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1.1 Atoms, elements and compounds

Key points

- All substances are made of atoms.
- Elements are made of only one type of atom.
- Chemical symbols are used to represent atoms.
- Compounds contain more than one element.

- There are about 100 different **elements** from which all substances are made. The periodic table is a list of the elements.

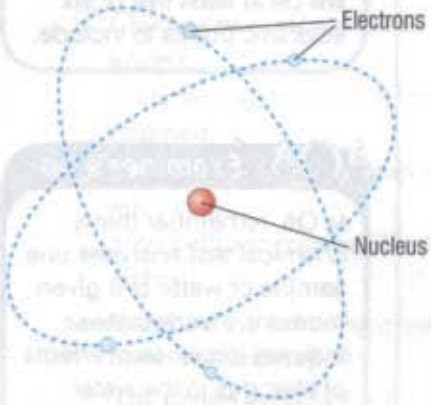
1 *What substances are shown in the periodic table?*

- Each element is made of one type of **atom**.
- Atoms are represented by chemical symbols, e.g. Na for an atom of sodium, O for an atom of oxygen.
- The elements in the periodic table are arranged in columns, called **groups**. The elements in a group usually have similar properties.

2 *What atom does H represent?*

- Atoms have a tiny **nucleus** surrounded by **electrons**.
- When elements react, their atoms join with atoms of other elements. **Compounds** are formed when two or more elements combine together.

3 *What type of substance is sodium chloride, NaCl?*



Atoms consist of a small nucleus surrounded by electrons

AQA Examiner's tip

Remember that a symbol represents one atom of an element.

Key words: element, atom, group, nucleus, electron, compound

Group numbers	1	2										3	4	5	6	7	0
																	He 2 Helium
	Li 3 Lithium	Be 4 Beryllium										B 5 Boron	C 6 Carbon	N 7 Nitrogen	O 8 Oxygen	F 9 Fluorine	Ne 10 Neon
	Na 11 Sodium	Mg 12 Magnesium										Al 13 Aluminium	Si 14 Silicon	P 15 Phosphorus	S 16 Sulfur	Cl 17 Chlorine	Ar 18 Argon
	K 19 Potassium	Ca 20 Calcium	Sc 21 Scandium	Ti 22 Titanium	V 23 Vanadium	Cr 24 Chromium	Mn 25 Manganese	Fe 26 Iron	Co 27 Cobalt	Ni 28 Nickel	Cu 29 Copper	Zn 30 Zinc	Ga 31 Gallium	Ge 32 Germanium	As 33 Arsenic	Se 34 Selenium	Br 35 Bromine	Kr 36 Krypton
	Rb 37 Rubidium	Sr 38 Strontium	Y 39 Yttrium	Zr 40 Zirconium	Nb 41 Niobium	Mo 42 Molybdenum	Tc 43 Technetium	Ru 44 Ruthenium	Rh 45 Rhodium	Pd 46 Palladium	Ag 47 Silver	Cd 48 Cadmium	In 49 Indium	Sn 50 Tin	Sb 51 Antimony	Te 52 Tellurium	I 53 Iodine	Xe 54 Xenon
	Cs 55 Caesium	Ba 56 Barium	Lanthanum see below	Hf 72 Hafnium	Ta 73 Tantalum	W 74 Tungsten	Re 75 Rhenium	Os 76 Osmium	Ir 77 Iridium	Pt 78 Platinum	Au 79 Gold	Hg 80 Mercury	Tl 81 Thallium	Pb 82 Lead	Bi 83 Bismuth	Po 84 Polonium	At 85 Astatine	Rn 86 Radon
	Fr 87 Francium	Ra 88 Radium	Actinium see below															

H 1 Hydrogen

The alkali metals

The alkaline earth metals

The transition metals

The halogens

The noble gases

Lanthanides	La 57 Lanthanum	Ce 58 Cerium	Pr 59 Praseodymium	Nd 60 Neodymium	Pm 61 Promethium	Sm 62 Samarium	Eu 63 Europium	Gd 64 Gadolinium	Tb 65 Terbium	Dy 66 Dysprosium	Ho 67 Holmium	Er 68 Erbium	Tm 69 Thulium	Yb 70 Ytterbium	Lu 71 Lutetium
Actinides	Ac 89 Actinium	Th 90 Thorium	Pa 91 Protactinium	U 92 Uranium	Np 93 Neptunium	Pu 94 Plutonium	Am 95 Americium	Cm 96 Curium	Bk 97 Berkelium	Cf 98 Californium	Es 99 Einsteinium	Fm 100 Fermium	Md 101 Mendelevium	No 102 Nobelium	Lr 103 Lawrencium

The periodic table shows the symbols for the elements

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1.2 Atomic structure

Key points

- The nucleus of an atom is made of protons and neutrons.
- Protons have a positive charge, electrons a negative charge and neutrons are not charged.
- The atomic number (or proton number) of an element is equal to the number of protons in the nucleus of its atoms.
- Elements are arranged in order of their atomic numbers in the periodic table.
- The mass number is the sum of the protons and neutrons in the nucleus of an atom.

- The nucleus at the centre of an atom contains two types of particle, called **protons** and **neutrons**. Protons have a positive charge and neutrons have no charge.
- Electrons are tiny negatively charged particles that move around the nucleus. An atom has no overall charge. That is because the number of protons is equal to the number of electrons and their charges are equal and opposite (proton +1 and electron –1).

1 *Why are atoms neutral?*

- All atoms of an element contain the same number of protons. This number is called the **atomic number** (or proton number) of the element. Elements are arranged in order of their atomic numbers in the periodic table. The atomic number is also the number of electrons in an atom of the element.
- The **mass number** is the total number of particles in the nucleus of an atom, so it is the number of protons plus the number of neutrons.

2 *How many protons, neutrons and electrons are there in an atom of aluminium (atomic number 13, mass number 27)?*

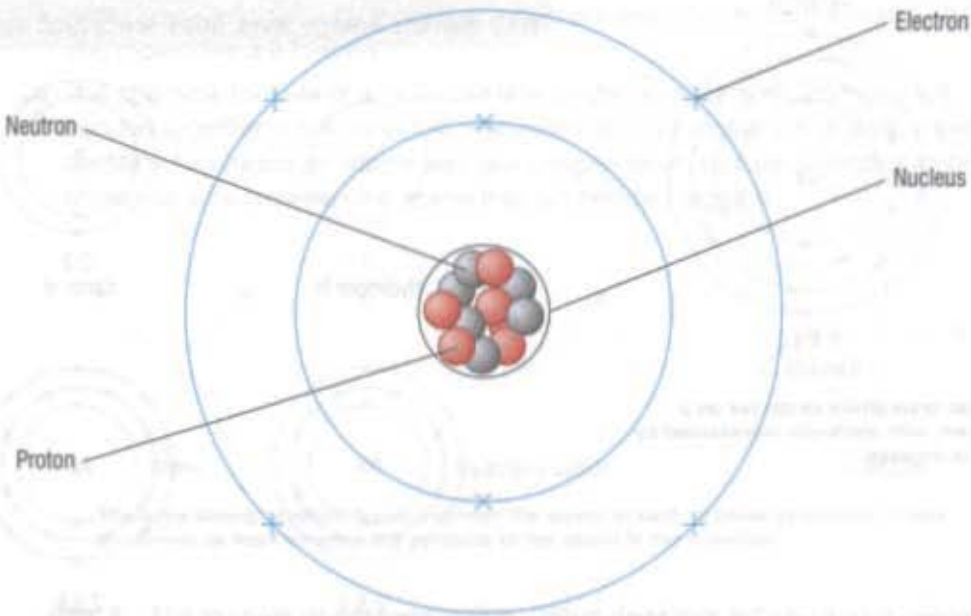
Maths skills

Work out the number of each type of particle in an atom of fluorine from its atomic number of 9 and its mass number of 19.

Number of protons = atomic number = 9

Number of electrons = number of protons = 9

Number of neutrons = mass number – atomic number = 19 – 9 = 10



Understanding the structure of an atom gives us important clues to the way substances react together

Key words: proton, neutron, atomic number, mass number

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1.3 The arrangement of electrons in atoms

Key points

- The atoms of the unreactive noble gases (in Group 0) all have very stable arrangements of electrons.
- Electrons in atoms are in energy levels that can be represented by shells.
- Electrons in the lowest energy level are in the shell closest to the nucleus.
- Electrons occupy the lowest energy levels first.
- All the elements in the same group of the periodic table have the same number of electrons in their highest energy level (outer shell).

- Each electron in an atom is in an **energy level**. Energy levels can be represent as **shells**, with electrons in the lowest energy level closest to the nucleus.
- The lowest energy level or first shell can hold two electrons, and the second energy level can hold eight. Electrons occupy the lowest possible energy level The **electronic structure** of neon with 10 electrons is 2,8. Sodium with 11 electrons has the electronic structure 2,8,1.

1 *Draw a diagram to show the electronic structure of an atom of aluminium (atomic number 13).*

- Elements in the same group of the periodic table have the same number of electrons in their highest energy level, e.g Group 1 elements have one electron their highest energy level.

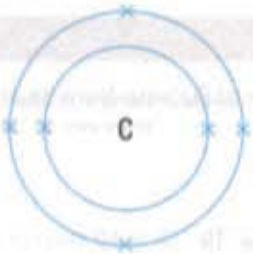
2 *Explain why nitrogen and phosphorus are both in Group 5 in the periodic table.*

- Group 1 elements include lithium, sodium and potassium. These elements rea quickly with water and with oxygen.
- The atoms of the unreactive noble gases (in Group 0) all have very stable arrangements of electrons.

Bump up your grade

You should be able to work out the numbers of protons, neutrons and electrons for any atom from its atomic number and mass number.

Key words: energy level, shell, electronic structure



2,6
Carbon C

2,8,8,2
Calcium Ca

We can draw shells as circles on a diagram, with electrons represented by dots or crosses

1
Hydrogen H

2,3
Boron B

2,6
Oxygen O

2,8,1
Sodium Na

2,8,8
Argon Ar

2,8,8,2
Calcium Ca

Once you know the pattern, you should be able to draw the energy levels of the electrons in any of first 20 atoms (given their atomic number)

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1.4 Forming bonds

Key points

- Compounds of metals bonded to non-metals have ionic bonds.
- The formula of an ionic compound shows the simplest ratio of ions.
- Compounds of non-metals have covalent bonds.
- The formula of a molecule shows the number of atoms in the molecule.

AQA Examiner's tip

The formula for ionic compounds and metallic elements is the simplest possible ratio, such as $MgCl_2$ or NaCl.

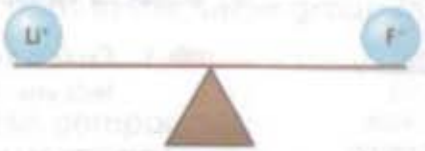
AQA Examiner's tip

For substances made of molecules the formula shows the number of atoms in the molecule, such as O_2 or C_2H_6.

- When different elements combine they form compounds.
- When a metal reacts with a non-metal, ions are formed. Metal atoms lose one or more electrons to form positively charged ions. Non-metal atoms gain electrons to form negatively charged ions. The oppositely charged ions attract each other strongly and the compound has **ionic bonds**.

1 *Name an example of a compound with ionic bonds.*

- The chemical formula of an ionic compound tells us the simplest ratio of ions in the compound. For example, NaCl shows that sodium chloride is made from equal numbers of sodium ions and chloride ions.

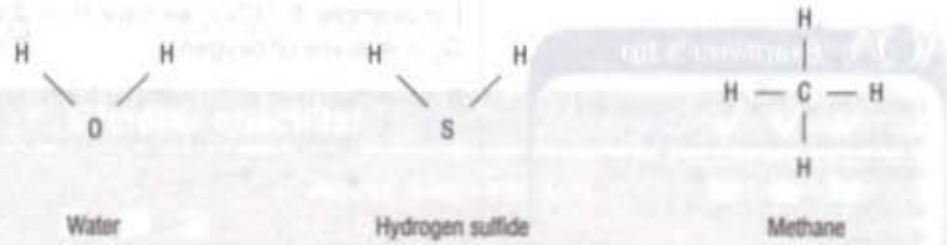


The positive and negative charge on the ions in a compound balance each other, making the total charge zero

The 2+ positive charge on the magnesium ion balances the two 1– negative charges on the chloride ions in magnesium chloride ($MgCl_2$)

2 *Calcium chloride has the formula $CaCl_2$. What does this tell you about the compound?*

- When non-metals combine, their atoms share electrons to form **covalent bonds** and molecules are formed.
- The chemical formula of a molecule tells us the number of atoms that have bonded together in the molecule. For example, H_2O shows that a water molecule contains two hydrogen atoms and one oxygen atom. Covalent bonds can be shown as lines between the atoms that are bonded together.



There are strong covalent bonds between the atoms in each of these molecules. These are shown as lines between the symbols of the atoms in the molecule.

3 *The formula of propane is C_3H_8. What does this tell you about propane?*

Key words: ionic bond, covalent bond

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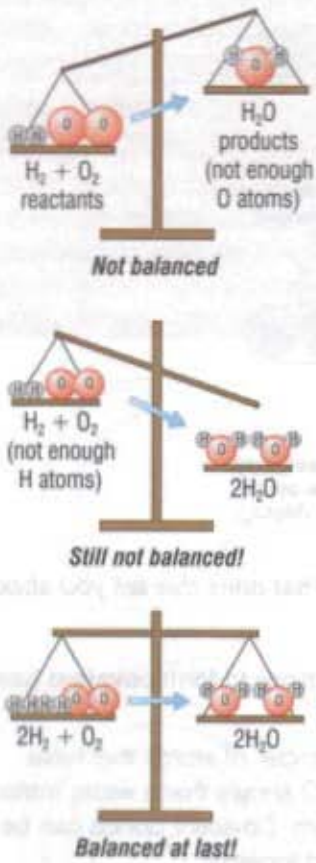
1.5 Chemical equations

Key points

- Atoms get re-arranged in chemical reactions.
- The mass of the products is equal to the mass of reactants.
- Symbol equations should always be balanced.

- In chemical reactions the atoms in the reactants re-arrange themselves to form new substances, the products.
- Atoms are neither created nor destroyed in a chemical reaction. So the number and type of atoms remains the same before and after the reaction.
- This means that the mass of the **products** equals the mass of **reactants**.
- It also means that we can write chemical equations to represent reactions.
- Word equations only give the names of the reactants and products. Symbol equations show the numbers and types of atoms in the reactants and products.
- When symbol equations are written they should always be balanced.
- This means that the numbers of each type of atom should be the same on both sides of a symbol equation.

1 *Explain as fully as you can what this balanced symbol equation tells you:* $Mg + 2HCl \rightarrow MgCl_2 + H_2$



Making an equation balance

Making an equation balance

Symbol equations are balanced by changing the large numbers in front of the formulae of the reactants and products.

You should balance equations by changing only the large numbers. Never change the small (subscript) numbers because this changes the formula of the substance.

2 *Balance these equations:* **a** $H_2 + Cl_2 \rightarrow HCl$
b $Na + O_2 \rightarrow Na_2O$
c $Na_2CO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

Bump up your grade

To improve your grade when taking the Higher Tier paper, learn how to balance a symbol equation given the formulae of the reactants and products.

Maths skills

In the formulae in symbol equations, small (subscript) numbers multiply only the atom they follow.

For example: In H_2SO_4 we have H_2 = 2 atoms of hydrogen, S = one atom of sulfur, O_4 = 4 atoms of oxygen.

If more than one atom within a formula has to be multiplied, brackets are used.

$Mg(NO_3)_2$ (one magnesium ion and two nitrate ions) is made from

one atom of magnesium 1×2 atoms of nitrogen $3 \times 2 = 6$ atoms of oxygen.

Large numbers multiply all atoms in the formula that follows. So $2CO_2$ (two molecules of carbon dioxide) shows a total of two carbon atoms and four oxygen atoms.

AQA Examiner's tip

Remember that in a balanced symbol equation a large number multiplies all of the atoms in the formula that follows.

Key words: product, reactant

1 Sort these substances into elements and compounds:
Ca, CH_4, H_2, HCl, MgO, Ne, O_2, SO_2.

2 What are the names and numbers of the particles in an atom of sodium (atomic number 11, mass number 23)?

3 What determines the order of the elements in the periodic table?

4 Draw a diagram to show the electronic structure of sulfur (atomic number 16).

5 Explain why boron and aluminium are both in the same group in the periodic table.

6 Name the type of bonds in each of these compounds:
CaO, C_2H_6, H_2O, KCl, $LiCl$, $MgCl_2$, NH_3, Na_2O, PCl_3.

7 Explain what happens to the atoms when a sodium atom reacts with a chlorine atom.

8 The equation for a reaction of lead nitrate is:
$Pb(NO_3)_2 + 2KI \rightarrow 2KNO_3 + PbI_2$

a Write a word equation for this reaction.

b Give the name and number of each type of atom in the products.

9 Calcium carbonate decomposes when heated to produce calcium oxide and carbon dioxide. 20.0 g of calcium carbonate produced 11.2 g of calcium oxide. What mass of carbon dioxide would be produced?

10 Balance these symbol equations: [H]

a $Ca + O_2 \rightarrow CaO$

b $Na + H_2O \rightarrow NaOH + H_2$

c $CH_4 + O_2 \rightarrow CO_2 + H_2O$

Chapter checklist

Tick when you have:

	✓	✓ ✓
reviewed it after your lesson	☑	☐ ☐
revised once – some questions right	☑	☑ ☐
revised twice – all questions right	☑	☑ ☑

Move on to another topic when you have all three ticks

	✓	✓	✓
Atoms, elements and compounds	☐	☐	☐
Atomic structure	☐	☐	☐
The arrangement of electrons in atoms	☐	☐	☐
Forming bonds	☐	☐	☐
Chemical equations	☐	☐	☐