

# Module 1: The Chemical Earth

## Supplementary material

### 1. Properties of elements and compounds (Section 1.2)

Table 1.2 on pages 7-8 contrasts the properties of a mixture, a compound and one of the elements making up the compound. Further contrasts between the properties of compounds and the elements that make them up are shown in the following tables.

**Table S1.1**  
Properties of the compound sodium chloride and the elements forming it

Sodium	Chlorine	Sodium chloride
lustrous silvery solid	pale yellow-green gas	white crystalline solid
soft and pliable		hard and brittle
melts at 98°C	condenses to liquid at -35°C	melts at 800°C
conducts electricity		solid does not conduct electricity
combines rapidly with atmospheric oxygen	unaffected by air	unaffected by air
violent chemical reaction with water	dissolves slightly in water	readily dissolves in water; solution conducts electricity
reacts chemically with chlorine, sulfur, phosphorus	reacts chemically with aluminium, zinc, copper	does not react with any elements

**Table S1.2**  
Properties of the compound carbon disulfide and the elements forming it

Carbon (graphite)	Sulfur	Carbon disulfide
black powdery solid	yellow solid	colourless liquid
odourless	odourless	unpleasant odour
melts at 3727°C	melts at 113°C	boils at 46°C melts (freezes) at -111°C
conducts electricity	does not conduct electricity	does not conduct electricity
burns in air	burns in air	does not burn in air
insoluble in hexane	insoluble in hexane	soluble in hexane

**Table S1.3**  
**Properties of haematite (iron(III) oxide) and the elements that make it up**

Iron(III) oxide, Fe <sub>2</sub> O <sub>3</sub> haematite	Iron, Fe	Oxygen, O <sub>2</sub>
red powder (solid) <sup>a</sup>	shiny grey solid	colourless gas
melting point 1565°C	melting point 1535°C	boiling point –183°C
density 5.2 g/mL	density 7.9 g/mL	—
does not conduct electricity; poor conductor of heat	good conductor of electricity and heat	does not conduct electricity; poor conductor of heat
hard and brittle	malleable and ductile	—
can be converted to a simpler substance, iron by heating with carbon so is a compound	cannot be decomposed into simpler substances so is an element	cannot be decomposed into simpler substances so is an element
fairly unreactive	burns when heated in oxygen to form Fe <sub>2</sub> O <sub>3</sub> ; rusts in moist air	reacts with many elements, both metals and non-metals

<sup>a</sup> often mined as a brown-black rock

## 2. Other examples of elements, compounds and mixtures

(to supplement the example on pages 8(bottom)–9)

**(b)** Copper is a pure substance. How do we show that it is an element? First it does not decompose when we heat it in the absence of air or when we pass an electric current through it. Secondly it undergoes a variety of chemical reactions with oxygen, chlorine, sulfur, nitric and sulfuric acids, silver nitrate solution, and so on. *And* in all of these reactions the copper-containing substance has a greater mass than the starting copper had. This shows that copper is an element, since it cannot be split directly or indirectly into two or more simpler substances.

Similar arguments were used for all the elements to prove that they were, in fact, elements.

**(c)** Lead nitrate is a white solid. It is soluble in water. It is homogeneous and its properties do not change after repeated purification procedures. Lead nitrate is therefore a pure substance. When lead nitrate is heated, a brown gas is evolved and a white solid remains. This solid is insoluble in water. Hence it is not just left-over lead nitrate. This new white solid always has a smaller mass than the sample of lead nitrate originally taken. Lead nitrate can therefore be decomposed into two other substances, a brown gas and another white solid. Lead nitrate is thus a *compound*. When heated it decomposes into nitrogen dioxide (the gas) and lead oxide, an insoluble white solid.

## 3. Other separation methods (Sections 1.6 to 1.13)

Sections 1.6 to 1.13 treat the separation methods that are specifically mentioned in the syllabus. Some other methods that are widely used will now be described.

### (a) Centrifuging

Sedimentation occurs quickly if the solid particles are relatively big or dense. For smaller particles it can take an inconveniently long time. Sedimentation can be speeded up by centrifuging the mixture. This

means putting the mixture in a suitable container and spinning it so that the solid particles get subjected to centrifugal forces which are much stronger than the force of gravity. This pushes the solid particles outwards and so away from the liquid. The machine that does this is called a **centrifuge**. In a laboratory centrifuge the mixture is placed in a large test tube which is then spun so that the solids are forced to the bottom of the tube; the clear liquid can then be decanted or sucked off. The photo below shows a laboratory centrifuge and a sample before and after centrifuging: it comes from *Conquering Chemistry HSC Course (CCHSC)*, page 201.



Paints are dispersions of small solid particles in liquids – water for water-based paints and hydrocarbons (petrol-like liquids) for oil paints. We would need to let paint stand for several weeks for the solids to settle to the bottom of the container. However if we centrifuge samples of paints, we can force the particles to settle out much more quickly. Blood is a dispersion of solids including red blood cells in an aqueous solution called plasma. We can separate the solid matter from the plasma by centrifuging.

Centrifuging is widely used in industry to separate solids from liquids. Sometimes the centrifuge is designed to fling the water or solution away from the solids as in domestic clothes washing machines. In sugar mills and refineries crystalline sugar is separated from the syrup from which it formed in a similar way: the syrup is flung outwards through holes in the spinning drum to leave almost dry sugar crystals inside.

### (b) Coagulation and decanting

When a suspension of very fine particles in water is boiled, the particles often collide with each other with such force (at the higher temperature) that they stick together and form much bigger (heavier) particles. These bigger particles then more readily settle to the bottom of the container and so allow the clear liquid or solution to be decanted off. This process of small particles combining to form bigger ones is called **coagulation**. A combination of coagulation and decanting (page 13) is commonly used to obtain better quality drinking water on extended wilderness camping trips: muddy water is boiled for half an hour or so (to coagulate the particles) then let stand overnight. By morning the clay (mud) has settled to the bottom and the clear water can be decanted off for drinking and cooking.

### (c) Magnetism

If one substance in a mixture is magnetic while the others are not, then we can separate out the magnetic substance with a magnet. A mixture of iron filings and sulfur can be separated in this way.

Magnetic separations are widely used to separate magnetic materials (mainly iron and steel) from municipal garbage.

### (d) Sublimation

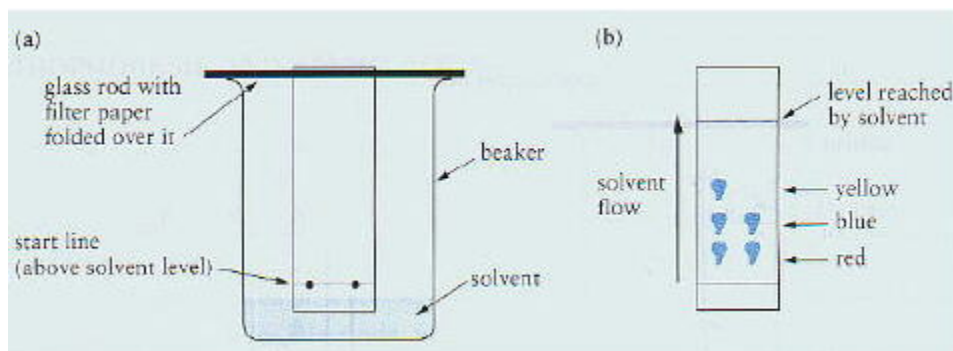
While most substances pass from solid to liquid to gas, there are some such as dry ice (solid carbon dioxide), iodine and ammonium chloride which change directly from solid to gas. This is called **sublimation**. If some iodine crystals are placed in a conical flask with a test tube containing ice water suspended in it as in photo on page 78 and gently heated, purple vapour will be seen to form from the crystals and it will condense back to crystals on the cool surface of the test tube. This is sublimation followed by condensation back to solid.

**Sublimation** is the process in which a solid changes directly to a gas without passing through the liquid state.

Sublimation can be used to separate mixtures such as ammonium chloride and sodium chloride (both soluble in water).

#### (e) Paper chromatography

Paper chromatography is a technique for separating mixtures. Separation occurs because the substances to be separated have different solubilities in two solvents. In school laboratories paper chromatography is often used to separate the components of various inks. A spot of ink is placed on a strip of filter paper which is then suspended in a suitable liquid. As the liquid creeps up the paper (by capillary attraction), it 'washes' the components of the ink upwards at different rates. After a few minutes different-coloured, separated spots can be seen as is shown in the diagram below (from page 477 of *CCHSC*).



The separation comes about because the different substances have different solubilities in the two liquids involved. One liquid is water trapped in the cellulose fibres of the paper (called the **stationary phase**) and the other is the liquid which moves up the paper (called the **mobile phase**). Substances with low solubility in the stationary phase and high solubility in the mobile phase move up the paper quickly. Those with high solubility in the stationary phase and low solubility in the mobile phase move slowly. Hence a separation occurs.

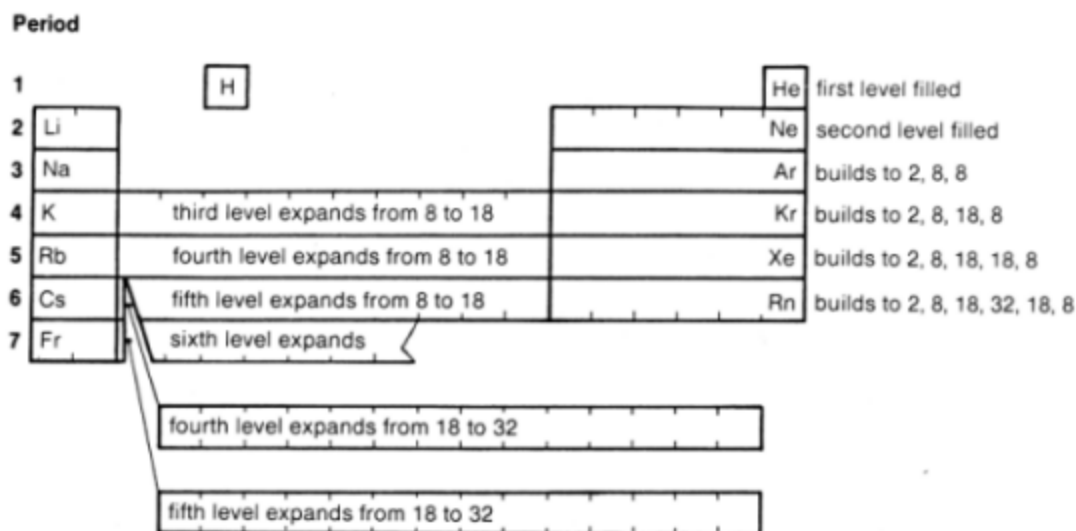
There is a whole range of techniques for separating or analysing mixtures which go under the name of **chromatography**. Paper chromatography is discussed further in *CCHSC* on pages 476-8 with gas chromatography briefly introduced on page 189 (of that book).

### 4. The Periodic Table and electron configuration (Section 2.13)

It is instructive to see how the Periodic Table relates to the filling of electron energy levels. We can use Figure 2.9(b) on page 53 to obtain the order in which energy levels are filled, and by working through the Periodic Table (see inside front cover) we get the schematic table shown below.

The *first* (extremely short) *period* (hydrogen and helium) corresponds to the filling of the first energy level. The *second period* corresponds to filling the second energy level (Li to Ne). The big horizontal gap has been left between Be and Al because in later periods we have to fit in extra elements.

The *third period* (Na to Ar) corresponds to semi-filling (going up to 8 electrons) the third energy level; this takes us to the stable argon configuration, 2, 8, 8.



The *fourth period* (the first long period) corresponds to first putting two electrons in the fourth level (K and Ca), then completing the third level (scandium through to zinc), and finally semi-filling the fourth level (to krypton 2, 8, 18, 8).

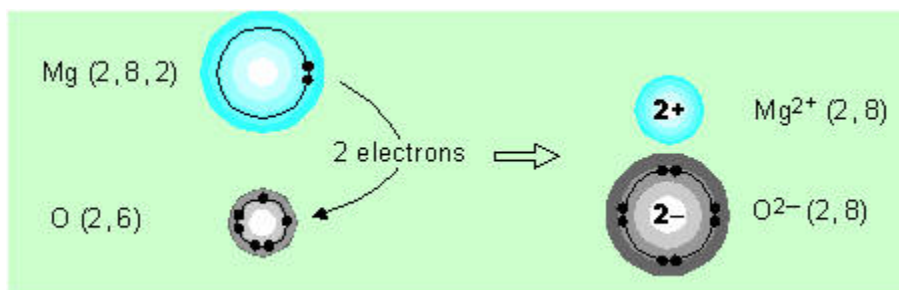
The *fifth period* is formed by putting two electrons into the fifth level (Rb and Sr), then building the fourth level from 8 to 18 in what is another transition series (yttrium to cadmium), and finally semi-filling the fifth level to 8, ending with xenon (2, 8, 18, 18, 8).

Similar patterns apply for Periods 6 and 7.

## 5. Another example of ionic bonding (Section 2.15)

### *Magnesium and oxygen combine to form magnesium oxide.*

Magnesium, with electron configuration (2, 8, 2), (Table 2.4), loses two electrons to become like neon (2, 8). Oxygen (2, 6) gains two electrons, also to become like neon.



By losing two electrons, the neutral magnesium atom becomes the doubly charged positive ion,  $\text{Mg}^{2+}$ . Similarly, by gaining two electrons, the neutral oxygen atom becomes the doubly charged negative ion,  $\text{O}^{2-}$ , called the **oxide ion**.

As each magnesium atom loses two electrons and each oxygen atom gains two electrons, the compound formed will consist of one oxygen atom per magnesium atom. Its formula will be  $\text{MgO}$ , which we may write as  $\text{Mg}^{2+}\text{O}^{2-}$  to emphasise the ionic bonding. Again there are no discrete molecules of  $\text{MgO}$  — just an infinite lattice of positive and negative ions very tightly bound together by electrostatic attraction.

## 6. More everyday applications (Section 3.5, page 85)

Several examples of the use of decomposition and direct combination reactions in everyday life are given in Section 3.5. Some additional ones are:

- sodium chloride solution is electrolysed to form chlorine and sodium hydroxide, two very important industrial chemicals (to be discussed in *CCHSC* Chapter 10); this same electrolysis is used in some home swimming pools for chlorination (sanitisation) of pool water
- in some industries water is electrolysed as a source of hydrogen gas (though this is not a major industrial source of hydrogen)
- decomposition of silver salts particularly silver bromide by light is the basis of photography
- ultraviolet light is used to decompose certain molecules in bacteria in some commercial sterilisers.
- the burning of sulfur (combination with oxygen) is used industrially to make sulfur dioxide which is then used to make sulfuric acid, the most widely used industrial chemical