Chapter 4: The Basics

An atom is the smallest part of an element that still has the properties of that element.

Subatomic particle	Location	Relative charge*	Relative mass*
Proton	Nucleus	+1	1
Electron	Energy levels	-1	$\frac{1}{1,840}$
Neutron	Nucleus	Neutral	1

All atoms are neutral. Neutral means they have no overall charge. **Every atom must have an equal number of protons and electrons** in order to be neutral.

Each element has a unique number of protons in the nuclei of its atoms.

The atomic number of an element is the number of protons in the nucleus of an atom of that element.

The mass number of an element is the number of protons and neutrons in the nucleus of an atom of that element.

Isotopes

Isotopes are atoms of the same element (i.e. they have the same atomic number) that have different mass numbers (i.e. different numbers of neutrons).

e.g. carbon-12, carbon-13 and carbon-14.

All contain 6 protons (and 6 electrons).
Carbon-12, with a mass number of 12, has (12 - 6 =) 6 neutrons.
Carbon-13, with a mass number of 13, has (13 - 6 =) 7 neutrons.
Carbon-14, with a mass number of 14, has (14 - 6 =) 8 neutrons.

The presence of these isotopes is indirectly indicated on the periodic table when giving the mass number of an atom – it is why they are not whole numbers.

Relative atomic mass is defined as the average mass of isotopes of an element, taking natural abundances into account, relative to one-twelfth the mass of a carbon-12 atom.

Calculating relative atomic masses

Example 2
Boron has two isotopes. The natural abundance of boron isotopes is 19.9% boron-10 and 80.1% boron-11. Calculate the relative atomic mass of a boron atom.

$$\frac{\textbf{(mass number of isotope x abundance) + (mass number of isotope x abundance)}}{\textbf{100}}$$

$$\frac{(10 \times 19.9) + (11 \times 80.1)}{100}$$

$$= \frac{1080.1}{100}$$

= 10.801

Pure substances

Pure substances: substances that have distinct properties and their composition doesn't vary from sample to sample. **Elements and compounds are both pure substances.**

An element is a substance that cannot be split into simpler substances by chemical means.

Elements can combine and join with other elements to make more complex substances, known as compounds.

A compound is a substance that is made up of two or more different elements chemically combined.

For example, water (H_2O) is a compound. Water is not an element, as it's possible to split water into two different substances – hydrogen (H) and oxygen (O). Another example of a compound is sulfuric acid, H_2SO_4. It is composed of hydrogen (H), sulfur (S) and oxygen (O).

Compounds, because they are made up of two or more substances, do not exist as atoms (remember, atoms are the smallest piece of an element that can exist). **Instead, compounds exist as molecules** (if they are covalent compounds **or ions** (ionic compounds).

Molecules

A molecule is a group of (two or more) atoms bound together by covalent bonds.

Covalent compounds exist as molecules. **Covalent compounds form when atoms share electrons in order to become more stable.**

As we've already seen, elements exist in nature as atoms, and compounds exist in nature as molecules or ions.

However, there is a group of elements that exists in nature not as atoms but as **diatomic molecules.** These elements exist as molecules made of two atoms of the element bonded to each other.

Element	Diatomic molecule
Hydrogen	H_2
Nitrogen	N_2
Fluorine	F_2
Oxygen	O_2
Iodine	I_2
Chlorine	Cl_2
Bromine	Br_2

Crack it!
Have
No
Fear
Of
Ice
Cold
Baths

Ions

Ionic compounds exist as ions. **Ions are formed when atoms lose or gain electrons in order to become more stable.**

An ion is a charged atom or molecule due to the loss or gain of electrons.

If an atom gains or loses an electron, **the negative charges no longer cancel out the positive charges.**

Positive ions are called cations, e.g. Na^+.

Negative ions are called anions, e.g. Cl^-.

Example 4

How many (a) protons, (b) neutrons, (c) electrons are there in the ion ${}^{20}_{40}Ca^{2+}$?

(a) 20 protons (atomic number of 20)

(b) 20 neutrons (40 – 20)

(c) A neutral atom of calcium would have 20 electrons. However, the charge of +2 tells us that two electrons have been lost. Therefore, this ion has 18 electrons.
20 − 2 = 18 electrons

Example 5
How many (a) protons, (b) neutrons, (c) electrons are there in the ion ${}^{17}_{35}Cl^-$?

(a) 17 protons (atomic number of 17)

(b) 18 neutrons (35 – 17)

(c) A neutral atom of chlorine would have 17 electrons.
However, here the charge of − (− is the same as writing −1) tells us the atom has gained an electron. 17 + 1 = 18 electrons

Mixtures

A mixture is made up of substances (elements and compounds) mingled together but not chemically combined.

An example of a mixture is salt and water. The salt and water are **mingled together but are not chemically combined** – i.e. they still exist independently as salt and water. **Each substance retains its chemical identity.**

Mixtures don't have distinct properties (e.g. they have variable melting and boiling points), and their composition can vary from sample to sample.

There are two types of mixtures:
Homogeneous mixtures = are uniform (the same) throughout
Heterogeneous mixtures = are not the same throughout

Separating mixtures

Filtration

Filtration is a separating technique that separates insoluble solids from liquids.

To filter a mixture of an insoluble solid and a liquid such as benzoic acid crystals and water, the mixture is poured through a funnel lined with filter paper. The insoluble solid remains on the filter paper and is the **residue**. The liquid passes through the filter paper through the funnel into the conical flask and is the **filtrate**.

Types of filtration

Gravity filtration

Gravity filtration uses gravity to filter the mixture – the mixture is poured through a funnel, and gravity pulls the liquid component through the filter paper down into the conical flask. This is the type you are used to from Junior Cycle.

Vacuum filtration

Vacuum filtration uses a Büchner flask rather than a conical flask. The Büchner flask and attached rubber tubing creates suction which pulls the liquid through the filter paper; this is faster and more efficient than gravity filtration and can also dry out the residue. For vacuum filtration, flat filter paper is used, which fits into the Büchner flask. It is not folded.

Evaporation

Evaporation is a separating technique that separates a soluble solid and a liquid by evaporating the liquid, leaving the solid behind.

Evaporation can be used to separate dissolved solids from a water sample. The solvent evaporates, and the solute remains behind in the evaporating dish.

Distillation

Distillation is a separating technique that separates the components of a mixture based on their boiling points.

The mixture is heated and the more volatile component will evaporate first. This vapour then passes through a condenser, cools, condenses, and can be collected. The liquid that is collected this way is called the distillate.

Distillation can be used to separate solvents from solutions, e.g. water from a solution of seawater (salt and water), and is useful if you wish to retain both the solute and solvent. However, distillation is more commonly used to separate two liquids with different boiling points – e.g. ethanol and water.

Ethanol has a lower boiling point (approx. 78°C) than water (100°C). The mixture is heated to a temperature that is higher than 78°C but lower than 100°C. The ethanol will evaporate, the water will not. The vaporised ethanol passes through the Liebig condenser and is cooled, condensed, and collected as a liquid. The water remains in the original boiling flask. The mixture has been successfully separated.