15 Atoms, elements, and compounds

In this chapter you will answer:

- What is an element?
- What are the parts inside an atom, what are their charges, and what are their relative masses?
- What is an isotope?
- How are electrons arranged inside an atom?
- What is a compound?
- What is a mixture?

About 200 years ago an Englishman called John Dalton introduced one of the most important theories in Chemistry: the atomic theory. His idea was that there are a small number of different types of atoms and these atoms can join together in different ways to produce thousands of new substances.

KEY WORDS

Element contains only one type of atom and all atoms have the same proton number

Proton a particle found in the nucleus of an atom, it has a positive charge and a relative mass of 1

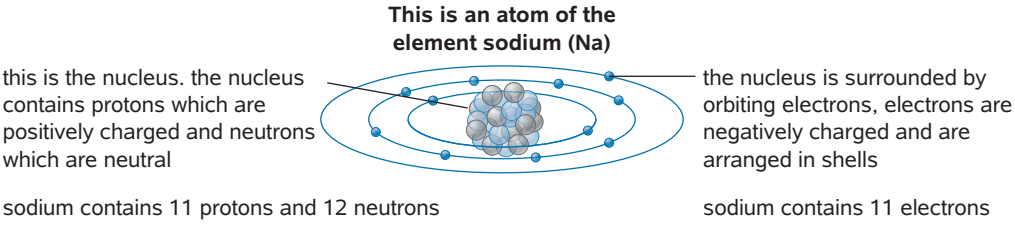
Neutron a particle found in the nucleus of an atom, it has no charge and a relative mass of 1

Electron a particle found outside the nucleus of an atom, it has a negative charge and a relative mass of 0.000543

15.1 Atoms

An **element** contains only one type of atom and cannot be broken down into anything simpler through chemical reactions. Everything around us is made up of atoms.

Atoms are made up of three types of subatomic particles called protons, neutrons, and electrons. The central part of an atom contains most of the mass of the atom. The **nucleus** is made of protons and neutrons. **Electrons** surround the nucleus and are arranged in orbits or rings (see diagram 15.1).



15.1 Electron orbits

Protons have a positive **charge** and a relative mass of 1.

Neutrons have no charge and a relative mass of 1.

Electrons have a negative charge and a very small relative mass of 0.000543.

In an atom, the number of protons and the number of electrons are the same. For this reason atoms have no overall electrical charge.

The number of protons in an atom is known as the **proton number** (or **atomic number**).

The number of protons plus the number of neutrons is known as the **nucleon number** (or **mass number**).

For example: sodium

Nucleon number (Z) – 11 protons and 12 neutrons ⟶ $^{23}_{11}Na$

Proton number (A) – number of protons or electrons ⟶ 11

All atoms of an element have the same proton number (the same number of protons and electrons). The chemical properties and chemical **reactions** of an element depend on the number of electrons present. Therefore all atoms of an element react in the same way because they have the same number of electrons.

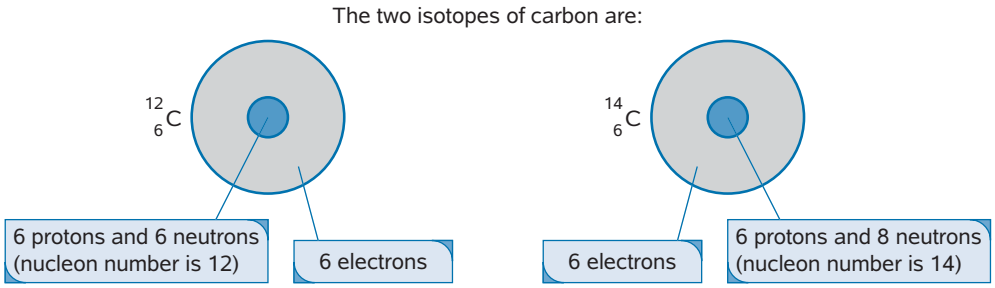
15.2 Isotopes

Some atoms of certain elements can have a different nucleon number because they have a different number of neutrons, but the same proton number as they have the same number of protons and electrons. Atoms of the same element that have different numbers of neutrons are known as **isotopes**.

For example, carbon has two isotopes.

KEY WORD

Isotopes atoms that have a different number of neutrons but the same number of protons and electrons



15.2 Carbon isotopes

The proportion of different isotopes in an element does not change the chemical properties of the element. However, the proportion of different isotopes in an element can affect the physical properties of an element such as the melting point, boiling point, and **density**.

Some isotopes are **radioactive**. This means that the nucleus is unstable and gives off **radiation**. Uranium is an example of a radioactive isotope. Radioactive isotopes can be used medically to treat cancer, find tumours, and follow the flow of fluids around the body. In industry, radioactive isotopes can be used to locate leaks in pipelines, measure the flow of substances through pipelines, and measure the thickness of metal foil.

Exercise

1 Answer in complete sentences.

a Why do some atoms of certain elements have a different nucleon number?

b What are different atoms of the same element called?

c Does the proportion of different isotopes change the chemical properties of an element?

d Can the proportion of different isotopes change the physical properties of an element?

e What is special about a radioactive isotope?

f Give three medical uses for radioactive isotopes.

g Give three industrial uses for radioactive isotopes.

15.3 Electron configuration in atoms

The way electrons are arranged around the nucleus is known as **electron configuration**. Electrons are arranged around the nucleus in energy levels or shells.

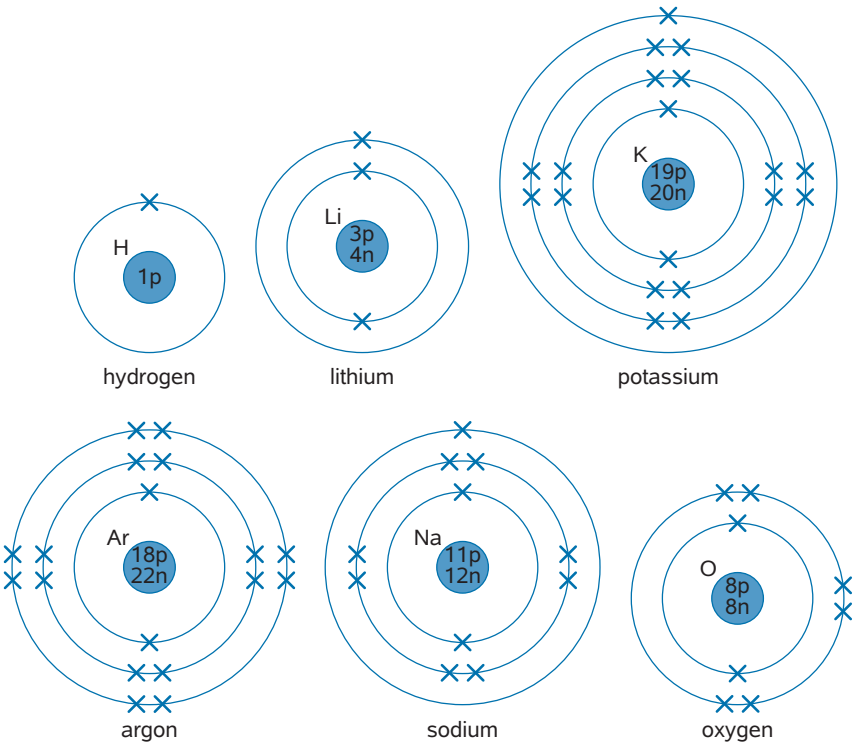
The first energy level or shell can only contain 2 electrons. The shells after this contain 8 electrons, as explained in the table below.

For example, the electron configuration for the element oxygen is written as 2,6 as oxygen has 8 electrons in total: 2 electrons in the first shell and 6 in the second shell. The electron configuration for potassium is 2,8,8,1 as potassium has 19 electrons in total: 2 electrons in the first shell, 8 in the second and third shell, and one in the last shell.

KEY WORDS

Electron configuration the way electrons are arranged around an atomic nucleus

Valency how many electrons are available for an element to bind to another element



15.3 Electron configuration in some common atoms

Number	Roman numeral
1	I
2	II
3	III
4	IV
5	V
6	VI
7	VII
8	VIII
0	0

Group numbers are always written in Roman numerals.

The number of electrons found in the outer shell is known as the number of **valency** electrons. The valency number refers to how many electrons are available for an element to bind to another element. All elements with the same number of valency electrons are found in the same group in the periodic table. Group numbers are always written in Roman numerals. Look at the table on the next page.

Element	Chemical symbol	Proton number	Electrons in energy level 1	Electrons in energy level 2	Electrons in energy level 3	Electrons in energy level 4	Electron configuration	Group
Hydrogen	H	1	1				1	I
Helium	He	2	2				2	II
Lithium	Li	3	2	1			2,1	I
Beryllium	Be	4	2	2			2,2	II
Boron	B	5	2	3			2,3	III
Carbon	C	6	2	4			2,4	IV
Nitrogen	N	7	2	5			2,5	V
Oxygen	O	8	2	6			2,6	VI
Fluorine	F	9	2	7			2,7	VII
Neon	Ne	10	2	8			2,8	0
Sodium	Na	11	2	8	1		2,8,1	I
Magnesium	Mg	12	2	8	2		2,8,2	II
Aluminium	Al	13	2	8	3		2,8,3	III
Silicon	Si	14	2	8	4		2,8,4	IV
Phosphorus	P	15	2	8	5		2,8,5	V
Sulfur	S	16	2	8	6		2,8,6	VI
Chlorine	Cl	17	2	8	7		2,8,7	VII
Argon	Ar	18	2	8	8		2,8,8	0
Potassium	K	19	2	8	8	1	2,8,8,1	I
Calcium	Ca	20	2	8	8	2	2,8,8,2	II

Elements with a full outer electron shell are the most stable elements and are found in group 0. All elements in this group are gases and are known as the noble gases.

Exercise

2 Match the words below to their meanings.

1 chemical symbol	**a** a particle with a positive charge and a relative mass of 1
2 electron configuration	**b** a particle with a negative charge and a relative mass of 0.000543
3 valency number	**c** the number of electrons are present in the outer shell which are available for binding the atom to another atom
4 group	**d** a short one or two letter code for each element
5 element	**e** the arrangement of electrons around a nucleus
6 proton	**f** elements with the same number of valency electrons
7 electron	**g** a substance containing only one type of atom

15.4 Compounds

A **compound** consists of atoms of two or more different elements chemically bonded together. For example, water is a compound made from the elements hydrogen and oxygen.

The properties of the compound formed are different to the elements that make it up. For example,the properties of water are different to the properties of both hydrogen and oxygen.

In order to separate a compound into the elements it contains, a chemical reaction must take place.

KEY WORD

Compound a substance made of two or more elements where atoms of different elements are joined together by chemical bonds

15.5 Mixtures

A **mixture** contains two or more substances mixed together but not chemically bonded together. The properties of the mixture are the same as the substances that make it up. As the parts of a mixture are not chemically bonded together they can be separated easily using physical methods such as **distillation**.

KEY WORD
Mixture contains two or more substances which are not joined together by chemical bonds

Exercise

3 Decide which of these sentences describe compounds (C) and which describe mixtures (M).

a Two substances not chemically bonded.
b Two substances chemically bonded.
c Properties are different to the elements which make up the new substance.
d Properties are the same as the substances which make it up.
e Substances can be separated by physical methods.
f Substances separated by a chemical reaction.

Extension

1 Copy the table below and then complete it with the correct information about protons, neutrons, and electrons.

	Location	Charge	Relative mass
Proton			
Neutron			
Electron			

2 Create a mindmap for the key ideas about isotopes from section 15.2.
3 Draw electron configuration diagrams for boron, sulfur, and calcium.
4 Find three examples of a compound and three examples of a mixture in your home.

Talking points

Discuss the differences between an element, a compound, and a mixture.

Think about the questions from the start of the chapter.
Can you answer these now?

- ◎ What is an element?
- ◎ What are the parts inside an atom, what are their charges, and what are their relative masses?
- ◎ What is an isotope?
- ◎ How are electrons arranged inside an atom?
- ◎ What is a compound?
- ◎ What is a mixture?