Draft specification subject to Ofqual feedback and accreditation

ATOMIC STRUCTURE AND THE PERIODIC TABLE

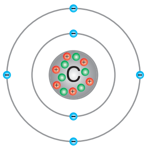
IDEAS YOU HAVE MET BEFORE:

ELEMENTS, MIXTURES AND COMPOUNDS

- Mixtures can be separated easily by filtering and other ways.
- Elements cannot be broken down by chemical means.
- Compounds are made from elements chemically combined.

ATOMS AND THEIR STRUCTURE

- Electrons have a negative charge.
- Atoms have a nucleus with a positive charge.
- Electrons orbit the nucleus in shells.



SOME ELEMENTS AND THEIR COMPOUNDS

- Helium is unreactive and used in balloons.
- Sodium chloride is used to flavour and preserve food.
- Chlorine is used to kill bacteria in swimming pools.

METALS IN THE PERIODIC TABLE

- Gold, silver and platinum are precious metals.
- Mercury is a liquid metal.
- Zinc, copper and iron are used to make many useful objects.

METALS AND NON-METALS

- Gold, iron, copper and lead are metals known for centuries.
- Oxygen and nitrogen are gases of the air.
- Sulfur is a yellow non-metal.

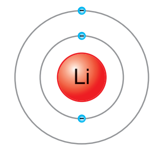
225106 AQA_Chemistry_CH1.indd 12 12/05/16 10:13 am

1

IN THIS CHAPTER YOU WILL FIND OUT ABOUT:

WHAT MODEL DO WE USE TO REPRESENT AN ATOM?

- Electrons fill the shells around the nucleus in set pattern orders.
- Protons and neutrons make up the nucleus.
- Electrons can be lost from or gained into the outer shell.

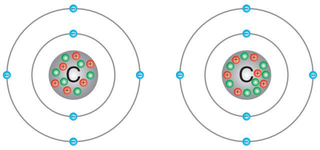


HOW DID THE MODEL OF THE ATOM DEVELOP?

- Atoms used to be thought of as small unbreakable spheres.
- Experiments led to ideas of atoms with a nucleus and electrons.
- Electrons in shells and the discovery of the neutron came later.

WHY CAN WE USE CARBON DATING?

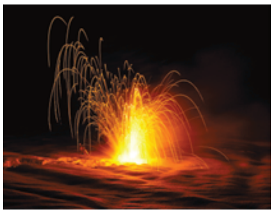
- Atoms of an element always have the same number of protons.
- They do not always have the same numbers of neutrons.
- Elements exist as different isotopes.



Spot the difference in these *isotopes*

WHY IS HELIUM SO UNREACTIVE AND SODIUM SO REACTIVE?

- The outer shell of helium can take no more electrons.
- The outer shell of sodium has 1 electron which it needs to lose.
- Metals need to lose electrons, non-metals do not.



WHAT IS THE DIFFERENCE BETWEEN METALS AND NON-METALS?

- Metals are shiny and sonorous, non-metals are dull or a gas.
- Metals often have high tensile strength and conduct electricity.
- Non-metal oxides are acidic.

Elements and compounds

Learning objectives:

- identify symbols of elements from the periodic table
- recognise compounds from their formula
- identify the elements in a compound.

KEY WORDS

balanced
compound
element
equation
symbol

All the elements are listed in the periodic table. The elements in the formulae of any compound, no matter how large, can be identified by using the periodic table.

Elements and compounds

An **element** is a substance that cannot be broken down chemically.

A **compound** is a substance that contains at least two different elements, chemically combined in fixed proportions.

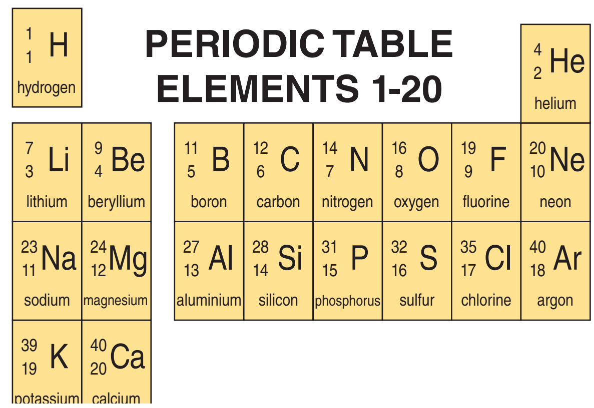


Figure 1.1 Two sections of the periodic table. Can you find magnesium and oxygen?

Figure 1.2 Magnesium (metal) reacts with oxygen (gas) to make magnesium oxide (white powder).

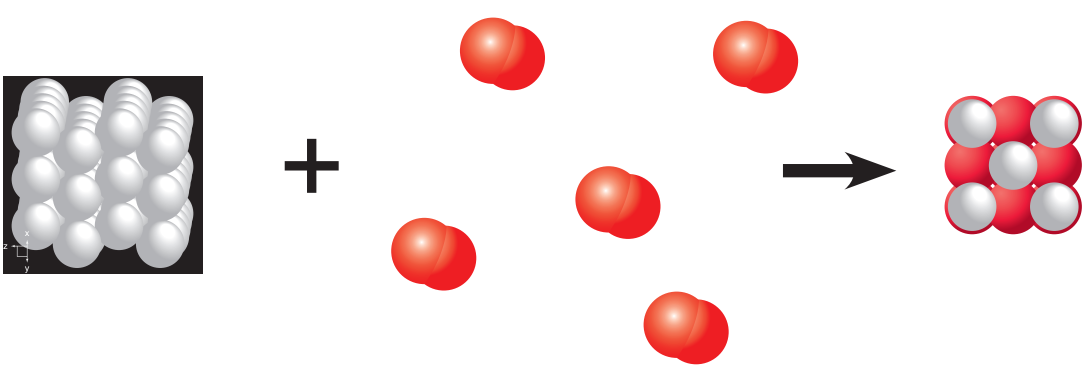


Figure 1.3 The reaction of the elements in Figure 1.2 can be represented by models of their atoms.

1. **Identify the following substances as elements or compounds.**

   copper　　copper chloride　　copper sulfate

2. **Name the elements in beryllium chloride.**

Compounds and elements

Copper is an **element**. It cannot be broken down into any other substances, but salt can.

The chemical name for common salt is sodium chloride. Sodium chloride is a **compound**. Sodium chloride can be broken down to make sodium and chlorine, but this is not easy to do because the sodium and chlorine are chemically combined. We need to use electricity to make sodium and chlorine from sodium chloride.

Sodium and chlorine cannot be broken down any further. Sodium and chlorine are elements.

There are only about 100 elements but these can join together chemically to make an enormous number of compounds. They need chemical reactions to do this.

3 **Identify the elements in potassium bromide.**

4 **Predict the products when lead iodide is split by electricity.**

KEY INFORMATION

When chlorine reacts to make a compound it chemically combines and becomes a chloride.

Similarly, bromine reacts to become a bromide and oxygen reacts to become an oxide.

Making the element copper into a compound

A chemical reaction is needed to make copper (an element) into a compound. If copper is burned in oxygen it forms copper oxide. Chemical reactions always involve the formation of one or more new substances, and often involve a detectable energy change.

Figure 1.4 Copper (an element) burning in oxygen (an element) to make copper oxide (a compound). This is normally done by heating the copper in crucibles.

5 **Name of the compound made from sodium and oxygen.**

6 **Oxygen can be removed from iron(III) oxide by carbon monoxide. Identify the element and compound produced.**

7 **Substance D reacted with hydrogen to form zinc and water. Explain whether substance D is an element or compound.**

DID YOU KNOW?

Compounds can only be separated into elements by chemical reactions.
To get the element copper back, the oxygen needs to be chemically removed. This is done using hydrogen. The oxygen combines with the hydrogen to make water, another compound.
copper oxide + hydrogen → copper + water

Atoms, formulae and equations

Learning objectives:

- explain that an element consists of the same type of atoms
- explain that atoms join together to make molecules
- explain how formulae represent elements and compounds.

KEY WORDS

compound
element
molecule

All substances are chemicals. Many people say "I don't want chemicals in my food" not realising that foods *are* chemicals. Our food is made of compounds and mixtures. Compounds are elements joined together in many different ways. In fact, we are all made of chemical compounds.

Figure 1.5 Vinegar is used in salad dressing. Its chemical name is ethanoic acid. Ethanoic acid is a compound made from carbon, hydrogen and oxygen.

Atoms and molecules

Elements are made up of atoms that are all the same.

Compounds are made up of atoms (or charged atoms) that are not the same.

CH_3COOH is a compound made from three elements. These are carbon, C, hydrogen, H, and oxygen, O. You will know it as vinegar. Its chemical name is ethanoic acid. The atoms join by sharing their electrons. The compound is made of molecules.

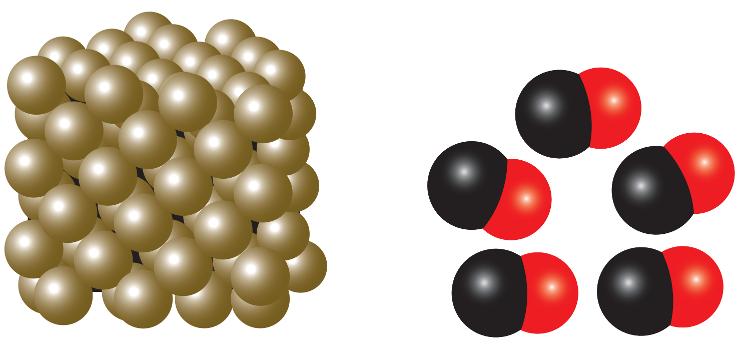


Figure 1.6 Gold is an element. Carbon monoxide is a compound. How could you tell by looking at these diagrams?

Figure 1.7 The molecule in vinegar CH_3COOH

If two or more atoms join together by sharing their electrons the atoms form a **molecule**.

Two examples of molecules are oxygen and water.

Figure 1.8 Which of these is a molecule of an element? How can you tell?

1. **Explain whether the following substances are elements or compounds.**

   C (carbon), CO_2 (carbon dioxide), Cl_2 (chlorine) and SO_3 (sulfur trioxide)

2. **For the substances below, write down:**

   a **the names of the elements**

   b **how many different types of atoms they contain**

   c **how many atoms are in the molecule overall.**

   CO_2 S_8 Cl_2 SO_3 C_{60} C_4H_{10}

KEY INFORMATION

In a chemical formula the number that is a subscript on the bottom right is the number of atoms in the molecule, for example C_2H_6 has two carbon atoms joined to six hydrogen atoms.

Formulae

You can see which elements are in a compound by looking at its **formula**. For example, the compound magnesium oxide (MgO) contains Mg (magnesium) and O (oxygen).

Look back at the section of the periodic table.

Elements from Group 1 and elements from Group 7 combine to make compounds in a fixed ratio of 1 : 1.

- The **formula** of lithium fluoride is LiF.

Elements from Group 2 and elements from Group 6 also combine to make compounds in a fixed ratio of 1 : 1.

- The formula of calcium oxide is CaO.

Elements from Group 2 and elements from Group 7 combine to make compounds in a fixed ratio of 1 : 2. The element that you need two of has a suffix '2' after the symbol.

- The formula of calcium fluoride is CaF_2.

Elements from Group 1 and elements from Group 6 combine to make compounds in a fixed ratio of 2 : 1. Again, the element that you need two of has a suffix '2' after the symbol.

- The formula of sodium sulfide is Na_2S.

3 Give the names of the elements in $MgSO_4$ and in CH_4.

4 Determine the formulae of lithium chloride, magnesium chloride and potassium oxide.

DID YOU KNOW?

Oxygen exists as a pair of atoms not as a single atom. Its formula is O_2. In a symbol equation, O_2 must be written not just O.

Equations and balancing

When magnesium reacts with oxygen it makes magnesium oxide.

The word **equation** is:

magnesium + oxygen → magnesium oxide

The **symbol** equation is:

Mg	+	O_2	→	MgO
1		2		1 1 ✗

This is not a **balanced** equation. We need to add '2' to the front of the formulae of magnesium and magnesium oxide. This gives:

2Mg	+	O_2	→	2MgO
2		2		2 2 ✓

KEY INFORMATION

In a balanced equation 'O_2' means a pair of atoms joined together in a molecule. '2Mg' means two separate atoms, where the '2' is added to balance the equation.

5 Write a balanced equation for the formation of sodium chloride from sodium, Na and chlorine, Cl_2.

6 Write a balanced equation for the formation of aluminium oxide Al_2O_3.

7 Complete and balance the following equation by suggesting values for D, E and F:

$$\mathbf{D}\ N_2 + \mathbf{E}\ O_2 \rightarrow \mathbf{F}\ NO_2$$

Mixtures

Learning objectives:

- recognise that all substances are chemicals
- understand that all substances are either mixtures, compounds or elements
- explain that mixtures can be separated.

KEY WORDS

chromatography
filtration
mixture
separation

You will have begun to use of a range of equipment to safely separate chemical mixtures and we need to extend this range of techniques. Filtering and distillation are probably familiar but fractional distillation can also be used to separate mixtures.

Mixtures

Many substances are made of mixtures. **Mixtures** can easily be **separated** because the chemicals in them are not joined together. Mixtures can be separated by filtration, crystallisation, simple distillation, fractional distillation and chromatography.

Figure 1.9 Separating mixtures

Let's take a mixture of salt and copper. To separate them we add water to the mixture. The salt dissolves but the copper does not. The salt solution can be filtered through a filter paper, leaving the copper behind as a residue. The salt solution can be crystallised to make solid salt crystals. These physical processes do not involve chemical reactions and no new substances are made.

After separating, salt and copper can be mixed again.

1. **Draw a diagram of the equipment used to filter salt solution from copper.**
2. **Explain why a blend of copper and salt is not a compound.**

Separating mixtures

A mixture consists of two or more elements or compounds not chemically combined together. The chemical properties of each substance in the mixture are unchanged. Mixtures can be separated by physical processes. These processes do not involve chemical reactions.

These separation processes include:

- filtration
- crystallisation
- distillation
- chromatography

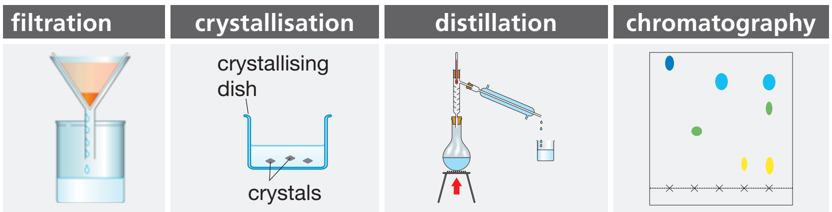


Figure 1.10 Techniques for separating mixtures.

KEY INFORMATION

Filtration separates insoluble substances from soluble substances and distillation separates liquids that have different boiling points.

3. **Which technique would be used to separate coloured inks in a mixture?**
4. **Which technique would be used to separate alcohol (boiling point 80°C) and water?**

Fractional distillation

Some mixtures are very complex and have many different components. These mixtures can be separated either (a) by using different techniques in sequence or (b) by the same technique which includes multiple seperations.

An example of the first approach is filtration followed by crystallisation.

An example of the second approach is fractional distillation, where different liquids with different boiling points are separated at different points in the process.

Fractional distillation works by using a tall tower of gaps and surfaces, which are gradually colder towards the top. The liquid mixture is heated at the bottom and the liquids boil together to make a mixture of gases. As each gas reaches a surface at the same temperature as its boiling point (or condensing point) that gas will condense and the condensed liquid will run off. The other gases continue up through the gaps until they reach the surface at their condensing temperature. Eventually nearly all the gases in the mixture will condense and be collected as separated liquids. The final gas is left at the top of the tower and is collected as a gas.

DID YOU KNOW?

Fractional distillation is used to separate the different substances in crude oil.

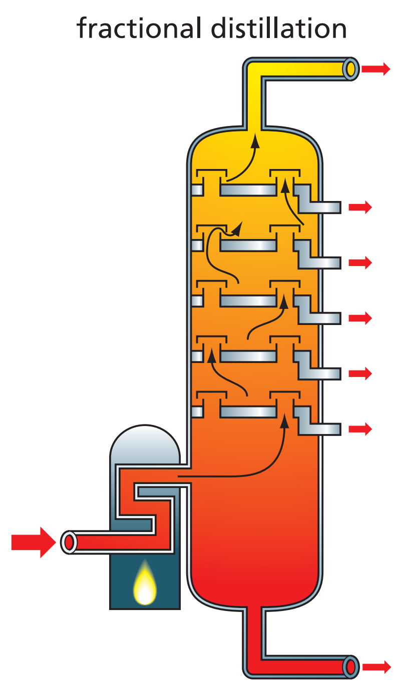


Figure 1.11 Fractional distillation of mixtures with different boiling points

5. **Suggest how you would collect a specimen of clean copper sulfate crystals from a mixture of solid copper sulfate, sand and alcohol.**
6. **Suggest the order of collection from a fractional distillation process of these liquids:**

   a (boiling point 85 °C)

   b (boiling point 100 °C)

   c (boiling point 35 °C)

   d (boiling point 165 °C)

Changing ideas about atoms

Learning objectives:

- describe how the atomic model has changed over time
- explain why the atomic model has changed over time
- understand that a theory is provisional until the next piece of evidence is available.

KEY WORDS

electron shell
Ernest Rutherford
Geiger and Marsden experiment
J. J. Thompson
James Chadwick
John Dalton
Niels Bohr

The idea of atoms has changed hugely over the years. At the moment, scientists believe atoms are very small, have a very small mass and are made of protons, electrons and neutrons. Our current theories were developed by imagination, evidence and advances in technology, with each new idea being built on the ideas of earlier scientists.

Developing the atomic theory

Explanations about atoms began about 400 BC, when the Greek philosopher Democritus described materials as being made of small particles. He called these particle 'atoms'. However, he had no evidence. It was just an idea.

Little more was suggested for more than 2000 years, but in 1803 the British scientist **John Dalton** used his observations to describe the atom in more detail. His model described an atom as a 'billiard ball'.

Figure 1.12 Dalton's idea of atoms: they were like tiny billiard balls.

Dalton's model was then changed as new evidence was found.

In 1897, 94 years later, **J. J. Thomson** discovered the electron. Thomson developed the way that the atom was thought of by using a 'plum pudding' model to describe atoms. Negative electrons were thought to be embedded in a ball of positive charge, rather like the fruit (the electrons) are part of a pudding (the ball of positive charge).

1. **Suggest why Dalton's atomic model did not include positive and negative charge.**
2. **Explain why the discovery of the electron changed the Dalton model of the atom.**

KEY INFORMATION

At each stage, the explanations of atomic theory were provisional until more convincing evidence was found to make the model better.

Changing theories

Sometimes ideas can develop rapidly because of unexpected results.

In 1909 **Geiger** and **Marsden** had really surprising results in their experiment with gold leaf and alpha particles. These results led Geiger, Marsden and **Rutherford** to propose a new idea that an atom has a nucleus. In 1911, Rutherford suggested the atom had a positively charged nucleus and much of the atom was empty space. This was the nuclear model of the atom.

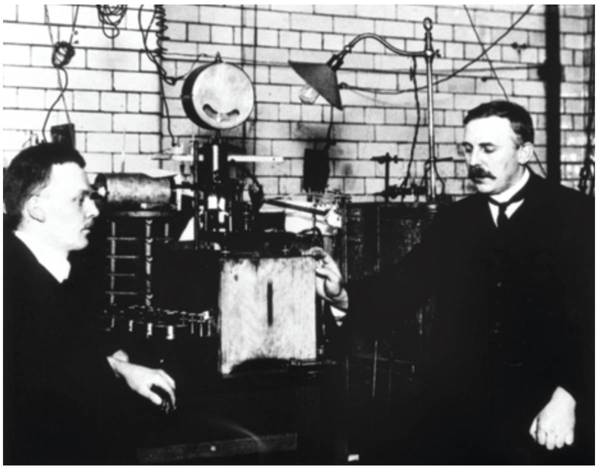


Figure 1.13 Rutherford and Geiger in their lab in Manchester, UK.

In 1913, **Niels Bohr** used theoretical calculations that agreed with experimental evidence to adapt the nuclear model. He explained that the electrons orbited the nucleus in definite orbits at specific distances from the nucleus. He explained that a fixed amount of energy (a *quantum* of energy) is needed for an electron to move from one orbit to the next. Electrons only exist in these orbits.

3. **Suggest why Bohr proposed that electrons orbited the nucleus in shells.**
4. **What is meant by the phrase 'quantum of energy'?**

Further development of atomic theory

Later experiments gradually led to the idea that the positive charge of any nucleus can be sub-divided into a whole number of smaller particles. Each of these particles had the same amount of positive charge. In 1920 the term 'proton' was first used in print for these particles.

In 1932, **James Chadwick** discovered the neutron. Again this discovery involved experimental evidence and mathematical analysis.

5. **Draw a timeline of the discoveries that led to our present understanding of the atomic theory.**
6. **Suggest why it was twelve years between finding protons and neutrons.**

DID YOU KNOW?

As a challenge you can find out about the Geiger and Marsden experiment that changed the theory from a 'plum-pudding' atom to a nuclear atom, it is a famous turning point in the understanding of atoms.

DID YOU KNOW?

The idea of atoms as small particles is not new. However, our ideas about the theory of atoms are still developing. Search on 'CERN LHC' to find out more.

Google search: 'timeline of development of atomic theory'

225106 AQA_Chemistry_CH1.indd 21 12/05/16 10:14 am

Modelling the atom

Learning objectives:

- describe the atom as a positively charged nucleus surrounded by negatively charged electrons
- explain that most of the mass of an atom is in the nucleus
- explain that the nuclear radius is much smaller than that of the atom and with most of the mass in the nucleus.

KEY WORDS

charge
electron
nucleus
electron shell

Atoms are the building blocks of all matter, both living and non-living, simple and complex. Atoms join together in millions of different ways to make *all* the materials around us. We can explain how *everything*, including ourselves, is made by using ideas and models of atoms.

Atoms

Individual atoms are very small. There are about ten million million atoms in this full stop.

An atom is made up of a **nucleus** that is surrounded by electrons.

- The nucleus carries the **positive charge**.
- **Electrons**, which surround the nucleus, each carry a **negative charge.**

It depends how it is measured but the diameter of an atom is about 10^{-10} m. That's 0.000 000 1 c. If we imagine that an atom is blown up to the size of a football stadium the nucleus would be the size of a peanut placed on the centre spot.

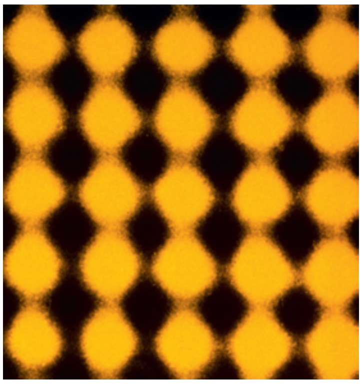


Figure 1.14 Image of gold atoms. Magnification x 16 000 000.

1. **What is the type of charge in the nucleus?**
2. **Helium has two positive charges in the nucleus. Predict the number of electrons in a helium atom.**

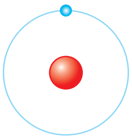


Figure 1.15 The structure of a hydrogen atom. What charge does an electron carry?

More on atoms

Electrons occupy the space around the nucleus in 'shells'. The space between the nucleus and the **electron shells** is empty space.

The nucleus contains most of the mass of the atom and the electrons contribute very little. On the other hand, the radius of the atom, where the electrons are orbiting, is much larger than the radius of the nucleus in the centre.

When we are talking about these differences we are talking about small sizes. Atoms are *very* small. A typical atomic radius is about 0.1 nm (1×10^{-10} m). The radius of a nucleus is less than one ten-thousandth of the radius of an atom (about 1×10^{-14} m).

Typical atomic radius	Typical radius of a nucleus
1×10^{-10} m	1×10^{-14} m

The radius of an atom is measured in many different ways. This is because the outer electron shell is not a fixed boundary, and so its position can only be measured approximately.

3 Most of the atom is empty space. What does this suggest about the size of an electron?

4 Explain why the radius of the nucleus is much smaller than the radius of the whole atom.

HIGHER TIER ONLY

Atoms are very small. A typical atomic radius is about 0.1 nm (1×10^{-10} m). However, the radius of an atom increases within a group of elements.

For example the atomic radii of Li, Na, K, increase as more electrons are 'added' to the atom.

5 Suggest why the radius of potassium is larger than the radius of lithium.

6 The positive charge on a Li nucleus is 3. The positive charge on a Ne nucleus is 10. As more negative electrons are added one by one to atoms from Li up to Ne the radius gets smaller, not bigger. Suggest why. Use ideas about opposite charges.

DID YOU KNOW?

An atom of gold has a mass of about 3.3×10^{-22} g and a radius of about 1.4×10^{-10} m. Most of the mass of the atom is in the middle, in the nucleus.

KEY INFORMATION

Remember that the typical radius of a nucleus is less than 1/10 000 th of the typical radius of an atom.

Relating charges and masses

Learning objectives:

- describe the structure of atoms
- recall the relative masses and charges of protons, neutrons and electrons
- explain why atoms are neutral.

KEY WORDS

atomic number
electron
neutral
neutron
proton
symbol

We have seen how ideas about atoms have changed over the years. Currently, scientists believe atoms are made of three important particles – protons, electrons and neutrons.

- The number of **protons** and **neutrons** are important in *nuclear reactions*.
- The numbers of protons and **electrons** are important in *chemical reactions*.

Structure of atoms

An atom is made up of a nucleus that is surrounded by electrons.

- The nucleus carries a positive charge.
- The electrons that surround the nucleus each carry a negative charge.

The nucleus of an atom is made up of protons and neutrons.

- Protons have a positive charge.
- Neutrons have no charge.

An atom always has the same number of protons (+) as electrons (–) so atoms are always **neutral**.

The **atomic number** is the number of protons in an atom. The atomic number for helium is 2 because it has two protons.

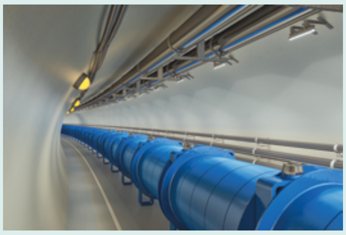
1. **Lithium has an atomic number of 3. Predict the number of electrons in lithium.**
2. **The neon atom has 10 protons. Explain why the neon atom is neutral.**
3. **Use the periodic table to identify the element with 3 protons.**
4. **Determine the number of protons in an atom of calcium, Ca.**

Masses and charges

The nucleus of an atom is made up of particles (protons and neutrons) that are much heavier than electrons. The relative masses and charges of electrons, protons and neutrons are shown in the table.

DID YOU KNOW?

Even these particles can be broken down further in huge particle accelerators such as the one built deep underneath Switzerland by a joint team of scientists and engineers from many European countries.



KEY INFORMATION

It is because a helium atom has two protons that it has an atomic number of 2.

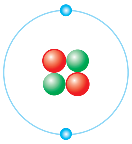


Figure 1.16 The structure of a helium atom. There are the same number of protons and electrons.

	Relative charge	Relative mass
Electron	–1	0.0005
Proton	+1	1
Neutron	0	1

DID YOU KNOW?

Electrons have such a small relative mass that it is usually treated as zero.

5 **A fluorine atom has 9 positive charges, 9 negative charges and a mass of 19. Describe the structure of its atom.**

6 **A chlorine atom has 17 electrons and a mass of 35. Describe the structure of its atom.**

Losing electrons

If an atom has an atomic number of 3 and a neutral charge, it must be a lithium atom. It has a neutral charge because the atom has three protons (+) and three electrons (–).

If the lithium atom loses one negatively charged electron it then becomes a *charged* particle with one positive charge that is not balanced out by a negative charge.

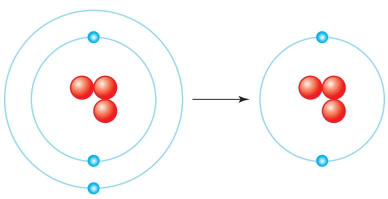


Figure 1.17 A neutral lithium atom loses an electron and becomes charged

	Atomic number	Number of protons	Number of electrons	Charge
Lithium atom	3	3	3	0
Lithium charged particle	3	3	2	+1

If an atom loses electrons and becomes charged, this charged particle is called a positive *ion.*

7 **If a magnesium atom loses 2 electrons it becomes a charged particle. It still has a mass of 24. Write out the atomic number, number of protons, number of electrons, number of neutrons and the charge of**

a **a magnesium atom**

b **a magnesium ion.**

8 **Explain why a magnesium atom is neutral but a magnesium ion is charged.**

9 **Nitride ions have a 3– charge. Work out the number of electrons in a nitride ion, given that the atomic number of nitrogen is 7.**

Sub-atomic particles

Learning objectives:

- use the definition of atomic number and mass number
- calculate the numbers of protons, neutrons and electrons in *atoms*
- calculate the numbers of sub-atomic particles in isotopes and ions.

KEY WORDS

atomic mass
isotope
neutrons
protons

Smoke detectors, archaeological dating and bone imaging all use isotopes. Some elements have more than one type of atom. These different types of atom have different numbers of neutrons and are called isotopes.

Atomic number and mass number

The nucleus of an atom is made up of **protons** and **neutrons**.

- The atomic number is the number of protons in an atom.
- The *mass number* of an atom is the total number of protons and neutrons in an atom.

If a particle has an atomic number of 11, a mass number of 23 and a neutral charge, it must have:

- 11 protons, because it has an atomic number of 11.
- 11 electrons, because there are 11 protons and the atom is neutral.
- 12 neutrons, because the mass number is 23 and there are already 11 protons (23 – 11 = 12).

Here are some more examples.

	Atomic number	Mass number	Number of protons	Number of electrons	Number of neutrons
Carbon	6	12	6	6	6
Fluorine	9	19	9	9	10
Sodium	11	23	11	11	12
Aluminium					

1. **Complete the row for an atom of aluminium, Al.**
2. **Work out the number of protons, electrons and neutrons in an atom with an atomic number of 15 and a mass number of 31.**

Isotopes

All atoms of carbon have 6 protons, so its atomic number is 6. Most carbon atoms have 6 neutrons, so the mass number is 6 + 6 = 12. This form of the carbon atom is written as ${}^{12}_{6}C$.

Another form of carbon, ${}^{14}_{6}C$, has an atomic number of 6 (6 protons) and a mass number of 14. It must therefore have 8 neutrons (14 – 6). ${}^{14}_{6}C$ is sometimes written as carbon-14. ${}^{12}_{6}C$ and ${}^{14}_{6}C$ are **isotopes** of carbon.

3 **Write the isotope symbol for an atom that has 17 protons and 18 neutrons.**

4 **Identify all the sub-atomic particles in an atom of carbon-13.**

KEY INFORMATION

In the symbol ${}^{12}_{6}C$, the smaller number (6) is the atomic number and the larger number (12) is the mass number.

Relative abundance of isotopes

Most elements have two or more isotopes. For example, hydrogen has three common isotopes.

Isotope	Electrons	Protons	Neutrons	Mass number
${}^{1}_{1}H$	1	1	0	1
${}^{2}_{1}H$	1	1	1	2
${}^{3}_{1}H$	1	1	2	3

The relative atomic mass of an element is the average mass of the different *isotopes* of an element. Chlorine's A_r of 35.5 is an average of the masses of the different isotopes of chlorine.

There are two main isotopes ${}^{35}_{17}Cl$ and ${}^{35}_{17}Cl$. If there were 50% of each of the isotopes what would be the average mass? The answer is 36. But there are less of the ${}^{35}_{17}Cl$ isotopes. So we need a *relative abundance* calculation:

$$A_r = \frac{\begin{pmatrix}\text{mass of first isotope} \\ \times\ \%\text{ of first isotope}\end{pmatrix} \times \begin{pmatrix}\text{mass of first isotope} \\ \%\text{ of second isotope}\end{pmatrix}}{100}$$

For example, for chlorine: the abundance values are:

75% ${}^{35}_{17}Cl$ and 25% ${}^{35}_{17}Cl$

Therefore:

$$A_r = \frac{(75 \times 35) + (25 \times 37)}{100}$$

$$= \frac{2625 + 925}{100}$$

$$= 35.5$$

5 **Explain the similarities and differences between the three isotopes of hydrogen.**

6 **Element X has two isotopes, mass 27 and 29. Calculate the relative atomic mass of X if the first isotope has abundance of 65% and the second isotope has 35% abundance.**

DID YOU KNOW?

The mass numbers of the isotopes of hydrogen are 1, 2 and 3. However, there are not equal proportions of each type of isotope in a sample of hydrogen gas, so the average atomic mass of hydrogen is 1.008.

Draft specification subject to Ofqual feedback and accreditation

Electronic structure

Learning objectives:

- explain how electrons occupy 'shells' in an order.
- describe the pattern of the electrons in shells for the first 20 elements.

KEY WORDS

electronic structure
electron shells
energy levels

The electrons of an atom are arranged in patterns. The electrons fill up shells in order until that shell can take no more electrons. The next electron goes into the next shell. These patterns are the key to the behaviour of atoms.

The 'build-up' of electrons

Electrons occupy shells around the nucleus. The **electron shell** nearest to the nucleus takes up to two electrons. The second shell takes up to eight electrons. The next electrons occupy a third shell.

Oxygen has an atomic number of 8. It has eight protons and so it has eight electrons in the space around the nucleus. The first two go into the first shell. As the first shell is now full, the next 6 electrons go into the second shell. The electron pattern for oxygen is then 2,6.

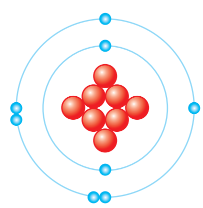


Figure 1.18 For oxygen, the eight electrons can written as 2,6 or be drawn like this.

1 **Draw the electron pattern for hydrogen and for lithium.**

2 **Write down the electron pattern for nitrogen.**

The shells are not fixed rings and are also known as **energy levels**.

Electron patterns and groups

The periodic table is arranged in order of 'proton number'.

There is a very important link between **electronic structure** and the periodic table. For example, let us consider an atom of an element that has the electronic structure of 2,8,6.

- This element has three electron shells, so it is in the third row of the periodic table.
- It has six electrons in its outer shell, so it is in the sixth column.
- Using the periodic table, we can find that its atomic number is 16 and it is the element sulfur, S.

		H hydrogen 1					He helium 2
Li lithium 3	Be beryllium 4	B boron 5	C carbon 6	N nitrogen 7	O oxygen 8	F fluorine 9	Ne neon 10
Na sodium 11	Mg magnesium 12	Al aluminium 13	Si silicon 14	P phosphorus 15	S sulfur 16	Cl chlorine 17	Ar argon 18
K potassium 19	Ca calcium 20						

this row has the elements of period 3

Figure 1.19 Period 3 contains the elements from sodium to argon.

We can also work the other way. Find the element with the atomic number 12 in the periodic table. This is magnesium, Mg.

- It is in the third row, so it has three electron shells.
- It is in the second column, so it has two electrons in its outer shell.
- It has the electronic structure of 2,8,2.

The column of elements is known as a **Group**. So column 2 is Group 2.

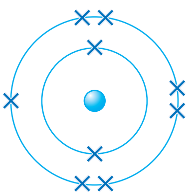


Figure 1.20 An atom of fluorine, 2,7.

3 **An atom of an element has an atomic number of 11.**

a Draw a diagram to show the pattern of electrons.

b Identify the element.

c Identify the group to which it belongs.

4 **Work out the electronic structure of the element that has an atomic number 9.**

5 **An element has a mass number of 40 and an electron arrangement of 2,8,8,2. Identify the element and work out the number of neutrons.**

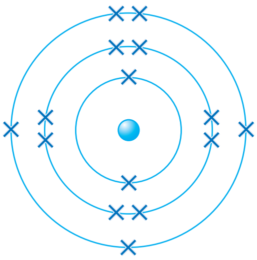


Figure 1.21 An atom of phosphorus, 2,8,5.

Maximum numbers

The electronic structure of each of the first 20 elements can be worked out using:

- the atomic number of the element
- the maximum number of electrons in each shell.

The third shell takes up to eight electrons before the fourth shell starts to fill. Element 19, potassium, has the electronic structure 2,8,8,1.

Use the periodic table to help you to answer these questions.

6 **Work out the electronic structure of argon.**

7 **Use a blank periodic table sheet to draw out the electronic structure of the first 20 elements, putting the diagram in the correct box. What do you notice about the group number and the number of electrons in the outer shell?**

8 **The electronic configuration for the ion of an unknown isotope $^{26}X^{3+}$ is 2,8.**

a Work out the atomic number of element X.

b Determine the number of neutrons in X.

c Explain which group in the periodic table element X is in.

DID YOU KNOW?

It took many years for scientists to work out the theory of electrons occupying shells. They started with the behaviour of elements and then looked for patterns.

KEY INFORMATION

Do not try to use this method to work out the electronic structure of gold, as it has 79 electrons.

The periodic table

Learning objectives:

- explain how the electronic structure of atoms follows a pattern
- recognise that the number of electrons in an element's outer shell corresponds to the element's group number
- explain that the electronic structure of transition metals position the elements into the transition metal block.

KEY WORDS

electron shells
energy levels
group
period

We know that the periodic table is arranged in rows and columns and the elements are written in order of their atomic number. So why are all the elements in the last column all unreactive gases? Why are all the elements in the first column highly reactive metals? The answer lies in the pattern of their electrons.

The order of elements and electron patterns

As we have seen, the elements in the periodic table are arranged in order of atomic number. Atomic number is the number of protons in an atom. As atoms are neutral, the atomic number also gives the number of electrons in an atom.

For example, the atomic number of hydrogen is 1, carbon is 6 and sodium is 11. This means that hydrogen is the first element in the table, carbon is the sixth and sodium is the eleventh.

We have also seen that electrons occupy energy levels (or shells). Each element has a pattern of electrons (known as its electronic structure) that is built up in a particular order.

The electronic structure of each of the first 20 elements can be worked out using:

- the atomic number of the element
- the maximum number of electrons allowed in each shell.

The third shell takes up to eight electrons before the fourth shell starts to fill. Element 20, therefore, has the electronic structure 2,8,8,2.

1. **Which element has the atomic number 13?**
2. **Which element has an electronic structure of 2,8,7?**

Arrangement of groups and periods

The first row of the periodic table contains the elements hydrogen and helium. These two elements only have electrons in the first shell (energy level).

Lithium's third electron goes into the next electron shell. Lithium starts a new row in the periodic table. This second row is called the second **period**.

KEY INFORMATION

Remember:

- **the first shell of electrons carries up to 2 electrons**
- **the second shell carries up to 8 electrons.**

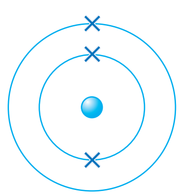


Figure 1.22 The electron pattern of a lithium atom.

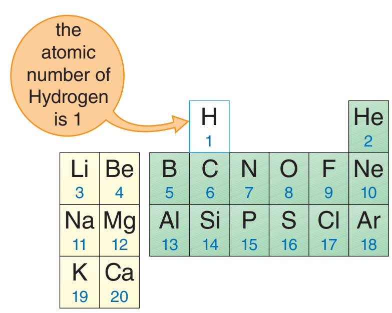


Figure 1.23 Lithium has an atomic number of 3. It has three protons and three electrons.

Let's consider an atom of the element that has the electronic structure of 2,8,2. We can work out that it is in the third row of the periodic table. This atom has three electron shells. It has two electrons in its outer shell. Its atomic number is 12. (You can work this out by adding up the number of electrons.) Looking at the periodic table the atom is of the element magnesium, 12.

So the element is therefore, in the third **period**.

Looking again, this atom only has two electrons in its outer shell, so it is in the second column. A column is known as a **group**. This second column is known as Group 2.

A column is known as a group. The group number refers to the number of electrons in the outside shell.

We have seen that the electron pattern for Li is 2,1. We can work out that the pattern for Na (11 electrons) is 2,8,1 and K (19 electrons) is 2,8,8,1. All of these elements have one electron in their outside shell. They are all in the first column. This column is known as Group 1.

KEY INFORMATION

The Periodic Table is arranged in rows (called periods). Each period number is the same as the number of electron shells. Each period contains the elements whose outside shell of electrons is 'filling up'.

3 **What is the pattern of electrons in the atom of the element with an atomic number 16? Identify the element, its group and its period.**

4 **To which group and period does the element chlorine belong?**

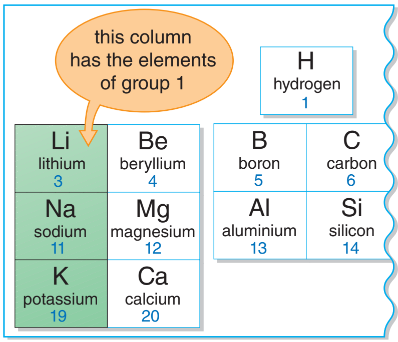


Figure 1.24 These elements are in the first column as they all have one electron in their outside shell.

Electronic structure and behaviour of elements

Element 20 has the electronic structure 2,8,8,2, and is in Group 2.

The fourth shell can take up to 18 electrons, but the next element (element number 21) is not in Group 3. Instead the next 10 elements (numbers 21 to 30) in period 4 are part of the first **transition element period**. Transition elements have characteristics that are similar to each other. For example, iron behaves more like copper than sodium.

Elements in groups often behave similarly to other elements in that group:

- the elements in Group 1 are all highly reactive metals
- the elements in Group 7 (the halogens) all react with Group 1 metals to make salts
- the elements in Group 0 are all unreactive (or noble) gases.

This pattern is because the *elements in each group have the same number of electrons in their outer shells.*

Use the periodic table to help you to answer these questions.

5 **What are the electronic structures of F and Cl? Why are they both found in Group 7?**

6 **Identify the elements in Group 6.**

225106 AQA_Chemistry_CH1.indd 31 12/05/16 10:14 am

Developing the periodic table

Learning objectives:

- describe the steps in the development of the periodic table
- explain how Mendeleev left spaces for undiscovered elements
- explain why the element order in the modern periodic table was changed
- explain how testing a prediction can support or refute a new scientific idea.

KEY WORDS

periodic
predictions
properties
patterns

Although some elements have been known about as parts of compounds since ancient times, many were only first isolated as elements in the last two centuries. For a long time, scientists trying to find patterns were working with an incomplete picture. It was like trying to do a 100-piece jigsaw puzzle with half of the pieces missing.

$^{51}_{23}$V vanadium	$^{52}_{24}$Cr chromium	?	$^{56}_{26}$Fe iron	$^{59}_{27}$Co cobalt	$^{59}_{28}$Ni nickel	?	$^{65}_{30}$Zn zinc
?	$^{96}_{42}$Mo molybdenum	$^{99}_{43}$Tc technetium	$^{101}_{44}$Ru ruthenium	?	$^{106}_{46}$Pd palladium	$^{108}_{47}$Ag silver	$^{112}_{48}$Cd cadmium
$^{181}_{73}$Ta tantalum	$^{184}_{74}$W tungsten	?	$^{190}_{76}$Os osmium	$^{192}_{77}$Ir iridium	?	$^{197}_{79}$Au gold	?

Figure 1.25 The element puzzle

The timeline of ideas

Some elements have been known since ancient times.

By 1829 Döbereiner had noticed that sometimes three elements had similar **properties**. He noticed **patterns** with:

lithium, sodium and potassium	calcium, strontium and barium	chlorine, bromine and iodine

These were called 'Döbereiner triads'.

Figure 1.26 Döbereiner

In 1860 a new list of more accurate atomic weights was published.

In 1865 John Newlands noticed that when he put the elements in atomic weight order (even though some then seemed to be in the wrong place) that there was often a pattern of similar properties every eight elements. He called his new *theory* the 'law of octaves'.

Döbereiner and Newlands noticed *patterns* in the properties of elements but did not make **predictions**.

1. **Describe the 'law of octaves'.**
2. **Suggest why there were so few elements for Döbereiner to test his theory on in 1829.**

REMEMBER!

You need to be able to explain that if germanium had not fitted into Mendeleev's pattern then the evidence would have *refuted* his predictions, but instead, it did fit his pattern so the new evidence *supported* his predictions.

Allowing for predictions

By 1869 the Russian scientist, Dmitri Mendeleev had also put the elements in order of their atomic weights. He also saw that some elements seemed to be in the wrong order. But crucially he:

- decided to swap some elements round so that the patterns of chemical behaviour fitted better
- was able to imagine that there were undiscovered elements
- brilliantly decided to leave gaps in his **periodic** table for later discoveries and used the patterns of chemical behaviour to decide where to leave these gaps.

He gave special names to these unknown elements in his gaps. He took the name of the element above the gap in that group and put the prefix 'eka' in front of the name. One unknown was eka-silicon (beyond silicon). This element was eventually discovered and was named germanium. Altogether three of these new elements were discovered within Mendeleev's lifetime.

Figure 1.27 Dmitri Mendeleev

3 **Mendeleev named one element eka-aluminium. It was later discovered. Identify the element.**

4 **Explain why some elements appeared to be in the wrong order.**

Discovering the unpredictable

Mendeleev died in 1907 and so did not live to see the discovery of sub-atomic particles, which gave the final evidence allowing the modern periodic table to be developed in the order of the *atomic number* of elements. His theory was supported, not refuted, by later evidence.

His theory was developed in 1869. Evidence from 1932 finally supported his theory, 63 years later. The evidence of isotopes finally explained why the order based on atomic weight was incorrect. The discovery of the neutron explained why the order of elements in the modern periodic table needs to be by the number of protons.

DID YOU KNOW?

Mendeleev did not win a Nobel Prize; however, he does have an element named after him. Look up which number this is.

5 **Mendeleev left gaps and made predictions for undiscovered elements in the his periodic table. Explain how the discovery of germanium supported this approach.**

6 **Search for an image of a new Periodic Table.**

- **a** **Give the atomic number of the last element before the central block begins.**
- **b** **Identify the missing elements in Figure 1.25.**

7 **Identify two elements in the periodic table that would be in the wrong position if they were ordered by atomic mass.**

8 **A student stated that 'The modern periodic table is complete'. Briefly explain whether you agree with the student.**

Comparing metals and non-metals

Learning objectives:

- recall a number of physical properties of metals and non-metals
- describe some chemical properties of metals and non-metals
- explain the differences between metals and non-metals on the basis of their characteristic physical and chemical properties.

KEY WORDS

electrical conductor
lustrous
tensile strength
thermal conductivity

Metals are useful materials as they have a wide range of properties. Gold jewellery does not corrode and it has an appealing colour and lustre. Copper has good thermal conductivity so is used for saucepans. Non-metal elements are mostly combined in compounds to be useful.

Figure 1.28 Many metals are instantly recognisable as metals because they are shiny and sonorous.

Physical properties

Most metals are instantly recognisable as they are shiny whereas non-metals are not. These are the other physical properties of metals and non-metals.

Metals	Non-metals
lustrous	dull
hard	soft, brittle or gas
high density	low density
high **tensile strength**	low or no tensile strength or gas
high melting point and boiling point	low melting point and boiling point
good conductors of heat	poor or no **thermal conductivity**
good **electrical conductivity**	poor or non conductors of electricity

Figure 1.29 Dating from 1779, this is the first bridge made from cast iron. Iron was used to make this bridge because it is very strong.

Figure 1.30 Sulfur, calcium and nitrogen are non-metals. They are not shiny and have low boiling points.

1. **Write down two physical properties of silver that make it more useful than sulfur for making cutlery.**
2. **Use the picture in Figure 1.30 and the table to explain why sulfur is not a metal.**

DID YOU KNOW?

Other physical properties of metals include being malleable or ductile.

Chemical properties

Chemical properties of metals are the result of reactions with oxygen or acids. Although copper is resistant to attack by oxygen and acid, (which is a reason why it is used for saucepans), many metals react with oxygen to make an oxide (such as calcium oxide and iron oxide).

Metals react with acids to make salts (such as zinc with sulfuric acid that makes zinc sulfate).

One chemical property of a non-metal is the result of the reaction with oxygen. Carbon reacts with oxygen to make carbon dioxide. Carbon dioxide dissolves in water to make a mildly acidic solution. This is what fizzy water contain.

Figure 1.31 Bottles of lemonade and cola with acidic carbon dioxide solution.

3. **Suggest a test to show that a solution of carbon dioxide is mildly acidic.**
4. **Predict the product of magnesium and nitric acid.**

Distinguishing properties

Sulfur and phosphorus both react with oxygen to make oxides. Both sulfur dioxide and phosphorus oxide turn universal indicator red. They are acidic oxides.	Calcium and potassium both react with oxygen to make oxides. Both calcium oxide and potassium oxide turn universal indicator blue. They are basic oxides.

Metals form basic oxides. Non-metals form acidic (or neutral) oxides.

KEY INFORMATION

You will soon need to know how to explain the chemical properties of metals and non-metals using knowledge about how they form ions.

5. **You have a sample of 'unknownium' oxide. Explain how you would use universal indicator to see if 'unknownium' was a metal or a non-metal.**
6. **An element makes an oxide that turns universal indicator red. Is the element a metal or a non-metal?**
7. **7 Element X has a low melting point of 63 °C, has low density, is a good electrical conductor and is malleable. Explain whether the oxide of X is likely to be acidic or basic.**

Draft specification subject to Ofqual feedback and accreditation

Metals and non-metals

KEY WORDS

ions
atomic structure
metalloids

Learning objectives:

- describe that metals are found on the left of the periodic table and non-metals on the right
- explain the differences between metals and non-metals based on their physical and chemical properties
- explain that metals form positive ions and non-metals do not.

Whether an element is a metal or a non-metal depends on the electronic structure of its atoms. The element is classified as a non-metal or a metal depending on whether it needs to gain or lose electrons and if some of its reactions are typical for a non-metal or a metal.

Metals and non-metals in the periodic table

Li lithium 3				N nitrogen 7	O oxygen 8		Ne neon 10
Na sodium 11	Mg magnesium 12			P phosphorus 15	S sulfur 16	Cl chlorine 17	
	Ca calcium 20						

Figure 1.32 Here are some metals and non-metals in the periodic table.

Looking at the periodic table you can see the metals lithium, sodium, magnesium and calcium on the left-hand side.

You can see the non-metals nitrogen, oxygen, sulfur, phosphorus, chlorine and neon on the right-hand side.

From your knowledge of chemistry so far try to draw a line that separates the metals from the non-metals.

DID YOU KNOW?

The line of elements separating the metals from the non-metals are called the metalloids.

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	0
			$^{1}_{1}$H hydrogen														$^{4}_{2}$He helium
$^{7}_{3}$Li lithium	$^{9}_{4}$Be beryllium											$^{11}_{5}$B boron	$^{12}_{6}$C carbon	$^{14}_{7}$N nitrogen	$^{16}_{8}$O oxygen	$^{19}_{9}$F fluorine	$^{20}_{10}$Ne neon
$^{23}_{11}$Na sodium	$^{24}_{12}$Mg magnesium											$^{27}_{13}$Al aluminium	$^{28}_{14}$Si silicon	$^{31}_{15}$P phosphorus	$^{32}_{16}$S sulfur	$^{35}_{17}$Cl chlorine	$^{40}_{18}$Ar argon
$^{39}_{19}$K potassium	$^{40}_{20}$Ca calcium	$^{45}_{21}$Sc scandium	$^{48}_{22}$Ti titanium	$^{51}_{23}$V vanadium	$^{52}_{24}$Cr chromium	$^{55}_{25}$Mn manganese	$^{56}_{26}$Fe iron	$^{59}_{27}$Co cobalt	$^{59}_{28}$Ni nickel	$^{64}_{29}$Cu copper	$^{65}_{30}$Zn zinc	$^{70}_{31}$Ga gallium	$^{73}_{32}$Ge germanium	$^{75}_{33}$As arsenic	$^{79}_{34}$Se selenium	$^{80}_{35}$Br bromine	$^{84}_{36}$Kr krypton
$^{85}_{37}$Rb rubidium	$^{88}_{38}$Sr strontium	$^{89}_{39}$Y yttrium	$^{91}_{40}$Zr zirconium	$^{93}_{41}$Nb niobium	$^{96}_{42}$Mo molybdenum	$^{99}_{43}$Tc technetium	$^{101}_{44}$Ru ruthenium	$^{103}_{45}$Rh rhodium	$^{106}_{46}$Pd palladium	$^{108}_{47}$Ag silver	$^{112}_{48}$Cd cadmium	$^{115}_{49}$In indium	$^{119}_{50}$Sn tin	$^{122}_{51}$Sb antimony	$^{128}_{52}$Te tellurium	$^{127}_{53}$I iodine	$^{131}_{54}$Xe xenon

Figure 1.33 Top section of the periodic table

1. **Find element 53. Is this element a metal or a non-metal?**
2. **Is element 26 a metal or a non-metal?**

Positions of elements in the table

Magnesium is a metal because of its **atomic structure.** It has two electrons in the outer shell, which can be easily lost from the atom. The electrons join another atom that needs more electrons. Because electrons have been lost, a positive **ion** has been made.

Magnesium makes a positive ion so it is a metal.

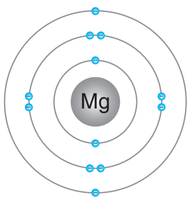


Figure 1.34 A magnesium atom with two electrons in the outer shell.

3. **Explain why aluminium is a metal, using knowledge about its atomic structure.**
4. **Explain why element number 8 is a non-metal. Use ideas about atomic structure.**

DID YOU KNOW?

Metal atoms are bonded together by their outer electrons. The atoms pack together and the outer electrons delocalise, which means that the outer electrons move through the ions as a 'sea' of electrons.

Electron transfer in metals and non-metals

When a metal, such as magnesium, reacts with oxygen, the metal loses electrons and oxygen gains electrons.

Magnesium + oxygen → magnesium oxide

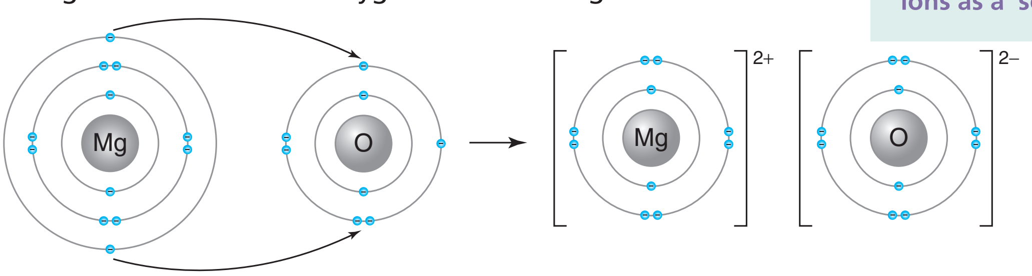


Figure 1.35

This is because metal atoms have a few outer electrons which they 'lose' to form ions. Oxygen accepts the electrons.

When a non-metal such as chlorine, reacts with a metal such as sodium, the non-metal gains an electron from the metal.

sodium + chlorine → sodium chloride

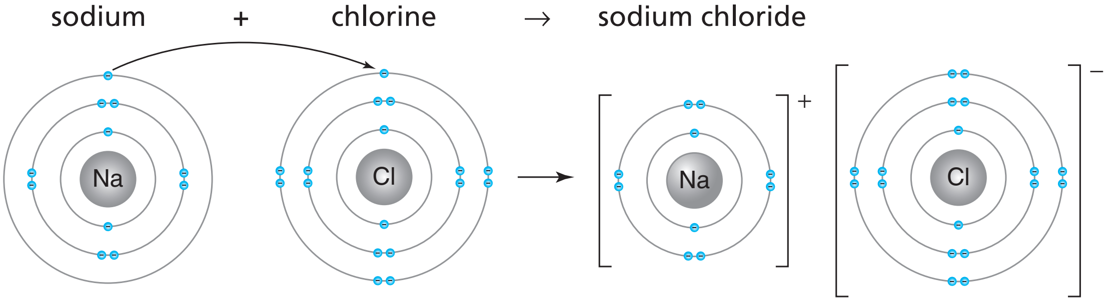


Figure 1.36

This is because non-metal atoms have empty spaces in their outer shell in which they 'gain' other electrons from metals to form negative ions. The non-metal does not form a positive ion.

5. **Explain why fluorine is a non-metal that can react with the metal, potassium, to form potassium fluoride.**
6. **The elements with atomic number 3 and 9 can react together. Explain why and work out the formula of the product.**

KEY INFORMATION

Metals make positive ions and non-metals do not.

The outer electrons

Learning objectives:

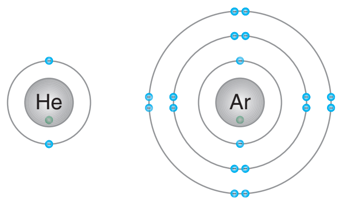
- recognise when electrons transfer
- recognise when atoms share electrons
- predict when electrons are transferred most easily.

KEY WORDS

transfer
share
electrons
outer shell

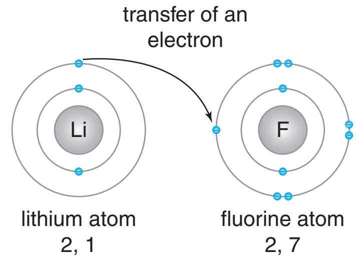
Stable atoms

The noble gases are all very unreactive. Their atoms are very stable and do not react with other atoms. This is because their outer shells contain eight electrons, (except He which contains two electrons). This stable number of electrons in the outer electron shell means there is no tendency to transfer electrons.



Less stable atoms

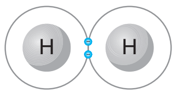
All other atoms are less stable. Their electrons move or share with other electrons to try to become as stable as the atoms with 8 electrons in their outer shell.



Chemical reactivity and chemical reactions depend on the number of electrons in the outer shell. (However, note that this is not always true in reactions of transition metals.)

Three things can happen to the electrons in the outer shell:

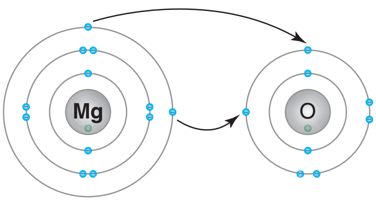
- they can be transferred to the outer shell of another atom
- they can have other electrons added to their outer shell from another atom
- they can be shared with another atom.



1. **Name two noble gases that have eight electrons in their outer shell.**
2. **Predict the number of 'outer' electrons lithium has.**

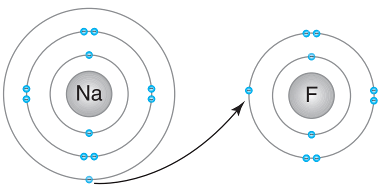
Transferring or sharing?

If an atom has one or two electrons in its outer shell these electrons will transfer out. They will transfer to the outer shell of another atom.



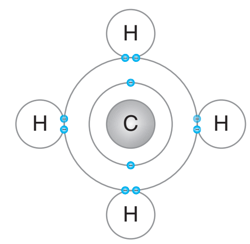
Adding in other electrons

If an atom has six or seven electrons in its outer shell, electrons from other atoms will add in to the 'spaces' to



make up a stable outer shell. They will transfer in from the outer shell of another atom.

If an atom has an unstable number of electrons in its outer shell this atom will share its electrons with electrons from other atoms. Common examples of atoms that do this are carbon and hydrogen. They also share electrons with each other and with oxygen atoms.

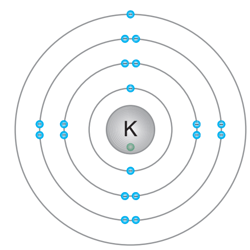


3 **Suggest how many 'spaces' in the outer shell an oxygen atom has.**

4 **Predict how many electrons are shared by two fluorine atoms.**

Transferring electrons

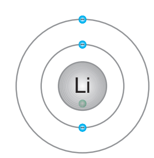
Some elements are more reactive than others. This can be because their outer electrons transfer *out* more easily than others or transfer *in* more easily than others.



Potassium and lithium both need to lose one electron to become stable atoms.

Potassium reacts more quickly than lithium.

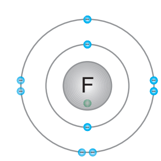
This is because the outer electron is further away from its nucleus in a potassium atom than in a lithium atom.



The 'pull' on the electron by the potassium nucleus is less than the 'pull' on the electron by the lithium nucleus. The electron of potassium is more easily lost (transferred out).

So potassium is more reactive.

Fluorine and bromine both need to gain one electron to become stable atoms.



Fluorine reacts more vigorously than bromine.

This is because the outer electron shell is nearer to its nucleus in a fluorine atom than in a bromine atom.

The 'pull' on the electron coming in to fill the 'space' in the fluorine outer ring by the fluorine nucleus is more than the 'pull' on the electron by the bromine nucleus. The electron of fluorine is more easily gained (transferred in). So fluorine is more reactive.

5 **Explain, using ideas about 'the pull of the nucleus' why sodium is more reactive than lithium.**

6 **Explain the reactivity of chlorine within group 7 in terms of the 'pull of the nucleus'.**

225106 AQA_Chemistry_CH1.indd 39 12/05/16 10:16 am

Exploring Group 0

Learning objectives:

- describe the unreactivity of the noble gases
- predict and explain the trends of boiling point of the noble gases (going down the group)
- explain how properties of the elements in Group 0 depend on the outer shell of electrons of their atoms.

KEY WORDS

elements
helium
neon
argon
density
unreactive

Ever wondered why helium rather than hydrogen is used in party balloons and for weather balloons? Hydrogen is less dense than helium and so a hydrogen balloon would 'float' better. However, hydrogen is highly flammable whereas helium is unreactive. The decision comes down to safety.

Figure 1.37 Helium balloons

Patterns in Group 0

If you find Group 0 on the periodic table, you will see these **elements** in order.

Group 0
Helium (He)
Neon (Ne)
Argon (Ar)
Krypton (Kr)
Xenon (Xe)

All the elements of Group 0 in the periodic table have two things in common.

- They are all **unreactive**.
- They are all gases.

The boiling points of the elements in Group 0 show a trend.

Helium has the lowest boiling point. This means the atoms of the element keep moving rapidly (as a gas) at lower temperatures than the atoms of xenon.

Boiling points (°C)	
He	–268
Ne	–246
Ar	–186
Kr	–153
Xe	–108

The trend is that the boiling points of the gases increase down the group.

EXTENSION

Mendeleev did not predict the noble gases. They were discovered much later by William Ramsey. You need to be able to explain that if the noble gases had not fitted into Mendeleev's pattern then the evidence would have *refuted* his predictions but instead they did fit his pattern so the new evidence *supported* his predictions.

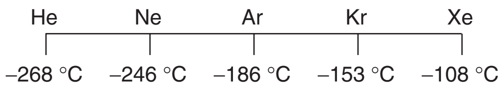


Figure 1.38

1. **Find the relative atomic mass of neon and argon. Determine which has the higher relative atomic mass.**
2. **There is a noble gas with a bigger relative atomic mass than Xe. Predict its boiling point.**

Why does helium stay as a gas at lower temperatures?

All the elements in Group 0 are gases.

These gases exist as single atoms, not molecules.

The smaller the atom the 'easier' it is for it to keep moving around rapidly.

So at lower temperatures the small atoms of helium move 'more easily' than the larger atoms of krypton. So krypton has a higher boiling point than helium.

3. **Describe how boiling point varies with relative atomic mass for Group 0 elements.**
4. **Suggest a relationship between the diameter of Group 0 atoms and their boiling point. Explain your answer.**

Why do elements in Group 0 exist as single atoms?

The elements of Group 0 do not make compounds with other elements and are unreactive.

They do not make compounds because the atoms have 8 electrons in their outer shell.

This is a very stable configuration. So there is no electron movement from one atom to another.

5. **Draw the electronic structure for helium. Explain why this atom does not join with any other atom.**
6. **Write out the electronic structure (in numbers) for argon. Explain why argon is unreactive but has a higher boiling point than helium.**
7. **One of the first noble gas compounds to be made was xenon tetrafluoride, made in 1962. It is a stable crystalline solid at room temperature.**
   - **a Complete and balance the following equation:**

     __ Xe + __ F_2 → ____
   - **b Suggest why it was a surprise that a noble gas compound had been made.**

DID YOU KNOW?

Helium is also used with neon in the lasers that scan supermarket barcodes.

Street lights used in long tunnels contain both neon and sodium. Argon is used for specialist welding and to fill the space between double glazed windows.

Find out what krypton and xenon are used for.

Figure 1.39 Neon lights were first used years ago.

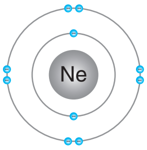


Figure 1.40 The electronic structure of neon. The outer shell is full.

Exploring Group 1

Learning objectives:

- explain why Group 1 metals are known as the alkali metals
- predict the properties of other Group 1 metals from trends down the group
- relate the properties of the alkali metals to the number of electrons in their outer shell.

KEY WORDS

alkali
density
indicator
ion
reactivity
stable electronic structure

Ever wondered how fireworks are made to have such stunning colours? It is because they have specific compounds added to them. Sodium compounds, for instance, produce a bright yellow colour against the night sky. Sodium is an element in the periodic table in the first column.

Figure 1.41 Which metal gives the firework this lilac colour?

Properties of Group 1 elements

Figure 1.42 This is sodium on water. Why does it float?

Lithium, sodium and potassium are Group 1 elements that are less **dense** than water.

Group 1 metals react vigorously with water and make hydrogen. Group 1 metals also burn in oxygen to form oxides. Sodium burns to make sodium oxide.

Figure 1.43 This is potassium when it burns in oxygen.

1. **Explain why sodium floats on water.**
2. **Identify the gas is given off when potassium reacts with water.**

Reaction trends of alkali metals

When lithium, sodium and potassium react with water, hydrogen is given off. A solution is also made in the reaction. It is an **alkali**. The alkali is the hydroxide of the metal. Sodium forms sodium hydroxide.

Lithium reacts vigorously with water.

Sodium reacts very vigorously with water.

Potassium reacts extremely vigorously with water and produces a lilac flame.

The word equation for the reaction between sodium and water is:

sodium + water → sodium hydroxide + hydrogen

The balanced symbol equation for the reaction is:

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

3 **Suggest a way to show that the solution is an alkali.**

4 **Describe the trend in reactivity down Group 1.**

5 **Predict the reactivity of rubidium with water. Justify your answer.**

Making ions

Alkali metals have similar chemical properties. This is because when they react their atoms need to lose one electron to form the electronic structure of a noble gas. This is then a **stable electronic structure.**

When the atom loses one electron it forms an **ion**. The atom becomes charged. It has one more positive charge in its nucleus than negative electrons surrounding it. So it is now a positive ion that carries a charge of +1.

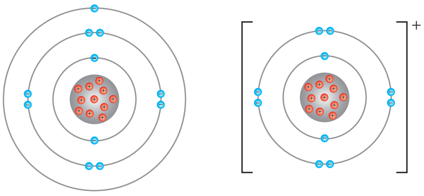


Figure 1.45 How alkali metals achieve a stable electronic structure

Sodium reacts with chlorine to make sodium chloride. The sodium makes an ion that carries a +1 charge. It makes an ionic compound. The compound is a white solid that dissolves in water to form a colourless solution. The other alkali metals make these compounds too.

6 **Explain why Group 1 atoms lose electrons.**

7 **Draw a 'dot and cross' diagram to show an Li ion.**

8 **Potassium reacts with oxygen to form an oxide.**

a **Write a balanced equation for the reaction.**

b **State the electron configurations of potassium and oxygen in the oxide.**

c **The oxide dissolves in water to form an alkaline solution. Identify this solution.**

REMEMBER!

You should try to remember the order of reactivity of the alkali metals.

DID YOU KNOW?

Sodium hydroxide can be used as oven cleaner. This picture shows you what can happen if you get sodium hydroxide on your skin.

Figure 1.44 Why do the instructions on the bottle tell you to use gloves?

Sodium hydroxide is more dangerous to get into the eyes than acids. The hydroxide ions travel to the back of the eyes and can irreversibly damage the retina.

That is why your teacher will always tell you to wear safety glasses when handling chemicals, especially alkalis.

225106 AQA_Chemistry_CH1.indd 43 12/05/16 10:16 am

Exploring Group 7

Learning objectives:

- recall that fluorine, chlorine, bromine and iodine are non-metals called halogens
- describe that they react vigorously with alkali metals
- construct balanced symbol equations for the reactions of metals with halogens.

KEY WORDS

bromine
chlorine
halogen
iodine

Group 7 elements are known as the halogens. The first use of chlorine was to bleach textiles and it is still used in chemicals for bleaching toilets. Chlorine is used to sterilise water which prevents diseases such as cholera from spreading. Chlorine was also used as a weapon in the First World War. The effects were devastating.

The halogens

Group 7 elements, fluorine, **chlorine**, **bromine** and **iodine**, are called the **halogens**.

Halogens are non-metals. Halogens exist as pairs of atoms, so their symbols are F_2, Cl_2, Br_2 and I_2.

They react vigorously with **metals** such as sodium, potassium and magnesium.

Potassium reacts with chlorine to make potassium chloride. The word equation is:

potassium + chlorine → potassium chloride

It is possible to construct a balanced symbol equation for the reaction

$$K + Cl_2 \rightarrow KCl \text{ (unbalanced)}$$

The halogens react with metals to make salts.

The halogens react with non-metals to make gases or liquids such as acids.

$$2K + Cl_2 \rightarrow 2KCl \text{ (balanced)}$$

1. **Give the balanced symbol equation for the reaction between sodium and bromine.**
2. **Identify the product of the reaction between lithium and fluorine.**

Group 3	4	5	6	7	0
					$^{4}_{2}$He helium
$^{11}_{5}$B boron	$^{12}_{6}$C carbon	$^{14}_{7}$N nitrogen	$^{16}_{8}$O oxygen	$^{19}_{9}$F fluorine	$^{20}_{10}$Ne neon
$^{27}_{13}$Al aluminium	$^{28}_{14}$Si silicon	$^{31}_{15}$P phosphorus	$^{32}_{16}$S sulfur	$^{35}_{17}$Cl chlorine	$^{40}_{18}$Ar argon
$^{70}_{31}$Ga gallium	$^{73}_{32}$Ge germanium	$^{75}_{33}$As arsenic	$^{79}_{34}$Se selenium	$^{80}_{35}$Br bromine	$^{84}_{36}$Kr krypton
$^{115}_{49}$In indium	$^{119}_{50}$Sn tin	$^{122}_{51}$Sb antimony	$^{128}_{52}$Te tellurium	$^{127}_{53}$I iodine	$^{131}_{54}$Xe xenon
$^{204}_{81}$Tl thallium	$^{207}_{82}$Pb lead	$^{209}_{83}$Bi bismuth	$^{210}_{84}$Po polonium	$^{210}_{85}$At astatine	$^{222}_{86}$Rn radon

Figure 1.46 Group 7 elements in the periodic table

DID YOU KNOW?

Silver bromide is a compound of bromine with silver. It was used in early photography as it turned from cream to a purplish colour when exposed to light.

Figure 1.47 Chlorine reacting with potassium to make potassium chloride

Group 7 trends

There is a **trend** in the physical appearance of the halogens at room temperature. Chlorine is a gas and iodine is a solid.

Figure 1.48 At room temperature chlorine is a green gas and iodine is a grey solid.
What colour is the toxic and volatile bromine?

Halogen	Atomic mass	Relative molecular mass	Melting point (°C)	Boiling point (°C)	State at room temperature
Chlorine		71	–101	–34	gas
Bromine	80	160	–7	59	
Iodine	127		114	184	

3 **Complete the data table.**

4 **Explain how the appearance of iodine in picture above is confirmed by the data column 5 of the table.**

5 **Describe the trend in boiling point as molecular mass changes.**

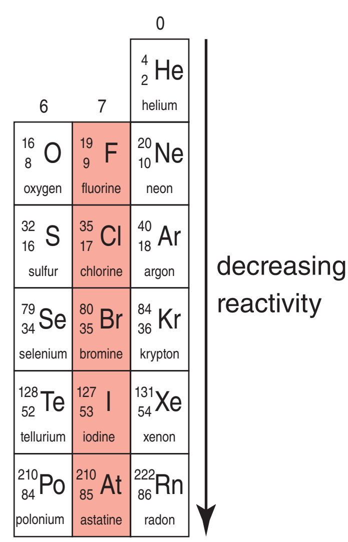


Figure 1.49

Displacement reactions of halogens

The **reactivity** of the halogens decreases down the group.

If halogens are bubbled through solutions of metal halides there are two possibilities: no reaction, or a **displacement** reaction.

If chlorine is bubbled through potassium bromide solution a displacement reaction occurs. An orange colour of bromine is seen. This is because chlorine is more reactive than bromine.

6 **Identify which halogens will displace iodine from a solution of potassium iodide. Justify your answer.**

7 **Write a balanced symbol equation for the reaction between chlorine and potassium iodide.**

8 **Astatine is at the bottom of Group 7. It is radioactive and extremely rare so its chemistry has not been well studied.**

a **Predict the state of astatine at room temperature.**

b **Write a balanced equation for the reaction between chlorine and sodium astatide, NaAt.**

c **Explain whether astatine, At_2, will react with sodium iodide, NaI.**

KEY INFORMATION

Bromine displaces iodine from iodide solutions. It is seen as a red-brown solution.

$Br_2 + 2KI \rightarrow 2KBr + I_2$
(red-brown solution)

Reaction trends and predicting reactions

Learning objectives:

- explain why the trends down the group in Group 1 and in Group 7 are different
- explain the changes across a period
- predict the reactions of elements with water, dilute acid or oxygen from their position in the periodic table.

KEY WORDS

electron arrangement
reactivity
trend

Fluorine, at the top of Group 7, is more reactive than iodine lower down the group. Yet why is caesium, lower down Group 1, so much more reactive with water than lithium at the top of the group? It is all to do with the electronic arrangement and the outer electrons.

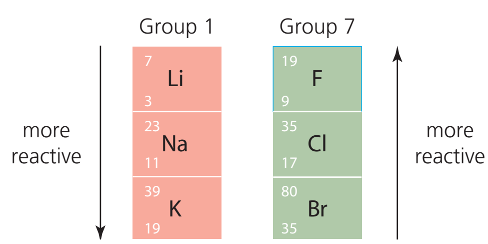


Figure 1.50 (a) Group 1; (b) Group 7

Opposite trends

The **trends** in **reactivity** in Group 1 and Group 7 are in the opposite directions.

Reactivity increases down Group 1 as the outer electron in a potassium atom is further away from the nucleus than in a lithium atom so there is 'less pull' on it by the nucleus so it is lost ***more*** easily. So potassium is more reactive than lithium.

Reactivity decreases down Group 7 as the electron trying to transfer into a bromine atom is further away from the nucleus than in a fluorine atom so there is 'less pull' on it by the nucleus so it transfers in ***less*** easily. So bromine is more reactive than fluorine.

1. **Explain why the element caesium (also in Group 1) is much more reactive than sodium.**
2. **Explain why astatine is less reactive than chlorine.**

DID YOU KNOW?

Caesium was used to make the first atomic clock in 1955.

Trends across the table

The trend across the table is from metallic to non-metallic.

The trends across and down the periodic table depend on atomic structure and the electronic configurations.

In Period 2 and 3 across the table the outer electrons will increase by one from Group 1 with one outer electron and Group 2 with two outer electrons up to Group 7 with seven outer electrons.

Group 1 elements lose one electron to form positive ions easily. It is more difficult for elements to lose two or three electrons so they are less reactive. Group 7 elements gain one electron to form ions.

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	0
			$^{1}_{1}$H hydrogen														$^{4}_{2}$He helium
$^{7}_{3}$Li lithium	$^{9}_{4}$Be beryllium											$^{11}_{5}$B boron	$^{12}_{6}$C carbon	$^{14}_{7}$N nitrogen	$^{16}_{8}$O oxygen	$^{19}_{9}$F fluorine	$^{20}_{10}$Ne neon
$^{23}_{11}$Na sodium	$^{24}_{12}$Mg magnesium											$^{27}_{13}$Al aluminium	$^{28}_{14}$Si silicon	$^{31}_{15}$P phosphorus	$^{32}_{16}$S sulfur	$^{35}_{17}$Cl chlorine	$^{40}_{18}$Ar argon
$^{39}_{19}$K potassium	$^{40}_{20}$Ca calcium	$^{45}_{21}$Sc scandium	$^{48}_{22}$Ti titanium	$^{51}_{23}$V vanadium	$^{52}_{24}$Cr chromium	$^{55}_{25}$Mn manganese	$^{56}_{26}$Fe iron	$^{59}_{27}$Co cobalt	$^{59}_{28}$Ni nickel	$^{64}_{29}$Cu copper	$^{65}_{30}$Zn zinc	$^{70}_{31}$Ga gallium	$^{73}_{32}$Ge germanium	$^{75}_{33}$As arsenic	$^{79}_{34}$Se selenium	$^{80}_{35}$Br bromine	$^{84}_{36}$Kr krypton

metals non-metals

Figure 1.51

3 **Explain why neon is an unreactive element.**

4 **Explain why sodium is a more reactive metal than aluminium.**

Predicting reactions

Knowing the position of an element in the periodic table will allow us to predict its behaviour with water, acid or oxygen.

From the trends that you know, make some predictions.

- Will barium be more reactive with dilute acid than magnesium?
- Will sulfur react more like phosphorus with oxygen or more like sodium?
- If bromine is bubbled through potassium chloride solution what reaction will there be?

Barium is lower down Group 2 than magnesium so will lose electrons more easily so is more reactive.

Sulfur is more like phosphorus as they are both non-metals, so they will react with oxygen in a similar way.

There will be no reaction because chlorine is more reactive than bromine and so will not be displaced.

5 **Predict how rubidium will behave with water, acid and oxygen, giving reasons for your predictions.**

6 **Predict how strontium will react with dilute acid and give reasons for your predictions.**

7 **Hydrogen reacts with halogens to form hydrogen halides.**

a **Give the balanced chemical equation for the reaction of chlorine with hydrogen.**

b **Chlorine and hydrogen explode in sunlight. Predict the reactivity of fluorine with hydrogen. Explain your answer.**

KEY INFORMATION

An atom with one or two electrons will tend to lose them to make positive ions. For example Na loses one electron to become Na^{+}.

Standard form and making estimates

Learning objectives:

- recognise the format of standard form
- convert decimals to standard form and vice versa
- make estimates without calculators so the answer in standard form seems reasonable.

KEY WORDS

standard form
decimal point

Here, we're looking at using expressions in standard form and seeing how this helps us understand the size of very small entities such as atoms and ions.

When we talked earlier about an atom we used a model to describe it. We imagined it as a sphere with a radius of about 0.000 000 000 1 m. We also saw that the radius of the nucleus of the atom is about 0.000 000 000 000 01 m. It is very awkward to keep writing so many zeros, it is easy to lose count and it is not so easy to see the comparison between one number and the other. Let's look at another way of writing these numbers using **standard form**.

KEY INFORMATION

Standard form is used to represent very large or very small numbers.
A number in standard form is written in the form *A* x 10^*n*, where 1 <= *A* < 10 and *n* is an integer. For numbers less than 1, *n* is negative.

Positive powers of ten for very large numbers

We write 1, 10 and 100 knowing what we mean. We can also write them as 1, 1 × 10 and 1 × 10 × 10. We also know that 10 × 10 is 10^2. So 100 is 10^2. We can write the numbers 1, 1 × 10 and 1 × 10^2.

Standard form	M	HTh	TTh	Th	H	T	U	.	t
							1	.	0
1 × 10						1	0	.	0
1 × 10^2					1	0	0	.	0
1 × 10^3				1	0	0	0	.	0
1 × 10^4			1	0	0	0	0	.	0
1 × 10^5		1	0	0	0	0	0	.	0
1 × 10^6	1	0	0	0	0	0	0	.	0

10^6 is NOT 10 multiplied by itself 6 times. It is 10 multiplied by itself 5 times.

What about writing bigger numbers in standard form?

The decimal point is fixed and the position, or place value of the most significant digit, shows how big a number is.

1. **Write 1 000 000 000 in standard form.**
2. **Write out the number 1 × 10^8**

REMEMBER!

1000 can be written as 1 × 10 × 100, which is the same as 1 × 10 × 10 × 10. How many tens? Three. So 1000 is written 1 × 10^3 (one times ten to the power of three). The number 3 tells you how many tens are in the multiplication.

To write 1 000 000 in standard form take the first number on the left, which is 1. Looking at the table, how many places do we have to move the 1 to the right to reach the decimal point? We have to move the 1 six places to the right. So in standard form 1 000 000 is 1×10^6. The number 6 tells you how many tens there are when you write the number as a multiplication of 10 (10 × 10 × 10 × 10 × 10 × 10).

Negative powers of ten for very small numbers

It is also possible to write numbers smaller than 1 in this form. 1 is divided by 10 it is 0.1. The number 1 has moved one place to the right of the decimal point. This is written as 1×10^{-1} in standard form. What is 1 divided by 100? The number 1 moves two places to the right of the decimal point to be 0.01. In standard form this is 1×10^{-2}.

standard form	O	.	t	h	th	Tth	Hth	milliionth
1×10^{-1}	0	.	1					
1×10^{-2}	0	.	0	1				
1×10^{-3}	0	.	0	0	1			
1×10^{-4}	0	.	0	0	0	1		
1×10^{-5}	0	.	0	0	0	0	1	
1×10^{-6}	0	.	0	0	0	0	0	1

Converting numbers to standard form

Standard form can also be used to represent numbers where the most significant digit is not one. For example , the ordinary number 6000 can be written as 6 × 1000 , or 6×10^3, in standard form.

Remember that standard form always has exactly one digit bigger than or equal to one but less than 10. 0.3×10^4 is not in standard form. It is 3×10^3 in standard form.

Some big and small numbers that you have already met in Chemistry are:

Avogadro's number	Atomic radius (m)	Nuclear radius (m)	Mass of a gold atom (g)	Nanoparticle (m)
6.023×10^{23}	1×10^{-10}	1×10^{-14}	3.3×10^{-22}	1×10^{-7}

When you calculate with big and small numbers using a calculator it is essential that you first estimate what your answer should look like. Making an estimate of the result of the calculation can save you from making mistakes with your calculator. The best way to estimate the answer without a calculator is to round the numbers sensibly and then carry out the calculation in your head.

3 **Write 0.000000000000000001 in standard form.**

4 **Write out the number 1×10^{-9}**

5 **Calculate:**

a) $6 \times 10^9 \times 3 \times 10^3$

b) $6 \times 10^9 \times 4 \times 10^{-2}$

c) $6 \times \frac{10^8}{2} \times 10^2$

6 **If you were able to lay the Avogadro's number of atoms in a straight line next to each other, how far would they stretch?**

7 **Calculate the mass of 3.0×10^{26} gold atoms using the mass of a single gold atom given in the data table.**

KEY INFORMATION

To multiply two numbers in standard form you simply add the indices or powers of the tens. For example, $2 \times 10^{15} \times 3 \times 10^9$ is 2×3 with 10^{15+9}, which is 6×10^{24} With smaller numbers $2 \times 10^{-15} \times 3 \times 10^{-9}$ is 6×10^{-24}

Draft specification subject to Ofqual feedback and accreditation

Check your progress

You should be able to:

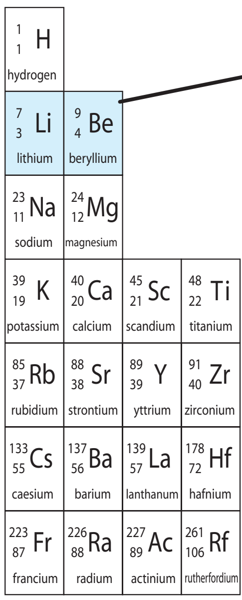
name compounds from their formula	→	recall the names of the first 20 elements in the periodic table and the elements in Groups 1 and 7	→	use symbol equations to describe chemical reactions
describe how to separate mixtures of elements and compounds	→	use word equations to describe chemical reactions	→	use balanced equations to describe reactions
explain that early models of the atom did not have shells with electrons	→	explain that early models of atoms developed as new evidence became available	→	explain why the scattering experiment led to a change in the atomic model
draw a diagram of a small nucleus containing protons and neutrons with orbiting electrons at a distance	→	calculate the numbers of sub-atomic particles in ions and isotopes given the atomic and mass numbers	→	complete data tables showing the atomic numbers, mass numbers and numbers of sub-atomic particles from symbols.
describe how Mendeleev was able to leave spaces for elements that had not yet been discovered	→	explain why the modern periodic table has the elements in order of atomic number	→	explain how Mendeleev was able to make predictions of as yet undiscovered elements such as eka-silicon
describe the pattern of the electrons in shells for the first 20 elements	→	explain how the electronic arrangement of atoms follows a pattern up to the atomic number 20	→	explain how the electronic arrangement of transition metal atoms put them into a period
describe a number of physical properties of metals and non-metals	→	explain that atoms of metals have 1, 2 or 3 electrons in their outer shell	→	explain that non-metals need to gain or share electrons during reactions and that metals need to lose electrons during reactions.
explain that non-metals are on the right-hand side of the periodic table	→	explain that non-metals have 4, 5 ,6, 7 or 8 electrons in their outer shell	→	predict the relative reactivity across the periods and give reasons
describe the unreactivity of the noble gases	→	explain the trend down Group 0 of increasing boiling point	→	explain the trend down Group 0 of increasing boiling point in terms of atomic mass
predict the reactions with water of Group 1 elements lower than potassium	→	predict and explain the relative reactivity down the groups	→	explain the trend down the group of increasing reactivity by electron structure
recall the colours of the halogens and the order of reactivity of chlorine, bromine and iodine	→	describe the order of reactivity and explain the displacement of halogens	→	predict displacement reaction outcomes of halogens other than chlorine, bromine and iodine.
explain that a stable outer shell of electrons makes noble gases unreactive	→	predict the properties of ‘unknown’ elements from their position in the group	→	explain the trend of increasing reactivity in terms of electron structure

225106 AQA_Chemistry_CH1.indd 50 12/05/16 10:16 am

Worked example

Sam and Alex are researching some properties of Group 1 metals.

1 Shade the section of the periodic table where the Group 1 metals are found.



This is incorrect. The first column needs to be shaded.

The two metals they are researching are sodium and potassium.

2 Write down two properties that these metals have.

They are shiny when cut

They have a very high density

The first property is correct. However, sodium and potassium float on water so have a density less than water. The student may be confusing group 1 metals with transition metals, which have high density.

Sam and Alex find out that sodium and potassium react with water. They find that sodium reacts with water to make sodium hydroxide and that hydrogen is given off.

3 Write a word equation for the reaction

sodium + water → sodium hydroxide

The reactants are correct but hydrogen needs to be written as a product on the right hand side.

Sam says that potassium reacts more vigorously than sodium but Alex says that they are in the same group so they react the same.

4 a Explain why Sam is correct about the trend.

The lower down the group the better they react

This answer could be expressed more clearly by substituting the word 'better' with 'more vigorously'.

b Explain why Sam is correct using ideas about the structure of atoms.

The bigger the atom the quicker the reaction

This answer needs more detail. The further away the outer electron is from the nucleus the more easily it is 'lost', as the pull by the positive nucleus on the negative electron is less.

End of chapter questions

Getting started [foundation tier]

1. Identify the gas given off when sodium reacts with water. 1 Mark
2. Which of the following is a noble gas? 1 Mark
   - **a** oxygen
   - **b** helium
   - **c** chlorine
   - **d** nitrogen
3. Suggest two differences between a metal and a non-metal? 2 Marks
4. An atom has 3 protons, 4 neutrons and 3 electrons. What is its atomic mass? 1 Mark
   - **a** 3
   - **b** 6
   - **c** 7
   - **d** 10
5. Determine the electron arrangement in an atom with 10 electrons. 1 Mark
6. Explain why an atom with an electron pattern of 2,8,1 is in Group 1 and Period 3 of the periodic table. 2 Marks
7. Jo and Gita test compounds of Group 1 metals with a flame test.

   Match the flame colour that they see with the correct metal of the compound. 2 Marks

yellow	lithium
crimson	potassium
lilac	sodium

Going further [foundation and higher tier]

8. When sodium reacts with water hydrogen is given off. Identify the other product. 1 Mark
9. To which group does chlorine belong? 1 Mark
   - **a** 0
   - **b** 1
   - **c** 6
   - **d** 7
10. Describe the trend of reactivity of the Group 1 metals. 2 Marks
11. Explain where the atom with an electron pattern of 2,8,2 is positioned in the periodic table. Suggest why it is a metal. 4 Marks
12. Halogen X has a boiling point of 59°C and halogen Y a boiling point of 184°C. 2 Marks
    - **a** Justify which halogen has the lower atomic number.
    - **b** Explain which halogen is more reactive.

More challenging [higher tier]

13 **Identify the number of electrons in an atom of $^{31}_{15}P$.** 1 Mark

14 **There are two atoms $^{28}_{14}Si$ and $^{30}_{14}Si$.**

Work out how many neutrons each atom contains. 1 Mark

15 **Explain why the reactivity of Group 1 metals increases down the group.** 2 Marks

16 **Francium is a highly radioactive and rare alkali metal.** 2 Marks

	Melting point / °C	Density / gcm^{-3}
Rb	39.3	1.53
Cs	28.4	1.93
Fr	**D**	**E**

Predict the melting point, **D**, and density, **E**, of francium using the data in the table.

17 **Chlorine (Cl_2) is bubbled into a solution of potassium iodide (KI).**

a **Describe the reaction.**
b **Explain why this reaction is able to take place.** 4 Marks

Most demanding [higher tier]

18 **Explain the number of the sub-atomic particles that make up the atom $^{31}_{15}P$.** 2 Marks

19 **Explain why the atom with an electron pattern of 2,8,6 is a non-metal. Explain why this atom is less reactive than the atom with an electron pattern of 2,6 or 2,7.** 4 Marks

20 **The table shows the data and properties for an element.**

Deduce which type of element it is, the group it belongs to and why it reacts so violently with water. 4 Marks

Atomic number	Electron pattern	Reaction with water
37	2,8,8,18,1	Violently, giving off hydrogen and forming an alkali

Total: 40 Marks