Edexcel

IGCSE

Chemistry

CODE: (4CH1)

Unit 01

Principles of chemistry

1.1 States of Matter

The Arrangement of the particles

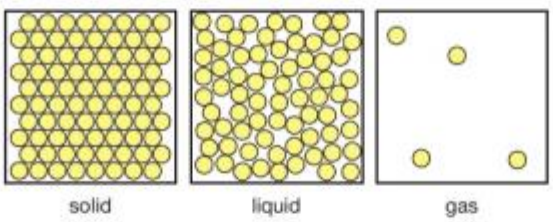
Think about these facts:

■You can't walk through a brick wall, but you can move (with some resistance - it pushes against you) through water. Moving through air is easy.

■When you melt most solids, their volume increases slightly. Most liquids are less dense than the solid they come from.

■If you boil about 5 cm3 of water, the steam will fill an average bucket.

The arrangement of the particles in solids, liquids and gases explains these facts.



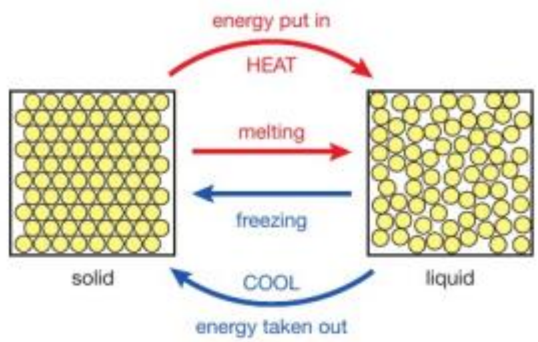
KEY POINTS

- You can't walk through a brick wall because of the strong forces of attraction between the particles – the particles can't move out of your way.
- You can swim through water because you can push the particles out of the way.
- It is easy to move through a gas because there are no forces between the particles.

Solid particles are arranged regularly and packed together, with strong forces of attraction. Liquid particles are less dense and have gaps, allowing them to move around. Gas particles move randomly at high speed, with no forces of attraction. Solid particles have less kinetic energy than liquid particles and gas particles.

Interconversions between the three states of Matter

Changing state between solid and liquid



A solid **melts** when heated, causing particles to vibrate faster and lose their attraction. The **melting point** is the temperature at which the solid melts, and the particles in the liquid have more kinetic energy, requiring energy to convert it.

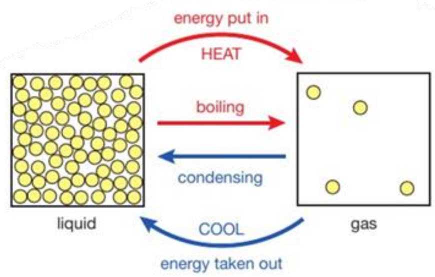
The liquid **freezes**, forming a solid. The temperature at which this occurs is called the **freezing point.**

Changing state between solid and liquid

There are two different ways this can happen, called **boiling** and **evaporation**.

boiling

Boiling occurs when a liquid's particles move fast enough to overcome attraction forces, resulting in a higher boiling point. When cooled, particles form and condense, forming a liquid.



▲ Figure 1.6 Boiling to become a gas – and condensing to become a liquid.

Evaporation

Evaporation occurs when particles at the surface of a liquid break away due to energy, forming a gas.

This process occurs in open or closed containers, where particles in the gas collide with particles at the surface. In a closed container, evaporation and condensation occur simultaneously, resulting in a gradual disappearance of the liquid.

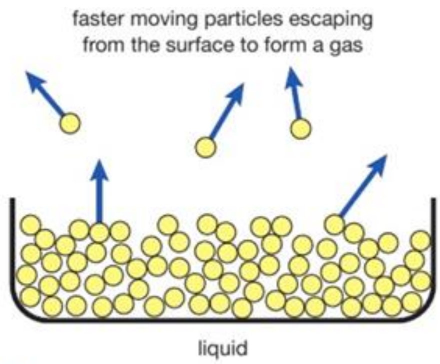


Figure 1.7 Evaporation.

Changing state between solid and gas: sublimation

The conversion of a solid into a gas is known as **sublimation** and the reverse process is usually called **deposition**.

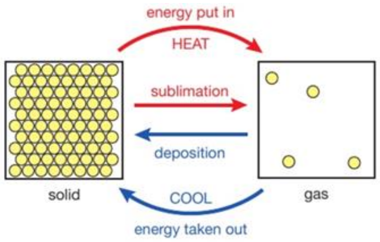
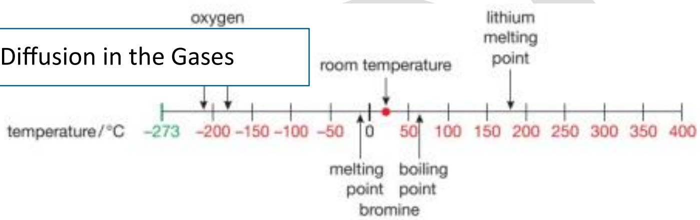


Figure 1.8 This change of state goes directly from a solid to a gas and from a gas to a solid.

Working out the physical state of substance at a particular temperature

A substance is a solid at temperatures below its melting point, between in melting point and its boiling point it is a liquid, and above its boiling point it is a gas.

Diffusion in the Gases



KEY POINT

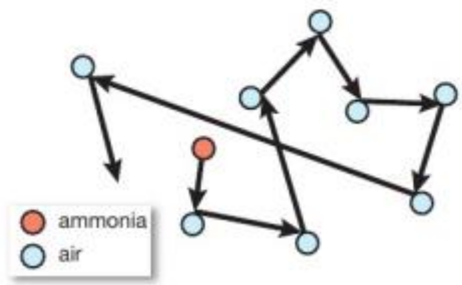
Room temperature is different in different places but in science it is usually taken to mean a temperature between 20 and 25 °C. Because there is not just one fixed value, for changes of state that occur near room temperature we must be careful when making comparisons and make clear what value is being used as room temperature.

Diffusion

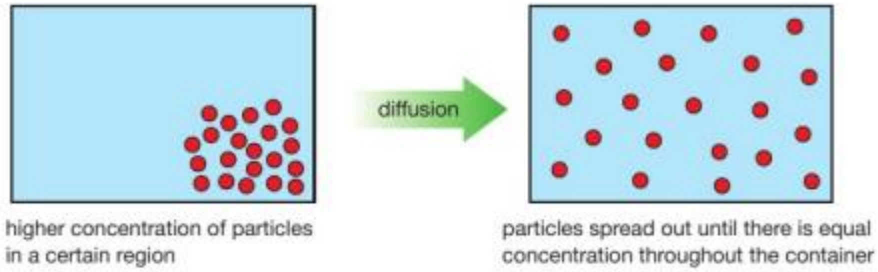
Diffusion in the Gases

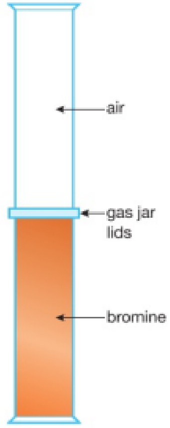
The Spreading out of particles in a gas or liquid is known as **Diffusion**.

A formal definition of diffusion is:
Diffusion is the spreading out of particles from where they are at a high concentration (there are lot of them in a certain volume) to where they are at a low concentration (there are fewer of them in a certain volume).



The apparatus in Figure 1.13 demonstrates diffusion in gases by comparing the brown color of bromine gas and air particles in two gas jars. When lids are removed, the brown color diffuses upwards, creating an even mixture. The same experiment can be performed with hydrogen and air, revealing identical explosions from both jars.





Show that Particles of different Gases travel at different speeds

The reaction between ammonia (NH_3) and hydrogen chloride (HCl) gases to give white solid ammonia chloride (NH_3Cl):

NH_3(g) + HCl (g) $\longrightarrow$ NH_4Cl(s)

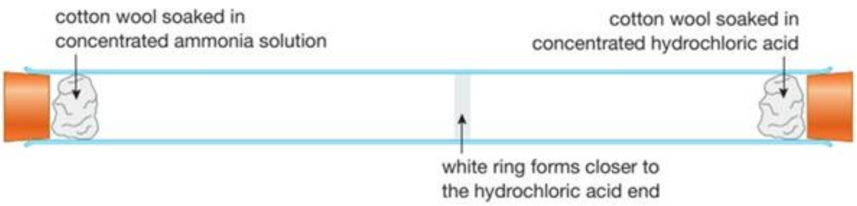


Figure 1.14 Demonstrating that particles in ammonia and hydrogen chloride travel at different speeds.

KEY POINT

You will learn about relative molecular mass in Chapter 5. The relative molecular mass of ammonia is 17 and that of hydrogen chloride is 36.5.

Cotton wool is soaked in concentrated ammonia solution and concentrated hydrochloric acid, then placed in a glass tube with rubber bungs. As the particles diffuse, a white ring of solid ammonium chloride forms, closer to the hydrochloric acid end. The ring forms further away from the ammonia end due to their lighter nature.

Diffusion in Liquids

Diffusion through a liquid is very slow if the liquid is completely still. If a small jar of strongly colored solution (such as potassium manganate (VII) solution) is placed in a gas jar of water, it can take days for the color to diffuse throughout all the water. This is because the particles in liquid move more slowly than the particles in a gas. The particles in a liquid are also much closer together than those in a gas and so there is less space of particles to move into without colliding with the other one.

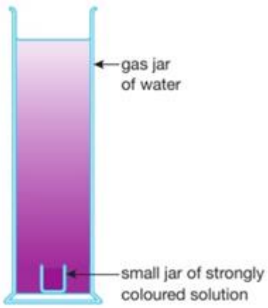


Figure 1.15 Demonstrating diffusion in liquids

The Dilution of colored solution

Imagine you dissolve 0.01 g of potassium manganate(VII) in 1 cm^3 of water to make a deep purple solution. If we take the volume of 1 drop as 0.05 cm^3 we can work out that there are 20 drops in 1 cm^3 and each drop will contain 0.0005 g of potassium manganate(VII).

If you dilute this solution by adding water until the total volume is 10 000 cm^3, you should still just be able to see the purple colour.

There are now 200 000 drops in the solution. In order to see the colour each drop must contain at least one 'particle' of potassium manganate(VII), so there must be at least 200 000 'particles' in 0.01 g of potassium manganate(VII). This means that each 'particle' can't weigh more than 50 billionths of a gram (0.00000005 g).

This answer is not even close to the real answer. A potassium manganate(VII) 'particle' actually weighs about 0.00000000000000000000026 g and there are about 38 000 000 000 000 000 000 particles in 0.01 g! In reality, you need very large numbers of particles in each drop in order to see the colour.

The Solubility of Solids

Solutes, Solubility and solvents

When a solution dissolves on a liquid:

- The substance that dissolves is called **solute**
- The liquid it dissolves in is called **solvent**
- The liquid form is a **solution.**

A **saturated solution** is a solution which contains as much as dissolve solid as possible at a particular temperature. There must be some undissolved

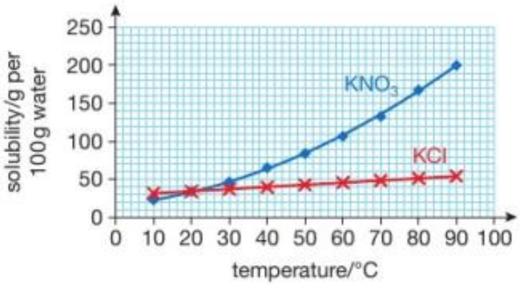
Figure 1.16 A saturated solution

Measuring Solubility

The **solubility** of a solid in a solvent at temperature is usually define as 'the mass of solvent which must dissolve in 100g of solvent at that temperature to form a saturated solution'.

Solubility Curves

The solubility of a solid change with temperature and you can plot this on a solubility curve.



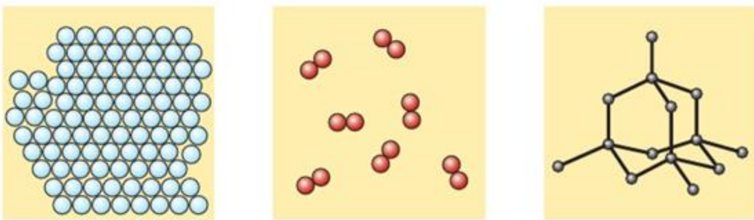
KEY POINT

The dashed lines marked on the graph come from answers to the next part of the question. In this case the solubility curve is virtually a straight line – this will not always be the case. If you are asked to draw a line of best fit this can be either a straight line or a curve.

1.2 Elements, Compounds and Mixtures

Elements

Elements are substance that can't be spilt into anything simple by chemical means. An element contains only one type of atom.



a pure metal such as magnesium | oxygen gas | diamond (a form of carbon)

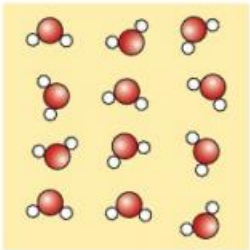
Figure 2.3 Elements contain only one type of atom.

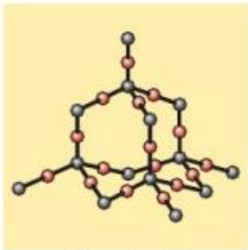
KEY POINT

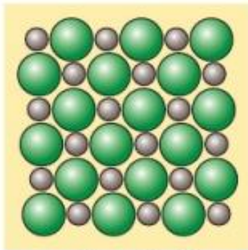
It isn't completely true to say that elements consist of only one type of atom. A better way of saying it would be that *all the atoms in an element have the same atomic number*. Most elements consist of mixtures of isotopes, which have the same atomic number, but different mass numbers (due to different numbers of neutrons). When we draw diagrams or make models, we aren't usually interested in the differences between the isotopes. Isotopes will be discussed in Chapter 3.

Compounds

Compounds are formed when two or more elements chemically combine

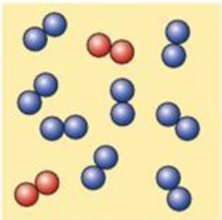

water

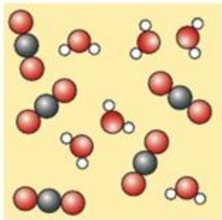

silicon dioxide


sodium chloride

Mixtures

In the mixture, the various substance is mixed, and no chemical reaction occurs.


mixture of elements – nitrogen and oxygen


mixture of compounds – carbon dioxide and water (vapour)

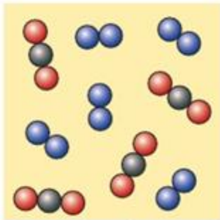

mixture of an element with a compound – carbon dioxide and nitrogen

Figure 2.5 Some mixtures

Simple different between mixtures and compounds

Proportions

In water, every single molecule has two hydrogen atoms combined with oxygen atom. In a mixture of hydrogen and oxygen gas, the two could be mixed in any proportion.

Properties

In a mixture of elements, each element keeps it own properties, but the properties of the compounds are quite different.

Eases of separation

Mixture can be separated by **Physical means**. Physical means are things like changing the temperature or dissolving parts of mixture in a solute such as water, method that don't involve any chemical reaction.

Melting point and boiling point

Pure substances, such as elements and pure compounds, melt and boil at fixed temperature.
Water

- Melting point 0^0 C
- Boiling point 100^0 C

Separation of mixtures

Separating mixtures in extremely important in chemistry

Filtration

Filtration can be used to separate a solid from liquid. The substance that left in the filter paper called the **residue** and the liquid that comes through is called **filtrate**.

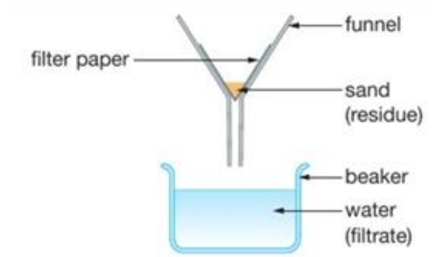
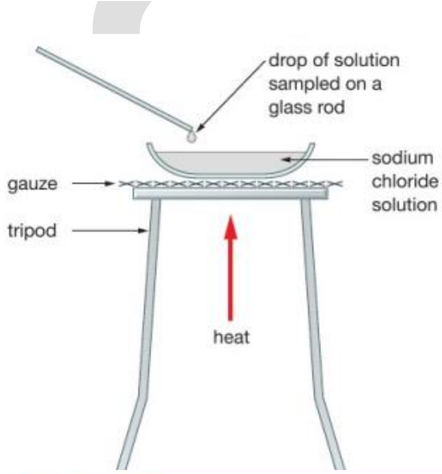


Figure 2.6 Filtration can be used to separate a mixture of sand and water.

Crystallization

Crystallization can be used to separate a solute from a solution.



Making pure salt form rock salt

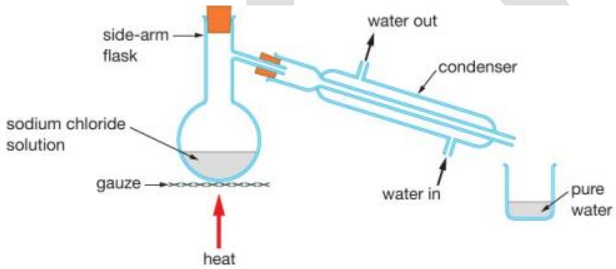
Rock salt consists of salt contaminated by various earthy or rocky impurities. These impurities can't be soluble in water.

KEY POINT

Notice that water is always fed into the condenser at the lower end. That way it fills the condenser jacket better and if the flow of water stops for any reason the condenser jacket remains full of water.

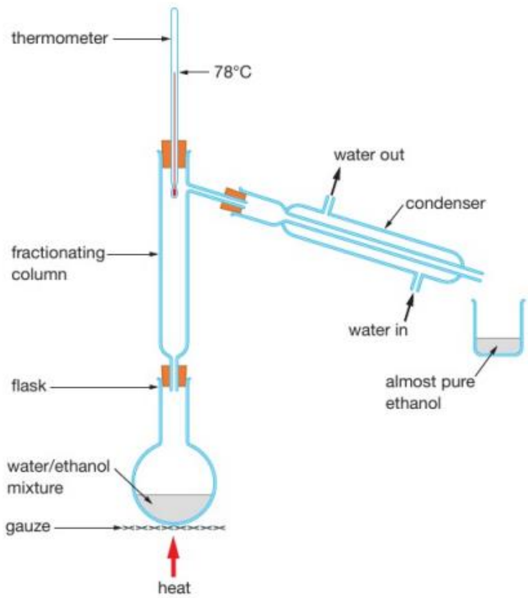
Simple Distillation

Simple distillation can be used to separate the compounds of a solution.



Fractional distillation

Fractional distillation is used to separate a mixture of liquid such as ethanol(alcohol) and water.



Paper Chromatography

Paper chromatography can be used to separate variety of mixtures.

Using paper chromatography in analysis

Paper chromatography can be used to identify specific dyes in a mixture, such as d1, d2, d3, and d4. An experiment involves drawing a pencil line on a larger sheet, marking the positions of the dyes, and allowing the chromatogram to develop.

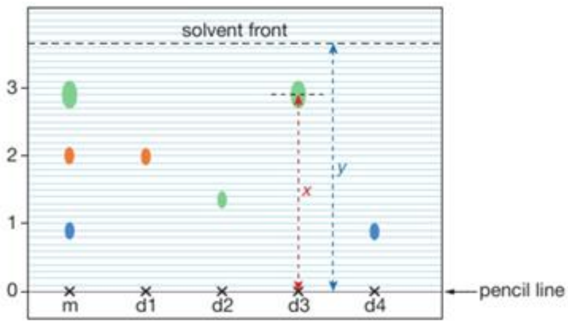


Figure 2.13 Paper chromatography can be used to analyse a mixture. Lines will not be present on your paper, but they have been added here to help you measure the distances.

R_f stands for **retardation factor.**

$$R_f = \frac{\text{distance moved by a spot (from the pencil line)}}{\text{distance moved by the solvent front (from the pencil line)}}$$

In Figure 2.13 $R_f = \frac{x}{y}$.

So in Figure 2.13 the R_f value for dye d3 is:

$$R_f = \frac{2.9\,\text{cm}}{3.6\,\text{cm}} = 0.81$$

The R_f values of the dyes in mixture m are:

blue spot: $R_f = \frac{0.9}{3.6} = 0.25$

orange spot: $R_f = \frac{2.0}{3.6} = 0.56$

green spot: $R_f = \frac{2.9}{3.6} = 0.81$

The R_f values of dyes d1 to d4 are:

d1: $R_f = 0.56$

d2: $R_f = 0.36$

d3: $R_f = 0.81$

d4: $R_f = 0.25$

1.3 Atomic Structure

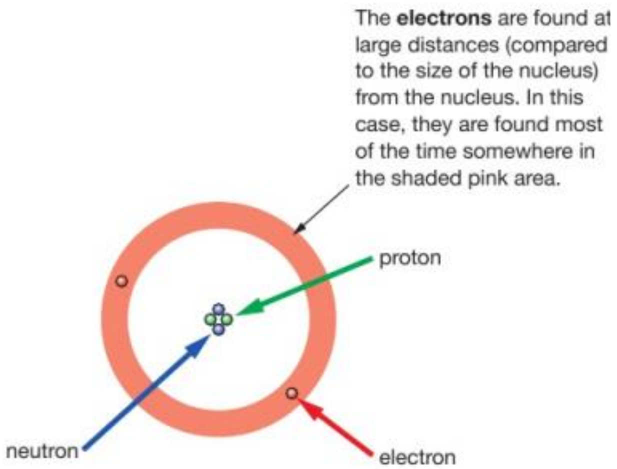
Atom is the smallest piece in that can be recognized as an element.

Atoms and Molecules

Atoms can be joined together to make a molecule. A **molecule** consists of two or more atoms chemical bonds.

The structure of the atom

Atoms are made of protons, neutrons and electrons. These particles are sometimes called sub-atomic because there are smaller than an atom.



KEY POINT

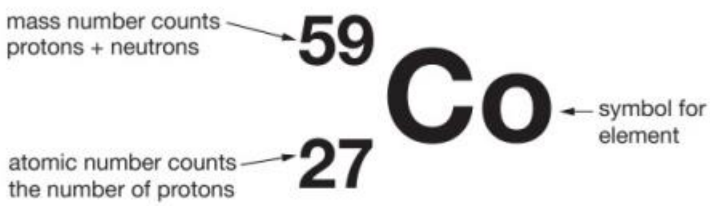
You may have come across diagrams of the atom in which the electrons are drawn orbiting the nucleus rather like planets around the sun. This can be misleading.
Electrons are constantly moving in the atom and it is impossible to know exactly where they are at any moment in time. You can only identify that they have a particular energy and that they are likely to be found in a certain region of space at some particular distance from the nucleus. Electrons with different energies are found at different distances from the nucleus.

Table 3.1 The properties of protons, neutrons and electrons

Particle	Relative mass	Relative charge
proton	1	+1
neutron	1	0
electron	1/1836	–1

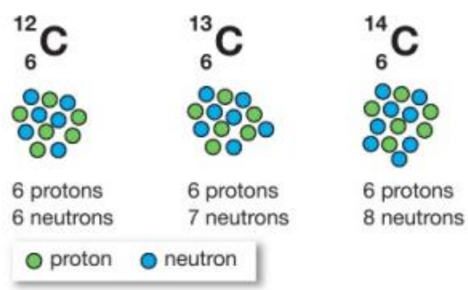
Atomic number and the Mass number

The number of protons in an atom's nucleus is called its **atomic number** or **proton number.**
Atomic number = number of protons
The **mass number** (**nucleon number**) counts the total number of protons and neutrons in a nucleus of a atom.
Mass number = no. of protons + no. of neutrons



Isotopes

These different atoms of Cardon are called **isotopes**.



Relative atomic mass

Chlorine apparels is to have a mass number of 35.5. if you calculated the number of neutrons chlorine:
Number of neutrons = 35.5 – 17 = 18.5
The number 35.5 is not actually the mass number of chlorine but rather the relative atomic mass (A_r).

35.5
Cl
chlorine
17

KEY POINT

The number above each symbol in the International GCSE Periodic Table papers is a relative atomic mass and not a mass number. However, in most cases the relative atomic mass stated is the same as the mass number of the most common isotope. The only exceptions to this are chlorine (35.5) and copper (63.5).

KEY POINT

This type of average is called a **weighted average** or weighted mean.

The

electrons

Counting the number of electrons in an atom

Atoms are electrically neutral. The charge on a proton (+1) is equal opposite to the charge on an electron (-1).
No. of electrons = no. of protons

The periodic table

- The number of protons in an atom is equal to the atomic number
- The number of electrons in an atom is equal to the number of protons
- The number of neutrons in an atom = mass number - atomic number

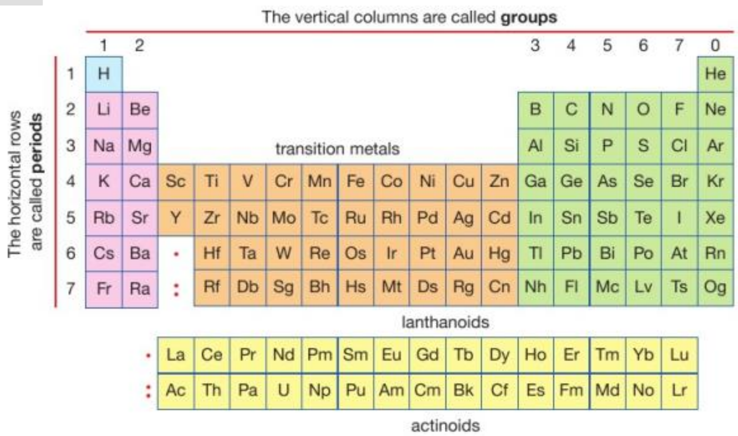
1.4 The Periodic table

The periodic table

The elements are arranged in order of atomic number – the number of protons in the nuclei of the atom.

The vertical column in the periodic table is called **groups.**

The horizontal rows are called **periods**.



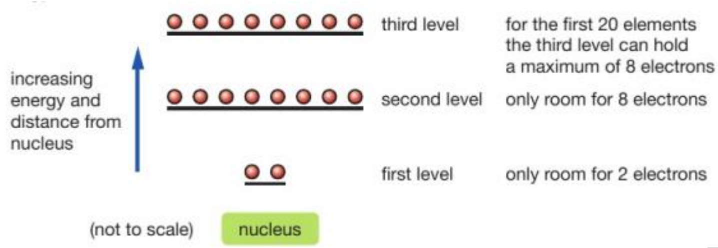
The periodic table and the number of protons, neutrons and electrons

You can use a periodic table and the number of protons, neutrons and electrons there are in atoms. Remember

- The number of protons in an atom is equal to the atomic number
- The number of electrons in an atom is equal to the number of protons
- The number of neutrons in an atom = mass number - atomic number

The arrangement of the electrons in the atom

The electrons move around the nucleus in a series of level called **energy level** or **shell.**

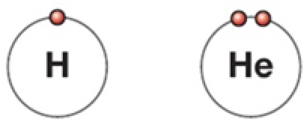


How to work out the arrangement of electrons in an atoms

The **electronic configuration** of an atom, such as chlorine, is determined by its atomic number, which is 17. The number of electrons in a neutral chlorine atom is equal to the number of protons. The electrons are arranged in shells, with the first shell taking up to 2 electrons, the second taking up to 8, and the third taking up to 7. The arrangement is verified by checking the correct number of electrons.

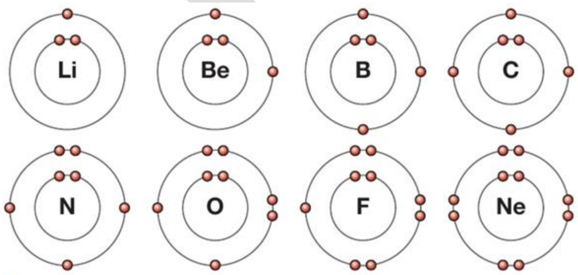
Drawing diagrams of electronic configuration

Atom diagrams typically use circles for energy levels, with dots or crosses for electrons. Hydrogen has one electron, while helium has two in the first shell.



▲ Figure 4.4 Electronic arrangements of hydrogen and helium

The helium electrons are sometimes shown as a pair (as here), and sometimes as two separate electrons on opposite sides of the circle. Either form is acceptable.
The next 8 atoms are drawn like this:



▲ Figure 4.5 The electronic arrangements of the elements in Period 2

KEY POINT

Drawing circles like this does not imply that the electrons are orbiting the nucleus along the circles.
The circles represent energy levels. The further away the level is from the nucleus, the higher its energy.
It is impossible to work out exactly how an electron is moving in that energy level.

Potassium and calcium will look like this

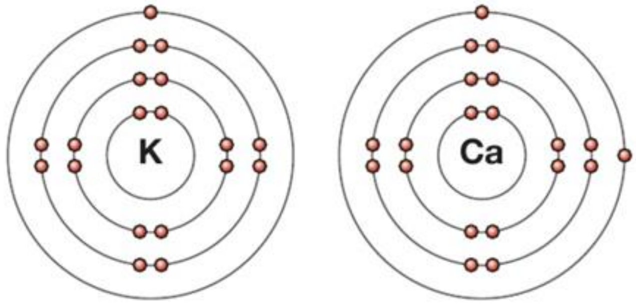
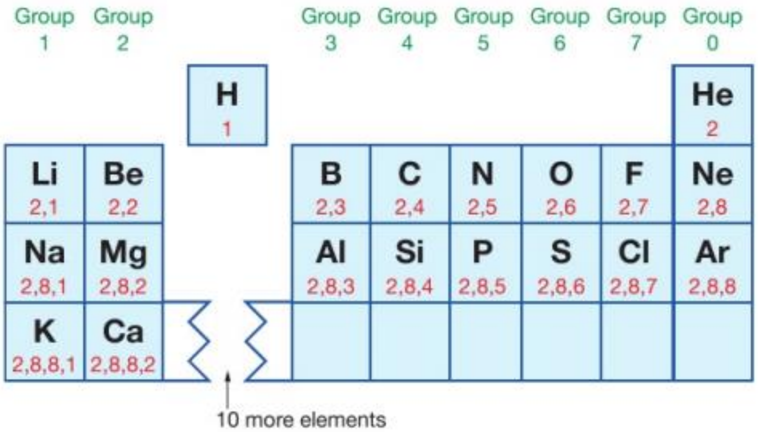


Figure 4.6 Electronic arrangements of potassium and calcium

Electronic configuration and the periodic table

The electronic configurations of the first 20 elements in the periodic table are shown in figure.



Two importance facts:

- Elements in the same group in the periodic table have the same numbers of electrons of their outer shell.
- The number of electrons in outer shell is the same as the group number of groups 1 to 7
- The period number gives the number of occupied shell or the highest occupied shell.

Elements in the same group in the periodic table have similar chemical properties

Groups in the periodic table contain elements with similar chemical properties they react in the same way.

- All the elements in group 1 reacts vigorously with water to form hydrogen to hydroxides with similar formulae.
- All the elements in group 7 reacts hydrogen to form compounds with similar formulae.
- All the elements in group 2 chlorides with similar formulae.

The Noble gases

The group 0 elements are known as **Noble gases** because they are almost completely unreactive.

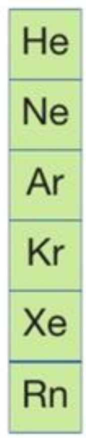


Figure 4.8 The noble gases

Metals and non - metals in the periodic table

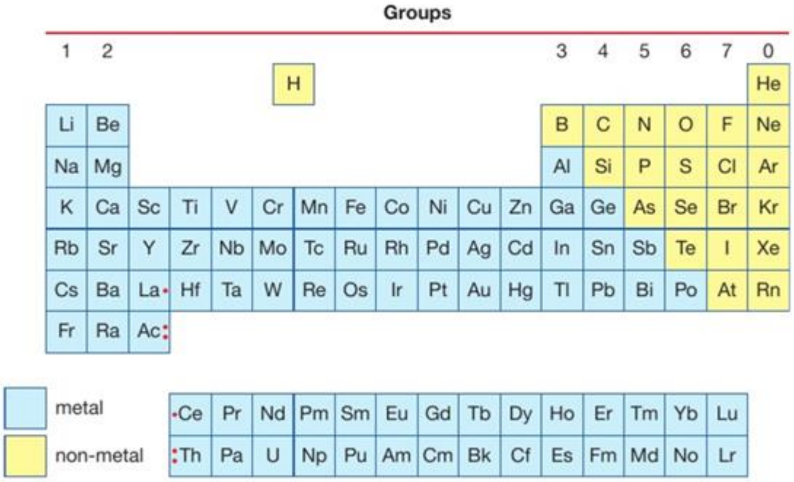


Figure 4.9 Metals and non-metals

Different between the properties of metals and non- metals

- Metal conduct electricity and non-metal don’t generally conduct electricity.
- Non-metal don’t conduct electricity.
- Metals generally form basic oxides.

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

copper(II) oxide + sulfuric acid → copper(II) sulfate + water

- Non-metals generally form acidic oxides.

$$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$$

carbon dioxide + sodium hydroxide → sodium carbonate + water

Metals

- Tend to be solid with higher melting and boiling points.
- High densities
- Are shiny when polished or cuts
- Are ductile
- Are good conduct of electricity and heat.
- From ionic compounds
- From positive ions in their compounds

Non-metals

- Tend to have low melting and boiling points.
- Tend to be brittle when there are solid.
- Don’t have the shine as metal
- Don’t usually conduct electricity.
- Are poor conducted for heat
- From both ionic and covalent compounds
- Tend to form negative ions is ionic compounds

KEY POINT

The reason the noble gas group is usually called Group 0 and not Group 8 (which would seem more sensible because most of the elements have 8 electrons in their outer shell) is because when they were first discovered it was believed that noble gases did not combine with anything, they had zero combining power (valency). This is the only group where the group number does not tell you the number of electrons in the outer shell! The key point is that the noble gases (except helium) have 8 electrons in their outer shell. You will see in Chapters 7 and 8 that atoms tend to form compounds by losing/gaining or sharing electrons so that they have 8 electrons in their outer shell. The noble gases already have 8 electrons in their outer shell so they do not do that.

KEY POINT

If a basic oxide is soluble in water it will dissolve to form an alkali. For example, sodium oxide reacts with water to form sodium hydroxide solution, an alkali. If an acidic oxide is soluble in water it will dissolve to form an acidic solution. For example, sulfur(IV) oxide reacts with water to form sulfurous acid.

KEY POINT

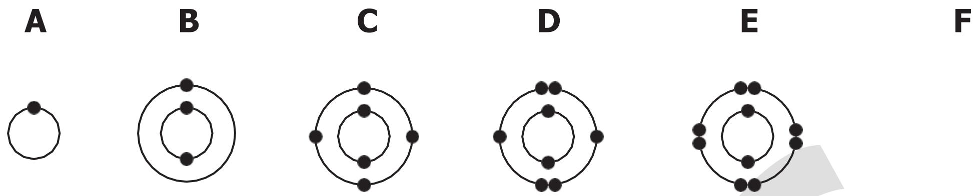
There are some exceptions to the rules. For example, some metals form amphoteric oxides (e.g. Al_2O_3), which react with acids and bases, and some non-metal oxides (e.g. CO) are neutral.

Figure 4.11 Mercury has most of the properties of a metal (high density, shiny, conducts electricity, forms positive ions); the exception is that it is a liquid at room temperature.

Figure 4.12 Sulfur crystals are shiny, but you wouldn’t mistake them for a metal.

Revision questions

1 The diagram shows the electronic configurations of six different atoms.



You may use the Periodic Table on page 2 to help you answer this question.Answer each part by writing one of the letters A, B, C, D, E or F in the box provided.
You may use each letter once, more than once or not at all.

Give the letter that represents an atom

I. Of a noble gas
II. That contains three protons
III. Of phosphorus
IV. Of an element in Group 4 of the Periodic Table
V. Of an element in Period 3 of the Periodic Table
VI. With a full outer shell of electrons

b) Atoms of A and D combine to form a compound containing covalent bonds.
i) Complete the sentence to describe a covalent bond.
A covalent bond is the electrostatic attraction between a pair of ....
and the…………………………of two atoms.

ii) Suggest, with reference to electronic configurations, the most likely formula of the compound formed between atoms of A and D.

2) This question is about hydrogen (H_2) and water.
a) Hydrogen is a gas at room temperature. It exists as simple molecules.

I. Draw a dot and cross diagram to show the arrangement of the electrons in ahydrogen molecule.
II. Explain why hydrogen has a very low boiling point.
III. Complete the table to show the number of protons, neutrons and electrons ineach of the three isotopes of hydrogen.

b) When hydrogen burns in oxygen, heat energy is transferred to the surroundings.

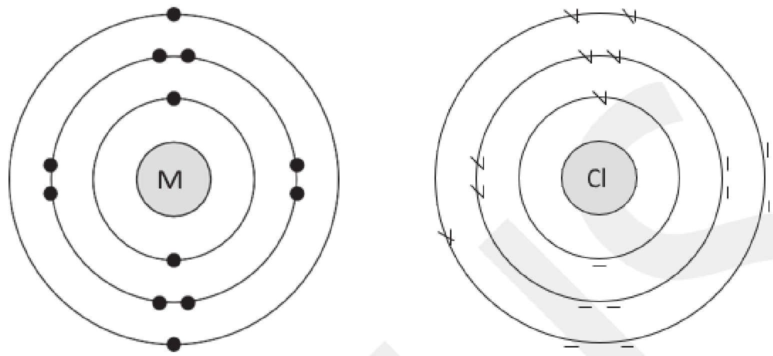
I. State the name given to a reaction in which heat energy is transferred to the surroundings.
II. Write a chemical equation to represent the reaction that takes place when hydrogen burns in oxygen.
III. Describe a chemical test to show that the product is water.
IV. Describe a physical test to show that the product is pure water.

3) This question is about bonding, structures and properties.
The box gives four types of structure.

giant covalent	iant ioni	iant metallic	sim

The table shows some properties of four substances, A, B, C and D.
Complete the table by giving the correct type of structure for each substance.
You may use each structure once, more than once or not at all.

b) Magnesium chloride ($MgCl_2$) is an ionic compound.
The diagram shows the electronic configurations of atoms of magnesium and chlorine.



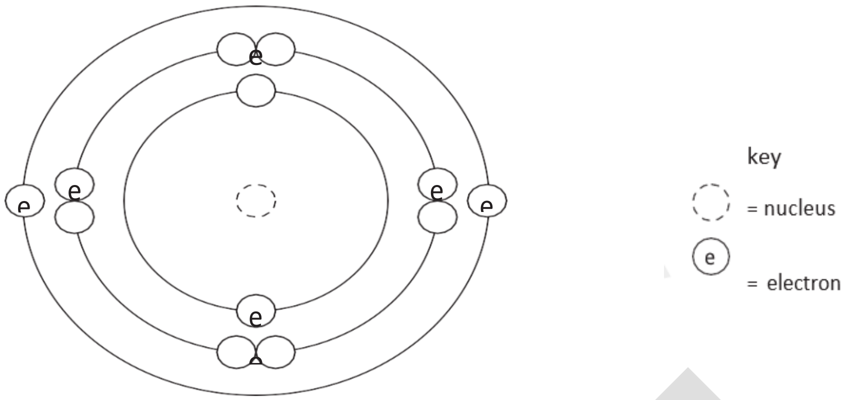
i)Describe how magnesium atoms and chlorine atoms form magnesium ionsand chloride ions.
ii)Draw a diagram to represent the electronic configurations of each of the ions in magnesium chloride. Show the charge on each ion.

c) A molecule of carbon dioxide contains double covalent bonds.
Complete the diagram, using dots and crosses, to show the arrangement of theouter electrons in a molecule of carbon dioxide.

O C O

d) Indium is a metal in Group 3 of the Periodic Table.
i) Describe the structure and bonding in indium.
ii)Explain why indium is malleable.

4)The diagram shows the electronic configuration of an atom of element X.



a) (i) How many protons does the nucleus of the atom contain?

ii)Which group of the Periodic Table contains element X?
Give a reason for your choice.
iii) Give the formula of the ion formed by element X in its compounds.

(b) Element X has three isotopes.

The table gives the mass number of each isotope and its percentage abundancein a sample of element X.

Mass number	Percentage abundance (%)
24	79.0
25	10.0
26	11.0

Calculate the relative atomic mass (A_r) of element X.Give your answer to one decimal place.

5) Boron is an element in Group 3 of the Periodic Table.
An atom of boron can be represented as $^{11}B_5$

a) Use numbers from the box to complete the sentences about

3	5	6	11	16

Each number may be used once, more than once or not at all.

I. The atomic number of boron is ....
II. The mass number of boron is ....
III. This atom of boron contains protons.
IV. This atom of boron contains neutrons.
V. This atom of boron contains electrons

b) Aluminium is another element in Group 3 of the Periodic Table.

Select a word or phrase from the box to complete each sentence about an atomof aluminium.

fewer	m e	the same number of

Each word or phrase may be used once, more than once or not at all.

Compared to an atom of boron, an atom of aluminium has

.... protons.

Compared to an atom of boron, an atom of aluminium has

.... netrons

Compared to an atom of boron, an atom of aluminium has

.... electrons in its **outer** shell.

(c) The electronic configuration of aluminium is

☒ **A** 2.3

☒ **B** 2.2.3

☒ **C** 2.2.8

☒ **D** 2.8.3