the _____ of atoms that you started with that are part of _____ products.

High atom economies are more sustainable, as they mean _____ atoms are being wasted in products that are not useful.

The percentage atom economy is calculated by:

atom economy = _____

Concentration

Concentration is the amount of solute in a _____ of solvent.

The unit of concentration is g/dm^3 . Concentration can be calculated using:

concentration (g/dm^3) = _____

Sometimes volume is measured in cm^3 :

volume (dm^3) = _____

- lots of solute in little solution = _____
- little solute in lots of solution = _____

Concentration in mol/dm^3

Concentration can also be measured in mol/dm^3 .

concentration of solution (mol/dm^3) = _____

You can use this formula and mass = moles $\times M_r$ to calculate _____.

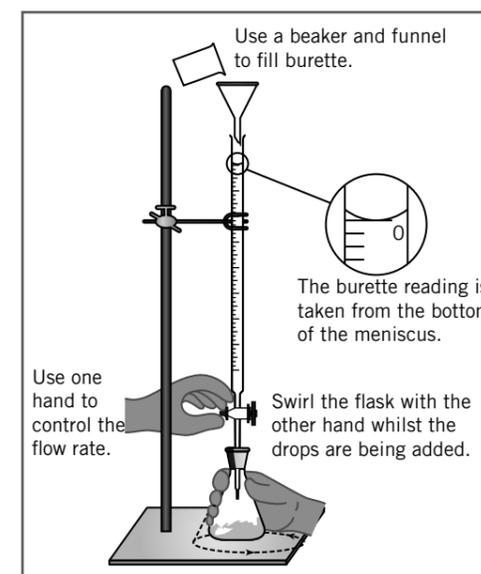
- The greater the mass of solute in solution, the greater the number of _____ of solute, and therefore the greater the _____.
- If the _____ number moles of solute is dissolved in a smaller volume of solution, the concentration will be _____.

mol is a the unit of moles

Titration

Titration is an experimental technique to work out the concentration of an _____ solution in the reaction between an _____ and an _____.

- 1 Use a _____ to extract a known volume of the solution with an unknown concentration. A pipette measures a _____ volume only.
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- 3 Add a few _____ of a suitable indicator to the conical flask.
- 4 Add the other solution with a known concentration to the _____.
- 5 Carry out a rough titration to find out approximately what volume of solution in the burette needs to be added to the solution in the conical flask. Add the solution from the burette to the solution in the conical flask 1 cm^3 at a time until the _____ is reached.
- 6 The _____ is when the indicator just changes _____.
- 7 Record the _____ of the end point as your rough value.
- 8 Now repeat steps 1–7, but as you approach the end point add the solution from the burette drop-by-drop. _____ the conical flask in between drops.
- 9 Record the volume of the end point.



Moles of gases (HT only)

At any given temperature and pressure, the same number of moles of a gas will _____ the same volume.

At room temperature (_____) and pressure (_____), one mole of *any* gas will occupy _____.

To calculate the number of moles of a gas:

$$\begin{aligned} \text{moles of a gas} &= \frac{\text{_____}}{24\text{ dm}^3} \\ \text{or} \\ \text{moles of a gas} &= \frac{\text{_____}}{\text{cm}^3} \end{aligned}$$

Calculating concentration

To calculate the concentration of the unknown solution (the solution in the conical flask):

- 1 Write a _____ for the reaction.
- 2 Calculate the moles used from the known solution using:

moles = _____

- 3 Use the _____ from the balanced symbol equation to deduce the number of moles present in the unknown solution.
- 4 Calculate the concentration of the unknown solution using:

concentration (mol/dm^3) = _____

Key terms

Make sure you can write a definition for these key terms.

atom economy burette concordant end point
excess reactant formula mass limiting reactant
percentage yield pipette room temperature and pressure
theoretical yield titration titre useful yield

Chapter 4: Calculations

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C4 questions

Answers

1	What is a mole?	
2	Give the value for Avogadro's constant.	
3	Which formula is used to calculate the number of moles from mass and M_r ?	
4	Which formula is used to calculate the mass of a substance from number of moles and M_r ?	
5	What is a limiting reactant?	
6	What is a unit for concentration?	
7	Which formula is used to calculate concentration from mass and volume?	
8	Which formula is used to calculate volume from concentration and mass?	
9	Which formula is used to calculate mass from concentration in g/dm^3 and volume?	
10	How can you convert a volume reading in cm^3 to dm^3 ?	
11	If the amount of solute in a solution is increased, what happens to its concentration?	
12	If the volume of water in a solution is increased, what happens to its concentration?	
13	What is the yield of a reaction?	
14	What is the theoretical yield of a reaction?	
15	Why is the actual yield always less than the theoretical yield?	<ul style="list-style-type: none">•••
16	What is the percentage yield?	
17	How is percentage yield calculated?	
18	What is atom economy?	
19	Why is a high atom economy desirable?	
20	How is percentage atom economy calculated?	

21 How can concentration in mol/dm^3 be calculated?

22 What is a titration?

23 What is the end-point?

24 How should solution be added from the burette close to the end point?

25 Why is a white tile used in titration?

26 What is a titre?

27 What volume does one mole of any gas occupy at room temperature and pressure?

Chapter 5: Chemical changes 1

Knowledge organiser

Reactions of metals

The **reactivity** of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have *high* reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have *low* reactivity.

Reactivity series

The reactivity series places metals in order of their reactivity. Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are non-metals.

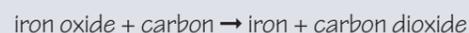
Reaction with water	Reaction with acid	Reactivity series		Extraction method		
		Metal	Reactivity			
fizzes, gives off hydrogen gas	explodes	potassium		electrolysis		
		sodium				
		lithium				
reacts very slowly	fizzes, gives off hydrogen gas	calcium			electrolysis	
		magnesium				
		aluminium (carbon) zinc				
no reaction	reacts slowly with warm acid	iron				reduction with carbon
		tin				
		lead (hydrogen) copper				
no reaction	no reaction	silver				
		gold				

Metal extraction

Some metals, like gold, are so unreactive that they are found as pure metals in the Earth's crust and can be mined.

Most metals exist as compounds in rock and have to be extracted from the rock. If there is enough metal compound in the rock to be worth extracting it is called an **ore**.

Metals that are less reactive than carbon can be extracted by reduction with carbon. For example:



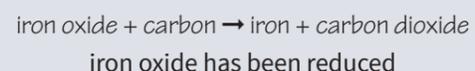
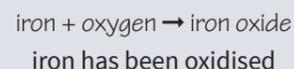
Metals that are more reactive than carbon can be extracted using a process called **electrolysis**.

Reduction and oxidation

If a substance gains oxygen in a reaction, it has been **oxidised**.

If a substance loses oxygen in a reaction, it has been **reduced**.

For example:



Salts

When acids react with metals or metal compounds, they form salts. A salt is a compound where the hydrogen from an acid has been replaced by a metal. For example nitric acid, HNO_3 , reacts with sodium to form NaNO_3 . The H in nitric acid is replaced with Na.

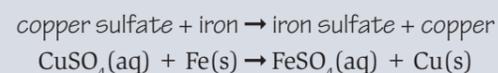
The table shows how to name salts.

Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula	HCl	H_2SO_4	HNO_3
Ions formed in solution	H^+ and Cl^-	2H^+ and SO_4^{2-}	H^+ and NO_3^-
Type of salt formed	metal chloride	metal sulfate	metal nitrate
Sodium salt example	sodium chloride, NaCl	sodium sulfate, Na_2SO_4	sodium nitrate, NaNO_3

Displacement reactions

In a **displacement** reaction a *more* reactive element takes the place of a *less* reactive element in a compound.

For example:

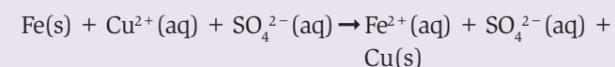


Iron is more reactive than copper, so iron displaces the copper in copper sulfate.

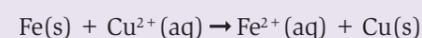
Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example, $\text{CuSO}_4(\text{aq})$ can be written as $\text{Cu}^{2+}(\text{aq})$ and $\text{SO}_4^{2-}(\text{aq})$.

The displacement reaction of copper sulfate and iron can be written as:



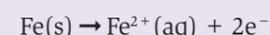
The SO_4^{2-} is unchanged in the reaction – it is a **spectator ion**. Spectator ions are removed from the equation to give an **ionic equation**:



Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:



A copper ion gains two electrons to form a copper atom:



These two equations are called **half equations** – they each show half of the ionic equation.

Reactivity and ions

A metal's reactivity depends on how readily it forms an **ion** by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with iron ions, not copper ions.

Steps for writing an ionic equation (HT only)

- 1 check symbol equation is balanced
- 2 identify all aqueous ionic compounds
- 3 write those compounds out as ions
- 4 remove spectator ions.

Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the loss or gain of electrons.

Oxidation is the *loss* of electrons, and reduction is the *gain* of electrons.

In the example displacement reaction:

- iron atoms have been oxidised
- copper ions have been reduced.

Acids and alkalis

Acids are compounds that, when dissolved in water, release H^+ ions. There are three main acids: sulfuric acid H_2SO_4 , nitric acid HNO_3 , and hydrochloric acid HCl.

Alkalis are compounds that, when dissolved in water, release OH^- ions.

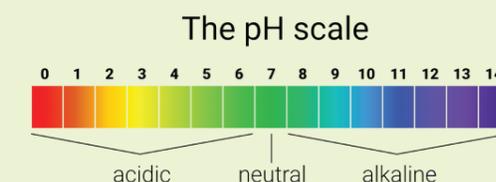
The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

- Aqueous solutions with $\text{pH} < 7$ are acidic.
- Aqueous solutions with $\text{pH} > 7$ are alkaline.
- Aqueous solutions with $\text{pH} = 7$ are neutral.

Indicators

Indicators can show if something is an acid or an alkali.

- **Universal indicator** can also tell us the approximate pH of a solution.
- Electronic pH probes can give us the exact pH of a solution.



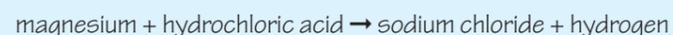
Chapter 5: Chemical changes 2

Knowledge organiser

Reactions of acids

Reactions of acids with metals

Acids react with some metals to form salts and hydrogen gas.



Neutralisation reactions

Reactions of acids with metal hydroxides

Acids react with metal hydroxides to form salts and water.



The ionic equation for this reaction is always:



Reactions of acids with metal oxides

Acids react with metal oxides to form salts and water.



Reactions of acids with metal carbonates

Acids react with metal carbonates to form a salt, water, and carbon dioxide.



Alkalis and bases

Bases neutralise acids to form water in **neutralisation** reactions. Some metal hydroxides dissolve in water to form alkaline solutions, called alkalis.

Some metal oxides and metal hydroxide do not dissolve in water. They are **bases**, but are not alkalis.

Strong and weak acids

Sulfuric acid, nitric acid, and hydrochloric acid, are all **strong acids**. This means that, when dissolved in water, every molecule splits up into ions – they are completely ionised:

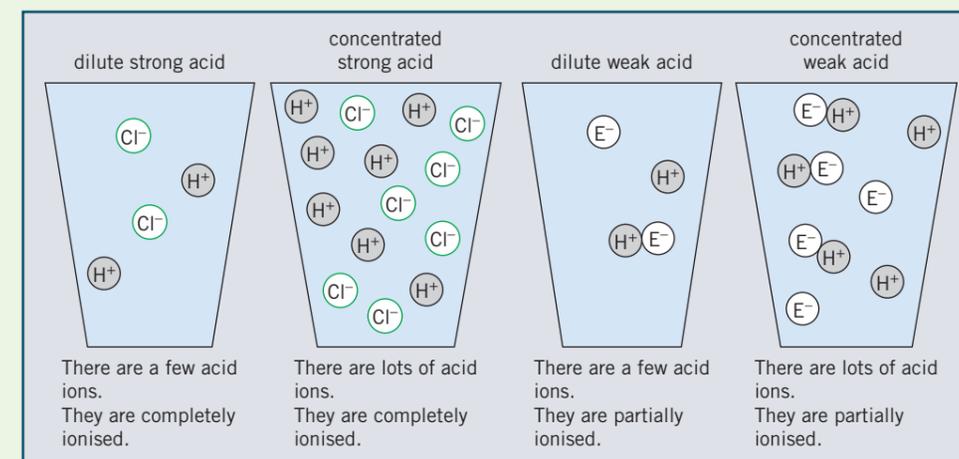
- $\text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
- $\text{HNO}_3(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$
- $\text{HCl}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$

Ethanoic acid, citric acid, and carbonic acid are **weak acids**. This means that only a percentage of their molecules split up into ions when dissolved in water – they are partially ionised. For a given concentration, the *stronger* the acid, the *lower* the pH.

Concentrated and dilute acids

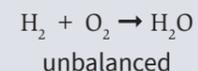
Concentration tells us how much of a substance there is dissolved in water:

- more concentrated acids have lots of acid in a small volume of water
- less concentrated acids (dilute acids) have little acid in a large volume of water.

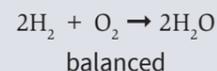
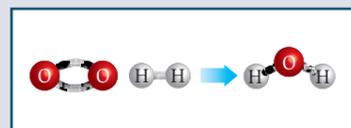


Balancing symbol equations

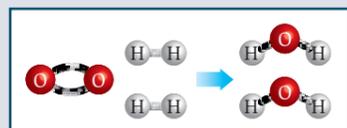
When writing symbol equations you need to ensure that the number of each atom on each side is equal.



there are 2 hydrogen atoms on each side, but 2 oxygen atoms in the reactants and 1 in the product



there are 4 hydrogen atoms on each side, and 2 oxygen atoms on each side



State symbols

A balanced symbol equation should also include state symbols.

State	Symbol
solid	(s)
liquid	(l)
gas	(g)
aqueous or dissolved in water	(aq)



Key terms

Make sure you can write a definition for these key terms.

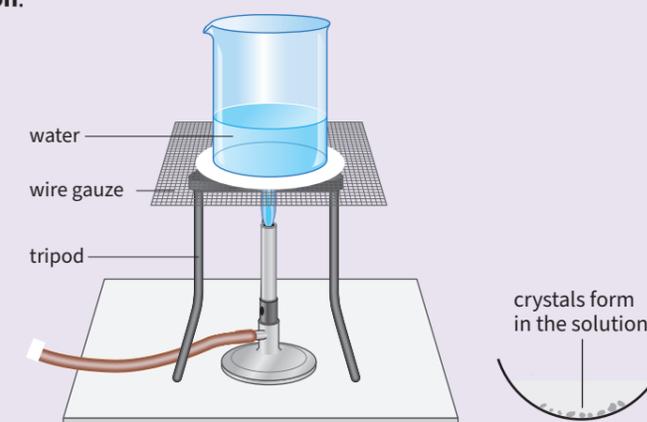
displacement metal ore electrolysis oxidation spectator ion extraction reactivity series reactivity series state symbols half equation reactivity series ion redox ionic equation reduction

Crystallisation

You can produce a solid salt from an insoluble base by **crystallisation**.

The experimental method is:

- Choose the correct acid and base to produce the salt.
- Put some of the dilute acid into a flask. Heat gently with a Bunsen burner.
- Add a small amount of the base and stir.
- Keep adding the base until no more reacts – the base is now in excess.
- Filter to remove the unreacted base.
- Add the remaining solution to an evaporating dish.
- Use a water bath or electric heater to evaporate the water. The salt crystals will be left behind.



Chapter 5: Chemical changes

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C5 questions		Answers
1	What does reactivity mean?	how vigorously a substance chemically reacts
2	How can metals be ordered by their reactivity?	by comparing their reactions with water, acid, or oxygen
3	What name is given to a list of metals ordered by their reactivity?	reactivity series
4	In terms of electrons, what makes some metals more reactive than others?	they lose their outer shell electron(s) more easily
5	Why are gold and silver found naturally as elements in the Earth's crust?	they are very unreactive
6	What is an ore?	rock containing enough of a metal compound to be economically worth extracting
7	How are metals less reactive than carbon extracted from their ores?	reduction with carbon
8	In terms of oxygen, what is oxidation?	addition of oxygen
9	In terms of oxygen, what is reduction?	removal of oxygen
10	Why can metals like potassium and aluminium not be extracted by reduction with carbon?	they are more reactive than carbon
11	How are metals more reactive than carbon extracted from their ores?	electrolysis
12	What is a displacement reaction?	a more reactive substance takes the place of a less reactive substance in a compound
13	What is an ionic equation?	equation which gives some substances as ions and has spectator ions removed
14	What type of substance is given as ions in an ionic equation?	ionic compounds in solution (or liquid)
15	What is a spectator ion?	ion that is unchanged in a reaction
16	What is a half equation?	equation that shows whether a substance is losing or gaining electrons
17	In terms of electrons, what is oxidation?	loss of electrons
18	In terms of electrons, what is reduction?	gain of electrons
19	In terms of pH, what is an acid?	a solution with a pH of less than 7
20	In terms of pH, what is a neutral solution?	a solution with a pH of 7
21	In terms of H ⁺ ions, what is an acid?	a substance that releases H ⁺ ions when dissolved in water
22	How is the amount of H ⁺ ions in a solution related to its pH?	the more H ⁺ ions, the lower the pH
23	What are the names and formulae of three main acids?	hydrochloric acid, HCl; sulfuric acid, H ₂ SO ₄ ; nitric acid, HNO ₃
24	How do you measure the pH of a substance?	universal indicator or pH probe
25	What is a strong acid?	an acid where the molecules or ions completely ionise in water
26	What is a weak acid?	an acid where the molecules or ions partially ionise in water
27	What is a salt?	compound formed when a metal ion takes the place of a hydrogen ion in an acid
28	Which type of salts do sulfuric acid, hydrochloric acid, and nitric acid form?	sulfates, chlorides, nitrates
29	What are the products of a reaction between a metal and an acid?	salt + hydrogen
30	What are the products of a reaction between a metal hydroxide and an acid?	salt + water
31	What are the products of a reaction between a metal oxide and an acid?	salt + water
32	What are the products of a reaction between a metal carbonate and an acid?	salt + water + carbon dioxide
33	What is a base?	substance that reacts with acids in neutralisation reactions
34	What is an alkali?	substance that dissolves in water to form a solution above pH 7
35	What is a neutralisation reaction?	a reaction between an acid and a base to produce water
36	What is the ionic equation for a reaction between an acid and an alkali?	H ⁺ (aq) + OH ⁻ (aq) → H ₂ O(l)
37	How can you obtain a solid salt from a solution?	crystallisation
38	When an acid reacts with a metal, which species is oxidised?	the metal
39	When an acid reacts with a metal, which species is reduced?	hydrogen
40	What are the four state symbols and what do they stand for?	(s) solid, (l) liquid, (g) gas, (aq) aqueous or dissolved in water

Chapter 5: Chemical changes 1

Knowledge organiser

Reactions of metals

The _____ of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have _____ reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have _____ reactivity.

Reactivity series

The reactivity series places _____ in order of their reactivity. Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are _____.

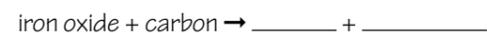
Reaction with water	Reaction with acid	Reactivity series		Extraction method	
		Metal	Reactivity		
		potassium	<div style="display: flex; align-items: center; justify-content: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">Decreasing reactivity</div> <div style="text-align: center;"> <div style="width: 100px; height: 100px; background: linear-gradient(to bottom, #e0e0e0, #f0f0f0); border: 1px solid #ccc; margin: 0 auto;"></div> <p style="margin: 0;">high reactivity</p> <p style="margin: 0;">low reactivity</p> </div> </div>		
		sodium			
		lithium			
		calcium			
		magnesium			
		aluminium (carbon) zinc			
		iron			
		tin			
		lead (hydrogen) copper			
		silver			
		gold			

Metal extraction

Some metals, like gold, are so _____ that they are found as pure metals in the Earth's _____ and can be mined.

Most metals exist as compounds in rock and have to be _____ from the rock. If there is enough metal compound in the rock to be worth extracting it is called an _____.

Metals that are _____ reactive than carbon can be extracted by _____ with carbon. For example:



Metals that are more reactive than carbon can be extracted using a process called _____.

Reduction and oxidation

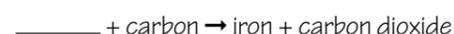
If a substance gains oxygen in a reaction, it has been _____.

If a substance loses oxygen in a reaction, it has been _____.

For example:



iron has been _____

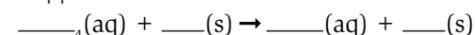
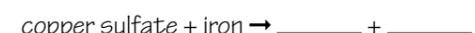


_____ has been reduced

Displacement reactions

In a **displacement** reaction a _____ reactive element takes the place of a *less* reactive element in a compound.

For example:



_____ is more reactive than copper, so iron displaces the copper in copper sulfate.

Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example, $\text{CuSO}_4(\text{aq})$ can be written as _____ and _____.

The displacement reaction of copper sulfate and iron can be written as:

The SO_4^{2-} is unchanged in the reaction – it is a _____.

Spectator ions are removed from the equation to give an **ionic equation**:

Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:



A copper ion gains two electrons to form a copper atom:



These two equations are called _____ – they each show half of the ionic equation.

Reactivity and ions

A metal's reactivity depends on how readily it forms an _____ by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with _____ ions, not _____ ions.

Steps for writing an ionic equation (HT only)

- 1.
- 2.
- 3.
- 4.

Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the _____ or _____ of electrons.

Oxidation is the _____ of electrons, and reduction is the _____ of electrons.

In the example displacement reaction:

- iron atoms have been _____
- copper ions have been _____.

Acids and alkalis

Acids are compounds that, when dissolved in water, release _____ ions. There are three main acids: _____, _____, and _____.

Alkalis are compounds that, when dissolved in water, release _____ ions.

The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

- Aqueous solutions with $\text{pH} < 7$ are _____.
- Aqueous solutions with $\text{pH} > 7$ are _____.
- Aqueous solutions with $\text{pH} = 7$ are _____.

Salts

When acids react with metals or metal compounds, they form _____. A salt is a compound where the _____ from an acid has been replaced by a metal. For example nitric acid, HNO_3 , reacts with sodium to form _____. The H in nitric acid is replaced with Na.

The table shows how to name salts.

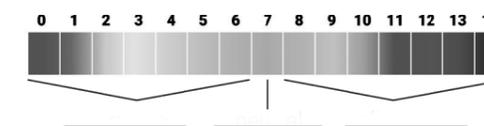
Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula			
Ions formed in solution			
Type of salt formed			
Sodium salt example			

Indicators

Indicators can show if something is an acid or an alkali.

- _____ can also tell us the approximate pH of a solution.
- _____ can give us the exact pH of a solution.

The pH scale



Chapter 5: Chemical changes

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C5 questions

Answers

1	What does reactivity mean?	
2	How can metals be ordered by their reactivity?	
3	What name is given to a list of metals ordered by their reactivity?	
4	In terms of electrons, what makes some metals more reactive than others?	
5	Why are gold and silver found naturally as elements in the Earth's crust?	
6	What is an ore?	
7	How are metals less reactive than carbon extracted from their ores?	
8	In terms of oxygen, what is oxidation?	
9	In terms of oxygen, what is reduction?	
10	Why can metals like potassium and aluminium not be extracted by reduction with carbon?	
11	How are metals more reactive than carbon extracted from their ores?	
12	What is a displacement reaction?	
13	What is an ionic equation?	
14	What type of substance is given as ions in an ionic equation?	
15	What is a spectator ion?	
16	What is a half equation?	
17	In terms of electrons, what is oxidation?	
18	In terms of electrons, what is reduction?	

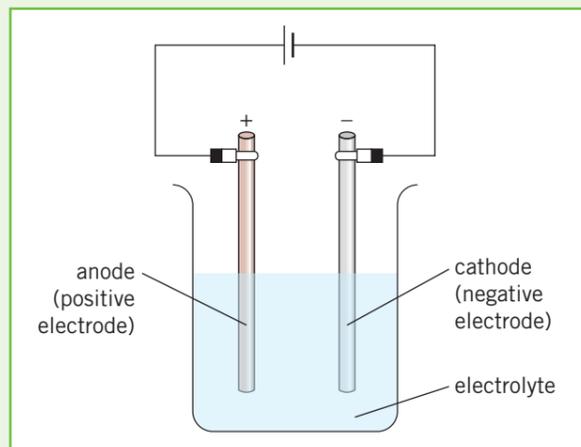
19	In terms of pH, what is an acid?	
20	In terms of pH, what is a neutral solution?	
21	In terms of H ⁺ ions, what is an acid?	
22	How is the amount of H ⁺ ions in a solution related to its pH?	
23	What are the names and formulae of three main acids?	
24	How do you measure the pH of a substance?	
25	What is a strong acid?	
26	What is a weak acid?	
27	What is a salt?	
28	Which type of salts do sulfuric acid, hydrochloric acid, and nitric acid form?	
29	What are the products of a reaction between a metal and an acid?	
30	What are the products of a reaction between a metal hydroxide and an acid?	
31	What are the products of a reaction between a metal oxide and an acid?	
32	What are the products of a reaction between a metal carbonate and an acid?	
33	What is a base?	
34	What is an alkali?	
35	What is a neutralisation reaction?	
36	What is the ionic equation for a reaction between an acid and an alkali?	
37	How can you obtain a solid salt from a solution?	
38	When an acid reacts with a metal, which species is oxidised?	
39	When an acid reacts with a metal, which species is reduced?	
40	What are the four state symbols and what do they stand for?	

Chapter 6: Electrolysis

Knowledge organiser

Electrolysis

In the process of **electrolysis**, an electric current is passed through an **electrolyte**. An electrolyte is a liquid or solution that contains ions and so can conduct electricity. This causes the ions to move to the **electrodes**, where they form pure elements.



Electrolysis of molten compounds

Solid ionic compounds do not conduct electricity as the ions cannot move. To undergo electrolysis they must be molten or dissolved, so the ions are free to move.

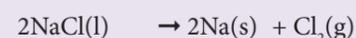
When an ionic compound is molten:

- The positive metal ions are *attracted* to the **cathode**, where they will *gain* electrons to form the pure metal
- The negative non-metal ions are *attracted* to the **anode**, where they will *lose* electrons and become the pure non-metal.

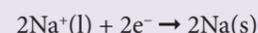
For example, molten sodium chloride, NaCl, can undergo electrolysis to form sodium at the cathode and chlorine at the anode.

Half equations (HT only)

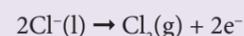
sodium chloride → sodium + chlorine



- at the cathode:



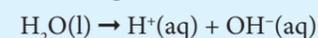
- at the anode:



Electrolysis of aqueous solutions

Solid ionic compounds can also undergo electrolysis when dissolved in water.

- It requires less energy to dissolve ionic compounds in water than it does to melt them.
- However, in the electrolysis of solutions, the pure elements are not always produced. This is because the water can also undergo ionisation:



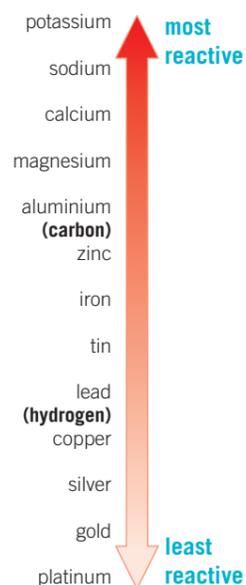
Products at the anode

In the electrolysis of a solution, if the non-metal contains oxygen then oxygen gas is formed at the anode:

- The $\text{OH}^-\text{(aq)}$ ions formed from the ionisation of water are attracted to the anode.
- The $\text{OH}^-\text{(aq)}$ ions lose electrons to the anode and form oxygen gas.
- $4\text{OH}^-\text{(aq)} \rightarrow \text{O}_2\text{(g)} + 2\text{H}_2\text{O(l)} + 4\text{e}^-$

If the non-metal ion is a halogen, then the halogen gas is formed at the anode.

- $2\text{Cl}^-\text{(aq)} \rightarrow \text{Cl}_2\text{(g)} + 2\text{e}^-$



Products at the cathode

In the electrolysis of a solution, if the metal is **more reactive** than hydrogen then hydrogen gas is formed at the cathode:

- The $\text{H}^+\text{(aq)}$ ions from the ionisation of water are attracted to the cathode and react with it.
- The $\text{H}^+\text{(aq)}$ ions gain electrons from the cathode and form hydrogen gas.
- $2\text{H}^+\text{(aq)} + 2\text{e}^- \rightarrow \text{H}_2\text{(g)}$
- The metal ions remain in solution.

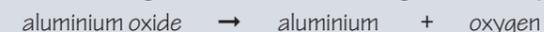
Electrolysis of aluminium oxide

Electrolysis can be used to extract metals from their ionic compounds.

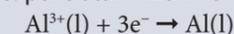
Electrolysis is used if the metal is more reactive than carbon.

Aluminium is extracted from aluminium oxide by electrolysis.

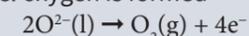
- The aluminium oxide is mixed with a substance called **cryolite**, which lowers the melting point.
- The mixture is then heated until it is molten.
- The resulting molten mixture undergoes electrolysis.



cathode: pure aluminium is formed

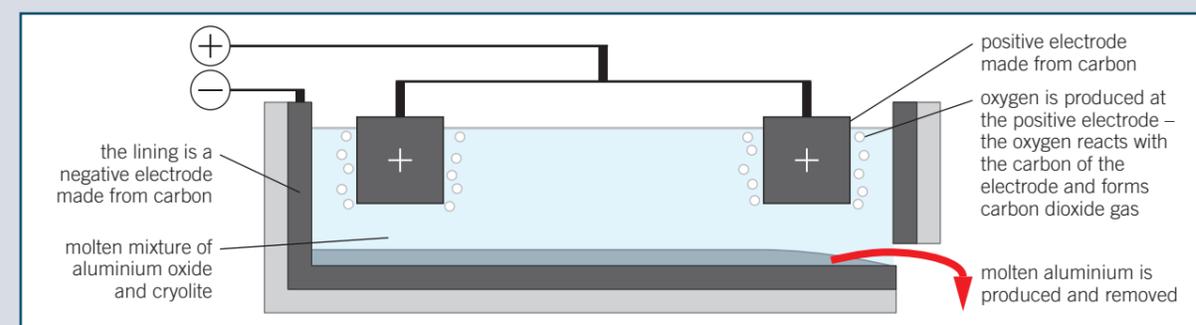


anode: oxygen is formed



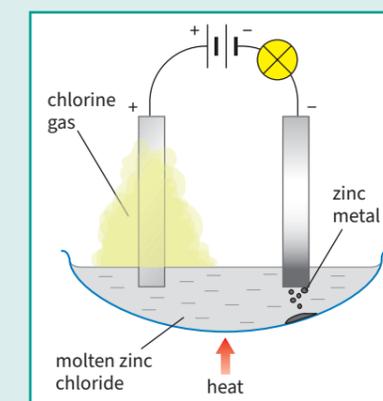
In the electrolysis of aluminium, the anode is made of graphite.

The graphite reacts with the oxygen to form carbon dioxide and so slowly wears away. It therefore needs to be replaced frequently.



Electrolysis of zinc chloride

Molten zinc chloride is broken down by electrolysis. This means zinc metal is collected at the cathode and a pale green chlorine gas is collected at the anode. Free ions from the molten zinc chloride are able to move around and carry electric currents, hence why the bulb lights up.



Key terms

Make sure you can write a definition for these key terms.

anode cathode cryolite electrode
electrolysis electrolyte reactivity

Chapter 6: Electrolysis

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C6 questions

Answers

1	What is electrolysis?	Put paper here	process of using electricity to extract elements from a compound
2	What is the name of the positive electrode?	Put paper here	anode
3	What is the name of the negative electrode?	Put paper here	cathode
4	What is an electrolyte?	Put paper here	liquid or solution that contains ions and so can conduct electricity
5	Where are metals formed?	Put paper here	cathode
6	Where are non-metals formed?	Put paper here	anode
7	How can ionic substances be electrolysed?	Put paper here	by melting or dissolving them, and then passing a direct current through them
8	Why can solid ionic substances not be electrolysed?	Put paper here	they do not conduct electricity, or the ions cannot move
9	In the electrolysis of solutions, when is the metal <i>not</i> produced at the cathode?	Put paper here	when the metal is more reactive than hydrogen
10	In the electrolysis of a metal halide solution, what is produced at the anode?	Put paper here	halogen
11	In the electrolysis of a metal sulfate solution, what is produced at the anode?	Put paper here	oxygen
12	What is the half equation for the ionisation of water?	Put paper here	$\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$
13	What metals are extracted from ionic compounds by using electrolysis?	Put paper here	metals that are more reactive than carbon
14	In the electrolysis of aluminium oxide, why is the aluminium oxide mixed with cryolite?	Put paper here	to lower the melting point
15	In the electrolysis of aluminium oxide, what are the anodes made of?	Put paper here	graphite
16	In the electrolysis of aluminium oxide, why do the anodes need to be replaced?	Put paper here	they react with the oxygen being formed

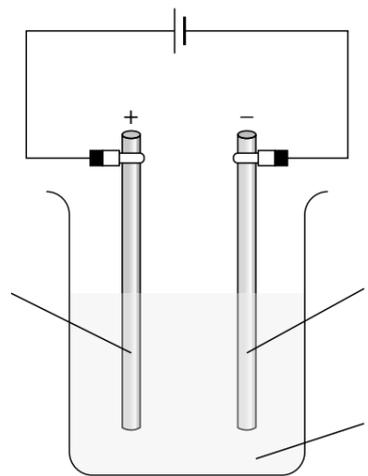
Chapter 6: Electrolysis

Knowledge organiser

Electrolysis

In the process of **electrolysis**, an electric _____ is passed through an **electrolyte**. An electrolyte is a _____ that contains _____ and so can conduct electricity. This causes the ions to move to the _____, where they form pure elements.

Label the diagram.



Electrolysis of molten compounds

Solid ionic compounds do not conduct electricity as the ions cannot move. To undergo electrolysis they must be _____ or dissolved, so the ions are free to move.

When an ionic compound is molten:

- The positive metal ions are *attracted* to the _____, where they will _____ electrons to form the pure metal
- The negative non-metal ions are *attracted* to the _____, where they will _____ electrons and become the pure non-metal.

For example, molten sodium chloride, NaCl, can undergo electrolysis to form _____ at the cathode and _____ at the anode.

Half equations (HT only)

sodium chloride → sodium + chlorine
_____ → _____ + _____

- at the cathode:
_____ + _____ → _____
- at the anode:
_____ → _____ + _____

Electrolysis of aluminium oxide

Electrolysis can be used to extract metals from their ionic compounds.

Electrolysis is used if the metal is more reactive than _____.

Aluminium is extracted from _____ by electrolysis.

- The aluminium oxide is mixed with a substance called _____, which lowers the melting point.
- The mixture is then heated until it is _____.
- The resulting molten mixture undergoes electrolysis.

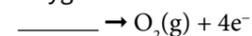
aluminium oxide → aluminium + oxygen



cathode: pure aluminium is formed

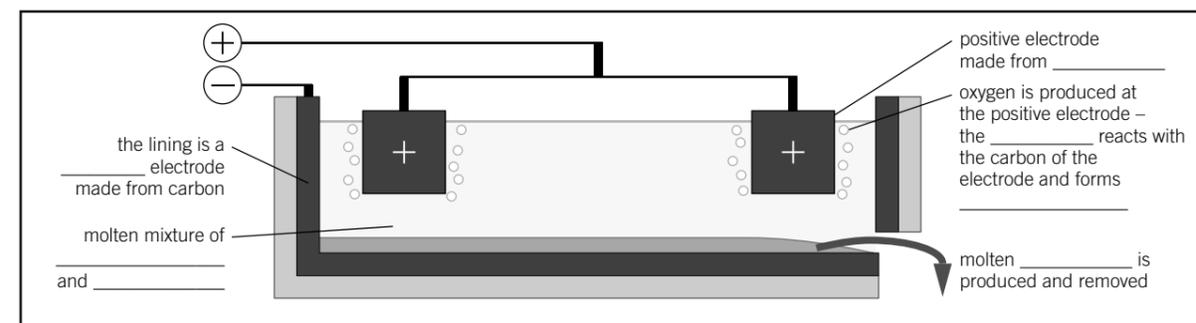


anode: oxygen is formed



In the electrolysis of aluminium, the anode is made of _____.

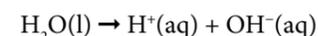
The graphite reacts with the _____ to form _____ and so slowly wears away. It therefore needs to be replaced frequently.



Electrolysis of aqueous solutions

Solid ionic compounds can also undergo electrolysis when dissolved in water.

- It requires _____ energy to dissolve ionic compounds in water than it does to melt them.
- However, in the electrolysis of solutions, the pure elements are not always produced. This is because the water can also undergo _____:



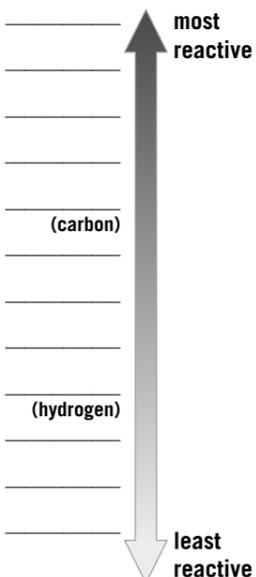
Products at the anode

In the electrolysis of a solution, if the non-metal contains oxygen then oxygen _____ is formed at the anode:

- The _____ ions formed from the ionisation of water are attracted to the anode.
- The $\text{OH}^-(\text{aq})$ ions _____ electrons to the anode and form oxygen gas.
- $4\text{OH}^-(\text{aq}) \rightarrow \text{_____}$

If the non-metal ion is a halogen, then the halogen gas is formed at the anode.

- $2\text{Cl}^-(\text{aq}) \rightarrow \text{_____}$



Products at the cathode

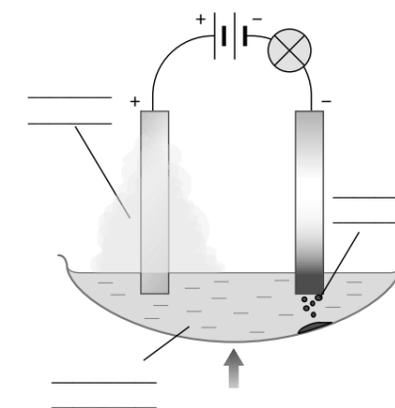
In the electrolysis of a solution, if the metal is _____ **reactive** than hydrogen then hydrogen gas is formed at the cathode:

- The _____ ions from the ionisation of water are attracted to the cathode and react with it.
- The $\text{H}^+(\text{aq})$ ions _____ electrons from the cathode and form hydrogen gas.
- $2\text{H}^+(\text{aq}) + \text{_____}$
- The metal ions remain in _____.

Electrolysis of zinc chloride

Molten zinc chloride is broken down by electrolysis. This means

_____ metal is collected at the _____ and a _____ is collected at the _____. Free _____ from the molten zinc chloride are able to move around and carry _____, hence why the bulb lights up. Label the diagram.



Key terms

Make sure you can write a definition for these key terms.

anode cathode cryolite electrode
electrolysis electrolyte reactivity

Chapter 6: Electrolysis

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C6 questions

Answers

- | C6 questions | Answers |
|--|---------|
| 1 What is electrolysis? | |
| 2 What is the name of the positive electrode? | |
| 3 What is the name of the negative electrode? | |
| 4 What is an electrolyte? | |
| 5 Where are metals formed? | |
| 6 Where are non-metals formed? | |
| 7 How can ionic substances be electrolysed? | |
| 8 Why can solid ionic substances not be electrolysed? | |
| 9 In the electrolysis of solutions, when is the metal <i>not</i> produced at the cathode? | |
| 10 In the electrolysis of a metal halide solution, what is produced at the anode? | |
| 11 In the electrolysis of a metal sulfate solution, what is produced at the anode? | |
| 12 What is the half equation for the ionisation of water? | |
| 13 What metals are extracted from ionic compounds by using electrolysis? | |
| 14 In the electrolysis of aluminium oxide, why is the aluminium oxide mixed with cryolite? | |
| 15 In the electrolysis of aluminium oxide, what are the anodes made of? | |
| 16 In the electrolysis of aluminium oxide, why do the anodes need to be replaced? | |

Chapter 7: Energy changes

Knowledge organiser

Energy changes

During a chemical reaction, energy transfers occur.

Energy can be transferred:

- to the surroundings – **exothermic**
- from the surroundings – **endothermic**

This energy transfer can cause a temperature change.

Energy is always conserved in chemical reactions.

This means that there is the same amount of energy in the Universe at the start of a chemical reaction as at the end of the chemical reaction.

The surroundings

When chemists say energy is transferred from or to “the surroundings” they mean “everything that isn’t the reaction”.

For example, imagine you have a reaction mixture in a test tube. If you measure the temperature in the test tube using a thermometer, the thermometer is then part of the surroundings.

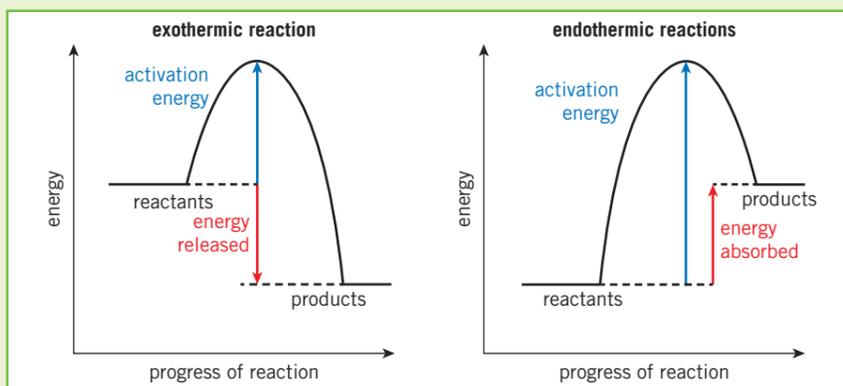
- If the thermometer records an increase in temperature, the reaction in the test tube is exothermic.
- If the thermometer records a decrease in temperature, the reaction in the test tube is endothermic.

Reaction	Energy transfer	Temperature change	Example	Everyday use	Bonds
exothermic	to the surroundings	temperature of the surroundings increases	<ul style="list-style-type: none"> oxidation combustion neutralisation 	<ul style="list-style-type: none"> self-heating cans hand warmers 	more energy released when making bonds than required to break bonds
endothermic	from the surroundings	temperature of the surroundings decreases	<ul style="list-style-type: none"> thermal decomposition citric acid and sodium hydrogen carbonate 	<ul style="list-style-type: none"> sports injury packs 	less energy released when making bonds than required to break bonds

Reaction profiles

A **reaction profile** shows whether a reaction is exothermic or endothermic.

The **activation energy** is the minimum amount of energy that particles must have to react when they collide.



Bonds (HT only)

Atoms are held together by strong chemical bonds. In a reaction, those bonds are broken and new ones are made between different atoms.

- Breaking a bond requires energy so is endothermic.
- Making a bond releases energy so is exothermic.

Breaking bonds

If a lot of energy is released when making the bonds and only a little energy is required to break them, then overall energy is released and the reaction as a whole is exothermic.

Making bonds

If a little energy is released when making the bonds and a lot is required to break them, then overall energy is taken in and the reaction as a whole is endothermic.

Bond calculations

Different bonds require different amounts of energy to be broken (their **bond energies**). To work out the overall energy change of a reaction, you need to:

- work out how much energy is required to break all the bonds in the reactants
- work out how much energy is released when making all the bonds in the products.

$$\text{overall energy transferred} = \text{energy required to break bonds} - \text{energy required to make bonds}$$

- A positive number means an endothermic reaction.
- A negative number means an exothermic number.

Chemical cells

In a metal displacement reaction, one metal is oxidised – it loses electrons. These electrons are transferred to another metal, which gains the electrons and so is reduced.

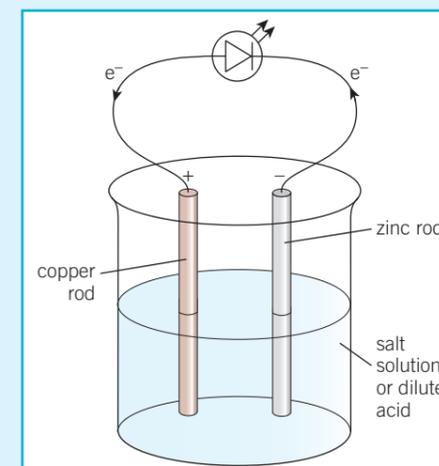
By using a **chemical cell** to conduct this reaction, the electron’s movement generates a current.

In the cell shown, the zinc atoms from the electrode lose electrons, turn into ions, and move into the solution.

The electrons travel through the circuit to the copper electrode, causing the LED to light up.

Once at the copper electrode, a metal ion *from the solution* will pick the electrons up and become a metal atom.

The greater the difference in reactivity between the two metals in the cell, the greater the potential difference produced.



Batteries

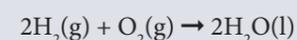
A **battery** is formed of two or more cells connected in series.

- Some batteries are **rechargeable**. An external electric current is applied, which reverses the reaction.
- Some batteries, like alkaline batteries, are not rechargeable because the reaction is not reversible. Once the reactants are used up, the chemical reaction stops and no more potential differences are released.

Hydrogen fuel cells

Fuel cells use a fuel and oxygen from the air to generate a potential difference.

Hydrogen fuel cells generate electricity from hydrogen and oxygen. The overall reaction is:



The hydrogen is oxidised to produce water.

There are different types of hydrogen fuel cell. In alkaline fuel cells, the half equations are below:

- $2\text{H}_2(\text{g}) + 4\text{OH}^-(\text{aq}) \rightarrow 4\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$
- $\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$

Advantages

- the only waste is water
- do not need to be electrically recharged

Disadvantages

- hydrogen is highly flammable and difficult to store
- hydrogen is often produced from non-renewable resources

Key terms

Make sure you can write a definition for these key terms.

activation energy battery
 bond energy chemical cell
 combustion endothermic
 exothermic fuel cell
 neutralisation oxidation
 reaction profile rechargeable
 thermal decomposition

Chapter 7: Energy changes

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C7 questions

Answers

1	What is an exothermic energy transfer?	Put paper here	transfer to the surroundings
2	What is an endothermic energy transfer?	Put paper here	transfer from the surroundings
3	What is a reaction profile?	Put paper here	diagram showing how the energy changes in a reaction
4	What is the activation energy?	Put paper here	minimum amount of energy required before a collision will result in a reaction
5	What is bond energy?	Put paper here	the energy required to break a bond or the energy released when a bond is formed
6	In terms of bond breaking and making, what is an exothermic reaction?	Put paper here	less energy is required to break the bonds than is released when making the bonds
7	In terms of bond breaking and making, what is an endothermic reaction?	Put paper here	more energy is required to break the bonds than is released when making the bonds
8	How are chemical cells made?	Put paper here	connect two different metals (electrodes) in a solution (electrolyte)
9	What is a battery?	Put paper here	two or more chemical cells connected in series
10	How does the potential difference of a cell depend on the metals that the electrodes are made of?	Put paper here	the bigger the difference in reactivity, the greater the potential difference
11	How can some cells be recharged?	Put paper here	by applying an external current
12	Why can some cells not be recharged?	Put paper here	the reaction cannot be reversed
13	What is a fuel cell?	Put paper here	cell that uses a fuel and oxygen to generate electricity
14	In the hydrogen fuel cell, what is the overall reaction?	Put paper here	$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$
15	In the alkaline hydrogen fuel cells, what are the half equations?	Put paper here	$2\text{H}_2(\text{g}) + 4\text{OH}^-(\text{aq}) \rightarrow 4\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$ $\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$
16	Give an advantage of the hydrogen fuel cell.	Put paper here	only product is water, do not need to be electrically recharged
17	Give a disadvantage of the hydrogen fuel cell.	Put paper here	hydrogen is flammable, difficult to store and is often produced from non-renewable sources

Chapter 7: Energy changes

Knowledge organiser

Energy changes

During a chemical reaction, energy transfers occur.

Energy can be transferred:

- to the surroundings - _____
- from the surroundings - _____

This energy transfer can cause a _____ change.

Energy is always conserved in chemical reactions.

This means that there is the _____

The surroundings

When chemists say energy is transferred from or to "the surroundings" they mean _____.

For example, imagine you have a reaction mixture in a test tube. If you measure the temperature in the test tube using a thermometer, the thermometer is then part of the surroundings.

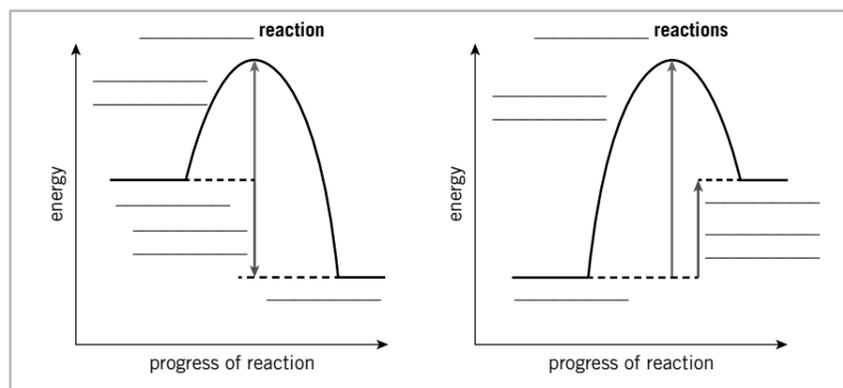
- If the thermometer records an increase in temperature, the reaction in the test tube is _____.
- If the thermometer records a decrease in temperature, the reaction in the test tube is _____.

Reaction	Energy transfer	Temperature change	Example	Everyday use	Bonds
exothermic			• • •	•	
endothermic			• •	•	

Reaction profiles

A _____ shows whether a reaction is exothermic or endothermic.

The _____ is the minimum amount of energy that particles must have to react when they _____.



Bonds (HT only)

Atoms are held together by strong _____ bonds. In a reaction, those bonds are _____ and new ones are made between _____ atoms.

- Breaking a bond _____ energy so is _____.
- Making a bond _____ energy so is _____.

Breaking bonds

If a lot of energy is released when _____ the bonds and only a _____ energy is required to break them, then overall energy is released and the reaction as a whole is _____.

Making bonds

If a _____ energy is released when making the bonds and a _____ is required to break them, then overall energy is taken in and the reaction as a whole is _____.

Bond calculations

Different bonds require different amounts of energy to be broken (their **bond energies**). To work out the overall energy change of a reaction, you need to:

- 1 work out how much energy is required to break all the bonds in the _____
- 2 work out how much energy is _____ when making all the bonds in the products.

$$\text{overall energy transferred} = \text{_____} - \text{_____}$$

- A _____ number means an endothermic reaction.
- A _____ number means an exothermic number.

Chemical cells

In a metal displacement reaction, one metal is _____ . These electrons are _____ to another metal, which gains the electrons and so is _____ .

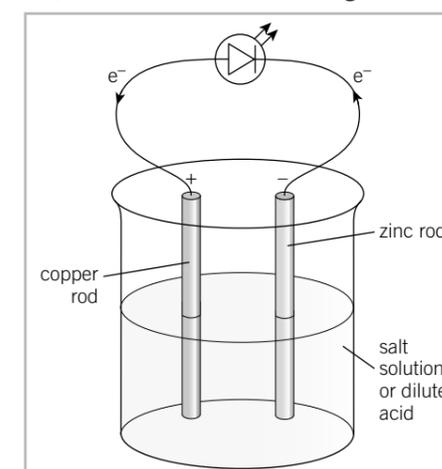
By using a **chemical cell** to conduct this reaction, the electron's movement generates a _____ .

In the cell shown, the zinc atoms from the electrode lose electrons, turn into _____, and move into the solution.

The _____ travel through the circuit to the _____ electrode, causing the LED to _____ .

Once at the copper electrode, a metal ion *from the solution* will pick the electrons up and become a _____ atom.

The greater the difference in reactivity between the two metals in the cell, the greater the _____ produced.



Batteries

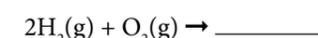
A **battery** is formed of _____ cells connected in _____ .

- Some batteries are _____. An external electric current is applied, which reverses the reaction.
- Some batteries, like _____ batteries, are not rechargeable because the reaction is not _____. Once the reactants are used up, the chemical reaction _____ and no more potential differences are _____.

Hydrogen fuel cells

Fuel cells use a _____ and _____ from the air to generate a potential difference.

_____ fuel cells generate electricity from hydrogen and oxygen. The overall reaction is:



The hydrogen is oxidised to produce _____.

There are different types of hydrogen fuel cell. In alkaline fuel cells, the half equations are below:

- $2\text{H}_2(\text{g}) + 4\text{OH}^-(\text{aq}) \rightarrow \text{_____} + \text{_____}$
- $\text{_____} + \text{_____} + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$

Advantages

-
-

Disadvantages

-
-



Key terms

Make sure you can write a definition for these key terms.

activation energy battery
 bond energy chemical cell
 combustion endothermic
 exothermic fuel cell
 neutralisation oxidation
 reaction profile rechargeable
 thermal decomposition

Chapter 7: Energy changes

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C7 questions

Answers

- 1 What is an exothermic energy transfer?
- 2 What is an endothermic energy transfer?
- 3 What is a reaction profile?
- 4 What is the activation energy?
- 5 What is bond energy?
- 6 In terms of bond breaking and making, what is an exothermic reaction?
- 7 In terms of bond breaking and making, what is an endothermic reaction?
- 8 How are chemical cells made?
- 9 What is a battery?
- 10 How does the potential difference of a cell depend on the metals that the electrodes are made of?
- 11 How can some cells be recharged?
- 12 Why can some cells not be recharged?
- 13 What is a fuel cell?
- 14 In the hydrogen fuel cell, what is the overall reaction?
- 15 In the alkaline hydrogen fuel cells, what are the half equations?
- 16 Give an advantage of the hydrogen fuel cell.
- 17 Give a disadvantage of the hydrogen fuel cell.

Chapter 8: Rates and equilibrium 1

Knowledge organiser

Rates of reaction

The **rate of a reaction** is how quickly the reactants turn into the products.

To calculate the rate of a reaction, you can measure:

- how quickly a reactant is used up

$$\text{mean rate of reaction} = \frac{\text{quantity of reactant used}}{\text{time taken}}$$

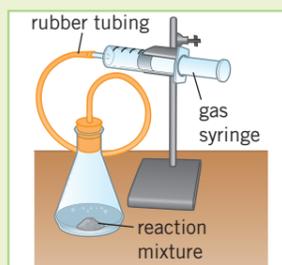
- how quickly a product is produced.

$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

For reactions that involve a gas, this can be done by measuring how the mass of the reaction changes or the volume of gas given off by the reaction.

Volume of gas produced

The reaction mixture is connected to a gas syringe or an upside down measuring cylinder. As the reaction proceeds the gas is collected.



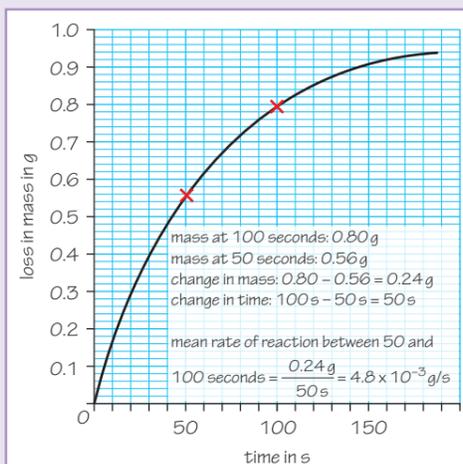
The rate for the reaction is then:

$$\text{rate} = \frac{\text{volume of gas produced}}{\text{time taken}}$$

Volume is measured in cm^3 and time in seconds, so the unit for rate is cm^3/s .

Mean rate between two points in time

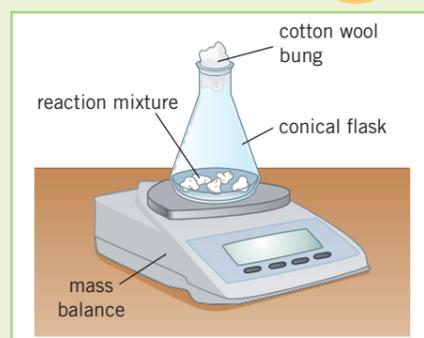
To get the mean rate of reaction between two points in time:



Change in mass



The reaction mixture is placed on a mass balance. As the reaction proceeds and the gaseous product is given off, the mass of the flask will decrease.



The rate for the reaction is then:

$$\text{rate} = \frac{\text{change in the mass}}{\text{time taken}}$$

The mass is measured in grams and time is measured in seconds. Therefore, the unit of rate is g/s .

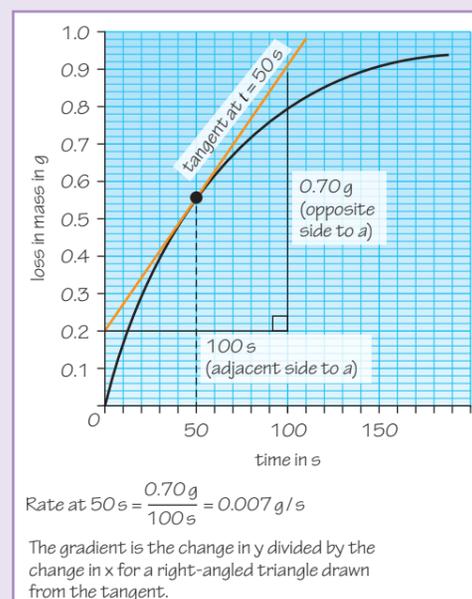
Calculating rate from graphs (HT only)

The results from an experiment can be plotted on a graph.

- A steep gradient means a high rate of reaction – the reaction happens quickly.
- A shallow gradient means a low rate of reaction – the reaction happens slowly.

Mean rate at specific time

To obtain the rate at a specific time draw a **tangent** to the graph and calculate its **gradient**.



Collision theory

For a reaction to occur, the reactant particles need to collide. When the particles collide, they need to have enough energy to react or they will just bounce apart. This amount of energy is called the **activation energy**.

You can increase the rate of a reaction by:

- increasing the **frequency of collisions**
- increasing the energy of the particles when they collide.

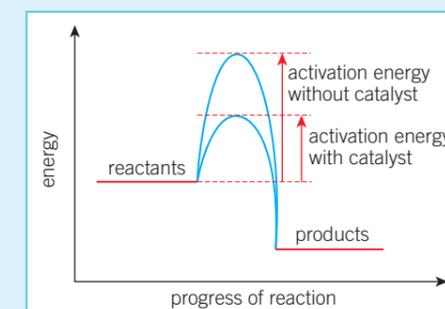
Factors affecting rate of reaction

Condition that increases rate	How is this condition caused?	Why it has that effect
increasing the temperature	Heat the container in which the reaction is taking place.	1 particles move faster, leading to more frequent collisions 2 particles have more energy, so more collisions result in a reaction note that these are two <i>separate</i> effects
increasing the concentration of solutions	Use a solution with more solute in the same volume of solvent.	there are more reactant particles in the reaction mixture, so collisions become more frequent
increasing the pressure of gases	Increase the number of gas particles you have in the container or make the container smaller.	less space between particles means more frequent collisions
increasing the surface area of solids	Cut the solid into smaller pieces, or grind it to create a powder, increasing the surface area. Larger pieces decrease the surface area.	only reactant particles on the surface of a solid are able to collide and react; the greater the surface area the more reactant particles are exposed, leading to more frequent collisions

Catalysts

Some reactions have specific substances called **catalysts** that can be added to increase the rate. These substances are not used up in the reaction.

A catalyst provides a different reaction pathway that has a lower activation energy. As such, more particles will collide with enough energy to react, so more collisions result in a reaction.



Chapter 8: Rates and equilibrium 2

Knowledge organiser

Reaction conditions

The conditions of a reaction refer to the external environment of the reaction. When the reaction occurs in a closed system, you can change the conditions by:

- changing the concentration of one of the substances
- changing the temperature of the entire reaction vessel
- changing the pressure inside the vessel.

Le Châtelier's principle (HT only)

At equilibrium, the amount of reactants and products is constant. In order to change the amounts of reactant and product at equilibrium the *conditions* of the reaction must be changed. The closed system will then counteract the change by favouring either the forward reaction or the reverse reaction. This is known as **Le Châtelier's principle**. For example, lowering the concentration of the product in the system causes the forward reaction to be **favoured** to increase the concentration of the product.

Changing concentrations (HT only)

Change	Effect	Explanation
decrease concentration of product	favours the forward reaction	opposes the change by making <i>less</i> reactant and <i>more</i> product
increase concentration of product	favours the reverse reaction	opposes the change by making <i>more</i> reactant and <i>less</i> product
decrease concentration of reactant	favours the reverse reaction	opposes the change by making <i>more</i> reactant and <i>less</i> product
increase concentration of reactant	favours the forward reaction	opposes the change by making <i>less</i> reactant and <i>more</i> product

Changing temperature (HT only)

Change	Effect	Explanation
increase temperature of surroundings	favours the endothermic reaction	opposes the change by decreasing the temperature of the surroundings
decrease temperature of surroundings	favours the exothermic reaction	opposes the change by increasing the temperature of the surroundings

Changing pressure (HT only)

Change	Effect	Explanation
increase the pressure	favours the reaction that results in fewer molecules	decreasing the number of molecules within the vessel opposes the change because it decrease pressure
decrease the pressure	favours the direction that results in more molecules	increasing the number of molecules within the vessel opposes the change because it increase pressure



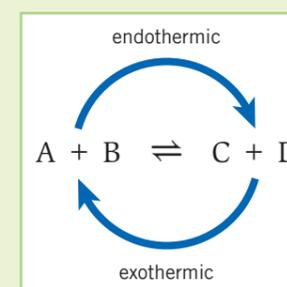
Key terms

Make sure you can write a definition for these key terms.

activation energy catalyst collision collision theory closed system
 conditions dynamic equilibrium frequency of collision gradient
 Le Châtelier's principle rate of reaction reversible reaction tangent

Reversible reactions

In some reactions, the products can react to produce the original reactants. This is called a **reversible reaction**. When writing chemical equations for reversible reactions, use the \rightleftharpoons symbol.



In this reaction:

- A and B can react to form C and D – the forward reaction
- C and D can react to form A and B – the reverse reaction.

The different directions of the reaction have opposite energy changes.

If the forward reaction is *endothermic*, the reverse reaction will be *exothermic*.

The same amount of energy is transferred in each direction.

Equilibrium

In a **closed system** no reactants or products can escape. If a reversible reaction is carried out in a closed system, it will eventually reach **dynamic equilibrium** – a point in time when the forward and reverse reactions have the same rate.

At dynamic equilibrium:

- the reactants are still turning into the products
- the products are still turning back into the reactants
- the rates* of these two processes are *equal*, so overall the amount of reactants and products are constant.

Dynamic equilibrium

At dynamic equilibrium the amount of reactant and product are constant, but not necessarily equal.

You could have a mixture of reactants and products in a 50:50 ratio, in a 75:25 ratio, or in any ratio at all. The **conditions** of the reaction are what change that ratio.

How dynamic equilibrium is reached

Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of A + B	high	decreasing	constant
Frequency of collisions A + B	high	decreasing	constant
Rate of forward reaction	high	decreasing	same as rate of reverse reaction
Amount of C + D	zero	increasing	constant
Frequency of collisions C + D	no collisions	increasing	constant
Rate of reverse reaction	zero	increasing	same as rate of forward reaction

Chapter 8: Rates and equilibrium

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C8 questions	Answers
1 What is the rate of a reaction?	how quickly reactants are used up or products are produced
2 What is the equation for calculating the mean rate of reaction?	mean rate = $\frac{\text{change in quantity of product or reactant}}{\text{time taken}}$
3 What is the unit for rate of reaction in a reaction involving a change in mass?	g/s
4 What is the unit for rate of reaction in a reaction involving a change in volume?	cm ³ /s
5 What is the activation energy?	the minimum amount of energy colliding particles have to have before a reaction will take place
6 What effect does increasing concentration have on the rate of reaction?	increases
7 Why does increasing concentration have this effect?	more reactant particles in the same volume lead to more frequent collisions
8 What effect does increasing pressure have on the rate of reaction?	increases
9 Why does increasing pressure have this effect?	less space between particles means more frequent collisions
10 What effect does increasing surface area have on the rate of reaction?	increases
11 Why does increasing surface area have this effect?	more reactant particles are exposed and able to collide, leading to more frequent collisions
12 What effect does increasing temperature have on the rate of reaction?	increases
13 Why does increasing temperature have this effect?	particles move faster, leading to more frequent collisions – particles have the same activation energy, so more collisions result in a reaction
14 What is a catalyst?	a substance that increases the rate of a reaction but is not used up in the reaction
15 How do catalysts increase the rate of a reaction?	lower the activation energy of the reaction, so more collisions result in a reaction
16 What is a reversible reaction?	the reactants turn into products and the products turn into reactants
17 Which symbol shows a reversible reaction?	\rightleftharpoons
18 What is dynamic equilibrium?	the point in a reversible reaction when the rate of the forward and reverse reactions are the same
19 What are the three reaction conditions that can be changed?	concentration, temperature, pressure
20 What is Le Châtelier's principle?	the position of equilibrium will shift to oppose external changes
21 What is the effect of increasing the concentration of reactants on a reaction at dynamic equilibrium?	favours the forward reaction

22 What is the effect of increasing the concentration of reactants on a reaction at dynamic equilibrium?	favours the forward reaction
23 What is the effect of decreasing the concentration of products on a reaction at dynamic equilibrium?	favours the forward reaction
24 What is the effect of increasing pressure on a reaction at dynamic equilibrium?	favours the reaction that leads to the fewest molecules
25 What is the effect of decreasing pressure on a reaction at dynamic equilibrium?	favours the reaction that leads to the most molecules
26 What is the effect of increasing temperature on a reaction at dynamic equilibrium?	favours the endothermic reaction
27 What is the effect of decreasing temperature on a reaction at dynamic equilibrium?	favours the exothermic reaction

Chapter 8: Rates and equilibrium 1

Knowledge organiser

Rates of reaction

The **rate of a reaction** is how quickly the _____ turn into the _____.

To calculate the rate of a reaction, you can measure:

- how quickly a reactant is used up

mean rate of reaction = _____

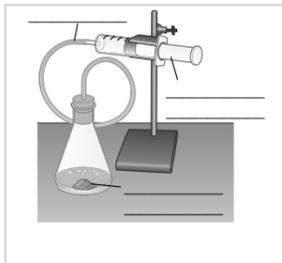
- how quickly a product is produced.

mean rate of reaction = _____

For reactions that involve a gas, this can be done by _____.

Volume of gas produced

The reaction mixture is connected to a _____ or an upside down measuring cylinder. As the reaction proceeds the gas is collected.



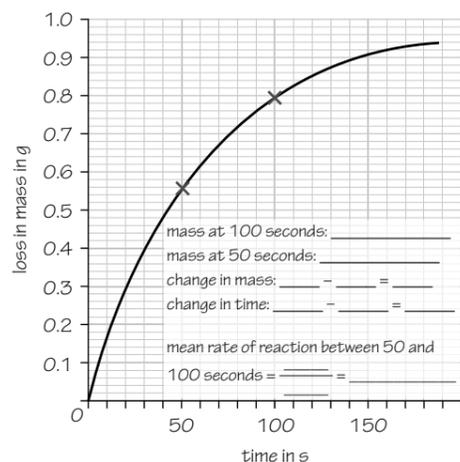
The rate for the reaction is then:

rate = _____

Volume is measured in _____ and time in _____, so the unit for rate is _____.

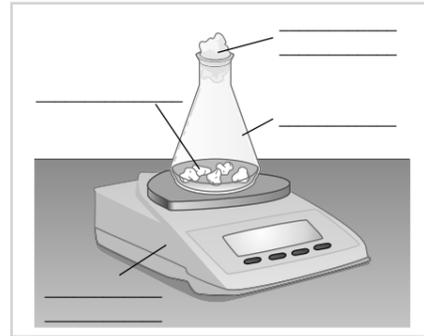
Mean rate between two points in time

To get the mean rate of reaction between two points in time:



Change in mass

The reaction mixture is placed on a mass balance. As the reaction proceeds and the _____ product is given off, the mass of the flask will _____.



The rate for the reaction is then:

rate = _____

The mass is measured in grams and time is measured in seconds. Therefore, the unit of rate is _____.

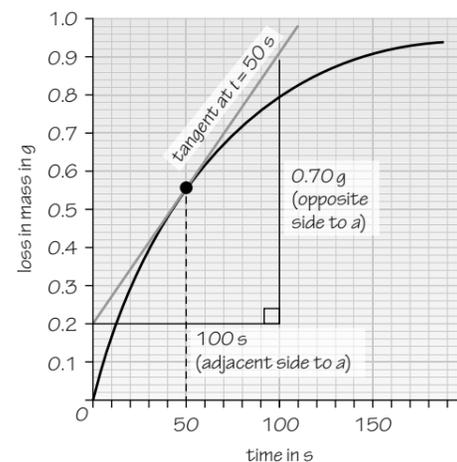
Calculating rate from graphs (HT only)

The results from an experiment can be plotted on a graph.

- A steep gradient means _____
- A shallow gradient means _____

Mean rate at specific time

To obtain the rate at a specific time draw a _____ to the graph and calculate its _____.



The gradient is the change in y divided by the change in x for a right-angled triangle drawn from the tangent.

Collision theory

For a reaction to occur, the reactant particles need to _____. When the particles collide, they need to have enough _____ to react or they will just bounce apart. This amount of energy is called the _____.

You can increase the rate of a reaction by:

- _____
- _____
- _____

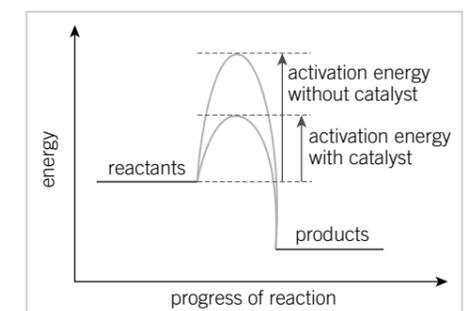
Factors affecting rate of reaction

Condition that increases rate	How is this condition caused?	Why it has that effect
increasing the temperature		1 2
increasing the concentration of solutions		
increasing the pressure of gases		
increasing the surface area of solids		

Catalysts

Some reactions have specific substances called _____ that can be added to increase the rate. These substances are not used up in the reaction.

A catalyst provides a different _____ that has a _____ activation energy. As such, more particles will collide with enough energy to react, so more collisions result in a reaction.



Chapter 8: Rates and equilibrium 2

Knowledge organiser

Reaction conditions

The conditions of a reaction refer to the external environment of the reaction. When the reaction occurs in a closed system, you can change the conditions by:

-
-
-

Le Châtelier's principle (HT only)

At equilibrium, the amount of reactants and products is constant. In order to change the amounts of reactant and product at equilibrium the _____ of the reaction must be changed. The closed system will then counteract the change by favouring either the _____ or the _____. This is known as **Le Châtelier's principle**.

Changing concentrations (HT only)

Change	Effect	Explanation
decrease concentration of product		
increase concentration of product		
decrease concentration of reactant		
increase concentration of reactant		

Changing temperature (HT only)

Change	Effect	Explanation
increase temperature of surroundings		
decrease temperature of surroundings		

Changing pressure (HT only)

Change	Effect	Explanation
increase the pressure		
decrease the pressure		



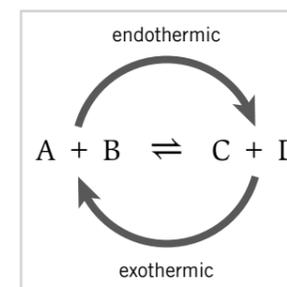
Key terms

Make sure you can write a definition for these key terms.

activation energy catalyst collision collision theory closed system
 conditions dynamic equilibrium frequency of collision gradient
 Le Châtelier's principle rate of reaction reversible reaction tangent

Reversible reactions

In some reactions, the products can react to produce the original reactants. This is called a **reversible reaction**. When writing chemical equations for reversible reactions, use the _____ symbol.



In this reaction:

- A and B can react to form C and D – the _____ reaction.
- C and D can react to form A and B – the _____ reaction.

The different directions of the reaction have _____ energy changes.

If the forward reaction is _____, the reverse reaction will be *exothermic*.

The same amount of energy is transferred in each _____.

Equilibrium

In a _____ system no reactants or products can escape. If a reversible reaction is carried out in a closed system, it will eventually reach _____ – a point in time when the forward and reverse reactions have the same rate.

At dynamic equilibrium:

-
-
-

Dynamic equilibrium

At dynamic equilibrium the amount of reactant and product are constant, but not necessarily _____.

You could have a mixture of reactants and products in a 50:50 ratio, in a 75:25 ratio, or in any ratio at all. The _____ of the reaction are what change that ratio.

How dynamic equilibrium is reached

Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of A + B	high	decreasing	_____
Frequency of collisions A + B	high	_____	_____
Rate of forward reaction	_____	_____	_____
Amount of C + D	_____	_____	_____
Frequency of collisions C + D	_____	_____	constant
Rate of reverse reaction	_____	_____	_____

Chapter 8: Rates and equilibrium

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C8 questions

Answers

- 1 What is the rate of a reaction?
- 2 What is the equation for calculating the mean rate of reaction?
- 3 What is the unit for rate of reaction in a reaction involving a change in mass?
- 4 What is the unit for rate of reaction in a reaction involving a change in volume?
- 5 What is the activation energy?
- 6 What effect does increasing concentration have on the rate of reaction?
- 7 Why does increasing concentration have this effect?
- 8 What effect does increasing pressure have on the rate of reaction?
- 9 Why does increasing pressure have this effect?
- 10 What effect does increasing surface area have on the rate of reaction?
- 11 Why does increasing surface area have this effect?
- 12 What effect does increasing temperature have on the rate of reaction?
- 13 Why does increasing temperature have this effect?
- 14 What is a catalyst?
- 15 How do catalysts increase the rate of a reaction?
- 16 What is a reversible reaction?
- 17 Which symbol shows a reversible reaction?
- 18 What is dynamic equilibrium?
- 19 What are the three reaction conditions that can be changed?
- 20 What is Le Châtelier's principle?
- 21 What is the effect of increasing the concentration of reactants on a reaction at dynamic equilibrium?

- 22 What is the effect of increasing the concentration of reactants on a reaction at dynamic equilibrium?
- 23 What is the effect of decreasing the concentration of products on a reaction at dynamic equilibrium?
- 24 What is the effect of increasing pressure on a reaction at dynamic equilibrium?
- 25 What is the effect of decreasing pressure on a reaction at dynamic equilibrium?
- 26 What is the effect of increasing temperature on a reaction at dynamic equilibrium?
- 27 What is the effect of decreasing temperature on a reaction at dynamic equilibrium?

Chapter 9: Crude oils and fuels

Knowledge organiser

Crude oil

Crude oil is incredibly important to our society and economy. It is formed from the remains of ancient biomass – living organisms (mostly plankton) that died many millions of years ago.

Raw crude oil is a thick black liquid made of a large number of different compounds mixed together. Most of the compounds are **hydrocarbons** of various sizes. Hydrocarbons are molecules made of carbon and hydrogen only.

Combustion

Hydrocarbons are used as **fuels**. This is because when they react with oxygen they release a lot of energy. This reaction is called **combustion**. Complete combustion is a type of combustion where the only products are carbon dioxide and water.

Properties

Whether or not a particular hydrocarbon is useful as a fuel depends on its properties:

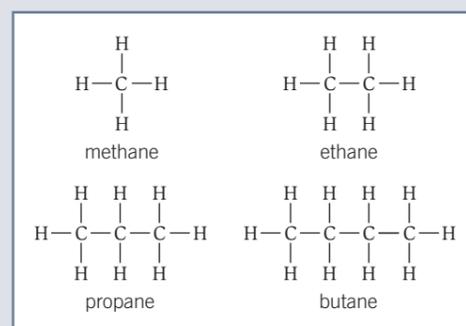
- **flammability** – how easily it burns
- **boiling point** – the temperature at which it boils
- **viscosity** – how thick it is

Its properties in turn depend on the length of the molecule.

Chain length	Flammability	Boiling point	Viscosity
long chain	low	high	high (very thick)
short chain	high	low	low (very runny)

Alkanes

One family of hydrocarbon molecules are called **alkanes**. Alkane molecules only have single bonds in them. The first four alkanes are:



The different alkanes have different numbers of carbon atoms and hydrogen atoms. You can always work the molecular formula of an alkane by using C_nH_{2n+2} .

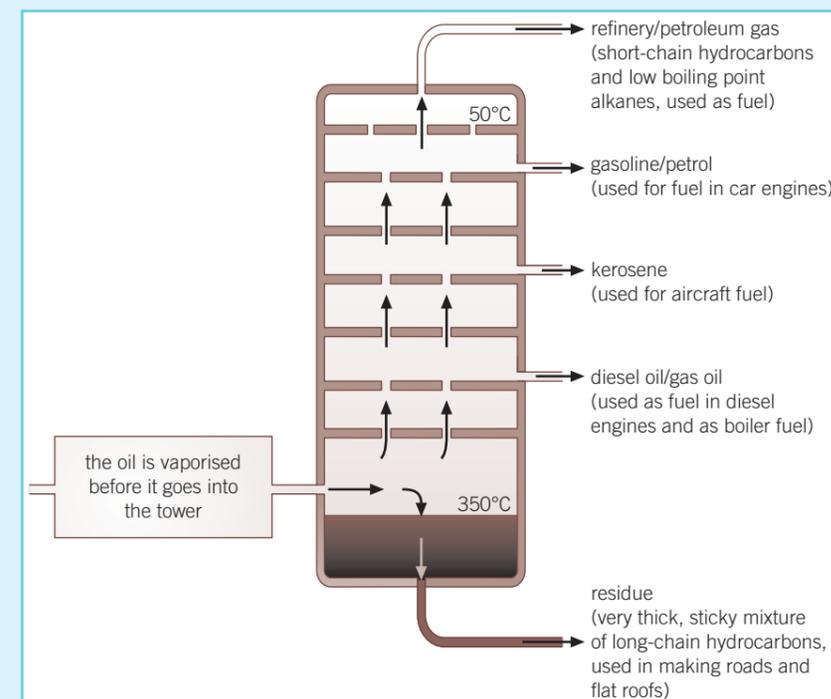
Fractional distillation

The different hydrocarbons in crude oil are separated into fractions based on their boiling points in a process called **fractional distillation**. All the molecules in a fraction have a similar number of carbon atoms, and so a similar boiling point.

The process takes place in a fractionating column, which is hot at the bottom and cooler at the top.

The process works like this:

- 1 crude oil is vapourised (turned into a gas by heating)
- 2 the hydrocarbon gases enter the column
- 3 the hydrocarbon gases rise up the column
- 4 as hydrocarbon gases rise up the column they cool down
- 5 when the different hydrocarbons reach their boiling point in the column they condense
- 6 the hydrocarbon fraction is collected.



Products from fractional distillation

Many useful products come from the separation of crude oil by fractional distillation.

Fuels	Feedstock	Useful materials produced
petrol, diesel oil, kerosene, heavy fuel oil, and liquefied petroleum gases	fractions form the raw material for other processes and the production of other substances	solvents, lubricants, polymers, and detergents

Cracking

Not all hydrocarbons are as useful as each other. Longer molecules tend to be less useful than shorter ones. As such, there is a higher demand for shorter-chain hydrocarbons than longer-chain hydrocarbons.

A process called **cracking** is used to break up longer hydrocarbons and turn them into shorter ones.

Cracking produces shorter alkanes and **alkenes**.

Two methods of cracking are:

- catalytic cracking – vaporise the hydrocarbons, then pass them over a hot catalyst
- steam cracking – mix the hydrocarbons with steam at a very high temperature

Alkenes

Alkenes are a family of hydrocarbons that contain double bonds between carbon atoms.

Alkenes are also used as fuels, and to produce polymers and many other materials.

They are much more reactive than alkanes. When mixed with bromine water, the bromine water turns from orange to colourless. This can be used to tell the difference between alkanes and alkenes.

Key terms

Make sure you can write a definition for these key terms.

alkanes alkenes boiling point combustion cracking crude oil feedstock
flammability fractional distillation fuel hydrocarbon viscosity

Chapter 9: Crude oil and fuels

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C9 questions

Answers

1	What is a hydrocarbon?	Put paper here	compound containing carbon and hydrogen only
2	How is crude oil formed?	Put paper here	over millions of years from the remains of ancient biomass
3	What are the alkanes?	Put paper here	hydrocarbons that only have single bonds
4	What are the first four alkanes?	Put paper here	methane, ethane, propane, butane
5	What is the general formula for the alkanes?	Put paper here	C_nH_{2n+2}
6	How does boiling point depend on the chain length?	Put paper here	longer the chain, higher the boiling point
7	How does viscosity depend on chain length?	Put paper here	longer the chain, higher the viscosity
8	How does flammability depend on chain length?	Put paper here	longer the chain, lower the flammability
9	How can the different alkanes in crude oil be separated?	Put paper here	fractional distillation
10	What is a fraction?	Put paper here	a group of hydrocarbons with similar chain lengths
11	Name five useful fuels produced from fractional distillation.	Put paper here	petrol, diesel oil, kerosene, heavy fuel oil, and liquefied petroleum gases
12	Name four useful materials produced from crude oil fractions.	Put paper here	solvents, lubricants, polymers, detergents
13	What is cracking?	Put paper here	breaking down a hydrocarbon with a long chain into smaller molecules
14	Name two methods to carry out cracking.	Put paper here	steam cracking and catalytic cracking
15	What are the products of cracking?	Put paper here	short chain alkanes and alkenes
16	What are alkenes?	Put paper here	hydrocarbons with a double bond
17	What are alkenes used for?	Put paper here	formation of polymers
18	Describe the reactivity of alkenes compared to alkanes.	Put paper here	alkenes are much more reactive
19	How can you test for alkenes?	Put paper here	alkenes turn orange bromine water colourless

Chapter 9: Crude oils and fuels

Knowledge organiser

Crude oil

Crude oil is incredibly important to our society and economy. It is formed from the remains of ancient _____ - living organisms (mostly _____) that died _____ of years ago.

Raw crude oil is a thick black _____ made of a large number of different _____ mixed together. Most of the compounds are _____ of various sizes. Hydrocarbons are _____.

Combustion

Hydrocarbons are used as _____. This is because when they react with _____ they release a lot of _____. This reaction is called _____. Complete combustion is a type of combustion where the only products are _____ and _____.

Properties

Whether or not a particular hydrocarbon is useful as a fuel depends on its properties:

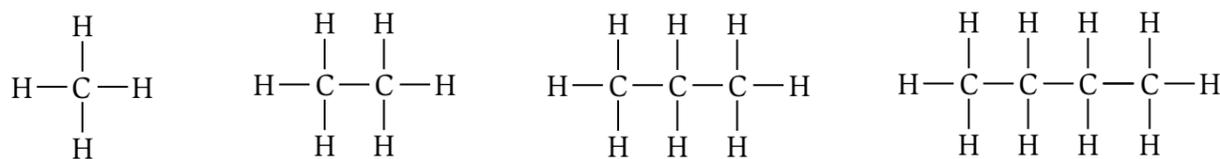
- _____ - how easily it burns
- _____ - the temperature at which it boils
- _____ - how thick it is

Its properties in turn depend on the length of the molecule. Complete the table.

Chain length	Flammability	Boiling point	Viscosity
long chain	low		
short chain			

Alkanes

One _____ of hydrocarbon molecules are called **alkanes**. Alkane molecules only have _____ bonds in them. The first four alkanes are:



The different alkanes have different numbers of carbon atoms and hydrogen atoms. You can always work the molecular formula of an alkane by using _____.

Key terms

Make sure you can write a definition for these key terms.

alkanes alkenes boiling point combustion cracking crude oil feedstock
 flammability fractional distillation fuel hydrocarbon viscosity

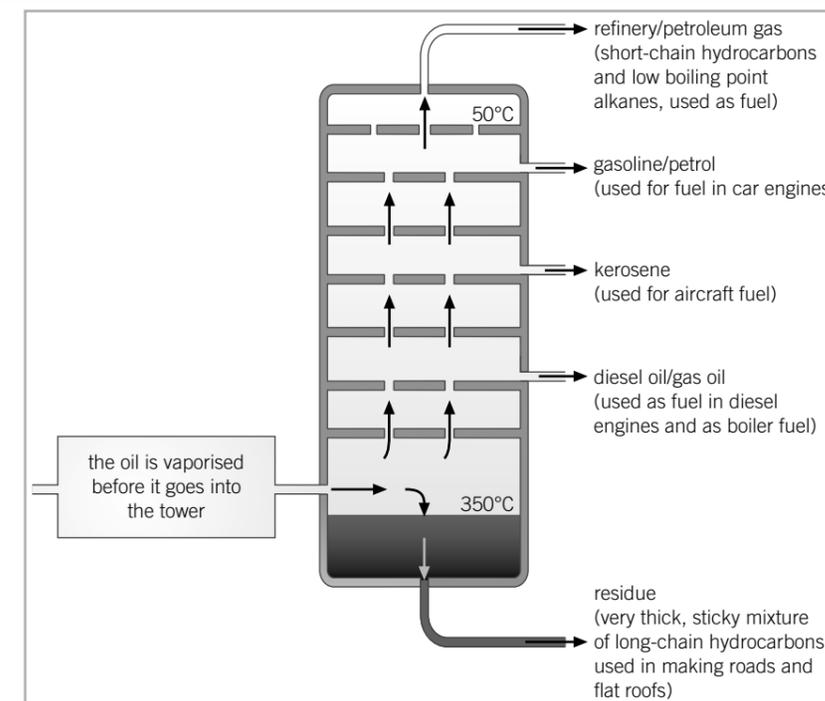
Fractional distillation

The different hydrocarbons in crude oil are separated into _____ based on their _____ points in a process called **fractional distillation**. All the molecules in a fraction have a similar number of _____ atoms, and so a similar boiling point.

The process takes place in a fractionating column, which is hot at the bottom and cooler at the top.

The process works like this:

- _____
- _____
- _____
- _____
- _____
- _____



Products from fractional distillation

Many useful products come from the separation of crude oil by fractional distillation.

Fuels	Feedstock	Useful materials produced
petrol, diesel oil, kerosene, heavy fuel oil, and liquefied petroleum gases		

Cracking

Not all hydrocarbons are as useful as each other. _____ tend to be less useful than shorter ones. As such, there is a higher demand for shorter-chain hydrocarbons than longer-chain hydrocarbons.

A process called **cracking** is used to _____ longer hydrocarbons and turn them into shorter ones.

Cracking produces shorter alkanes and **alkenes**.

Two methods of cracking are:

- _____
- _____

Alkenes

Alkenes are a family of hydrocarbons that contain _____ between carbon atoms.

Alkenes are also used as _____, and to produce _____ and many other materials.

They are much more reactive than _____. When mixed with bromine water, the bromine water turns from _____ to _____. This can be used to tell the difference between alkanes and alkenes.

Chapter 9: Crude oil and fuels

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C9 questions

Answers

- | C9 questions | Answers |
|--|---------|
| 1 What is a hydrocarbon? | |
| 2 How is crude oil formed? | |
| 3 What are the alkanes? | |
| 4 What are the first four alkanes? | |
| 5 What is the general formula for the alkanes? | |
| 6 How does boiling point depend on the chain length? | |
| 7 How does viscosity depend on chain length? | |
| 8 How does flammability depend on chain length? | |
| 9 How can the different alkanes in crude oil be separated? | |
| 10 What is a fraction? | |
| 11 Name five useful fuels produced from fractional distillation. | |
| 12 Name four useful materials produced from crude oil fractions. | |
| 13 What is cracking? | |
| 14 Name two methods to carry out cracking. | |
| 15 What are the products of cracking? | |
| 16 What are alkenes? | |
| 17 What are alkenes used for? | |
| 18 Describe the reactivity of alkenes compared to alkanes. | |
| 19 How can you test for alkenes? | |

Chapter 10: Organic reactions

Knowledge organiser

Organic chemistry

There are lots of different 'families' of carbon-containing compounds, for example, alkanes and **alkenes**. These families are called a **homologous series**. Each compound within a homologous series has similar properties and reactions. They all contain specific atoms in specific orders, called the **functional group**.

Homologous series	Functional group	First four of homologous series	Formation	Uses	Combustion reaction	Other reactions	Other information
alkenes		 ethene, C ₂ H ₄ propene, C ₃ H ₆ butene, C ₄ H ₈ pentene, C ₅ H ₁₀	cracking	<ul style="list-style-type: none"> formation of polymers a chemical feedstock 	<ul style="list-style-type: none"> complete combustion produces carbon dioxide and water incomplete combustion more likely, resulting in a smoky yellow flame both types of alkene combustion release less energy per mole than alkanes 	<p>Addition with halogens The two atoms from the halogen molecule are <i>added</i> across the carbon-carbon double bond.</p> $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ <p>Addition with hydrogen The two atoms from the hydrogen molecule are <i>added</i> across the carbon-carbon double bond to form an alkane.</p> $C_2H_4 + H_2 \rightarrow C_2H_6$ <p>Addition with steam React with steam at high temperature and pressure in the presence of a catalyst to form alcohols.</p> $C_2H_4 + H_2O \rightarrow C_2H_5OH$	<p>Alkenes are called unsaturated because they have double bonds. As such, atoms can be added to the molecule by breaking the double bond.</p> <p>This contrasts with alkanes which are called saturated as there is no space to add more atoms.</p> <p>Alkenes have a general formula C_nH_{2n}.</p>
alcohols	-OH	 methanol ethanol propanol butanol	Ethanol can be formed from the fermentation of sugar – warm a sealed mixture of yeast and a sugar solution. glucose → ethanol + carbon dioxide $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$	<ul style="list-style-type: none"> ethanol is used in alcoholic drinks first four alcohols mix easily with water, so are used as solvents for substances that don't dissolve in water common in perfumes, aftershaves and mouthwashes 	<ul style="list-style-type: none"> short alcohols are very effective fuels and combust easily, burning with a blue flame and producing carbon dioxide and water $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$	<p>Reaction with sodium Alcohols react with sodium to release hydrogen. The product from this reaction is called an alkoxide, which if added to water forms a strongly alkaline solution.</p> <p>Oxidation Alcohols can react with oxidising agents, like potassium dichromate, to form carboxylic acids.</p>	<p>Alcohols are highly flammable and must not be handled near naked flames.</p>
carboxylic acids		 methanoic acid ethanoic acid propanoic acid butanoic acid	oxidation of alcohols	<ul style="list-style-type: none"> ethanoic acid is used in vinegar 	<ul style="list-style-type: none"> carboxylic acids can undergo combustion, but we do not generally do this or use them as a fuel 	<p>Carboxylic acids react in the same way as other acids.</p> <p>Reaction with sodium carbonate Carboxylic acids react with bases to form salts. For example, carboxylic acids react with a metal carbonate to produce a salt, carbon dioxide, and water.</p> <p>Reaction with alcohols Carboxylic acids react with alcohols to make water and esters. The reaction requires sulfuric acid as a catalyst.</p> <p>Esters have distinctive smells and are used in perfumes and flavourings. The product of ethanol and ethanoic acid is ethyl ethanoate.</p>	<p>(HT only) When added to water, carboxylic acids are partially ionised to form weakly acidic solutions. They are weak acids.</p>



Key terms

Make sure you can write a definition for these key terms.

addition reaction alcohols alkene alkoxide carboxylic acid ester fermentation cracking functional group homologous series oxidation oxidising agent saturated unsaturated

Chapter 10: Organic reactions

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C10 questions

Answers

1	What is a homologous series?	Put paper here	a group of compounds with the same functional group
2	What is a functional group?	Put paper here	a group of atoms that determines the properties of a compound
3	What are alkenes?	Put paper here	a homologous series with a double carbon-carbon bond
4	What is the general formula for alkenes?	Put paper here	C_nH_{2n}
5	What is the product from an addition reaction of an alkene with a halogen?	Put paper here	a haloalkane
6	What is the product from the addition reaction of an alkene with hydrogen?	Put paper here	an alkane
7	What conditions are required for the addition reaction of an alkene with steam?	Put paper here	high temperature, high pressure, and a catalyst
8	What are alcohols?	Put paper here	a homologous series with an -OH group
9	How are alcohols produced?	Put paper here	steam with an alkene or fermentation
10	What conditions are required to produce alcohols by fermenting?	Put paper here	sugar solution with yeast mixed in, warm, sealed vessel
11	Name the first four alcohols.	Put paper here	methanol, ethanol, propanol, butanol
12	What are the products of a reaction between an alcohol and sodium?	Put paper here	hydrogen and an alkoxide
13	What is the organic product formed by the oxidation of an alcohol?	Put paper here	carboxylic acid
14	Name an oxidising agent.	Put paper here	acidified potassium dichromate
15	What are carboxylic acids?	Put paper here	a homologous series with a -COOH group
16	What do carboxylic acids form when they react with sodium carbonate?	Put paper here	salt, carbon dioxide, water
17	How are carboxylic acids produced?	Put paper here	oxidation of alcohols
18	Name the first four carboxylic acids.	Put paper here	methanoic acid, ethanoic acid, propanoic acid, butanoic acid
19	What is the organic product of a reaction between a carboxylic acid and an alcohol?	Put paper here	an ester
20	What catalyst is normally used in the formation of esters?	Put paper here	concentrated sulfuric acid
21	What occurs when pure carboxylic acids are added to water?	Put paper here	a weak acid is formed

Chapter 10: Organic reactions

Knowledge organiser

Organic chemistry

There are lots of different 'families' of carbon-containing compounds, for example, alkanes and **alkenes**. These families are called a _____. Each compound within a homologous series has similar properties and reactions. They all contain specific atoms in specific orders, called the _____ group. **Complete the table and draw the structural diagrams in the relevant boxes.**

Homologous series	Functional group	First four of homologous series	Formation	Uses	Combustion reaction	Other reactions	Other information
alkenes				<ul style="list-style-type: none"> complete combustion produces _____ and _____ incomplete combustion more likely, resulting in a _____ flame both types of alkene combustion release _____ per mole than alkanes 	<p>Addition with halogens The two atoms from the halogen molecule are _____ across the carbon - carbon double bond. Draw the structural diagram of the reaction.</p> $\text{C}_2\text{H}_4 + \text{Br}_2 \rightarrow \text{C}_2\text{H}_4\text{Br}_2$ <div style="border: 1px solid black; width: 100px; height: 30px; margin: 5px auto;"></div> <p>Addition with hydrogen The two atoms from the hydrogen molecule are _____ across the carbon - carbon double bond to form an _____. Draw the structural diagram of the reaction.</p> $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$ <div style="border: 1px solid black; width: 100px; height: 30px; margin: 5px auto;"></div> <p>Addition with steam React with steam at high _____ and _____ in the presence of a _____ to form alcohols. Draw the structural diagram of the reaction.</p> $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$ <div style="border: 1px solid black; width: 100px; height: 30px; margin: 5px auto;"></div>	Alkenes are called _____ because they have double bonds. As such, atoms can be added to the molecule by breaking the double bond. This contrasts with alkanes which are called _____ as there is no space to add more atoms. Alkenes have a general formula _____.	
alcohols			$\text{_____} \rightarrow \text{_____}$ $+ \text{_____}$ $\text{_____ (aq)} \rightarrow \text{_____ (aq)}$ $+ \text{_____}$	<ul style="list-style-type: none"> short alcohols are very effective _____ and combust easily, burning with a _____ flame and producing carbon dioxide and water $2 \text{_____} + 3 \text{_____} \rightarrow 2 \text{_____} + 4 \text{_____}$	<p>Reaction with sodium Alcohols react with _____ to release hydrogen. The product from this reaction is called an _____, which if added to water forms a strongly alkaline solution.</p> <p>Oxidation Alcohols can react with _____, like potassium dichromate, to form carboxylic acids.</p>	Alcohols are highly flammable and must not be handled near _____ flames.	
carboxylic acids				<ul style="list-style-type: none"> carboxylic acids can undergo _____, but we do not generally do this or use them as a fuel 	<p>Carboxylic acids react in the same way as other acids.</p> <p>Reaction with sodium carbonate Carboxylic acids react with bases to form _____. For example, carboxylic acids react with a metal carbonate to produce a salt, carbon dioxide, and water.</p> <p>Reaction with alcohols Carboxylic acids react with alcohols to make _____ and _____. The reaction requires _____ as a catalyst.</p> <p>Esters have distinctive smells and are used in perfumes and flavourings. The product of ethanol and ethanoic acid is _____.</p>	<div style="text-align: center;"> $\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C}=\text{O} \\ \quad \diagdown \\ \text{H} \quad \quad \text{O} \\ \quad \quad \quad \\ \quad \quad \quad \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \quad \\ \quad \quad \quad \text{H} \quad \text{H} \end{array}$ </div> <p>(HT only) When added to water, carboxylic acids are _____ to form weakly acidic solutions. They are weak acids.</p>	



Key terms

Make sure you can write a definition for these key terms.

addition reaction alcohols alkene alkoxide carboxylic acid ester fermentation cracking functional group homologous series oxidation oxidising agent saturated unsaturated

Chapter 10: Organic reactions

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C10 questions

Answers

- | C10 questions | Answers |
|--|---------|
| 1 What is a homologous series? | |
| 2 What is a functional group? | |
| 3 What are alkenes? | |
| 4 What is the general formula for alkenes? | |
| 5 What is the product from an addition reaction of an alkene with a halogen? | |
| 6 What is the product from the addition reaction of an alkene with hydrogen? | |
| 7 What conditions are required for the addition reaction of an alkene with steam? | |
| 8 What are alcohols? | |
| 9 How are alcohols produced? | |
| 10 What conditions are required to produce alcohols by fermenting? | |
| 11 Name the first four alcohols. | |
| 12 What are the products of a reaction between an alcohol and sodium? | |
| 13 What is the organic product formed by the oxidation of an alcohol? | |
| 14 Name an oxidising agent. | |
| 15 What are carboxylic acids? | |
| 16 What do carboxylic acids form when they react with sodium carbonate? | |
| 17 How are carboxylic acids produced? | |
| 18 Name the first four carboxylic acids. | |
| 19 What is the organic product of a reaction between a carboxylic acid and an alcohol? | |
| 20 What catalyst is normally used in the formation of esters? | |
| 21 What occurs when pure carboxylic acids are added to water? | |

Chapter 11: Polymers

Knowledge organiser

Polymers

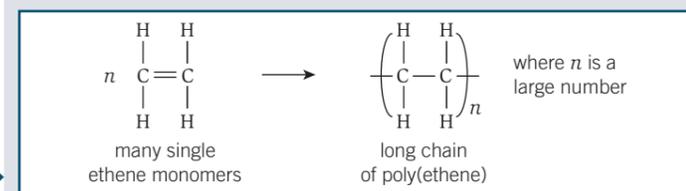
Polymers are very long molecules made up of lots of smaller molecules joined together in a repeating pattern. The smaller molecules are called **monomers**. The process of turning many monomers into a polymer is called polymerisation.

There are two main types of polymerisation.

Type of polymerisation	Monomers	Products of polymerisation
addition polymerisation	molecules with C=C bonds, such as alkenes	just the polymer
condensation polymerisation	diols, dicarboxylic acids, or diamines	polymer and water

Addition polymerisation

Addition polymerisation starts with molecules with a C=C bond (e.g., alkenes) as the monomer. The carbon-carbon double bond breaks in each molecule, and the carbon atoms then link together.



The n refers to a large number of molecules. The rounded brackets and the bonds sticking out of them represent where the next molecule in the chain goes.

The inside of the brackets is known as the **repeating unit** – the section that repeats over and over again many thousands of times in the polymer.

Addition polymers are named after the monomer used to create them.

- An addition polymer made of ethene is called poly(ethene).
- An addition polymer made of propene is called poly(propene).

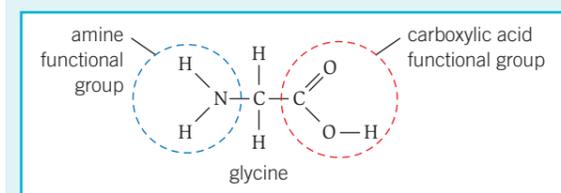
Natural polymers

Amino acids and proteins (HT only)

Condensation reactions can also happen with just one monomer molecule, so long as the molecule has two different functional groups.

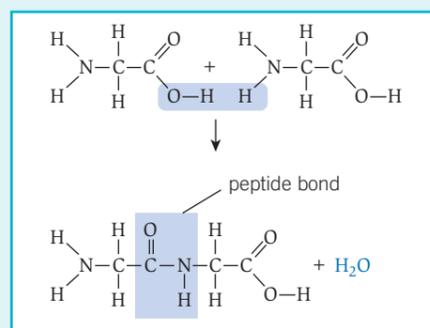
Amino acids have an **amine** functional group and a carboxylic acid functional group. The amine functional group has a nitrogen bonded to a carbon and two hydrogens.

Glycine is the simplest amino acid.



When many molecules of glycine react together they form a **polypeptide**.

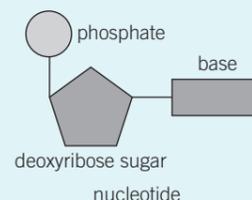
There are many different types of amino acids. They can react together to form many different polypeptides. When lots of polypeptides come together they form something called a **protein**.



DNA

All genetic information is stored in **DNA**. Genetic information contains the instructions for the functioning and development of living organisms.

DNA is made of two long polymers that wind around each other in a double helix. The polymers are made of four different monomers called **nucleotides**.



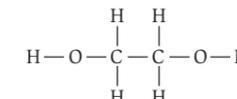
Starch and cellulose

Starch and cellulose are another two **natural polymers**. Both of these are made from glucose molecules joined together. Whether the resulting polymer is starch or cellulose depends on how the glucose molecules form chains with each other.

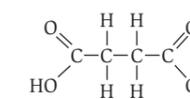
Condensation polymerisation (HT only)

Condensation polymerisation can involve two different monomers, each has *two* functional groups.

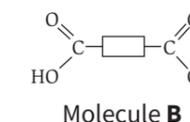
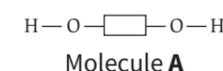
Molecule **A** is a diol. It has two –OH groups: one at either end.



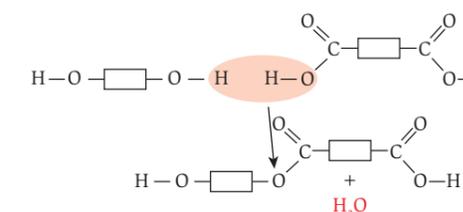
Molecule **B** is a **dicarboxylic acid**. It has a carboxylic acid group at either end.



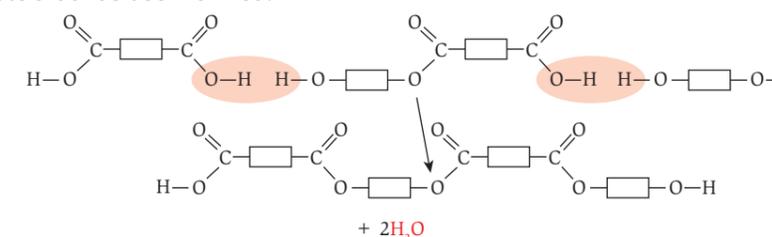
To simplify the diagrams, a rectangle is used to represent $\begin{matrix} H & H \\ | & | \\ C & - & C \\ | & | \\ H & H \end{matrix}$.



When molecule **A** and molecule **B** react together, the –OH group from the carboxylic acid and a hydrogen atom from the –OH group on the alcohol join together to form water.



Another molecule **B** and another molecule **A** can now react with either side of the molecule that has been formed.



You could keep adding more molecules in the pattern ABABABABA. Every time a molecule is added, a water molecule is produced. This type of reaction is called a **condensation reaction**.

If you keep adding molecules, a condensation polymer is produced. This is represented by:



When diols (compounds with two –OH groups) and dicarboxylic acids react together, they form polyesters.

Key terms

Make sure you can write a definition for these key terms.

addition polymerisation amine amino acid condensation polymerisation DNA
monomer natural polymer nucleotide polymer polypeptide protein repeating unit

Chapter 11: Polymers

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C11 questions

Answers

1	What are monomers?	Put paper here	small molecules that join together to form a long chain
2	What is a polymer?	Put paper here	a very long molecule made of repeating units
3	What is a repeating unit?	Put paper here	the smallest part of a polymer that repeats itself throughout the chain
4	What is polymerisation?	Put paper here	a reaction that turns multiple monomers into polymers
5	What are the two types of polymerisation?	Put paper here	addition and condensation
6	What kind of monomers are involved in addition polymerisation?	Put paper here	molecules with C=C bonds, such as alkenes
7	What kind of monomers are involved in condensation polymerisation?	Put paper here	monomers with two functional groups
8	What other products are made in condensation polymerisation?	Put paper here	water (normally)
9	What does n represent in an equation showing polymerisation?	Put paper here	a very large number
10	What is a natural polymer?	Put paper here	a polymer that is produced naturally by organisms
11	Give four examples of natural polymers.	Put paper here	polypeptides, starch, cellulose, DNA
12	What are amino acids?	Put paper here	the building blocks for polypeptides and proteins, which have an amine and a carboxylic acid group
13	What is a polypeptide?	Put paper here	a polymer made from many amino acids
14	What is a protein?	Put paper here	a polymer made from amino acids
15	Which monomer makes up starch and cellulose?	Put paper here	glucose
16	What is DNA?	Put paper here	a molecule containing genetic information
17	Which monomers are DNA made of?	Put paper here	nucleotides
18	How is DNA arranged?	Put paper here	double helix

Chapter 11: Polymers

Knowledge organiser

Polymers

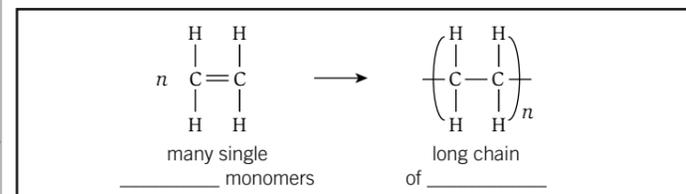
Polymers are very _____ molecules made up of lots of smaller molecules joined together in a _____ pattern. The smaller molecules are called _____. The process of turning many monomers into a polymer is called _____.

There are two main types of polymerisation.

Type of polymerisation	Monomers	Products of polymerisation
_____ polymerisation	molecules with C=C bonds, such as _____	just the polymer
_____ polymerisation	diols, dicarboxylic acids, or diamines	polymer and _____

Addition polymerisation

Addition polymerisation starts with molecules with a _____ (e.g., alkenes) as the monomer. The carbon-carbon double bond breaks in each molecule, and the carbon atoms then link together.



The n refers to _____. The rounded brackets and the bonds sticking out of them represent where the next molecule in the chain goes.

The inside of the brackets is known as the _____ - the section that repeats over and over again many thousands of times in the polymer.

Addition polymers are named after the monomer used to create them.

- An addition polymer made of ethene is called _____.
- An addition polymer made of _____ is called poly(propene).

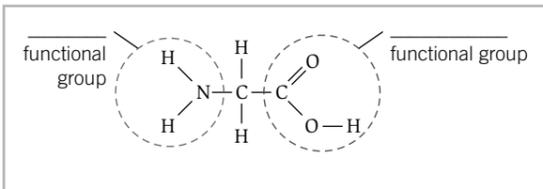
Natural polymers

Amino acids and proteins (HT only)

_____ reactions can also happen with just one monomer molecule, so long as the molecule has _____ different functional groups.

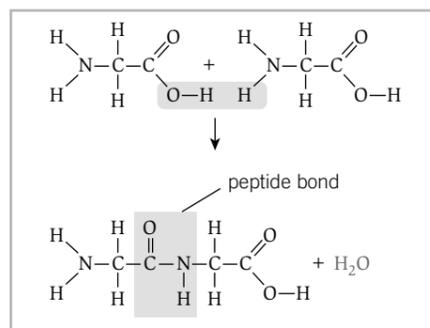
Amino acids have an _____ functional group and a _____ functional group. The amine functional group has a _____ bonded to a carbon and two hydrogens.

_____ is the simplest amino acid.



When many molecules of glycine react together they form a _____.

There are many different types of amino acids. They can react together to form many different polypeptides. When lots of polypeptides come together they form something called a _____.

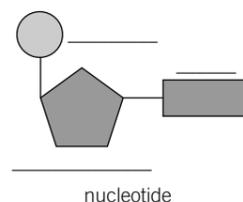


DNA

All genetic information is stored in _____. Genetic information contains the instructions for the functioning and development of _____.

DNA is made of _____.

The polymers are made of four different monomers called _____.



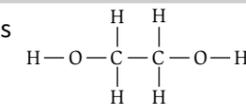
Starch and cellulose

Starch and cellulose are another two **natural polymers**. Both of these are made from _____ molecules joined together. Whether the resulting polymer is starch or cellulose depends on how the glucose molecules form _____ with each other.

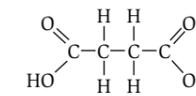
Condensation polymerisation (HT only)

Condensation polymerisation can involve two different monomers, each has *two* functional groups.

Molecule **A** is a _____. It has two _____ groups: one at _____ either end.



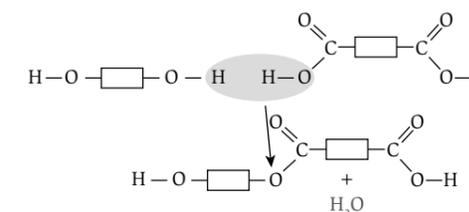
Molecule **B** is a _____. It has a _____ group at _____ either end.



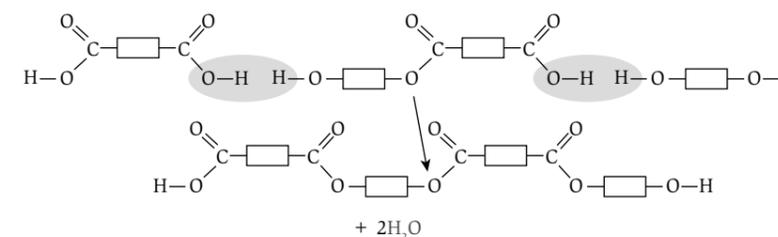
To simplify the diagrams, a rectangle is used to represent $\begin{array}{c} \text{H} \quad \text{H} \\ | \quad | \\ \text{---} \text{C} - \text{C} \text{---} \\ | \quad | \\ \text{H} \quad \text{H} \end{array}$. Draw molecules A and B.



When molecule **A** and molecule **B** react together, the _____ group from the _____ and a hydrogen atom from the -OH group on the _____ join together to form _____.

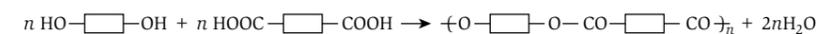


Another molecule _____ and another molecule _____ can now react with either side of the molecule that has been formed.



You could keep adding more molecules in the pattern ABABABABA. Every time a molecule is added, a _____ molecule is produced. This type of reaction is called a _____ reaction.

If you keep adding molecules, a condensation polymer is produced. This is represented by:



When diols (compounds with two -OH groups) and dicarboxylic acids react together, they form _____.

Key terms

Make sure you can write a definition for these key terms.

addition polymerisation amine amino acid condensation polymerisation DNA
monomer natural polymer nucleotide polymer polypeptide protein repeating unit

Chapter 11: Polymers

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C11 questions

Answers

1 What are monomers?

2 What is a polymer?

3 What is a repeating unit?

4 What is polymerisation?

5 What are the two types of polymerisation?

6 What kind of monomers are involved in addition polymerisation?

7 What kind of monomers are involved in condensation polymerisation?

8 What other products are made in condensation polymerisation?

9 What does n represent in an equation showing polymerisation?

10 What is a natural polymer?

11 Give four examples of natural polymers.

12 What are amino acids?

13 What is a polypeptide?

14 What is a protein?

15 Which monomer makes up starch and cellulose?

16 What is DNA?

17 Which monomers are DNA made of?

18 How is DNA arranged?

Chapter 12: Chemical analysis

Knowledge organiser

Pure and impure

In chemistry, a **pure** substance contains a single element or compound that is not mixed with any other substance.

Pure substances melt and boil at specific temperatures.

An **impure** substance contains more than one type of element or compound in a **mixture**.

Impure substances melt and boil at a range of temperatures.

Formulations

Formulations are examples of mixtures. They have many different components (substances that make them up) in very specific proportions (amounts compared to each other).

Scientists spend a lot of time trying to get the right components in the right proportions to make the most useful product.

Formulations include fuels, cleaning agents, paints, alloys, fertilisers, and foods.

Testing gases

Common gases can be identified using the follow tests:

Gas	What you do	What you observe if gas is present
hydrogen	hold a lighted splint near the gas	hear a squeaky pop
oxygen	hold a glowing splint near the gas	splint re-lights
carbon dioxide	bubble the gas through limewater	the limewater turns milky (cloudy white)
chlorine	hold a piece of damp litmus near the gas	bleaches the litmus white

Flame tests

Substances containing metals can produce a coloured light in a flame. This can be used to identify the metal. However, if there is more than one metal in the substance then this method will not work, as the colours mix and intense colours mask more subtle colours.

Metal	Flame colour
lithium	crimson
sodium	yellow
potassium	lilac
calcium	orange-red
copper	green

Instrumental methods

Instrumental analysis involves using complex scientific equipment to test substances.

Instrumental methods are rapid and accurate. They are also sensitive, which means they can give results even with very small amounts of substance.

Flame emission spectroscopy

Flame emission spectroscopy is a type of instrumental analysis similar to a **flame test**.

The sample solution is put into a flame and the light given off is passed through a spectroscope. Instead of a human observing a colour, the instrument tells you exactly which wavelength of light is being given off as a line spectrum. You can then compare the spectrum to a reference to establish the identity of your sample. You can also measure the concentration of the substance in your sample solution.

Chromatography

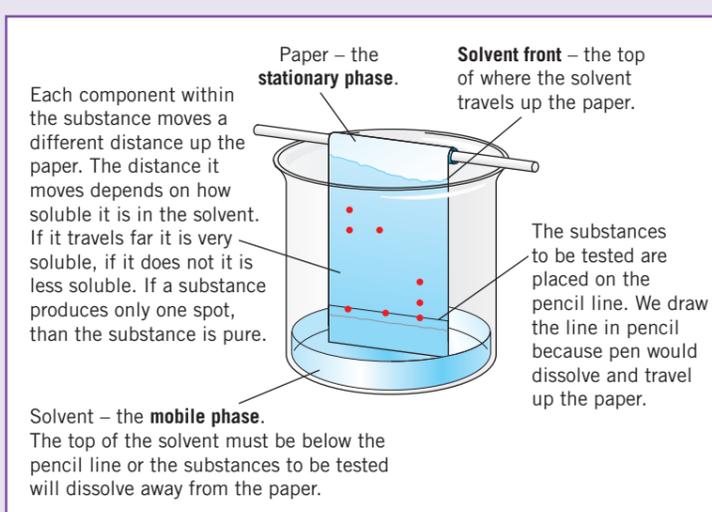
Chromatography is a method to separate different components in a mixture. It is set up as shown here, with a piece of paper in a beaker containing a small amount of solvent.

The **R_f value** is a ratio of how far up the paper a certain spot moves compared to how far the **solvent** has travelled.

$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$

It will always be a number between 0 and 1.

The R_f value depends on the solvent and the temperature, and different substances will have different R_f values. The R_f values for particular solvents can be used to identify a substance.



Testing for cations

Metal ions always have a positive charge (i.e., they are cations). Sodium hydroxide solution can be used to identify some metal ions.

Cation	Positive result
aluminium ions, Al ³⁺	on slow addition of excess sodium hydroxide solution, white precipitate forms that eventually dissolves again with excess sodium hydroxide
calcium ions, Ca ²⁺	on addition of excess sodium hydroxide solution, white precipitate that does not dissolve
magnesium ions, Mg ²⁺	on addition of excess sodium hydroxide solution, white precipitate that does not dissolve
copper(II) ions, Cu ²⁺	forms a blue precipitate
iron(II) ions, Fe ²⁺	forms a green precipitate
iron(III) ions, Fe ³⁺	forms a brown precipitate

Testing for anions

Anion	Test	Positive result
carbonate, CO ₃ ²⁻	add dilute acid	carbon dioxide gas formed which can be test for with limewater
chloride, Cl ⁻	add silver nitrate solution in the presence of nitric acid	white precipitate formed
bromide, Br ⁻	add silver nitrate solution in the presence of nitric acid	cream precipitate formed
iodide, I ⁻	add silver nitrate solution in the presence of nitric acid	yellow precipitate formed
sulfate, SO ₄ ²⁻	add barium chloride solution in the presence of hydrochloric acid	white precipitate formed

Key terms

Make sure you can write a definition for these key terms.

chromatography flame emission spectroscopy flame test formulation impure instrumental analysis
mobile phase precipitate pure R_f value solvent solvent front stationary phase

Chapter 12: Chemical analysis

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C12 questions

Answers

1	In chemistry, what is a pure substance?	Put paper here	something made of only one type of substance
2	What is the difference between the melting and boiling points of a pure and impure substance?	Put paper here	pure – sharp/one specific temperature impure – broad/occurs across a range of temperatures
3	What is a formulation?	Put paper here	a mixture designed for a specific purpose
4	What are some examples of formulations?	Put paper here	fuels, cleaning agents, paints, medicines, alloys, fertilisers, and foods
5	What is chromatography?	Put paper here	a process for separating coloured mixtures
6	How is R_f calculated?	Put paper here	$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$
7	What is the test for hydrogen?	Put paper here	a lit splint gives squeaky pop
8	What is the test for oxygen?	Put paper here	re-lights a glowing splint
9	What is the test for carbon dioxide?	Put paper here	turns limewater milky if bubbled through it
10	What is the test for chlorine?	Put paper here	bleaches damp litmus paper
11	What is the test for aluminium, calcium, and magnesium ions?	Put paper here	forms white precipitate with sodium hydroxide solution
12	How can aluminium ions be distinguished from calcium and magnesium ones?	Put paper here	the white precipitate will dissolve with excess sodium hydroxide
13	What colour precipitates are formed when sodium hydroxide solution is added to solutions of copper(II), iron(II), and iron(III) ions?	Put paper here	copper(II) ions form blue precipitate, iron(II) ions form green precipitate, iron(III) ions form brown precipitate
14	What is the test for a halide ion?	Put paper here	add silver nitrate and nitric acid: chloride forms white precipitate, bromide forms cream precipitate, iodide forms yellow precipitate
15	What is the test for a carbonate ion?	Put paper here	carbon dioxide gas formed on addition of acid
16	What is the test for a sulfate ion?	Put paper here	white precipitate formed with hydrochloric acid and barium chloride
17	What colours are produced by different metals in a flame test?	Put paper here	lithium – crimson; sodium – yellow; potassium – lilac; calcium – orange-red; copper – green
18	What is instrumental analysis?	Put paper here	using complex scientific equipment to identify substances
19	What are the three advantages of instrumental analysis?	Put paper here	rapid, accurate, and sensitive
20	What information does flame emission spectroscopy produce?	Put paper here	the wavelength of light given off by a metal in a flame to identity of the metal and its concentration

Chapter 12: Chemical analysis

Knowledge organiser

Pure and impure

In chemistry, a _____ substance contains a single element or compound that is not _____ with any other substance.

Pure substances melt and boil at _____ temperatures.

An **impure** substance contains more than one type of element or compound in a _____.

Impure substances melt and boil at a _____ of temperatures.

Formulations

Formulations are examples of mixtures. They have many different _____ (substances that make them up) in very specific _____ (amounts compared to each other).

Scientists spend a lot of time trying to get the right components in the right proportions to make the most useful product.

Formulations include _____.

Testing gases

Common gases can be identified using the follow tests:

Gas	What you do	What you observe if gas is present
hydrogen		
	hold a glowing splint near the gas	splint re-lights
	bubble the gas through limewater	the limewater turns milky (cloudy white)
chlorine		

Flame tests

Substances containing metals can produce a coloured light in a flame. This can be used to identify the metal. However, if there is more than one metal in the substance then this method will not work, as the colours mix and intense colours mask more subtle colours.

Metal	Flame colour
lithium	
sodium	
potassium	
	orange-red
	green

Instrumental methods

Instrumental analysis involves using complex scientific equipment to test substances.

Instrumental methods are rapid and accurate. They are also sensitive, which means _____.

Flame emission spectroscopy

Flame emission spectroscopy is a type of instrumental analysis similar to a _____.

The sample solution is put into a flame and the light given off is passed through a _____. Instead of a human observing a colour, the instrument tells you exactly which _____ of light is being given off as a _____. You can then compare the spectrum to a _____ to establish the identity of your sample. You can also measure the _____ of the substance in your sample solution.

Chromatography

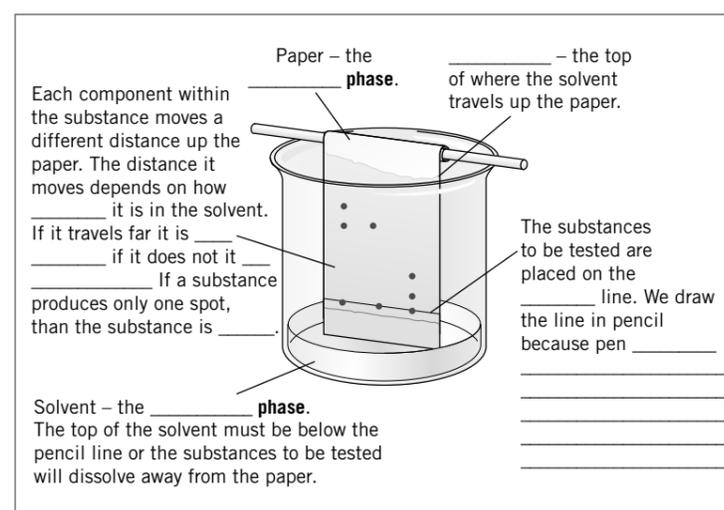
Chromatography is a method to _____ different components in a mixture. It is set up as shown here, with a piece of paper in a _____ containing a small amount of _____.

The **R_f value** is a _____ of how far up the paper a certain spot moves compared to how far the **solvent** has travelled.

$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$

It will always be a number between _____ and _____.

The R_f value depends on the solvent and the _____, and different substances will have different R_f values. The R_f values for particular solvents can be used to identify a substance.



Testing for cations

Metal ions always have a _____ charge (i.e., they are cations). Sodium hydroxide solution can be used to identify some metal ions.

Cation	Positive result
aluminium ions, Al ³⁺	
calcium ions, Ca ²⁺	
magnesium ions, Mg ²⁺	
copper(II) ions, Cu ²⁺	
	forms a green precipitate
iron(III) ions, Fe ³⁺	

Testing for anions

Anion	Test	Positive result
carbonate, CO ₃ ²⁻		
chloride, Cl ⁻		
	add silver nitrate solution in the presence of nitric acid	cream precipitate formed
iodide, I ⁻		
	add barium chloride solution in the presence of hydrochloric acid	white precipitate formed

Key terms

Make sure you can write a definition for these key terms.

chromatography flame emission spectroscopy flame test formulation impure instrumental analysis
 mobile phase precipitate pure R_f value solvent solvent front stationary phase

Chapter 12: Chemical analysis

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C12 questions

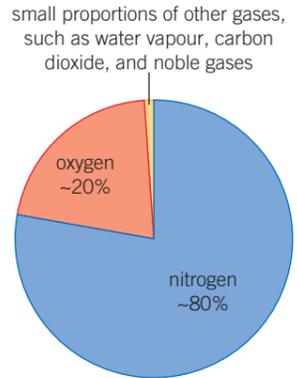
Answers

- 1 In chemistry, what is a pure substance?
- 2 What is the difference between the melting and boiling points of a pure and impure substance?
- 3 What is a formulation?
- 4 What are some examples of formulations?
- 5 What is chromatography?
- 6 How is R_f calculated?
- 7 What is the test for hydrogen?
- 8 What is the test for oxygen?
- 9 What is the test for carbon dioxide?
- 10 What is the test for chlorine?
- 11 What is the test for aluminium, calcium, and magnesium ions?
- 12 How can aluminium ions be distinguished from calcium and magnesium ones?
- 13 What colour precipitates are formed when sodium hydroxide solution is added to solutions of copper(II), iron(II), and iron(III) ions?
- 14 What is the test for a halide ion?
- 15 What is the test for a carbonate ion?
- 16 What is the test for a sulfate ion?
- 17 What colours are produced by different metals in a flame test?
- 18 What is instrumental analysis?
- 19 What are the three advantages of instrumental analysis?
- 20 What information does flame emission spectroscopy produce?

Chapter 13: The Earth's atmosphere

Knowledge organiser

The Earth's changing atmosphere

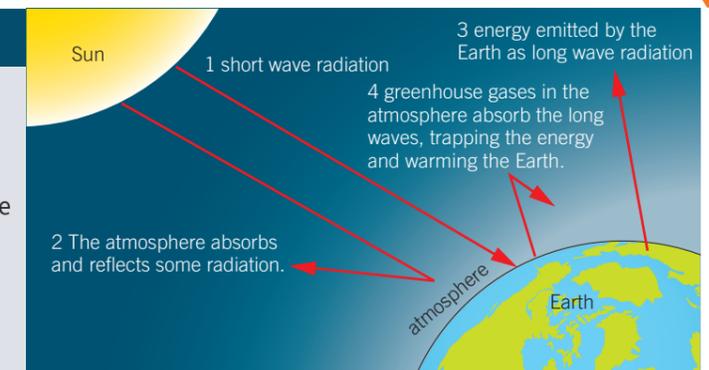
Period	Proportions of gases	Evidence
about 4.6 billion years ago to about 2.7 billion years ago	<ul style="list-style-type: none"> carbon dioxide, CO₂ Released by volcanoes. Biggest component of the atmosphere. oxygen, O₂ Very little oxygen present. nitrogen, N₂ Released by volcanoes. water vapour, H₂O Released by volcanoes. Existed as vapour as Earth was too hot for it to condense. other gases Ammonia, NH₃, and methane, CH₄, may also have been present. 	Because it was billions of years ago there is very little evidence to draw upon.
about 2.7 billion years ago to about 200 million years ago	<ul style="list-style-type: none"> carbon dioxide, CO₂ Amount in atmosphere begins to reduce because: <ul style="list-style-type: none"> water condenses to form the oceans, in which CO₂ then dissolves algae (and later plants) start to photosynthesise $\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$ $6\text{CO}_2 + 6\text{H}_2\text{O} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ CO₂ precipitates in the oceans as solid carbonates (sediments) that form rocks CO₂ taken in by plants and animals. When they die, the carbon in them is locked up as fossil fuels oxygen, O₂ Starts to increase as a product of photosynthesis. nitrogen, N₂ Continues to increase. Nitrogen is a very stable molecule so any process that produces it causes the overall amount to build up over time. water vapour, H₂O Starts to decrease. As the Earth cools, the vapour condenses and forms the oceans. 	Still limited as billions of years ago, but can look at processes that happen today (like photosynthesis) and make theories about the past.
about 200 million years ago until the present	<ul style="list-style-type: none"> carbon dioxide, CO₂ about 0.04% oxygen, O₂ about 20% nitrogen, N₂ about 80% water vapour, H₂O Very little overall. Collects in large clouds as part of the water cycle. other gases Small proportions of other gases such as the noble gases. 	Ice core evidence for millions of years ago and lots of global measurements taken recently.

Greenhouse gases

Greenhouse gases, such as carbon dioxide, methane, and water vapour, absorb radiation and maintain temperatures on the Earth to support life.

However, in the last 150 years, more greenhouse gases have been released due to human activities.

- carbon dioxide – combustion of fossil fuels, deforestation
- methane – planting rice fields, cattle farming



Global warming

Scientists have gathered peer-reviewed evidence to demonstrate that increasing the amount of greenhouse gases in the atmosphere will increase the overall average temperature of the Earth. This is called **global warming**.

However, it is difficult to make predictions about the atmosphere as it is so big and complex. This leads some people to doubt what scientists say.

Global climate change

Global warming leads to another process called **global climate change** – how the overall weather patterns over many years and across the entire planet will change.

There are many different effects of climate change, including:

- sea levels rising
- extreme weather events
- changes in the amount and time of rainfall
- changes to ecosystems and habitats
- polar ice caps melting.

Carbon footprints

Increasing the amount of greenhouse gases in the atmosphere increases the global average temperature of the Earth, which results in global climate change.

As such, it is important to reduce the release of greenhouse gases into the atmosphere. The amount of carbon dioxide and methane that is released into the atmosphere by a product, person, or process is called its **carbon footprint**.

Other pollutants released in combustion of fuels

Pollutant	Origin	Effect
carbon monoxide	incomplete combustion of fuels	colourless and odourless toxic gas
particulates (soot and unburnt hydrocarbons)	incomplete combustion of fuels especially in diesel engines	global dimming , respiratory problems, potential to cause cancer
sulfur dioxide	sulfur impurities in the fuel reacting with oxygen from the air	acid rain and respiratory problems
oxides of nitrogen	nitrogen from the air being heated near an engine and reacting with oxygen	acid rain and respiratory problems

Key terms

Make sure you can write a definition for these key terms.

acid rain atmosphere carbon footprint global climate change carbon monoxide global dimming global warming greenhouse gas particulate pollutant

Chapter 13: The Earth's atmosphere

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C13 questions

Answers

1	What is the atmosphere?	Put paper here	a layer of gas surrounding the Earth
2	What was the early atmosphere composed of?	Put paper here	mostly carbon dioxide
3	How did the oceans form?	Put paper here	water vapour condensing as the Earth cooled
4	How did the amount of carbon dioxide in the atmosphere decrease to today's levels?	Put paper here	dissolved in the oceans, photosynthesis, converted to fossil fuels, precipitated as insoluble metal carbonates
5	When did life start to appear, and what was the impact of this on oxygen in the atmosphere?	Put paper here	about 2.7 billion years ago; amount of atmospheric oxygen increased as it was released in photosynthesis
6	How has the amount of nitrogen in the atmosphere changed over time?	Put paper here	increased slowly as it is a very stable molecule
7	Why can scientists not be sure about the composition of the Earth's early atmosphere?	Put paper here	it was billions of years ago and evidence is limited
8	What is the current composition of the atmosphere?	Put paper here	approximately 80% nitrogen, 20% oxygen, and trace amounts of other gases such as carbon dioxide, water vapour, and noble gases
9	What is a greenhouse gas?	Put paper here	a gas that traps radiation from the Sun
10	What type of radiation do greenhouse gases absorb?	Put paper here	longer wavelength infrared radiation
11	Name three greenhouse gases.	Put paper here	methane, carbon dioxide, water vapour
12	Give two ways recent human activities have increased the amount of atmospheric carbon dioxide.	Put paper here	burning fossil fuels, deforestation
13	Give two ways recent human activities have increased the amount of atmospheric methane.	Put paper here	rice farming, cattle farming
14	What is global warming?	Put paper here	an increase in the overall global average temperature
15	What is global climate change?	Put paper here	the change in long-term weather patterns across the planet
16	What are some possible effects of climate change?	Put paper here	sea levels rising, extreme weather events, changes in the amount and time of rainfall, changes to ecosystems and habitats, polar ice caps melting
17	What is a carbon footprint?	Put paper here	the amount of carbon a product, process, or person releases into the atmosphere over its lifetime
18	How is carbon monoxide formed, and what is the danger associated with it?	Put paper here	incomplete combustion; colourless and odourless toxic gas
19	How are particulates formed, and what are the dangers associated with them?	Put paper here	incomplete combustion; global dimming, respiratory problems, potential to cause cancer
20	How is sulfur dioxide formed, and what are the dangers associated with it?	Put paper here	sulfur impurities in fossil fuels react with oxygen during combustion; acid rain, respiratory problems
21	How are oxides of nitrogen formed, and what are the dangers associated with them?	Put paper here	atmospheric oxygen and nitrogen react in the heat of a combustion engine; acid rain, respiratory problems

Chapter 13: The Earth's atmosphere

Knowledge organiser

The Earth's changing atmosphere

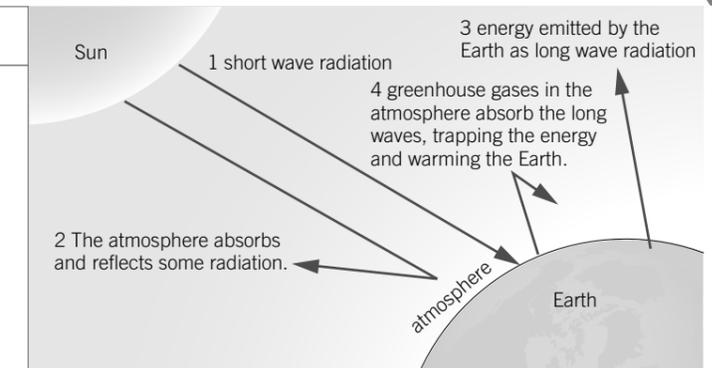
Period	Proportions of gases	Evidence
about 4.6 billion years ago to about 2.7 billion years ago	<ul style="list-style-type: none"> carbon dioxide, CO₂ Released by _____. Biggest component of the _____. oxygen, O₂ _____ oxygen present. nitrogen, N₂ Released by _____. water vapour, H₂O Released by _____. Existed as vapour as Earth was too hot for it to _____. other gases _____, and _____, may also have been present. 	
about 2.7 billion years ago to about 200 million years ago	<ul style="list-style-type: none"> carbon dioxide, CO₂ Amount in atmosphere begins to _____ because: <ul style="list-style-type: none"> water condenses to form the _____, in which CO₂ then _____ algae (and later plants) start to _____ $\text{carbon dioxide} + \text{water} \xrightarrow{\quad} \text{_____} + \text{_____}$ $\text{_____} + \text{_____} \xrightarrow{\quad} \text{_____} + \text{_____}$ CO₂ precipitates in the oceans as solid _____ (sediments) that form rocks CO₂ taken in by plants and animals. When they die, the carbon in them is locked up as _____ oxygen, O₂ Starts to _____ as a product of photosynthesis. nitrogen, N₂ Continues to increase. Nitrogen is a very _____ molecule so any process that produces it causes the overall amount to build up over time. water vapour, H₂O Starts to _____. As the Earth cools, the vapour condenses and forms the oceans. 	
about 200 million years ago until the present	<ul style="list-style-type: none"> carbon dioxide, CO₂ about _____ oxygen, O₂ about _____ nitrogen, N₂ about _____ water vapour, H₂O Very little overall. Collects in large clouds as part of the _____. other gases Small proportions of other gases such as the _____. <div style="text-align: center;"> <p>small proportions of other gases, such as water vapour, carbon dioxide, and noble gases</p> </div>	

Greenhouse gases

Greenhouse gases, such as _____, _____ and _____, absorb radiation and maintain temperatures on the Earth to support life.

However, in the last 150 years, more greenhouse gases have been released due to human activities.

- carbon dioxide – combustion of _____,
- _____
- methane – planting _____, _____



Global warming

Scientists have gathered peer-reviewed evidence to demonstrate that increasing the amount of _____ in the atmosphere will increase the overall _____ temperature of the Earth. This is called **global warming**.

However, it is difficult to make predictions about the atmosphere as it is so big and complex. This leads some people to doubt what scientists say.

Global climate change

Global warming leads to another process called **global climate change** – how the overall weather patterns over many years and across the entire planet will change.

There are many different effects of climate change, including:

-
-
-
-
-

Carbon footprints

Increasing the amount of greenhouse gases in the atmosphere increases the _____ of the Earth, which results in global climate change.

As such, it is important to reduce the release of greenhouse gases into the atmosphere. The amount of carbon dioxide and methane that is released into the atmosphere by a product, person, or process is called its _____.

Other pollutants released in combustion of fuels

Pollutant	Origin	Effect
carbon monoxide		
particulates (soot and unburnt hydrocarbons)		
sulfur dioxide		
oxides of nitrogen		

Key terms

Make sure you can write a definition for these key terms.

acid rain atmosphere carbon footprint global climate change carbon monoxide global dimming global warming greenhouse gas particulate pollutant

Chapter 13: The Earth's atmosphere

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C13 questions

Answers

1	What is the atmosphere?	
2	What was the early atmosphere composed of?	
3	How did the oceans form?	
4	How did the amount of carbon dioxide in the atmosphere decrease to today's levels?	
5	When did life start to appear, and what was the impact of this on oxygen in the atmosphere?	
6	How has the amount of nitrogen in the atmosphere changed over time?	
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11	Name three greenhouse gases.	
12	Give two ways recent human activities have increased the amount of atmospheric carbon dioxide.	
13	Give two ways recent human activities have increased the amount of atmospheric methane.	
14	What is global warming?	
15	What is global climate change?	
16	What are some possible effects of climate change?	
17	What is a carbon footprint?	
18	How is carbon monoxide formed, and what is the danger associated with it?	
19	How are particulates formed, and what are the dangers associated with them?	
20	How is sulfur dioxide formed, and what are the dangers associated with it?	
21	How are oxides of nitrogen formed, and what are the dangers associated with them?	

Chapter 14: The Earth's resources 1

Knowledge organiser

Natural and synthetic resources

We use the Earth's resources to provide us with warmth, fuel, shelter, food, and transport.

- Natural resources are used for food, timber, clothing, and fuels.
- Synthetic resources are made by scientists. They can replace or supplement natural resources.

When choosing and synthesising resources, it is important to consider **sustainable development**. This is development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Finite and renewable resources

Some resources are **finite**. This means that they will eventually run out.

Fossil fuels are an example of a finite resource. They take so long to form that we use them faster than they are naturally formed.

Resources that will not run out are called **renewable** resources.

Wood is an example of a renewable resource. Trees can be grown to replace any that are cut down for wood.

Potable water

Water is a vital resource for life. **Potable** water is water that is safe to drink. However, most water on Earth is not potable.

Type of water	What it has in it
pure water	just water molecules and nothing else
potable water	water molecules, low levels of salts, safe levels of harmful microbes
salty water (sea water)	water molecules, dangerously high levels of salt, can have high levels of harmful microbes
fresh water (from rivers, lakes, or underground)	water molecules, low levels of salt, often has harmful microbes at high levels

Fresh water

In the UK, potable water is produced from rain water that collects in lakes and rivers. To produce potable water:

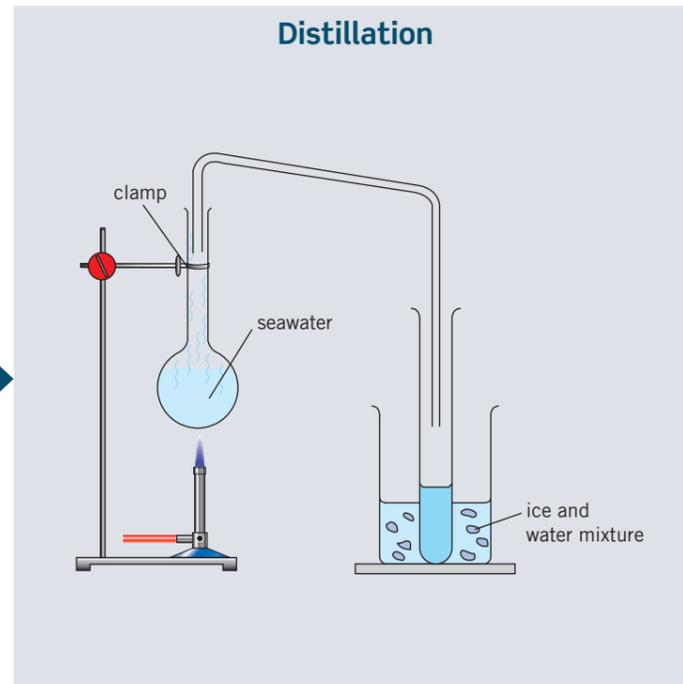
- 1 Choose an appropriate source of fresh water.
- 2 Pass the water through filters to remove large objects.
- 3 **Sterilise** the water to kill any microbes using ozone, chlorine, or UV light.

Salty water

Some countries do not have lots of fresh water available. **Desalination** is the process to turn saltwater into potable water. This requires a lot of energy and can be done by:

- distillation
- reverse osmosis

Reverse osmosis involves using membranes to separate the salts dissolved in the water. The water needs to be pressurised and the salty water corrodes the pumps. As such, it is an expensive process.



Waste water

Human activities produce lots of waste water as sewage, agricultural waste, and industrial waste.

- **Sewage** and agricultural waste contain organic matter and harmful microbes.
- Industrial waste contains organic matter and harmful chemicals.

These need to be removed before the water can be put back into the environment.

Treating sewage water

screening and grit removal

The sewage passes through a metal grid that filters out large objects.

sedimentation

The sewage is left so that solid sediments settle out of the water. The sediments sink to the bottom of the tank. The liquid sits above the sediment.

Treating sludge

sewage sludge

This sediment is called **sludge**. Sludge contains organic matter, water, dissolved compounds, and small solid particles.

anaerobic treatment

Bacteria are added to digest the organic matter. These bacteria break down the matter anaerobically – with a limited supply of oxygen.

biogas

The anaerobic digestion of sludge produces biogas. Biogas is a mixture of methane, carbon dioxide and hydrogen sulfide. It can be used as fuel.

remaining sludge used as fuel

The remaining sludge can be dried out and can also be burnt as a fuel.

Treating effluent

effluent

The remaining liquid is called **effluent**. This effluent has no solid matter visible, but still contains some matter and harmful microorganisms.

aerobic treatment

Bacteria are added to the effluent. These bacteria feed on organic matter and the harmful microorganisms in the effluent. The bacteria break down the matter by aerobic respiration – oxygen needs to be present.

bacteria removed

The bacteria are allowed to settle out of the water.

discharged back to rivers

The water is now safe enough to be released back into the environment.

Chapter 14: The Earth's resources

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C14 questions

Answers

1	What do we use the Earth's resources for?	Put paper here	warmth, shelter, food, fuel, transport
2	What are some examples of natural resources?	Put paper here	cotton, wool, timber
3	What are some examples of synthetic resources?	Put paper here	plastic, polyester, acrylic
4	What is a finite resource?	Put paper here	a resource that will eventually run out
5	What is sustainable development?	Put paper here	development that meets the needs of current generations without compromising the ability of future generations to meet their own needs
6	What are the four main types of water?	Put paper here	pure water, salt water, fresh water, potable water
7	What is potable water?	Put paper here	water that is safe to drink
8	In the UK, how is potable water extracted from fresh water?	Put paper here	filtration and sterilisation
9	What is sterilisation?	Put paper here	killing microbes
10	What are three examples of sterilising agents?	Put paper here	chlorine gas, UV light, and ozone
11	How can potable water be produced from salt water?	Put paper here	desalination
12	How can desalination be carried out?	Put paper here	distillation or reverse osmosis
13	What are the three main types of waste water?	Put paper here	sewage, agricultural waste, industrial waste
14	What can waste water contain?	Put paper here	organic matter, harmful microbes, harmful chemicals
15	What is the first step in processing waste water?	Put paper here	screening and grit removal
16	What is sedimentation?	Put paper here	separating the waste water into sludge and effluent
17	How is sludge treated?	Put paper here	anaerobic respiration
18	How is effluent treated?	Put paper here	aerobic respiration
19	What is phytomining?	Put paper here	using plants to extract copper
20	What is bioleaching?	Put paper here	using bacteria to extract copper
21	What is a life cycle assessment?	Put paper here	a way of assessing the energy costs and environmental effect of a product across its lifetime
22	What are the four stages of a life cycle assessment?	Put paper here	<ul style="list-style-type: none">• extracting and processing raw materials• manufacturing and packaging• use and operation during its lifetime• disposal at the end of its useful life
23	How can we reduce the amount of new materials manufactured?	Put paper here	by reducing, reusing, or recycling products
24	In what ways can materials that are not recycled be disposed?	Put paper here	landfill or incineration

Chapter 14: The Earth's resources 1

Knowledge organiser

Natural and synthetic resources

We use the Earth's resources to provide us with warmth, fuel, shelter, food, and transport.

- Natural resources are used for _____, _____, _____ and _____.
- _____ resources are made by scientists. They can replace or supplement natural resources.

When choosing and synthesising resources, it is important to consider _____. This is development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Finite and renewable resources

Some resources are **finite**. This means that _____.

_____ are an example of a finite resource. They take so long to form that we use them faster than they are naturally formed.

Resources that will not run out are called _____ resources.

_____ is an example of a renewable resource. Trees can be grown to replace any that are cut down for wood.

Potable water

Water is a vital resource for life. _____ water is water that is safe to drink. However, most water on Earth is not potable.

Type of water	What it has in it
pure water	
potable water	
salty water (sea water)	
fresh water (from rivers, lakes, or underground)	

Fresh water

In the UK, potable water is produced from rain water that collects in lakes and rivers. To produce potable water:

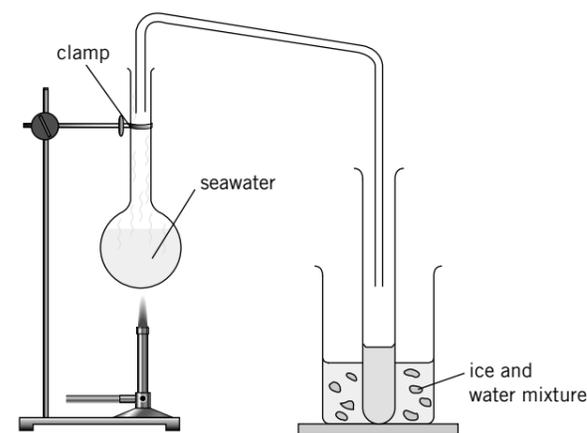
1. _____
2. _____
3. _____

Salty water

Some countries do not have lots of fresh water available. _____ is the process to turn saltwater into potable water. This requires a lot of _____ and can be done by:

- _____
 - _____
- Reverse osmosis involves using _____ to separate the salts dissolved in the water. The water needs to be _____ and the salty water corrodes the pumps. As such, it is an _____ process.

Distillation



Waste water

Human activities produce lots of waste water as _____, _____ and _____.

- **Sewage** and agricultural waste contain _____.
- Industrial waste contains _____.

These need to be removed before the water can be put back into the environment.

Treating sewage water

screening and grit removal

The sewage passes through a _____ that _____ out large objects.

sedimentation

The sewage is left so that _____ settle out of the water. The sediments sink to the bottom of the tank. The liquid sits above the sediment.

Treating sludge

sewage sludge

This sediment is called _____. Sludge contains _____.

anaerobic treatment

_____ are added to digest the organic matter. These bacteria break down the matter anaerobically – with a limited supply of _____.

biogas

The anaerobic digestion of sludge produces _____. Biogas is a mixture of _____, _____ and _____ sulfide. It can be used as fuel.

remaining sludge used as fuel

The remaining sludge can be dried out and can also be _____ as a fuel.

Treating effluent

effluent

The remaining liquid is called **effluent**. This effluent has no solid matter visible, but still contains some matter and harmful _____.

aerobic treatment

_____ are added to the effluent. These bacteria feed on organic matter and the harmful microorganisms in the effluent. The bacteria break down the matter by aerobic respiration – _____ needs to be present.

bacteria removed

The bacteria are allowed to settle out of the water.

discharged back to rivers

The water is now safe enough to be released back into the _____.

Chapter 14: The Earth's resources 2

Knowledge organiser

Metal extraction (HT only)

Metals are used for many different things. Some metals can be extracted from their ores by _____ or _____.

However, metal ores are a _____ resources and these processes require lots of energy.

Scientists are looking for new ways to extract metals that are more sustainable.

Phytomining and **bioleaching** are two alternative processes used to extract _____ from low grade ores (ores with only a little copper in them).

Phytomining

1. _____
2. _____
3. _____
4. _____

Bioleaching

1. _____
2. _____
3. _____

Both of these methods avoid the digging, moving, and disposing of large amounts of rock associated with traditional mining techniques.

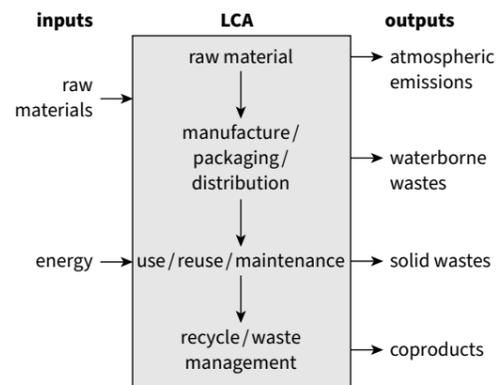
Life cycle assessment

A **life cycle assessment (LCA)** is a way of looking at the whole life of a product and assessing its impact on the environment and sustainability. It is broken down into four categories:

-
-
-
-

Some parts of an LCA are _____, such as the amount of water used or waste produced in the production of a product.

However, other parts of an LCA require judgements, such as the _____ effect, and so LCAs are not a completely objective process.



Key terms

Make sure you can write a definition for these key terms.

- aerobic anaerobic biodegrade bioleaching distillation effluent
 finite resources life cycle assessment phytomining potable water recycling
 renewable resources reverse osmosis screening sedimentation sewage
 sludge sterilisation sustainable development

Disposal of products

When someone finishes with a product, it can be:

-
-
-
-

The table shows information about the extraction, processing, and disposal of some common materials. This information is used when making a LCA.

Material	Extraction/processing	Disposal
metal	• • •	• •
plastic	•	• • •
paper	•	• • •
glass	•	• •
ceramics	• •	• •

Chapter 14: The Earth's resources

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C14 questions

Answers

- 1 What do we use the Earth's resources for?
- 2 What are some examples of natural resources?
- 3 What are some examples of synthetic resources?
- 4 What is a finite resource?
- 5 What is sustainable development?
- 6 What are the four main types of water?
- 7 What is potable water?
- 8 In the UK, how is potable water extracted from fresh water?
- 9 What is sterilisation?
- 10 What are three examples of sterilising agents?
- 11 How can potable water be produced from salt water?
- 12 How can desalination be carried out?
- 13 What are the three main types of waste water?
- 14 What can waste water contain?
- 15 What is the first step in processing waste water?
- 16 What is sedimentation?
- 17 How is sludge treated?
- 18 How is effluent treated?
- 19 What is phytomining?
- 20 What is bioleaching?
- 21 What is a life cycle assessment?
- 22 What are the four stages of a life cycle assessment?
- 23 How can we reduce the amount of new materials manufactured?
- 24 In what ways can materials that are not recycled be disposed?

-
-
-
-

Chapter 15: Making our resources 1

Knowledge organiser

Corrosion

Corrosion is when a material reacts with substances in the environment and eventually wears away. Corrosion can be prevented in two ways:

- physical barriers
- sacrificial protection

Rusting is an example of corrosion. It is caused by iron reacting with oxygen *and* water from the environment.

Physical barriers

The material is covered with a physical barrier like grease, paint, or a thin layer of another metal by a process called electroplating.

Aluminium reacts with oxygen to make a very thin layer of aluminium oxide around the metal that acts as a physical barrier. This layer then protects the rest of the metal from corrosion.

Sacrificial protection

A more reactive substance is placed on the material. The more reactive substance will react with the environment, and not the main material.

For example, iron is **galvanised** with zinc. The zinc then reacts with the oxygen and water in place of the iron.

Alloys

Alloys allow us to tailor the properties of metals to specific uses.

Alloy	Composition	Properties	Use
bronze	copper and tin	resistant to corrosion	statues, decorative items, ship propellers
brass	copper and zinc	very hard but workable	door fittings, taps, musical instruments
gold alloys	mostly gold with copper, silver and zinc added	attractive, corrosion resistant, hardness depends on carat	jewellery the proportion of gold is measured in carats. 24 carat gold contains 100% gold, 18 carat gold contains 75% gold
high carbon steel	iron with 1-2% carbon	strong but brittle	cutting tools, metal presses
low carbon steel	iron with <1% carbon	soft, easy to shape	extensive use in manufacture of cars, machinery, ships, containers, structural steel
stainless steel	iron with chromium and nickel	resistant to corrosion, hard	cutlery, plumbing
aluminium alloys	over 300 alloys available	low density, properties depend on composition	aircraft, military uses

Ceramics

Ceramics are materials with versatile properties that can have many different uses.

Ceramic	Manufacture	Properties	Uses
soda-lime glass	heat a mixture of sand, sodium carbonate, limestone	transparent, brittle	everyday glass objects
borosilicate glass	heat sand and boron trioxide	higher melting point than soda-lime glass	oven glassware, laboratory glassware
clay ceramics (pottery + bricks)	shape wet clay then heat in a furnace	hard, brittle, easy to shape before manufacture, resistant to corrosion	crockery, construction, plumbing fixtures

Polymers

The properties of polymers depend on

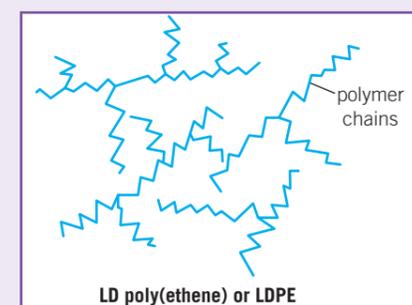
- the monomers that make them up
- the conditions under which they are made.

For example, **low density poly(ethene)** and **high density poly(ethene)** are both made from ethene monomers but have very different properties due to the way that the polymer chains line up in the material.

Low density poly(ethene)

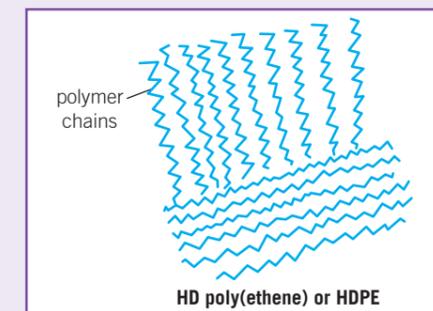
LDPE is formed when the addition polymerisation reaction of ethene is carried out under high pressure and in the presence of a small amount of oxygen.

The branched polymer chains cannot pack together, so causing the low density of the polymer.



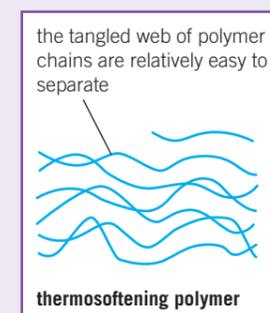
High density poly(ethene)

HDPE is formed when the addition polymerisation reaction of ethene is carried out using a catalyst at 50 °C. The polymer chains are straight and can pack tightly together, so causing the high density of the polymer.



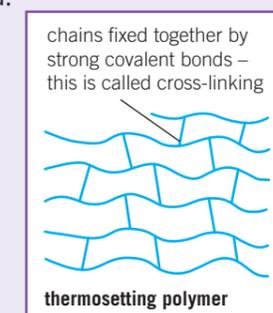
Thermosoftening polymers

Thermosoftening polymers do not have links between the different chains, and soften when they are heated.



Thermosetting polymers

Thermosetting polymers have strong links between the different chains, and do not melt when they are heated.



Composites

Composites are made from a main material (called a **matrix**) with fragments or fibres of other materials (called **reinforcements**) added into them. This means the material's properties can be made more useful.

Plywood and reinforced concrete are examples of composites.

Chapter 15: Making our resources 2

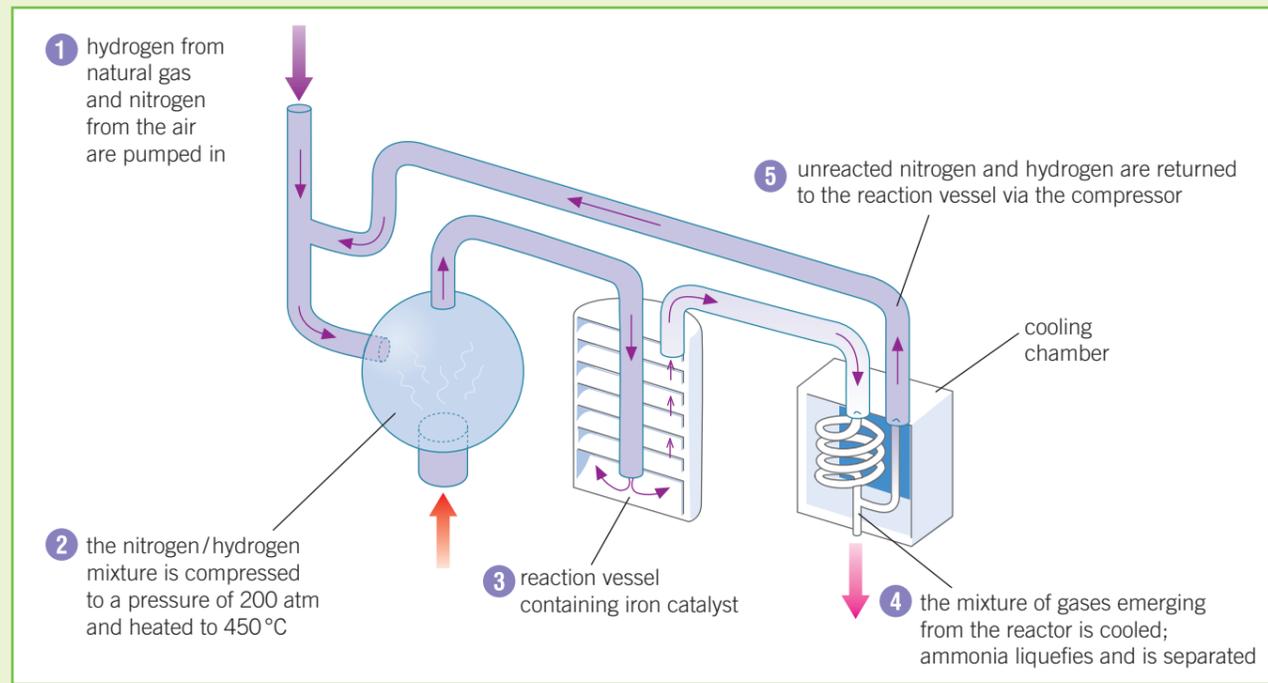
Knowledge organiser

The Haber process

Fertilisers are important chemicals used to improve the growth of crop plants. Ammonia is a vital component of many fertilisers. It is produced in the **Haber process**:

- nitrogen + hydrogen \rightleftharpoons ammonia
- $N_2(g) + 2H_2(g) \rightleftharpoons 2NH_3(g)$

It is a reversible reaction, so the conditions affect the yield.



Conditions

Compromise

The conditions used for the Haber process are a *compromise* to balance yield, cost, and rate.

- an iron catalyst
- temperatures of about 450°C
- pressure of about 200 atmospheres

Temperature

The forward reaction is exothermic. Therefore, lowering the temperature would increase the yield of ammonia, but would also decrease the rate of reaction.

Pressure

There are fewer gas molecules on the product side, so increasing the pressure would increase the yield and the rate of reaction. However, it is very expensive to increase the pressure.

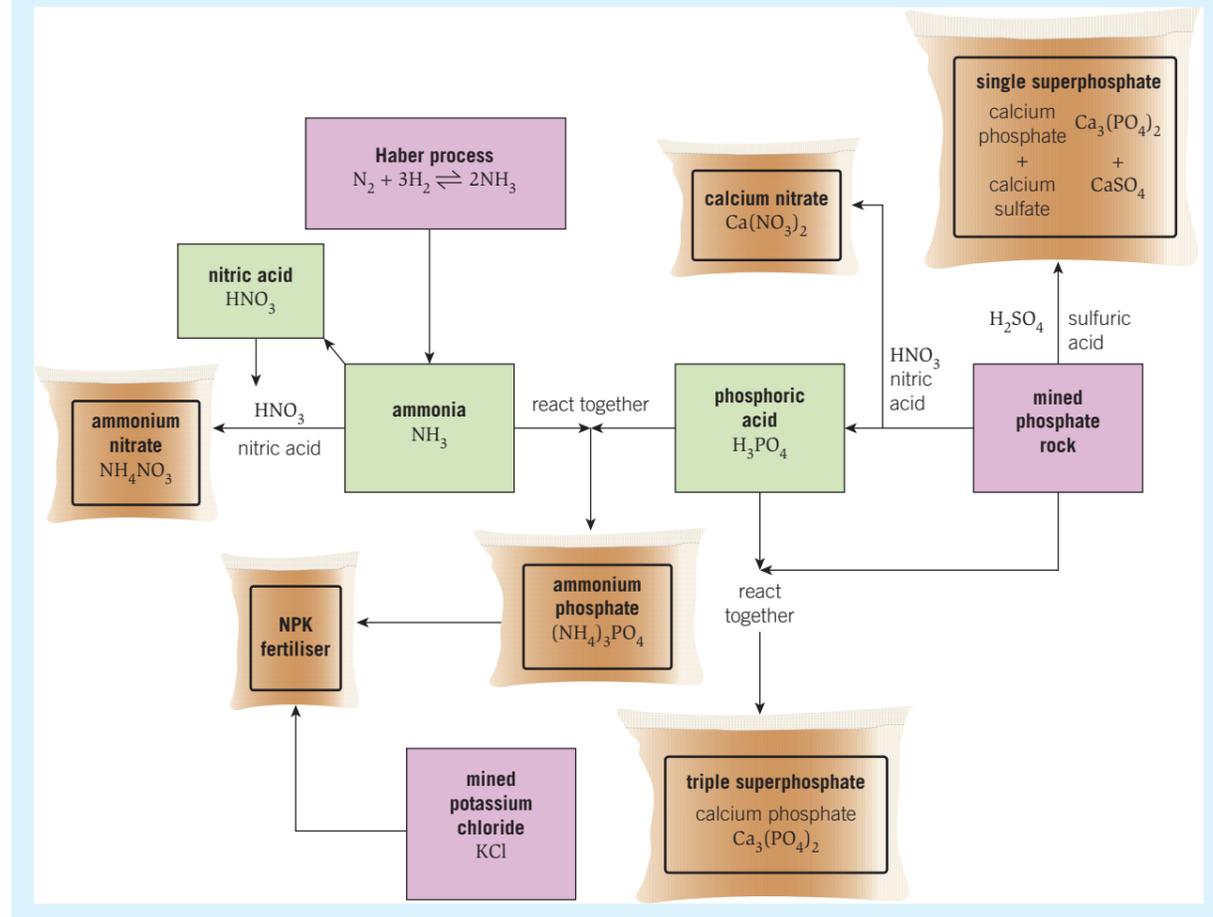
Catalyst

Iron is an effective catalyst for the Haber process. It does not increase the yield, but does increase the rate.

Fertilisers

Fertilisers are produced industrially to increase the amount of food obtained from crops. Compounds containing nitrogen, phosphorous, and potassium are used, and fertilisers with all three in them are called **NPK fertilisers**.

NPK fertilisers are formulations. Some of the substances that go into NPK fertilisers can be mined straight from the ground (like potassium chloride or potassium sulfate). Others, like phosphate rock, need to be processed first. Phosphate rock can react with different acids to make different products, which can either be used as fertilisers on their own or added to an NPK fertiliser.



Laboratory vs. industry

The compounds found in fertilisers can be produced in the laboratory as well as industrially:

	laboratory	industrial
Quantities produced	small	large
Process	batch (do it once)	continuous (can keep doing it)
Apparatus	glass	stainless steel
Speed	slow	fast



Key terms

Make sure you can write a definition for these key terms.

alloy ceramic composite corrosion galvanise Haber process matrix NPK fertiliser reinforce rusting thermosetting thermosoftening

Chapter 15: Making our resources

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C15 questions

Answers

1	What is corrosion?	Put paper here	the destruction of a material through reactions with substances in the environment
2	What physical barriers be used to protect against corrosion?	Put paper here	grease, paint, a thin layer of metal
3	What is sacrificial protection?	Put paper here	adding a more reactive metal to the surface of a material
4	How is rust formed?	Put paper here	reaction between iron, water, and oxygen
5	What are two alloys of copper?	Put paper here	brass and bronze
6	What are gold alloys in jewellery made from?	Put paper here	gold with copper, zinc, and silver
7	What are steel alloys made from?	Put paper here	iron, carbon, and other metals
8	What is a property of aluminium alloys?	Put paper here	generally have low densities
9	What is the main difference between soda-lime and borosilicate glass?	Put paper here	borosilicate glass has a much higher melting point
10	Give two examples of clay ceramics.	Put paper here	pottery and bricks
11	What two things do the properties of polymers depend on?	Put paper here	monomers and the conditions under which they are formed
12	What is the main difference between thermosetting and thermosoftening polymers?	Put paper here	thermosetting polymers do not soften when heated, thermosoftening polymers do
13	What is a composite?	Put paper here	a mixture of a matrix and reinforcements
14	Name two composites.	Put paper here	plywood and reinforced concrete
15	What is the balanced symbol equation for the Haber process?	Put paper here	$\text{N}_2(\text{g}) + 2\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
16	What is the ammonia used for?	Put paper here	fertilisers
17	What is the effect of increasing the temperature of the Haber process on the yield, rate, and cost?	Put paper here	decrease yield, increase rate, increase cost
18	What is the effect of increasing the pressure of the Haber process on the yield, rate and cost?	Put paper here	increase yield, increase rate, increase cost
19	What catalyst do we use for the Haber process?	Put paper here	iron
20	What are the conditions for the Haber process?	Put paper here	450 °C, 200 atm, iron catalyst
21	What is an NPK fertiliser?	Put paper here	a formulation containing soluble compounds of nitrogen, phosphorous, and potassium

Chapter 15: Making our resources 1

Knowledge organiser

Corrosion

Corrosion is when _____. Corrosion can be prevented in two ways:

- _____
- _____

_____ is an example of corrosion. It is caused by iron reacting with oxygen *and* water from the environment.

Physical barriers

The material is covered with a physical barrier like grease, paint, or a thin layer of another metal by a process called _____.

Aluminium reacts with oxygen to make a very thin layer of _____ around the metal that acts as a physical barrier. This layer then protects the rest of the metal from corrosion.

Sacrificial protection

A more _____ substance is placed on the material. The more reactive substance will react with the _____, and not the main material.

For example, iron is **galvanised** with zinc. The zinc then reacts with the _____ and _____ in place of the iron.

Alloys

Alloys allow us to tailor the properties of metals to specific uses.

Alloy	Composition	Properties	Use
bronze			
brass			
gold alloys			
high carbon steel			
low carbon steel			
stainless steel			
aluminium alloys			

Ceramics

Ceramics are materials with versatile properties that can have many different uses.

Ceramic	Manufacture	Properties	Uses
soda-lime glass			
borosilicate glass			
clay ceramics (pottery + bricks)			

Polymers

The properties of polymers depend on

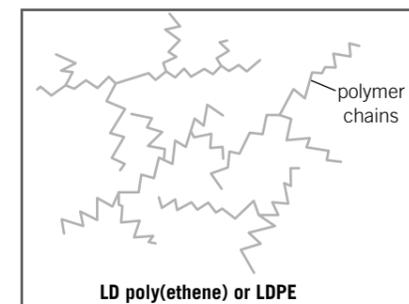
- _____
- _____

For example, **low density poly(ethene)** and **high density poly(ethene)** are both made from _____ monomers but have very different properties due to the way that the polymer chains line up in the material.

Low density poly(ethene)

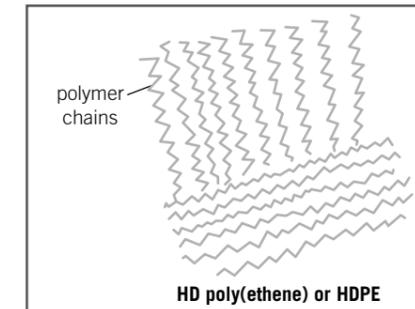
LDPE is formed when the _____ polymerisation reaction of ethene is carried out under _____ and in the presence of a small amount of _____.

The branched polymer chains _____ pack together, so causing the low density of the polymer.



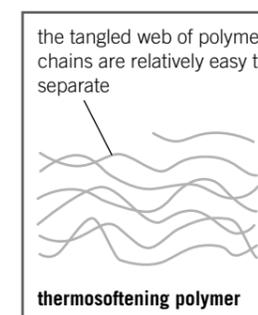
High density poly(ethene)

HDPE is formed when the _____ polymerisation reaction of ethene is carried out using a _____ at _____ °C. The polymer chains are _____ and can pack tightly together, so causing the high density of the polymer.



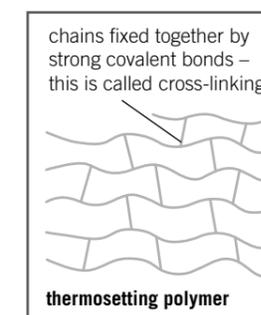
Thermosoftening polymers

Thermosoftening polymers do not have _____ between the different chains, and _____ when they are heated.



Thermosetting polymers

Thermosetting polymers have _____ links between the different chains, and do not melt when they are heated.



Composites

Composites are made from a main material (called a _____) with fragments or fibres of other materials (called _____) added into them. This means the material's properties can be made more useful.

_____ and _____ are examples of composites.

Chapter 15: Making our resources 2

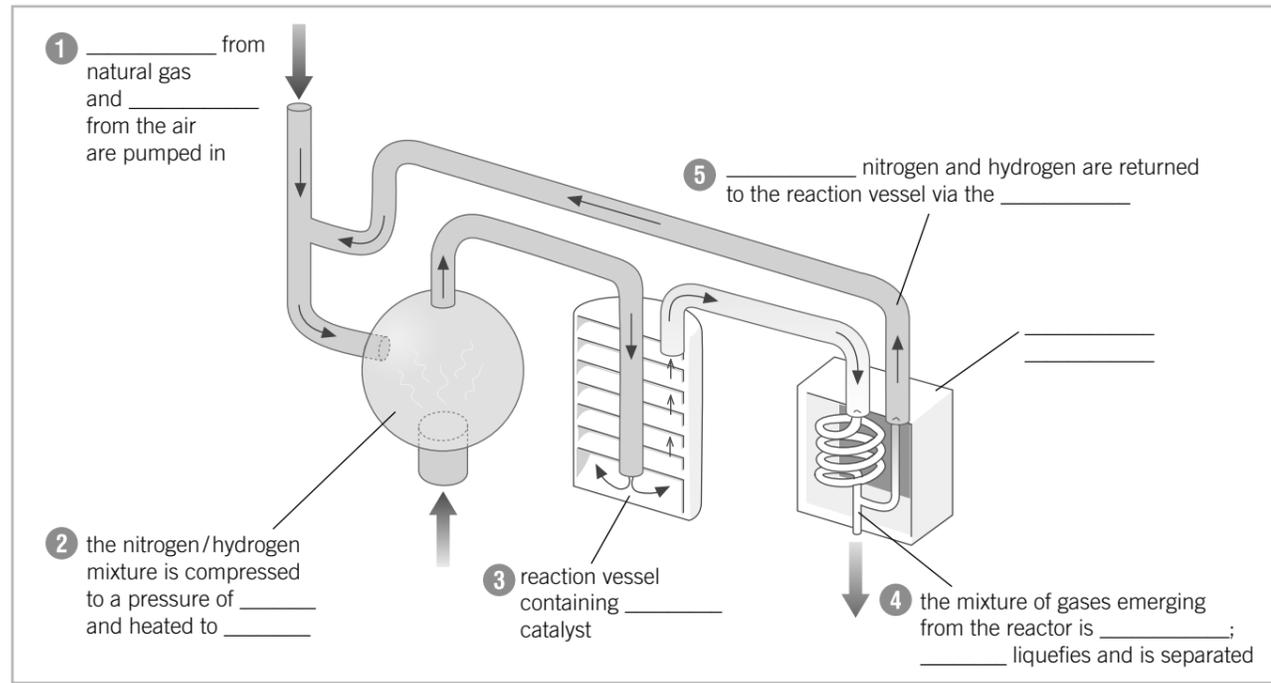
Knowledge organiser

The Haber process

Fertilisers are important chemicals used to _____. Ammonia is a vital component of many fertilisers. It is produced in the **Haber process**:

- nitrogen + hydrogen \rightleftharpoons ammonia
- _____(g) + _____(g) \rightleftharpoons _____(g)

It is a reversible reaction, so the conditions affect the yield.



Conditions

Compromise

The conditions used for the Haber process are a *compromise* to balance yield, cost, and rate. Name the conditions.

-
-
-

Temperature

The forward reaction is _____. Therefore, lowering the temperature would _____ the yield of ammonia, but would also _____ the rate of reaction.

Pressure

There are fewer gas molecules on the _____ side, so increasing the pressure would _____ the yield and the rate of reaction. However, it is very _____ to increase the pressure.

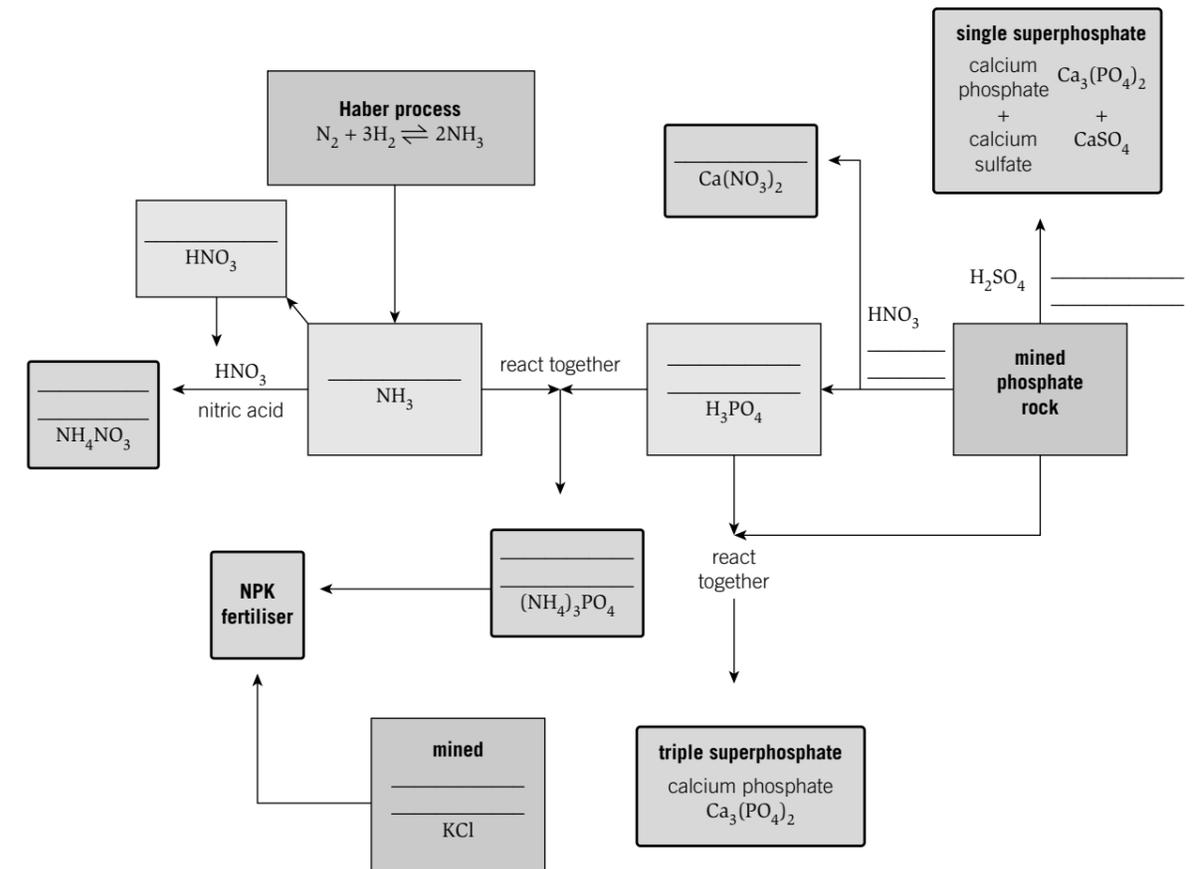
Catalyst

Iron is an effective catalyst for the Haber process. It does not increase the yield, but does _____ the rate.

Fertilisers

Fertilisers are produced industrially to increase the amount of food obtained from crops. Compounds containing nitrogen, phosphorous, and potassium are used, and fertilisers with all three in them are called _____.

NPK fertilisers are formulations. Some of the substances that go into NPK fertilisers can be _____ straight from the ground (like potassium chloride or potassium sulfate). Others, like phosphate rock, need to be processed first. Phosphate rock can react with different _____ to make different products, which can either be used as fertilisers on their own or added to an NPK fertiliser. Name the substances.



Laboratory vs. industry

The compounds found in fertilisers can be produced in the laboratory as well as industrially:

	laboratory	industrial
Quantities produced		
Process		
Apparatus		
Speed		



Key terms

Make sure you can write a definition for these key terms.

alloy ceramic composite corrosion galvanise Haber process matrix NPK fertiliser reinforce rusting thermosetting thermosoftening

Chapter 15: Making our resources

Retrieval questions

Answer the following questions using the information from the knowledge organiser.

C15 questions

Answers

- 1 What is corrosion?
- 2 What physical barriers be used to protect against corrosion?
- 3 What is sacrificial protection?
- 4 How is rust formed?
- 5 What are two alloys of copper?
- 6 What are gold alloys in jewellery made from?
- 7 What are steel alloys made from?
- 8 What is a property of aluminium alloys?
- 9 What is the main difference between soda-lime and borosilicate glass?
- 10 Give two examples of clay ceramics.
- 11 What two things do the properties of polymers depend on?
- 12 What is the main difference between thermosetting and thermosoftening polymers?
- 13 What is a composite?
- 14 Name two composites.
- 15 What is the balanced symbol equation for the Haber process?
- 16 What is the ammonia used for?
- 17 What is the effect of increasing the temperature of the Haber process on the yield, rate, and cost?
- 18 What is the effect of increasing the pressure of the Haber process on the yield, rate and cost?
- 19 What catalyst do we use for the Haber process?
- 20 What are the conditions for the Haber process?
- 21 What is an NPK fertiliser?