# GCSE Science (Modular) - Module 8 Revision Guide (Chemistry)

## Foundation Tier

### Properties of solids, liquids and gases

The different properties of solids, liquids and gases can be explained by imagining that everything is made up of very small particles:

- The particles in a solid are very close together. This is why solids have a definite volume.
- The particles cannot move from place to place; the only way they can move is to vibrate about a fixed place. This is why solids have a definite shape.

- The particles of a liquid are also close together. This is why liquids have a definite volume.
- The particles can move around each other. This is why a liquid can be poured and why it takes the shape of a container as it is filled.

- The particles of a gas are well spread out. This is why gases are very light compared with a similar volume of a solid or a liquid, and can be squeezed into a smaller space (they are compressible).
- The particles of a gas move around very quickly in all directions. This is why gases spread out (diffuse) and mix completely with each other.

### Change of state and dissolving

When the particles of a substance gain or lose energy, the substance may change its state.

If energy is supplied to a solid, its particles vibrate more violently; they may separate from each other and become free to move. This is melting. The temperature at which a solid melts is called its melting point.

Heating a liquid makes its particles move around more quickly. Particles, which have enough energy, may overcome attractive forces and escape from the liquid and become a gas. This is evaporation. When the temperature is higher, more particles have enough energy to escape so evaporation is faster. If the temperature is high enough, a liquid boils. The temperature at which a liquid boils is called its boiling point.

Dissolving: as liquid particles move, they may separate the particles of an added solute from each other.

### What happens when elements react?

All substances are made of atoms. There are over 90 different sorts of atoms. A substance that contains only one sort of atom is called an element. Atoms have a small central nucleus made up of protons and neutrons around which there are electrons. The relative masses of protons, neutrons and electrons, and their relative electric charges are shown in the table on the right.

| | Mass | Charge |
|---|---|---|
| proton | 1 | +1 |
| neutron | 1 | 0 |
| electron | negligible | –1 |

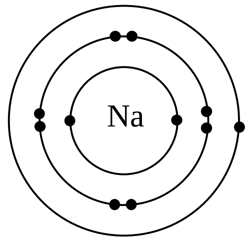
In an atom, the number of electrons = the number of protons in the nucleus.
The atom has no overall electrical charge.

All atoms of a particular element have the same number of protons. The number of protons in an atom is called its **proton number** (atomic number). Atoms of different elements have different numbers of protons.

The total number of protons and neutrons in an atom is called its **mass number**. Atoms of the same element can have different numbers of neutrons; these atoms are called **isotopes** of that element.

You should be able to represent and interpret atoms shown in this way: $^{\text{mass number } 23}_{\text{proton number } 11}\text{Na}$

Electrons occupy particular energy levels. Each electron in an atom is at a particular energy level. The electrons in an atom occupy the lowest available energy levels. You should be able to show the electronic structure of the first twenty elements of the periodic table in the following forms:

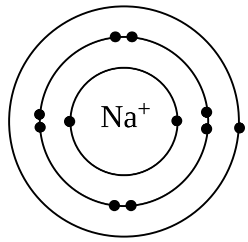
for sodium: 

and 2,8,1

Compounds are substances that contain atoms of two or more elements, joined by chemical bonds. Most substances are compounds.

Atoms can form bonds by gaining or losing electrons to form electrically charged particles called ions. Atoms can also form chemical bonds by sharing electrons.

You should be able to show the electronic structure of the ions in sodium chloride (NaCl), magnesium oxide (MgO) and calcium chloride ($CaCl_2$) in the following forms:

for sodium ion, $Na^+$ 

and $(2,8)^+$

An **ionic compound** is a giant structure of ions. Atoms that share electrons can also form giant structures. Substances with giant structures have high melting points and boiling points.

Atoms that share electrons often form **molecules**. There are chemical bonds between the atoms in each molecule but not between the molecules. Molecular substances have low melting points and boiling points.

<u>How can chemical elements be grouped into families?</u>

The chemical elements can be arranged in the order of the proton number (atomic number) of their atoms. The list you get can then be arranged in rows so that elements with similar properties are in the same columns, known as **Groups**. The resulting table is called the **periodic table**.

The periodic table is also an arrangement of the elements in terms of their electronic structure.
From left to right, across each horizontal row (period) of the periodic table, a particular energy level is gradually filled up with electrons; in the next period, the next energy level is filled with electrons.
The similarities and differences between the properties of elements in the same group of the periodic table can be explained by the electronic structure of their atoms.

There have been several attempts to classify the elements in a systematic way including those by Newlands and Mendeleev, which have lead to the modern periodic table. You should be able to:

- describe early attempts to classify the elements; and
- explain how the growth of chemical knowledge has led to the periodic table in its present form.

Group 1

The elements in Group 1 of the periodic table (called the alkali metals):

- are metals;
- react with non-metals to form ionic compounds in which the metal ion carries a 1+ charge;
- react with water releasing hydrogen;
- form hydroxides that dissolve in water to give alkaline solutions.

The further down group 1 an element is, the more reactive the element, and the lower its melting point and boiling point. When a piece of lithium, sodium or potassium is placed in cold water the metal floats, may melt and moves around the surface of the water. The metal reacts with the water to form a metal hydroxide solution and hydrogen gas. The more reactive the metal, the more vigorous is the reaction with water.

Group 7

The elements in Group 7 of the periodic table (called the halogens):

- are non-metals;
- have coloured vapours;
- consist of molecules which are made up of pairs of atoms;
- form ionic salts with metals in which the chloride, bromide or iodide ion carries a 1– charge;
- form molecular compounds with other non-metallic elements.

The further down group 7 an element is, the less reactive the element, and the higher its melting and boiling point. A more reactive halogen can **displace** a less reactive halogen from an aqueous solution of its salt.

Group 0

The elements in Group 0 of the periodic table (called the noble gases):

- are all chemically very unreactive gases;
- exist as individual atoms rather than as diatomic gases like other gaseous elements;
- are used as inert gases in filament lamps and in electrical discharge tubes;

Transition metals

In the centre of the periodic table is a block of metallic elements, called transition metals, which include iron and copper. The transition metals:

- have high melting points;
- can often be used as catalysts;
- form coloured compounds.

Compounds of metals and halogens

Sodium chloride (common salt) is a compound of an alkali metal and a halogen. It is found in large quantities in the sea and in underground deposits.

The electrolysis of sodium chloride solution (brine) is an important industrial process. Chlorine gas is formed at the positive electrode and hydrogen gas at the negative electrode. A solution of sodium hydroxide is also formed. Each of these products can be used to make other useful materials:

- chlorine is used to kill bacteria in drinking water and in swimming pools, and to manufacture disinfectants, bleach and the plastic (polymer) PVC;
- hydrogen is used in the manufacture of ammonia and margarine;
- sodium hydroxide is used in the manufacture of soap, paper and ceramics.

A simple laboratory test for chlorine is that it bleaches damp litmus paper (blue litmus → red → white).

Silver chloride, silver bromide and silver iodide (silver halides) are reduced to silver by the action of light, X-rays and the radiation from radioactive substances. They are used to make photographic film and photographic paper. Hydrogen halides are gases that dissolve in water to produce acidic solutions.

Chemical symbols, formulae and equations

A chemical reaction can be described using a word equation: reactants → products
You should be able to write word equations for all reactions in your tier of the syllabus.

Each element is represented by a different symbol (see Data Book for symbols of elements).
The symbols for elements are used to write chemical formulae for compounds: these show the ratios of atoms from different elements that are combined to form the compounds.

You should be able to write down the correct formulae for simple ionic compounds (see the Data Book for the formulae of, and charges on, common ions). You should be able to recall the formulae of all simple covalent compounds in your tier of the syllabus. You should be able to interpret chemical formulae or symbolic representations of molecules in terms of the elements present and the ratios of their atoms.

Chemical reactions can be represented using the chemical formulae for the reactants and the products. You should be able to interpret supplied symbol equations, including the state symbols (s), (l), (g) and (aq).

# GCSE Science (Modular) - Module 8 Revision Guide (Chemistry)

## Higher Tier

### Properties of solids, liquids and gases

The different properties of solids, liquids and gases can be explained by imagining that everything is made up of very small particles:

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### Change of state and dissolving

When the particles of a substance gain or lose energy, the substance may change its state.

If energy is supplied to a solid, its particles vibrate more violently; they may separate from each other and become free to move. This is melting. The temperature at which a solid melts is called its melting point.

Heating a liquid makes its particles move around more quickly. Particles that have enough energy may overcome attractive forces and escape from the liquid and become a gas. This is evaporation. When the temperature is higher, more particles have enough energy to escape so evaporation is faster. If the temperature is high enough, a liquid boils. The temperature at which a liquid boils is called its boiling point.

Dissolving: as liquid particles move, they may separate the particles of an added solute from each other.

### What happens when elements react?

All substances are made of atoms. There are over 90 different sorts of atoms. A substance that contains only one sort of atom is called an element. Atoms have a small central nucleus made up of protons and neutrons around which there are electrons. The relative masses of protons, neutrons and electrons, and their relative electric charges are shown in the table on the right.

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In an atom, the number of electrons = the number of protons in the nucleus.
The atom has no overall electrical charge.

All atoms of a particular element have the same number of protons. The number of protons in an atom is called its **proton number** (atomic number). Atoms of different elements have different numbers of protons.

The total number of protons and neutrons in an atom is called its **mass number**. Atoms of the same element can have different numbers of neutrons; these atoms are called **isotopes** of that element.

You should be able to represent and interpret atoms shown in this way: $^{\text{mass number } 23}_{\text{proton number } 11}\text{Na}$

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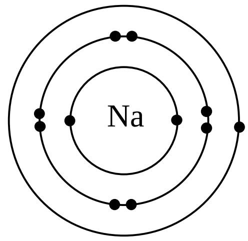


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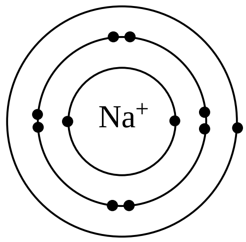



and $(2,8)^+$

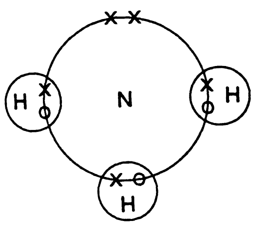
An **ionic compound** is a giant structure of ions. The ions are formed when atoms of one element gain electrons from or lose electrons to the atoms of another element. The atoms that lose electrons become positively charged ions and the atoms that gain electrons become negatively charged ions. These ions now have the electronic structure of a noble gas. Atoms that share electrons can also form giant structures. Substances with giant structures have high melting points and boiling points.

Atoms that share electrons often form **molecules**. There are chemical bonds between the atoms in each molecule but not between the molecules. Molecular substances have low melting points and boiling points.

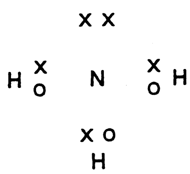
In molecules, the atoms are held together because they share pairs of electrons in the highest occupied energy levels of atoms. The strong bonds between the atoms are called covalent bonds.

You should be able to represent the covalent bonds in water ($H_2O$), ammonia ($NH_3$), hydrogen ($H_2$), hydrogen chloride (HCl), methane ($CH_4$) and oxygen ($O_2$) in the following forms:

for ammonia ($NH_3$)




and/or

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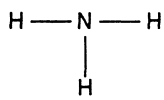

How can we explain the different properties of different types of substance?

Different types of substance have different properties because of differences in the forces between the particles from which they are made. Simple molecular compounds are gases, liquids or solids, which have relatively, low melting points and boiling points and do not conduct electricity. This is because:

- the forces between the molecules (intermolecular forces) are weak; and
- the molecules do not carry an overall electric charge.

Diamond and graphite (forms of carbon) and silicon dioxide (silica) are giant covalent structures of atoms. Because of the large number of covalent bonds in their structures, they have very high melting points.
In diamond each carbon atom forms four covalent bonds in a rigid, giant covalent structure.
In graphite each carbon atom forms three covalent bonds and the carbon atoms form layers, which are free to slide over each other. In graphite there are free electrons, which allow graphite to conduct electricity.

Ionic compounds are held together by strong forces of attraction between oppositely charged ions. This is the ionic bond. Ionic compounds form regular structures (giant ionic lattices) in which the strong forces between oppositely charged ions result in these compounds having high melting points and high boiling points. When they are melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move.

Metals consist of giant structures in which the electrons from the highest occupied (outer) energy levels of metal atoms are free to move through the whole structure. These electrons:

- hold the atoms together in a regular structure;
- allow the atoms to slide over each other; and
- allow the metal to conduct heat and electricity.

Plastics are polymers, which consist of a tangled mass of very long molecules in which the atoms are joined by strong covalent bonds to form long chains. In a **thermosoftening** plastic the forces between the chains are weak so the plastic softens when heated and hardens again when cooled. When a **thermosetting** plastic is first heated covalent bonds are formed between adjacent chains. These strong cross-linkages prevent thermosetting plastics from being softened and therefore from being re-moulded.

How can chemical elements be grouped into families?

The chemical elements can be arranged in the order of the proton number (atomic number) of their atoms. The list you get can then be arranged in rows so that elements with similar properties are in the same columns, known as **Groups**. The resulting table is called the **periodic table**.

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Group 1

The elements in Group 1 of the periodic table (called the alkali metals):

- are metals;
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- react with water releasing hydrogen;
- form hydroxides, which dissolve in water to give alkaline solutions.

The further down group 1 an element is, the more reactive the element, and the lower its melting point and boiling point. When a piece of lithium, sodium or potassium is placed in cold water the metal floats, may melt and moves around the surface of the water. The metal reacts with the water to form a metal hydroxide solution and hydrogen gas. The more reactive the metal, the more vigorous is the reaction with water.

Group 7

The elements in Group 7 of the periodic table (called the halogens):

- are non-metals;
- have coloured vapours;
- consist of molecules which are made up of pairs of atoms;
- form ionic salts with metals in which the chloride, bromide or iodide ion carries a 1– charge;
- form molecular compounds with other non-metallic elements.

The further down group 7 an element is, the less reactive the element, and the higher its melting and boiling point. A more reactive halogen can **displace** a less reactive halogen from an aqueous solution of its salt.

Group 0

The elements in Group 0 of the periodic table (called the noble gases):

- are all chemically very unreactive gases;
- exist as individual atoms rather than as diatomic gases like other gaseous elements;
- are used as inert gases in filament lamps and in electrical discharge tubes;

Transition metals

In the centre of the periodic table is a block of metallic elements, called transition metals, which include iron and copper. The transition metals:

- have high melting points;
- can often be used as catalysts;
- form coloured compounds.

How can the similarities between elements in the same group be explained?

Elements in the same group have similar properties because they have the same number of electrons in the highest occupied (outer) energy level. The higher this energy level:

- the more easily electrons are lost;
- the less easily electrons are gained.

These ideas explain the trends in the reactivity of elements in Groups 1 and 7 of the periodic table.

Group 0 elements (noble gases) are unreactive and monatomic because their highest occupied energy level is full so that atoms have no tendency to gain, to lose or to share electrons.

Compounds of metals and halogens

Sodium chloride (common salt) is a compound of an alkali metal and a halogen. It is found in large quantities in the sea and in underground deposits.

The electrolysis of sodium chloride solution (brine) is an important industrial process. Chlorine gas is formed at the positive electrode and hydrogen gas at the negative electrode. A solution of sodium hydroxide is also formed. Each of these products can be used to make other useful materials:

- chlorine is used to kill bacteria in drinking water and in swimming pools, and to manufacture disinfectants, bleach and the plastic (polymer) PVC;
- hydrogen is used in the manufacture of ammonia and margarine;
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A simple laboratory test for chlorine is that it bleaches damp litmus paper (blue litmus → red → white).

Silver chloride, silver bromide and silver iodide (silver halides) are reduced to silver by the action of light, X-rays and the radiation from radioactive substances. They are used to make photographic film and photographic paper. Hydrogen halides are gases, which dissolve in water to produce acidic solutions.

Chemical symbols, formulae and equations

A chemical reaction can be described using a word equation: reactants → products
You should be able to write word equations for all reactions in your tier of the syllabus.

Each element is represented by a different symbol (see Data Book for symbols of elements).
The symbols for elements are used to write chemical formulae for compounds: these show the ratios of atoms from different elements that are combined to form the compounds.

You should be able to write down the correct formulae for simple ionic compounds (see the Data Book for the formulae of, and charges on, common ions). You should be able to recall the formulae of all simple covalent compounds in your tier of the syllabus. You should be able to interpret chemical formulae or symbolic representations of molecules in terms of the elements present and the ratios of their atoms.

Chemical reactions can be represented using the chemical formulae for the reactants and the products.
You should be able to interpret supplied symbol equations, including the state symbols (s), (l), (g) and (aq).

The total mass of the product(s) of a chemical reaction is always exactly equal to the total mass of the reactant(s). This is because the products of a chemical reaction are made up from exactly the same atoms as the reactants. Symbol chemical equations must, therefore, always be balanced: the total number of atoms of each element on the reactants side of the equation must be equal to the total number of atoms of the same element on the products side of the equation. You should be able to:

- balance supplied symbol equations;
- write a balanced symbol equation from a supplied word equation.

During electrolysis, ions gain or lose electrons at the electrodes. Electrically neutral atoms or molecules are released. You should be able to complete and balance supplied half equations for the reactions occurring at the electrodes during electrolysis. The supplied equations will include information about the charge of the ion and the atomic or molecular nature of the product. For example, when supplied with:

$Cl^- - e^- \rightleftharpoons Cl_2$ you should be able to produce $2Cl^- - 2e^- \rightleftharpoons Cl_2$