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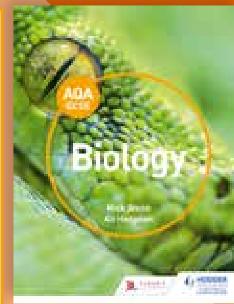

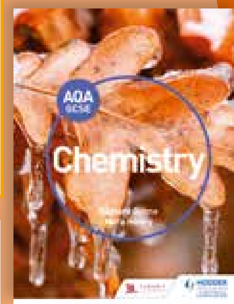

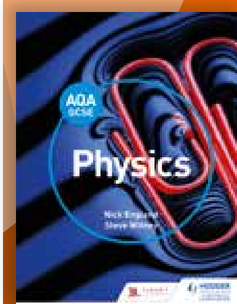

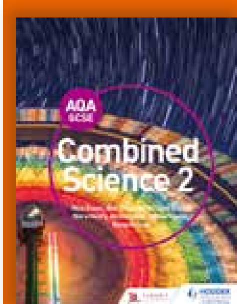

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Chemistry

Richard Grime
Nora Henry

DYNAMIC LEARNING

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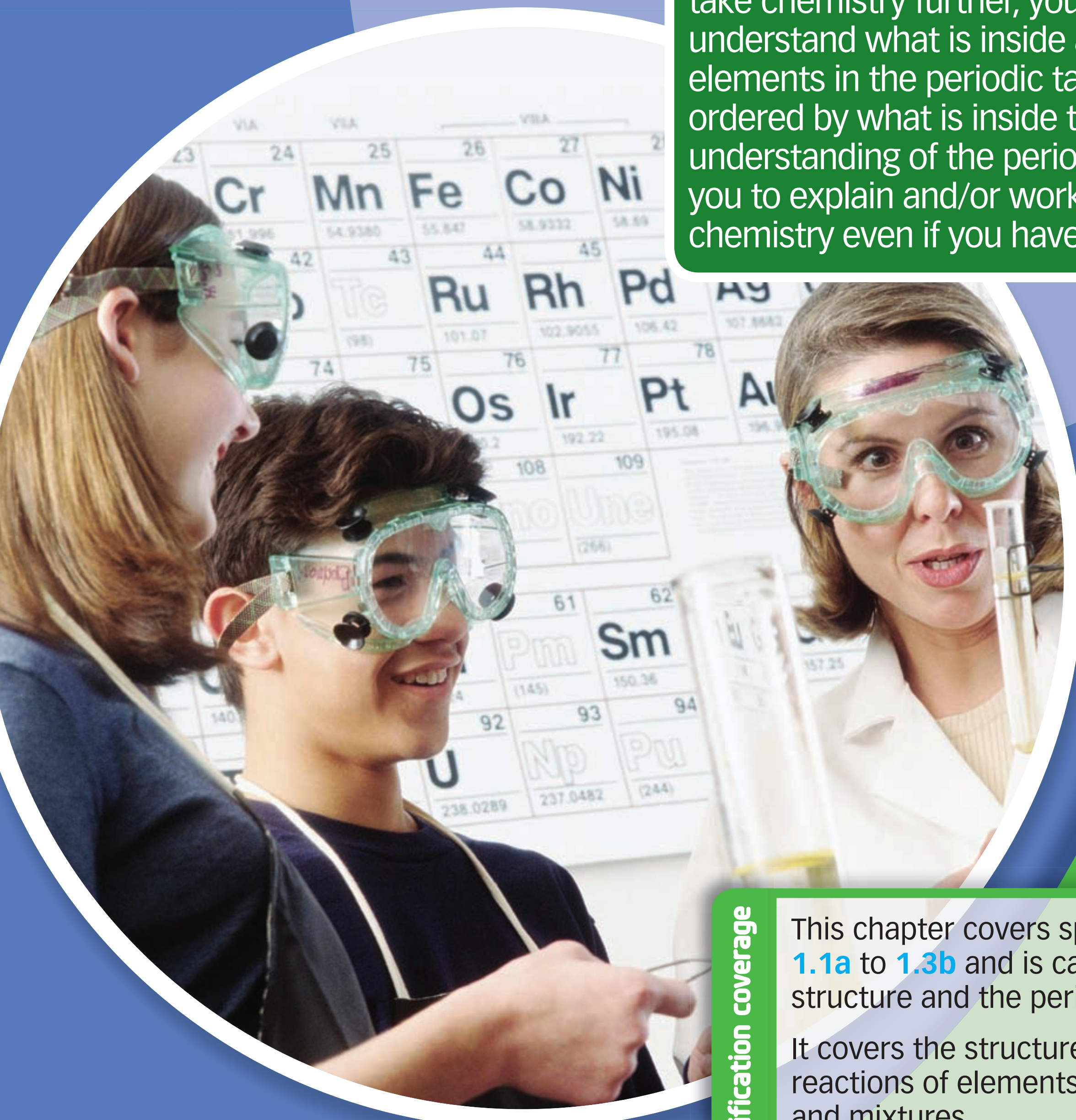
Contents

1 Atomic structure and the periodic table

Until you reached GCSE, Chemistry was studied at the particle level. In order to take chemistry further, you now need to understand what is inside atoms. The elements in the periodic table are ordered by what is inside their atoms. An understanding of the periodic table allows you to explain and/or work out a lot of chemistry even if you have never studied it.



Specification coverage

This chapter covers specification points 1.1a to 1.3b and is called Atomic structure and the periodic table.

It covers the structure of atoms, reactions of elements, the periodic table and mixtures.

Prior knowledge

Previously you could have learned:

- Elements are made of particles called atoms.
- Elements are substances containing only one type of atom – this means they cannot be broken down into simpler substances.
- Each element has its own symbol and is listed in the periodic table.
- Elements are either metals or non-metals.
- Compounds are substances made from atoms of different elements joined together.
- Compounds have different properties to the elements from which they are made.
- Compounds are difficult to break back down into their elements.
- Substances in mixtures are not chemically joined to each other.
- Substances in mixtures can be separated easily by a range of techniques.

Test yourself on prior knowledge

1 What is an element?
2 What is a compound?
3 Why do compounds have different properties from the elements from which they are made?
4 List some differences between metals and non-metals.
5 Why is it easy to separate the substances in a mixture but not to break apart a compound?
6 Name four methods of separating mixtures.

Structure of atoms

TIP
Remember that:
protons are **p**ositive
neutrons are **n**eutral
leaving electrons as negative

TIP
The charge of a proton can be written as + or +1. The charge of an electron can be written as –1 or –.

KEY TERM
Atom The smallest part of an element that can exist. A particle with no electric charge made up of a nucleus containing protons and neutrons surrounded by electrons in energy levels.

Protons, neutrons and electrons

Atoms are the smallest part of an element that can exist. Atoms are made up of smaller particles called **protons**, **neutrons** and **electrons**. The table below shows the relative mass and electric charge of these particles. The mass is given relative to the mass of a proton. Protons and neutrons have the same mass as each other while electrons are much lighter.

	Proton	Neutron	Electron
Relative mass	1	1	very small
Relative charge	+1	0	–1

The structure of atoms

Atoms are very small. Typical atoms have a radius of about 0.1 nm (0.0000000001 m, that is 1×10^{-10} m). Atoms have a central **nucleus** which contains protons and neutrons. The nucleus is surrounded by electrons. The electrons move around the nucleus in **energy levels** or **shells**.

TIP

1 nm = 1 × 10^{-9} m (0.000000001 m)

TIP

The SI units for length are metres (m).

KEY TERMS

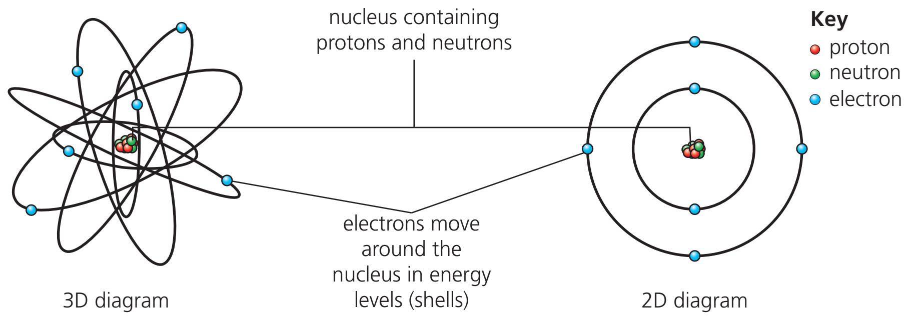
Proton Positively charged particle found inside the nucleus of atoms.

Neutron Neutral particle found inside the nucleus of atoms.

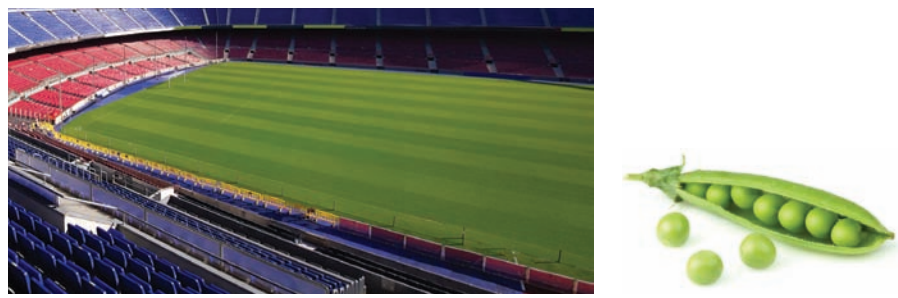
Electron Negatively charged particle found in energy levels (shells) outside the nucleus inside atoms.

Nucleus Central part of an atom containing protons and neutrons.

Energy level (shell) The region an electron occupies outside the nucleus inside an atom.



The nucleus is tiny compared to the size of the atom as a whole. The radius of the nucleus is less than 1/10000th of that of the atom (1 × 10^{-14} m). This difference in size between a nucleus and an atom is equivalent to a pea placed in the middle of a football pitch.



▲ **Figure 1.1** The size of the nucleus compared to the atom is like a pea compared to a football pitch.

The nucleus contains protons and neutrons. These are much heavier than electrons. This means that most of the mass of the atom is contained in the tiny nucleus in the middle.

Test yourself

1 The radius of a hydrogen atom is 2.5 × 10^{-11} m. Write this in nanometres.
2 Carbon atoms have a radius of 0.070 nm. Write this in standard form in the units of metres.
3 The radius of a chlorine atom is 1 × 10^{-10} m and the radius of a silicon atom is 0.060 nm. Which atom is bigger?
4 Sodium atoms have a radius of 0.180 nm. The nucleus of an atom is about 10 000 times smaller. Estimate the radius of the nucleus of a sodium atom. Write your answer in both nanometres and metres.

Atomic number and mass number

The number of protons that an atom contains is called its **atomic number**. Atoms of different elements have different numbers of protons. It is the number of protons that determines which element an atom is. For example, all atoms with 6 protons are carbon atoms, while all atoms with 7 protons are nitrogen atoms.

KEY TERM

Atomic number Number of protons in an atom.

> **TIP**
> A carbon atom is neutral because it contains 6 protons (charge + 6) and 6 electrons (charge – 6) and so has no overall charge.

> **KEY TERM**
> **Mass number** Number of protons + number of neutrons in an atom.

All atoms are neutral, which means they have no overall electric charge. This is because the number of protons (which are positively charged) is the same as the number of electrons (which are negatively charged).

Most of the mass of an atom is due to the protons and neutrons. Protons and neutrons have the same mass as each other. The **mass number** of an atom is the sum of the number of protons and neutrons in an atom. For example, an atom of sodium has 11 protons and 12 neutrons and so has a mass number of 23.

> **ATOMIC NUMBER** = number of protons
>
> **MASS NUMBER** = number of protons + number of neutrons

The atomic number and mass number of an atom can be used to work out the number of protons, neutrons and electrons in an atom:

- number of protons = atomic number
- number of neutrons = mass number – atomic number
- number of electrons = atomic number (*only for atoms, not ions*).

The mass number and atomic number of atoms can be shown as in Figure 1.2.

Atoms are often shown in the form ^{23}Na. As the atom is a sodium atom, it must have an atomic number of 11 and so it is not necessary to include the atomic number.

mass number = 23

atomic number = 11

$^{23}_{11}Na$

mass number: protons + neutrons
atomic number: protons
number of protons = 11
number of neutrons = 23 – 11 = 12
number of electrons = 11

▲ Figure 1.2

> **Example**
> How many protons, neutrons and electrons are there in an atom of ^{81}Br?
>
> **Answer**
> Number of protons: As the atom is a bromine atom, we can see from looking at the periodic table that the atomic number is 35 and so the atom must have 35 protons.
>
> Number of neutrons: 81 – 35 = 46 (the mass number minus the number of protons).
>
> Number of electrons: 35 (the same as the number of protons).

Isotopes

> **KEY TERM**
> **Isotopes** Atoms with the same number of protons but a different number of neutrons.

For most elements there are atoms with different numbers of neutrons. Atoms with the same number of protons but a different number of neutrons are called **isotopes**. This means that isotopes have the same atomic number but a different mass number.

For example, carbon has three isotopes and so there are three different types of carbon atoms. These are shown in the table below. These three isotopes are all carbon atoms because they all contain 6 protons, but they each have a different number of neutrons.

Atom	^{12}C	^{13}C	^{14}C
Protons	6	6	6
Neutrons	6	7	8
Electrons	6	6	6

Isotopes have a different mass, but their chemical properties are the *same* because they contain the same number of electrons.

Test yourself

5 List the three particles found inside atoms.
6 Identify the particle found inside the nucleus of atoms that has no charge.
7 Atoms contain positive and negative particles. Explain why atoms are neutral.
8 How many protons, neutrons and electrons are there in an atom of ^{31}P?
9 What is it about the atom ^{39}K that makes it an atom of potassium?
10 Describe the similarities and differences between atoms of the isotopes ^{35}Cl and ^{37}Cl.

Show you can...

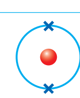
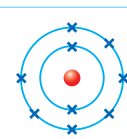
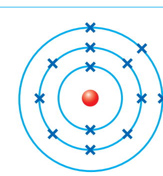
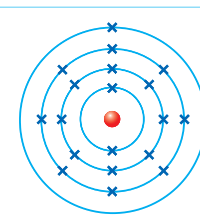
Copy and complete the table for each of the elements listed.

Element	Atomic number	Mass number	Number of protons	Number of electrons	Number of neutrons
^{7}Li					
^{27}Al					
^{24}Mg					
^{39}K					
^{107}Ag					

Electron arrangement

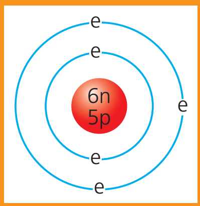
The electrons in an atom are in energy levels, also known as shells. Electrons occupy the lowest available energy levels. The lowest energy level (the first shell) is the one closest to the nucleus and can hold up to two electrons. Up to eight electrons occupy the second energy level (the second shell) with the next eight electrons occupying the third energy level (third shell). The next two electrons occupy the fourth energy level (fourth shell).

The arrangement of electrons in some atoms are shown in the table. The electronic structure can be drawn on a diagram or written using numbers. For example, the electron structure of aluminium is 2,8,3 which means that it has two electrons in the first energy level, eight electrons in the second energy level and three electrons in the third energy level.

Atom	He	F	Al	K
Atomic number	2	9	13	19
Number of electrons	2	9	13	19
Electron structure (written)	2	2,7	2,8,3	2,8,8,1
Electron structure (drawn)				

Show you can…

The diagram shows an atom of an element X, where: **e** represents an electron; **n** represents a neutron; and **p** represents a proton.



a) Name the element X.
b) Write the electronic structure of X.
c) What is the mass number of this atom of element X?
d) Name the part of the atom shaded red.

Test yourself

11 Write the electronic structure of the following atoms: ^{16}O, ^{23}Na, ^{40}Ca.
12 Lithium atoms contain 3 electrons and have the electronic structure 2,1. Explain why the electrons are not all in the first shell.

TIP
It is usual to write ion charges with the number before the +/– sign, such as 2+, but it is not wrong to write it as +2.

Ions

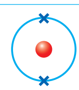
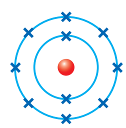
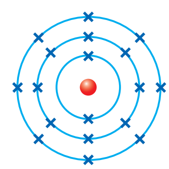
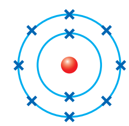
Ions are particles with an electric charge because they do not contain the same number of protons and electrons. Remember that protons are positive and electrons are negative. Positive ions have more protons than electrons. Negative ions have more electrons than protons.

KEY TERM
Ion An electrically charged particle containing different numbers of protons and neutrons.

For example:

- An ion with 11 protons (total charge 11+) and 10 electrons (total charge 10–) will have an overall charge of 1+.
- An ion with 16 protons (total charge 16+) and 18 electrons (total charge 18–) will have an overall charge of 2–.

The table shows some common ions.

Ion	Li^+	Al^{3+}	Cl^-	O^{2-}
Atomic number	3	13	17	8
Number of protons	3 (charge 3+)	13 (charge 13+)	17 (charge 17+)	8 (charge 8+)
Number of electrons	2 (charge 2–)	10 (charge 10–)	18 (charge 18–)	10 (charge 10–)
Overall charge	1+	3+	1–	2–
Electron structure (written)	2	2,8	2,8,8	2,8
Electron structure (drawn)				

TIP
Positive ions have more protons than electrons. Negative ions have more electrons than protons. This is because electrons are negatively charged.

Ions have the same electron structure as the elements in Group 0 of the periodic table. These are very stable electron structures where the outer energy level is full.

Group 0 element	He	Ne	Ar
Electron structure	2	2,8	2,8,8
Common ions with the same electron structure	Li^+, Be^{2+}	O^{2-}, F^-, Na^+, Mg^{2+}, Al^{3+}	S^{2-}, Cl^-, K^+, Ca^{2+}

The hydrogen ion (H^+) is the only common ion that does not have the electron structure of a Group 0 element. It does not have any electrons at all. This makes it a very special ion with special properties, and it is the H^+ ion that is responsible for the behaviour of acids.

Test yourself

13 What is the electric charge of a particle with 19 protons and 18 electrons?
14 What is the electric charge of a particle with 7 protons and 10 electrons?
15 What is the electron structure of the P^{3-} ion?
16 How many protons, neutrons and electrons are there in the $^{19}F^{-}$ ion?
17 What is the link between the electron structure of ions and the Group 0 elements?

Show you can...

The table gives some information about six different particles, A, B, C, D, E and F. Some particles are atoms and some are ions. (The letters are not chemical symbols).

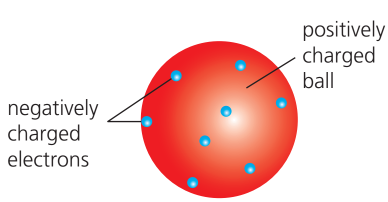
Particle	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons	Electronic structure
A	18	40				2,8,8
B		27	13			2,8
C			20	20	20	
D		35	17			2,8,7
E	16	32			18	
F	17			20	17	

a) Copy and complete the table.
b) Particle C is an atom. Explain, using the information in the table, why particle C is an atom.
c) Particle E is a negative ion. What is the charge on this ion?
d) Which two atoms are isotopes of the same element?

Development of ideas about the structure of atoms

The idea that everything was made of particles called atoms was accepted in the early 1800s after work by John Dalton. At that time, however, people thought that atoms were the smallest possible particles and the word *atom* comes from the Greek word *atomos* which means something that cannot be divided.

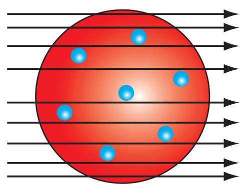
However, in 1897 the electron was discovered by J.J. Thompson while carrying out experiments on the conduction of electricity through gases. He discovered that electrons were tiny, negatively charged particles that were much smaller and lighter than atoms. He came up with what was called the 'plum-pudding' model of the atom. In this model, the atom was a ball of positive charge with the negative electrons spread through the atom.



plum-pudding model of the atom (1897)

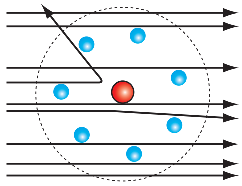
A few years later in 1911, this model was replaced following some remarkable work from Hans Geiger and Ernest Marsden working with Ernest Rutherford. They fired alpha particles (He^{2+} ions) at a very thin piece of gold foil. They expected the particles to pass straight through the foil but a tiny fraction were deflected or even bounced back. This did not fit in with the plum-pudding model. Rutherford worked out that the scattering of some of the alpha particles meant that there must be a tiny, positive nucleus at the centre of each atom. This new model was known as the nuclear model.

plum-pudding model (1897)



The alpha particles would all be expected to travel straight through the gold foil according to the plumpudding model

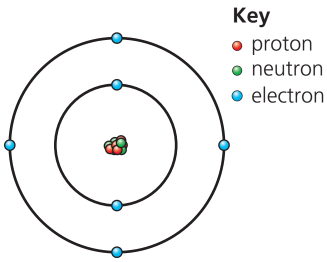
nuclear model following Geiger and Marsden's experiment (1911, but revised since)



A tiny fraction of alpha particles were deflected or bounced back. Rutherford worked out that there must be a tiny, positive nucleus to explain this

In 1913, Neils Bohr adapted the nuclear model to suggest that the electrons moved in stable orbits at specific distances from the nucleus called shells. Bohr's theoretical calculations agreed with observations from experiments.

Further experiments led to the idea that the positive charge of the nucleus was made up from particles which were given the name protons.



2D diagram

Today's model of an atom

Scientists realised that there was some mass in atoms that could not be explained by this model, and in 1932 James Chadwick discovered a new particle inside the nucleus that had the same mass as a proton but had no electric charge. This particle was given the name neutron.

The model has been developed further since then, but the basic idea of atoms being made up of a tiny central nucleus containing protons and neutrons surrounded by electrons in shells remains.

The development of ideas about atomic structure shows very well how scientific models and theories develop over time. When new discoveries are made, models and theories may have to be altered or sometimes completely replaced if they do not fit in with the new discoveries.

Test yourself

18 What was discovered that led to scientists realising that atoms were made up of smaller particles?

19 Why was the plum-pudding model replaced?

20 Why would a nucleus deflect an alpha particle?

Show you can...

Use a table to compare and contrast the plum-pudding model, the nuclear model and today's model of an atom.

Reactions of elements

KEY TERM

Element A substance containing only one type of atom. A substance that cannot be broken down into simpler substances by chemical methods.

TIP

When writing symbols you must be very careful to ensure your capital letters cannot be mistaken for small letters and vice versa.

Elements in the periodic table

An **element** is a substance containing only one type of atom. For example, in the element carbon all the atoms are carbon atoms meaning that all the atoms have 6 protons and so have the atomic number 6. Elements cannot be broken down into simpler substances.

Atoms are known with atomic numbers up to just over 100. This means that there are just over 100 elements. All the elements are listed in the periodic table. The elements are listed in order of atomic number.

Atoms of each element are given their own symbol, each with one, two or three letters. The first letter is always a capital letter with any further letters being small letters. For example, carbon has the symbol C while copper has the symbol Cu.

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** Iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Ti** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm** (145)	62 **Sm** 150	63 **Eu** 152	64 **Gd** 157	65 **Tb** 159	66 **Dy** 162	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173	71 **Lu** 175
90 **Th** 232	91 **Pa** 231	92 **U** 238	93 **Np** 237	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Key
relative atomic mass
atomic symbol
name
atomic (proton) number

TIP

The periodic table shows relative atomic mass and not mass number. This is the average mass of the isotopes of each element.

Metals and non-metals

Over three-quarters of the elements are metals, with most of the rest being non-metals. Typical properties of metals and non-metals are shown in the table, although there are some exceptions.

	Metals	Non-metals
Melting and boiling points	High	Low
Conductivity	Conduct heat and electricity	Do not conduct heat or electricity (except graphite)
Density	High density	Low density
Appearance	Shiny when polished	Dull
Malleability	Can be hammered into shape	Brittle as solids
Reaction with non-metals	React to form positive ions in ionic compounds	React to form molecules
Reaction with metals	No reaction	React to form negative ions in ionic compounds
pH of oxides	Metal oxides are bases	Non-metal oxides are acidic

There are a few elements around the dividing line between metals and non-metals, such as silicon and germanium, that are hard to classify as they have some properties of metals and some of non-metals.

Test yourself

21 Is each of the following elements a metal or non-metal?

a) Element **1** is a dull solid at room temperature that easily melts when warmed.

b) Element **2** is a dense solid that conducts heat.

c) Element **3** reacts with oxygen to form an oxide which dissolves in rain water to form acid rain.

d) Element **4** reacts with chlorine to form a compound made of molecules.

e) Element **5** reacts with sodium to form a compound made of ions.

Show you can...

The photograph shows the elements magnesium and oxygen reacting to form a single product.

a) State two differences in the physical properties of magnesium and oxygen.

b) Suggest the name of the product of this reaction.

c) Is the product acidic or basic?

d) Does the product consist of ions or molecules?

KEY TERM

Compound Substance made from different elements chemically joined together.

Reactions between elements

When elements react with each other they form compounds. **Compounds** are substances made from different elements bonded together.

When elements react with each other, electrons are either shared with other elements or transferred from one element to another. This is done so that atoms obtain the stable electron structure of the Group 0 elements with only full shells of electrons.

The table shows what happens in general when elements react with each other.

Elements reacting	What happens to the electrons to get full outer shells	Type of particles formed	Type of compound formed	Example
Non-metal + non-metal	Electrons shared	Molecules (where atoms are joined to each other by covalent bonds)	Simple molecular compound	Hydrogen reacts with oxygen by sharing electrons and forming molecules of water
Metal + non-metal	Electrons transferred from metal to non-metal	Positive and negative ions	Ionic compound	Sodium reacts with chlorine by transferring electrons from sodium to chlorine to form sodium chloride which is made of ions
Metal + metal	No reaction as both metals cannot lose electrons			

Test yourself

22 Do the following elements react with each other, and if they do, what type of compound is formed?

a) potassium + oxygen
b) bromine + iodine
c) oxygen + sulfur
d) sulfur + magnesium
e) calcium + potassium
f) nitrogen + hydrogen

Show you can...

The electronic structures of the atoms of 5 different elements, A, B, C, D and E, are shown below.

A: 2,8,8 B: 2,8,8,1 C: 2,6 D: 2,1 E: 2,8,7

Using the letters A, B, C, D or E choose:

a) An unreactive element.
b) Two elements found in the same Group of the periodic table.
c) An element whose atoms will form ions with a charge of 2–.
d) Two elements that react to form an ionic compound.
e) Two elements that react to form a covalent compound.

The periodic table

Electron structure and the periodic table

The elements are placed in the periodic table in order of increasing atomic number (the number of protons). The diagram shows the first 36 elements in the periodic table.

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
								1 H									2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr

The table can be seen as arranging the elements by electron structure. Across each period each energy level (shell) is gradually filled, with the next shell being filled in the next period. The electron structure of the first 20 elements is shown here.

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
								1 H									2 He
2,1 Li	2,2 Be											2,3 B	2,4 C	2,5 N	2,6 O	2,7 F	2,8 Ne
2,8,1 Na	2,8,2 Mg											2,8,3 Al	2,8,4 Si	2,8,5 P	2,8,6 S	2,8,7 Cl	2,8,8 Ar
2,8,8,1 K	2,8,8,2 Ca																

TIP

In Group 0 all the elements have full outer shells. Helium has 2 elctrons in its outer shell while the other elements have got 8 electrons in their outer shells.

Elements in the same group have the same number of electrons in their outer shell. The number of electrons in the outer shell equals the Group number. For example, all the elements in Group 1 have 1 electron their outer shell (Li = 2,1; Na = 2,8,1; K = 2,8,8,1). All the elements in Group 7 have 7 electrons in their outer shell (F = 2,7; Cl = 2,8,7). The only exception to this is Group 0 where elements have a full outer shell.

All the elements in the same group have similar chemical properties because they have the same number of electrons in their outer shell.

The chemical properties of the elements in the periodic table repeat at regular (periodic) intervals. This is why it is called the periodic table.

Show you can...

Element A has electronic structure 2,8,1.

a) Explain why element A is not found in Group 5.

b) Determine the atomic number of A.

KEY TERM

Noble gases The elements in Group 0 of the periodic table (including helium, neon and argon).

Test yourself

23 In what order are the elements in the periodic table?

24 In which group of the periodic table do the elements with these electron structures belong?

a) 2,8,4

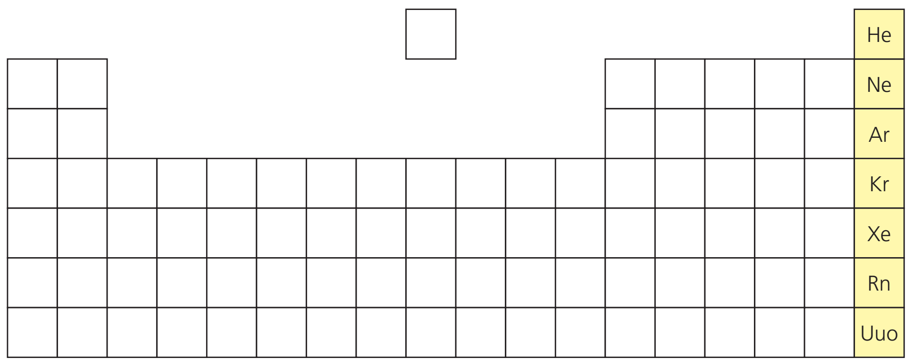
b) 2,8,8,1

c) 2,8,18,3

25 Explain why the periodic table has the word periodic in its name.

Group 0 – the noble gases

The main elements of Group 0 are helium, neon, argon, krypton, xenon and radon. They are known as the **noble gases**. These atoms all have full outer shells. Helium's outer shell is full with 2 electrons while the others have 8 electrons in their outer shells.



Element	Formula	Appearance at room temperature	Number of electrons in outer shell	Relative mass of atoms	Boiling point (°C)
Helium	He	Colourless gas	2	4	–269
Neon	Ne	Colourless gas	8	20	–246
Argon	Ar	Colourless gas	8	40	–190
Krypton	Kr	Colourless gas	8	85	–157
Xenon	Xe	Colourless gas	8	131	–111
Radon	Rn	Colourless gas	8	222	–62

Properties of the noble gases

Metals or non-metals?	All the elements are non-metals.
Boiling points	The noble gases are all colourless gases. The boiling points increase as the atoms get heavier going down the group.
Reactivity	The Group 0 elements are very unreactive because they have full outer shells and already have stable electron arrangements.

Test yourself

26 Why are the noble gases unreactive?

27 Why are the noble gases referred to as being in Group 0 rather than Group 8?

28 Some atoms of element 118 (Uuo) have been produced. Element 118 is in Group 0. Predict the chemical and physical properties of this element.

Show you can...

Copy and complete the table:

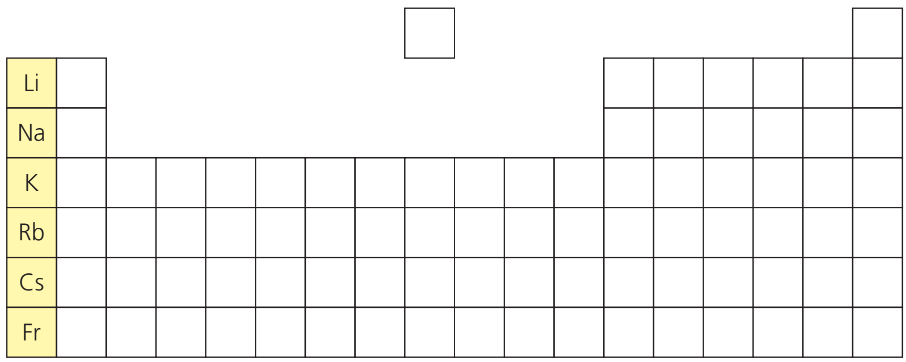
Element	Reactive or unreactive?	Metal or non-metal?	Solid, liquid or gas at room temperature?	Electronic structure
He				
Ar				

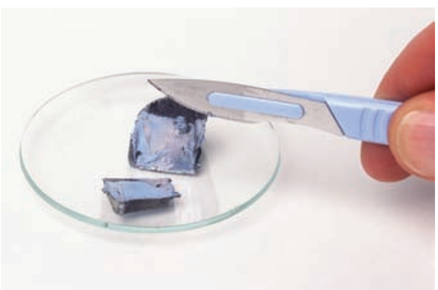
Group 1 – the alkali metals

KEY TERM

Alkali metals The elements in Group 1 of the periodic table (including lithium, sodium and potassium).

The main elements of Group 1 are lithium, sodium, potassium, rubidium and caesium. They are known as the **alkali metals**. They are all soft metals that can be cut with a knife. They are very reactive and so are stored in bottles of oil to stop them reacting with water and oxygen.





▲ **Figure 1.3** The alkali metals are all soft and can be cut with a knife.

Element	Formula	Appearance at room temperature	Number of electrons in outer shell	Relative mass of atoms	Melting point in °C	Density in g/cm^3
Lithium	Li	Silvery-grey metal	1	7	180	0.53
Sodium	Na	Silvery-grey metal	1	23	98	0.97
Potassium	K	Silvery-grey metal	1	39	63	0.89
Rubidium	Rb	Silvery-grey metal	1	85	39	1.53
Caesium	Cs	Silvery-grey metal	1	133	28	1.93

Properties of the alkali metals

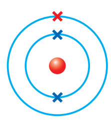
Metals or non-metals?	• All the elements are metals.
Melting points	• The alkali metals are all solids at room temperature. • The melting points decrease as the atoms get bigger going down the group.
Density	• The alkali metals have low densities for metals. • Lithium, sodium and potassium all float on water as they are less dense than water.
Reaction with non-metals	• The metals all react easily with non-metals by the transfer of electrons from the metal to the non-metal forming compounds made of ions. • Alkali metals always form 1+ ions (e.g. Li^+, Na^+, K^+, Rb^+, Cs^+) as they have one electron in their outer shell which they lose when they react to get a full outer shell.
Reaction with water	• The alkali metals all react with water, releasing hydrogen gas and forming a solution containing a metal hydroxide: alkali metal + water → metal hydroxide + hydrogen: e.g. $2Na + 2H_2O \rightarrow 2\,NaOH + H_2$ • The solution of the metal hydroxide that is formed is alkaline.
Compounds made from Group 1 metals	• Compounds made from alkali metals: • are ionic • are white solids • dissolve in water to form colourless solutions

Reactivity trend of the alkali metals

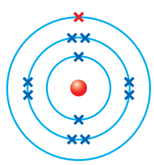
The alkali metals get more reactive the further down the group. This can be seen when the alkali metals react with water.

	Lithium	Potassium	Caesium
Description	Fizzes, moves on the surface of the water 	Fizzes, melts, burns with lilac flame, moves on the surface of the water 	Explosive reaction, melts, burns 

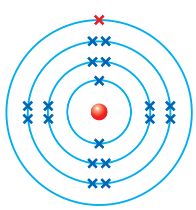
When the alkali metals react they are losing their outer shell electron in order to get a full outer shell. The further down the group, the further away the outer electron is from the nucleus as the atoms get bigger. This means that the outer electron is less strongly attracted to the nucleus and so easier to lose. The easier the electron is to lose, the more reactive the alkali metal.



lithium (2, 1)



sodium (2, 8, 1)



potassium (2, 8, 8, 1)

The further down the group, the further the outer electron is from the nucleus

Test yourself

29 Why are the alkali metals reactive?

30 Write word and balanced symbol equations for the reaction of potassium with water.

31 Explain why the solution formed when potassium reacts with water has a high pH.

32 Potassium reacts with chlorine to form an ionic compound. Explain why this reaction happens.

33 Explain why potassium is more reactive than sodium.

34 Francium is the last element in Group 1. Predict the chemical and physical properties of francium.

Show you can...

This question gives information about the reaction of Group 2 elements with water (which is not in the specification) and tests your ability to interpret data.

Element	Reactivity with water	Name of product
Be	No reaction	No products
Mg	Reacts very slowly with cold water	Magnesium hydroxide and hydrogen
Ca	Reacts moderately with cold water	Calcium hydroxide and hydrogen
Sr	Reacts rapidly with cold water	Strontium hydroxide and hydrogen
Ba	Reacts very rapidly with cold water	Barium hydroxide and hydrogen

Use the information in the table and your own knowledge of Group 1 elements to compare and contrast the reactions of Group 1 and Group 2 elements with water.

In your answer compare:

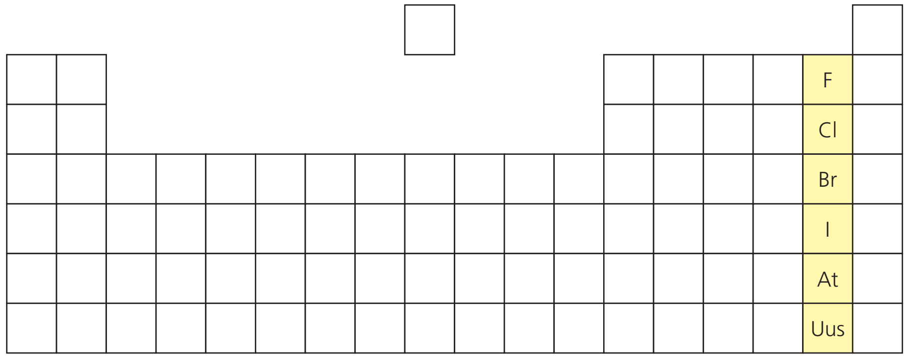
a) The products formed.
b) The reactivity of the Group 1 elements compared to the Group 2 elements.
c) The trend in reactivity down both groups.

TIP

A molecule is a particle made from atoms joined together by covalent bonds.

Group 7 – the halogens

The main elements of Group 7 are fluorine, chlorine, bromine and iodine. They are known as the **halogens**. The particles in each of the elements are molecules containing two atoms (**diatomic molecules**), such as F_2, Cl_2, Br_2 and I_2.



Element	Formula	Appearance at room temperature	Number of electrons in outer shell	Relative mass of molecules	Melting point in °C	Boiling point in °C
Fluorine	F_2	Pale yellow gas	7	38	–220	–188
Chlorine	Cl_2	Pale green gas	7	71	–102	–34
Bromine	Br_2	Dark orange liquid	7	160	–7	59
Iodine	I_2	Grey solid	7	254	114	184

KEY TERMS

Halogens The elements in Group 7 of the periodic table (including fluorine, chlorine, bromine and iodine).

Diatomic molecule A molecule containing two atoms.

Halides Compounds made from Group 7 elements.

Properties of the halogens

Metals or non-metals?	• Fluorine, chlorine, bromine and iodine are all non-metals.
Toxicity	• Each of the halogens is toxic.
Melting and boiling points	• The halogens have low melting and boiling points. • The melting and boiling points increase as the molecules get heavier going down the group.
Reaction with non-metals	• The halogens react with other non-metals by sharing electrons to form compounds made of molecules.
Reaction with metals	• The halogens all react easily with metals by the transfer of electrons from the metal to the halogen forming compounds made of ions. • Halogens always form 1– ions (e.g. F^-, Cl^-, Br^-, I^-, all known as halide ions as they have seven electrons in their outer shell and gain one more electron when the react to get a full outer shell.

▲ **Figure 1.4** The displacement reaction between aluminium and iron oxide is used to produce hot, molten iron metal to weld railway lines together.

Reactivity trend of the halogens

The halogens get less reactive the further down the group. This can be seen by looking at which halogens can displace each other from compounds. Compounds containing halogens, such as sodium chloride and potassium bromide are often called **halides** or halide compounds.

A more reactive element can displace a less reactive element from a compound. This can be seen with metals when a more reactive metal can displace a less reactive metal from a compound. For example, aluminium can displace iron from iron oxide because aluminium is more reactive than iron.

aluminium + iron oxide → aluminium oxide + iron

TIP
In all these reactions a non-metal is displacing another non-metal.

In a similar way, a more reactive non-metal can displace a less reactive non-metal from a compound. This means that a more reactive halogen can displace a less reactive halogen from a halide compound.

This can be seen when aqueous solutions of the halogens react with aqueous solutions of halide compounds (aqueous means dissolved in water).

	Chlorine (aq)	Bromine (aq)	Iodine (aq)
Potassium chloride (aq)		No reaction Bromine cannot displace chlorine	No reaction Iodine cannot displace chlorine
Potassium bromide (aq)	chlorine + potassium bromide → potassium chloride + bromine $Cl_2 + 2\ KBr \rightarrow 2\ KCl + Br_2$ $(Cl_2 + 2\ Br^- \rightarrow 2\ Cl^- + Br_2)$ Yellow solution formed (due to production of bromine) Chlorine displaces bromine		No reaction Iodine cannot displace bromine
Potassium iodide (aq)	chlorine + potassium iodide → potassium chloride + iodine $Cl_2 + 2\ KI \rightarrow 2\ KCl + I_2$ $(Cl_2 + 2\ I^- \rightarrow 2\ Cl^- + I_2)$ Brown solution formed (due to production of iodine) Chlorine displaces iodine	bromine + potassium iodide → potassium bromide + bromine $Br_2 + 2\ KI \rightarrow 2\ KBr + I_2$ $(Br_2 + 2\ I^- \rightarrow 2\ Br^- + I_2)$ Brown solution formed (due to production of iodine) Bromine displaces iodine	

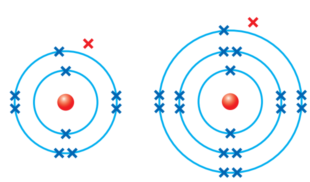
▲ **Figure 1.5** Colourless chlorine water reacts with colourless potassium bromide solution to form yellow bromine.

It can be seen from these reactions that the trend in reactivity for these three halogens is:

Most reactive   Chlorine
↑   Bromine
Least reactive   Iodine

In general, the further down the group the less reactive the halogen. The higher up the group, the more reactive the halogen. This means that fluorine is the most reactive halogen. You will not do experiments with fluorine because it is very reactive and toxic.

When the halogens react they gain one electron in order to get a full outer shell. The further down the group, the electron gained is further away from the nucleus as the atoms get bigger. This means that the electron gained is less strongly attracted to the nucleus and so harder to gain. The harder the electron is to gain, the less reactive the halogen.



The further down the group, the further the electron gained is from the nucleus

TIP
The explanation for the reactivity trend in Group 7 is about the distance between the nucleus and the electron gained which is from **outside** the atom – it is not about the outer shell electrons.

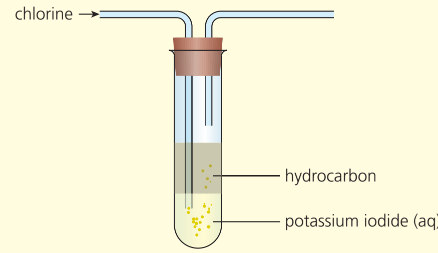
Test yourself

35 Why are the halogens reactive?
36 All the halogens are made of diatomic molecules. What are diatomic molecules?
37 Predict what would happen and why if fluorine and sodium chloride were mixed.
38 Bromine reacts with chlorine to form a molecular compound. Explain why this reaction happens.
39 Explain why chlorine is more reactive than bromine.

Practical

Reactions of the halogens

The diagram shows chlorine gas being passed through a dilute solution of potassium iodide. The upper layer is a hydrocarbon solvent. A colour change occurs in the potassium iodide solution due to the displacement reaction that occurs.



1 a) What is the most important safety precaution, which must be taken when carrying out this experiment?

b) Explain why a displacement reaction occurs between chlorine and potassium iodide.

c) Name the products of the displacement reaction which occurs.

d) What is the colour change that occurs in the potassium iodide solution?

e) Write a balanced symbol equation for the reaction between chlorine and potassium iodide.

f) If this experiment was repeated using bromine, instead of chlorine, explain if the observations would be different.

2 The halogens are more soluble in hydrocarbon solvents than in water and produce coloured solutions. When the aqueous layer is shaken with the hydrocarbon solvent most of the displaced hydrocarbon dissolves in the upper layer.

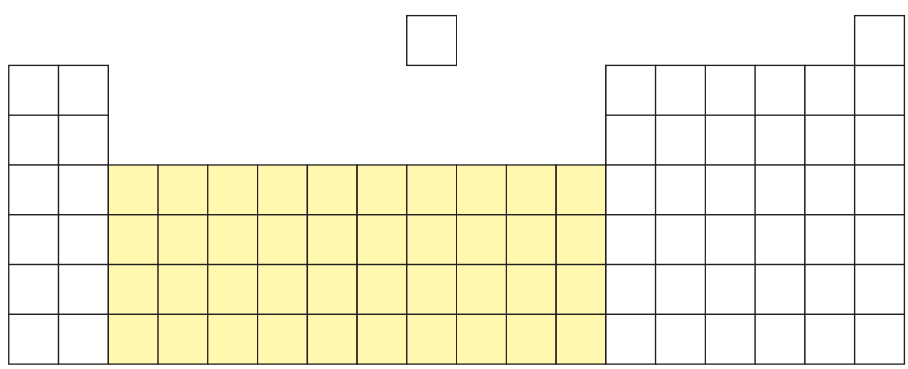
a) Explain the meaning of the word solvent.

b) Use the information in the table to suggest what happens to the hydrocarbon solvent, after shaking.

Halogen	Colour of halogen dissolved in hydrocarbon solvent
Chlorine	Pale green
Bromine	Orange
Iodine	Purple

The transition metals

The transition metals are in the block in the middle of the periodic table between Groups 2 and 3. They are all metals including many common metals such as chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni) and copper (Cu).



Transition metals have some properties in common with the alkali metals, but many differences.

▲ **Figure 1.6** The Statue of Liberty in New York is coated with a copper compound which is green.

KEY TERM

Catalyst A substance that speeds up a chemical reaction but is not used up.

	Group 1 – alkali metals	Transition metals
Similarities	Conduct heat	
	Conduct electricity	
	React with non-metals to form ionic compounds	
	Shiny when polished	
Differences	Low melting points	High melting points (except mercury)
	Low density	High density
	Very soft	Stronger and harder
	Very reactive (e.g. with water and oxygen)	Low reactivity (e.g. with water and oxygen)
	React to form 1+ ions (e.g. Na^+)	React to form ions with different charges (e.g. iron forms Fe^{2+} and Fe^{3+})
	Compounds are white	Compounds are coloured
	Do not act as catalysts	Metals and their compounds are often **catalysts** (catalysts speed up reactions but are not used up themselves)

Test yourself

35 What are the transition metals?

36 List some ways in which the transition metals are similar to the alkali metals.

37 List some ways in which the transition metals are different from the alkali metals.

38 What is a catalyst?

◀ **Figure 1.7** Margarine is made by reacting plant oils (e.g. sunflower oil) with hydrogen using a nickel catalyst.

Note: A section on *History of the periodic table* will be included in the full version.

Mixtures

KEY TERM

Mixture More than one substance which are not chemically joined together.

Mixtures compared to compounds

A **mixture** consists of two or more substances that are mixed together and not chemically combined. In a mixture, each substance has its own properties. Mixtures are very different to compounds.

	Compound	Mixture
Description	A substance made from two or more elements chemically bonded together. A compound is a single substance with its own unique properties	Two or more substances each with their own properties (the different substances are not chemically joined to each other)
Proportions	Each compound has a fixed proportion of elements (so each compound has a fixed formula)	There can be any amount of each substance in the mixture
Separation	Very difficult to separate compounds back into elements – it has to be done by a chemical reaction as the elements are chemically joined	Easy to separate the substances in a mixture because they are not chemically joined (and so no chemical reaction is needed)

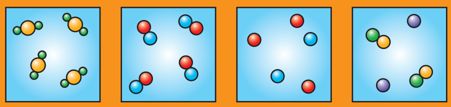
Sodium is a very reactive, dangerous, grey metal that reacts vigorously with water. Chlorine is a pale green, toxic gas that is very reactive. In a mixture of sodium and chorine each substance keeps its own properties as a grey metal and green gas, respectively. It is easy to separate the sodium and chlorine because they are not chemically joined together.

However, if heated together sodium reacts with chlorine to make the compound sodium chloride. Sodium chloride is very different from both sodium and chlorine. Sodium chloride is a white solid that is not very reactive and is safe to eat. It is very difficult to break sodium chloride back down into the elements because the sodium and chlorine are chemically joined together.

Sodium	Chlorine	Sodium chloride (salt)
		
Grey, highly reactive, dangerous metal	Green, highly reactive, toxic gas	White, unreactive, non-toxic solid (that we eat)

Show you can...

For each of the substances A, B, C, D decide if it is an element, compound or mixture.



(A) (B) (C) (D)

If any substance is a mixture decide if it is a mixture of elements, a mixture of elements and compounds, or a mixture of compounds.

TIP

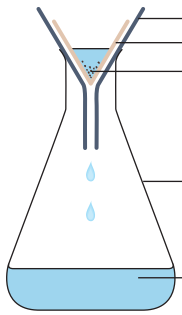
Some definitions of key words:

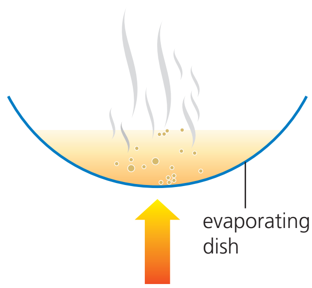
- solute: the substance that dissolves in a solvent
- solvent: the liquid that a solute dissolves in
- solution: a solute dissolved in a solvent
- soluble: when a substance will dissolved in a solvent
- insoluble: when a substance does not dissolve in a solvent.

Separating mixtures

The substances in a mixture are quite easy to separate because the substances are not chemically joined to each other. Different methods are used depending on what type of mixture there is.

Type of mixture	Insoluble solid and liquid	Soluble solid dissolved in a solvent	Soluble solids dissolved in a solvent	Two miscible liquids (liquids that mix)	Two immiscible liquids (liquids that do not mix)
Method of separation	Filtration	Evaporation (to obtain solid) Crystallisation (to obtain sold) Simple distillation (to obtain solvent)	Chromatography	Fractional distillation	Separating funnel





KEY TERMS

Filtrate Liquid that comes through the filter paper during filtration.

Residue Solid left on the filter paper during filtration.

Saturated A solution in which no more solute can dissolve at that temperature.

Filtration

This method is used to separate an insoluble solid from a liquid. For example, it could be used to separate sand from water.

The mixture is poured through a funnel containing a piece of filter paper. The liquid (called the **filtrate**) passes through the paper and the solid (called the **residue**) remains on the filter paper.

Evaporation

This method is used to separate a dissolved solid from the solvent it is dissolved in. For example, it could be used to separate salt from water.

The mixture is placed in an evaporating dish and heated until all the solvent has all evaporated or boiled, leaving the solid in the evaporating basin.

Crystallisation

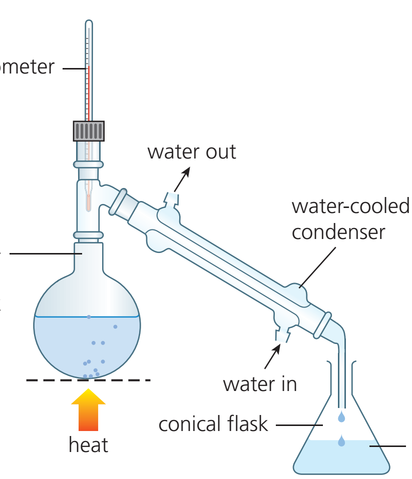
This method is also used to separate a dissolved solid from the solvent it is dissolved in. For example, it could be used to separate copper sulfate crystals from a solution of copper sulfate.

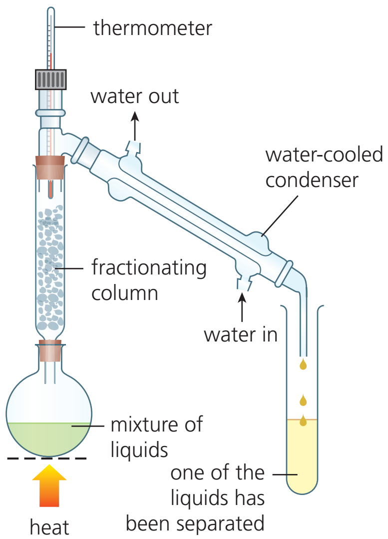
The mixture is heated to boil off some of the solvent to create a hot, saturated solution. A **saturated** solution is one in which no more solute can dissolve at that temperature. As it cools down, the solute becomes less soluble and so cannot remain dissolved, so some of the solute crystallises out of the solution as crystals. The crystals can then be separated from the rest of the solution by filtration.

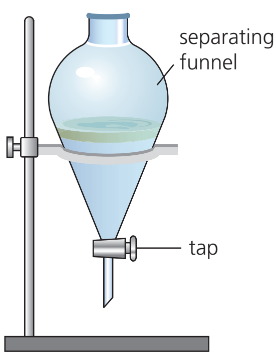
Distillation

This method is used to separate the solvent from a solution. For example, it could be used to separate pure water from sea water.

The mixture is heated and the solvent boils. The vaporised solvent passes through a water-cooled condenser where it cools and condenses. The condenser directs the condensed solvent into a container away from the original solution.







▲ **Figure 1.8** Substances separate as they move up the paper with the solvent at different speeds.

KEY TERMS

Miscible Liquids that mix together.

Immiscible Liquids that do not mix together and separate into layers.

Separating funnel Glass container with a tap used to separate immiscible liquids.

Fractional distillation

Liquids that mix together are called **miscible** liquids. Water and alcohol are examples of miscible liquids. Fractional distillation is used to separate mixtures of miscible liquids.
It works because the liquids have different boiling points.

In the laboratory, fractional distillation is done by gradually heating up the mixture so the liquids boil one by one as the temperature rises. The apparatus used is similar to that for simple distillation, but a long column (called a fractionating column) is used to help keep the different liquids apart as they boil in turn. This gives more time for each liquid to be collected from the condenser before the next liquid boils.

In industry, such as in the fractional distillation of crude oil (see Chapter 7), the whole mixture is vaporised and then condensed in a fractionating column which is hot at the bottom and cold at the top. The liquids will condense at different heights in the fractionating column.

Separating funnel

Liquids that do mix together are called **immiscible** liquids. Hydrocarbons and water are examples of liquids that are immiscible with each other. They can be separated in a **separating funnel**. The liquids form two layers and the bottom layer can be removed using the tap at the bottom of the funnel. The liquid with the greater density is the lower layer.

Chromatography

There are many forms of chromatography. Paper chromatography is used to separate mixtures of substances dissolved in a solvent.

A piece of chromatography paper is placed in a solvent and the solvent soaks up the paper. The substances move up the paper at different speeds and so are separated. Chromatography is studied further in Chapter 8.

Test yourself

39 How would you separate the following mixtures?

a) alcohol from a mixture of alcohol and water
b) magnesium hydroxide from a suspension of insoluble magnesium hydroxide in water
c) pure dry cleaning solvent from waste dry cleaning solvent containing dissolved dirt
d) sunflower oil and water
e) food colourings in a sweet.

Show you can...

Three common methods of separation include filtration, distillation and fractional distillation.

For each method of these separation methods pick two words or phrases from the list and insert them in the table with an explanation of their meaning:

condenser, distillate, fractionating column, filtrate, miscible liquids, residue.

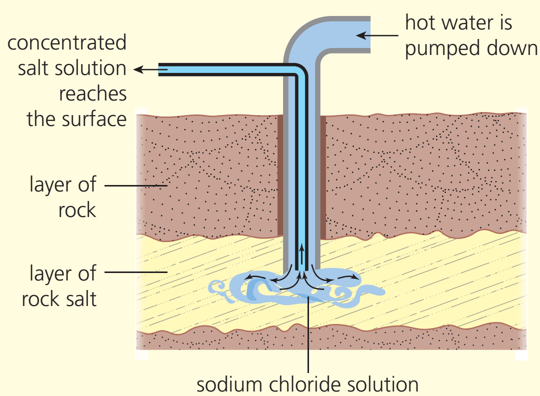
Also include the type of mixture separated by each method.

	Filtration	Distillation	Fractional distillation
Type of mixture separated			
Important word and definition			
Important word and definition			

Practical

Rock salt

Common salt is sodium chloride and is found naturally in large amounts in seawater or in underground deposits. Sodium chloride can be extracted from underground by the process of solution mining.



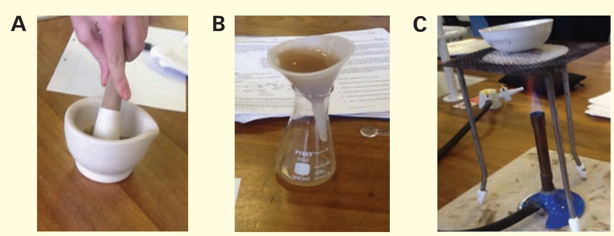
1 a) On what physical property of sodium chloride does this process depend?
   b) Suggest one reason why solution mining uses a lot of energy.
   c) Suggest one negative effect which solution mining has on the environment.
   d) Suggest how sodium chloride is obtained from the concentrated salt solution.

Rock salt is a mixture of salt and sand and clay. To separate pure salt from rock salt, the method used in the laboratory is listed below.

2 Choose one step of the method (i–vi) which is best represented in each photograph.

Method:

i Place 8 spatulas of rock salt into a mortar and grind using a pestle.
ii Place the rock salt into a beaker and quarter fill with water.
iii Place on a gauze and tripod and heat, stirring with a glass rod. Stop heating when the salt has dissolved – the sand and clay will be left.
iv Allow to cool and then filter.
v Heat until half the volume of liquid is left.
vi Place the evaporating basin on the windowsill to evaporate off the rest of the water slowly. Pure salt crystals should be left.



3 a) Why is rock salt considered to be a mixture?
   b) What was the purpose of grinding the rock salt?
   c) Why was the mixture heated and stirred?
   d) State what the filtrate contains.
   e) State what the residue contains.
   f) Explain why the salt obtained may still be contaminated with sand and suggest how you would improve your experiment to obtain a purer sample of salt.

Chapter review questions

1 Choose from the following list of elements to answer the questions below:

bromine calcium krypton nickel nitrogen potassium silicon

a) Which element is most like lithium?

b) Which element is most like iron?

c) Which element is most like helium?

d) Which element is most like fluorine?

e) Which element is most like carbon?

2 In which group or area of the periodic table would you find these elements?

a) Element **A** has 7 electrons in its outer shell.

b) Element **B** reacts vigorously with water to give off hydrogen gas and an alkaline solution.

c) Element **C** is a metal with 4 electrons in its outer shell.

d) Element **D** is a colourless gas that does not react at all.

e) Element **E** forms coloured compounds.

f) Element **F** is toxic and is made of diatomic molecules.

g) Element **G** forms 1– ions when it reacts with metals to form ionic compounds

h) Element **H** can form both 1+ and 2+ ions

i) Element **I** is a metal that floats on water

j) Element **J** has the electron structure 2,8,18,6

k) Element **K** has 12 protons

l) Element **L** has a full outer shell

m) Element **M** can act as a catalyst

3 Look at the following atoms and ions.

^{12}C ^{14}C $^{16}O^{2-}$ $^{19}F^{-}$ ^{20}Ne

Which of these atoms and ions, if any,

a) are isotopes? b) have 9 protons? c) have 10 electrons?

d) have 10 neutrons? e) have more protons than electrons?

4 Caesium atoms are among the largest atoms. A caesium atom has a radius of 0.260 nm. Write this in metres in standard form.

5 A colourless solution of sodium iodide was added to a yellow solution of bromine. The yellow colour of the solution darkened to brown as the sodium iodide was added.

a) Explain why the solution darkened.

b) Write an ionic equation for the reaction that took place.

c) Explain, in terms of electrons, why this reaction took place.

Note: More Chapter review questions will be available in the full version.

Practice questions

1 How many electrons are there in a potassium ion (K^+)?

A 18 **B** 19

C 20 **D** 39 [1 mark]

2 In which of the following atoms is the number of protons greater than then number of neutrons?

A ^{2}H **B** ^{3}He

C ^{10}B **D** ^{16}O [1 mark]

3 An aluminium atom contains three types of particle.

a) Copy and complete the table below to show the name, relative mass and relative charge of each particle in an aluminium atom. [4 marks]

Particle	Relative charge	Relative mass
Proton		1
		Very small
Neutron	0	

b) Complete the sentences below, about an aluminium ion by circling one of the words in bold. [4 marks]

i) In an aluminium atom, the protons and neutrons are in the **nucleus/shells**.

ii) The number of protons in an aluminium atom is the **atomic number/group number/mass number**.

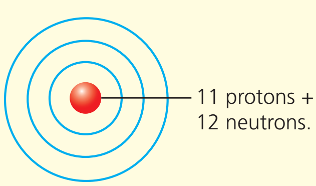
iii) The sum of the number of protons and neutrons in an aluminium atom is the **atomic number/group number/mass number.**

iv) The number of electrons in an aluminium atom is **13/14/27**.

4 The structure of the atom has caused debate for thousands of years. In the late 19th century the 'plum-pudding model' of the atom was proposed. This was replaced at the beginning of the 20th century with the nuclear model of the atom which is the basis of the model we use today.

a) Describe the differences between the 'plum-pudding' model of the atom and the model of the atom we use today. [5 marks]

b) The diagram represents an atom of an element. The electrons are missing from the diagram.



i) State the atomic number of this element. [1 mark]

ii) State the mass number of this element. [1 mark]

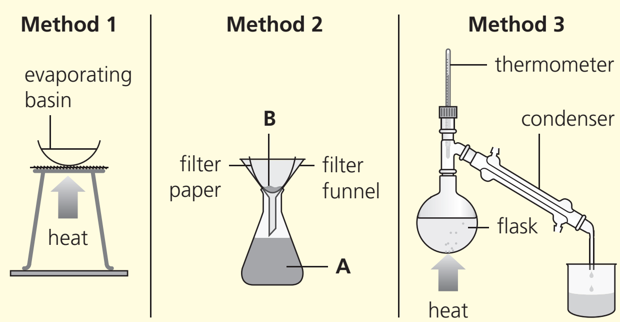
iii) Name the part of the atom in which the protons and neutrons are found. [1 mark]

iv) Copy and complete the diagram to show the electronic configuration of the atom, using x to represent an electron. [1 mark]

c) The table shows some information for several atoms and simple ions. Copy and complete the table. [6 marks]

Atom/Ion	Number of protons	Electronic structure
	7	2,5
S^{2-}		
Ca^{2+}		
	12	2,8

5 Mixtures may be separated in the laboratory in many different ways. Three different methods of separating mixtures are shown below.



a) Name each method of separation. [3 marks]

b) Which method (**1**, **2** or **3**) would be most suitable for obtaining water from potassium chloride solution? [1 mark]

c) Which method would be most suitable for removing sand from a mixture of sand and water? [1 mark]

d) What general term is used for liquid **A** and solid **B** in method 2? [2 marks]

e) Explain fully why Method 2 would **not** be suitable to separate copper(II) sulfate from copper(II) sulfate solution. [1 mark]

6 Dmitri Mendeleev produced a table that is the basis of the modern periodic table. Describe the key features of Mendeleev's table and explain why his table came to be accepted over time by scientists. [6 marks]

7 The alkali metals and the transition metals are all metals. Identify some ways in which these metals are similar and some ways in which they are different. [6 marks]

Note: More Practice questions will be available in the full version.

Working scientifically: How theories change over time

After the discovery of the new element phosphorus in 1649, scientists began to think about the definition of an element. In 1789 Antoine-Laurent de Lavoisier produced a table similar to that below of simple substances, or elements, which could not be broken down further by chemical reactions.

In addition to many elements which form the basis of our modern periodic table, Lavoisier's list also included 'light' and 'caloric' (heat) which at the time were believed to be material substances. Lavoisier incorrectly classified some compounds as elements because high temperature smelting equipment or electricity was not available to break down these compounds. The incorrect classification of these compounds as elements was due to a lack of technology as much as a lack of knowledge.

A version of the periodic table hangs on the wall of almost every chemistry laboratory across the world – it summarises much of our knowledge of chemistry. The history of the periodic table illustrates how scientific theories change over time.

Acid-making elements	Gas making elements	Metallic elements	Earth elements
Sulfur	Light	Cobalt mercury, tin	Lime (calcium oxide)
Phosphorus	Caloric (heat)	Copper, nickel, iron	Magnesia (magnesium oxide)
Charcoal (carbon)	Oxygen	Gold, lead, silver, zinc	Barytes (barium sulfate)
	Azote (nitrogen)	Manganese, tungsten	Argila (aluminium oxide)
	Hydrogen	Platina (platinum)	Silex (silicon dioxide)

Questions

1. What is an element?
2. Which elements in Lavoisier's table also appear in today's periodic table?
3. Which group of elements did Lavoisier classify correctly?
4. Why do you think sulfur, phosphorus and charcoal are described as 'acid-making' elements?
5. Which substances in Lavoisier's list, from your own modern knowledge, are compounds? Why do you think Lavoisier thought these were elements?

Following on from the work of Lavoisier, in the early 19th century Johann Döbereiner noted that certain elements could be arranged in groups of three because they have similar properties. For example

- **lithium, sodium and potassium – very reactive metals that produce alkalis with water**
- **calcium, strontium and barium – reactive metals but with higher melting points and different formula of their oxides**
- **chlorine, bromine and iodine – low melting point, coloured, reactive non-metals.**

Note: A double-page spread version of this section will be available in the full version.

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First teaching from September 2016

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