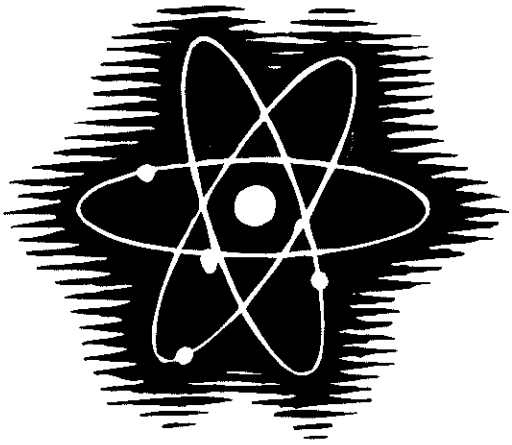
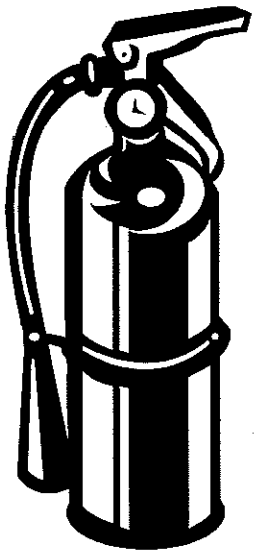
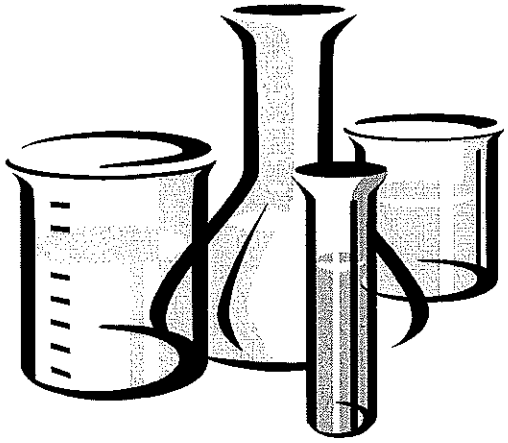




Chemical Changes and Structure
Atomic Structure and Bonding
National 4/5



The Elements

There are about 100 elements known to scientists at present. About 90 occur naturally in the earth. Every substance you see around you is made up from these elements.

Each element has a **chemical symbol**. This is a "shorthand" way of representing an element. Each element has its own chemical symbol. Modern symbols for elements consist of one or two. The **first** letter is **always a capital** letter; the second is always a small letter.

The elements above 103 have a symbol consisting of three letters to represent their names. For example, number 105 is called Unnilipentium, symbol Unp

Some naturally occurring elements are radioactive, for example, radium.

Plutonium and other elements above 92 are made in nuclear reactors.

Some elements are named after scientists, e.g. Einsteinium, and others are named after places, e.g. Californium.

SYMBOLS of the first twenty ELEMENTS

Atomic No	Symbol	Name of Element
1	H	
2	He	
3	Li	
4		Beryllium
5	B	
6	C	
7		Nitrogen
8	O	
9	F	
10		Neon

Atomic No	Symbol	Name of Element
11		Sodium
12	Mg	
13	Al	
14		Silicon
15	P	
16		Sulphur
17	Cl	
18	Ar	
19	K	
20		Calcium

Elements

There are about 100 elements, grouped together in the Periodic Table.

Each element has a **Name** and a **Symbol**.

For example,

carbon	**C**
aluminium	**Al**
helium	**He**
oxygen	**O_2**

Elements can be classified as:

- Metals and non metals
- Solids, liquids and gases
- Naturally occurring and made by scientists

Families of Elements

A Group is a **column** of elements in the Periodic Table

Group 1 are the **alkali metals** which are a family of very reactive metals.

Group 7 are the **halogens** which are a family of very reactive non metals

Group 0 are the **noble gases** which are a family of very unreactive elements.

The transition metals are a block of metals found between Groups 2 and 3 in the Periodic Table. Many of the transition metals are used as catalysts in chemical reactions.

The Periodic Table

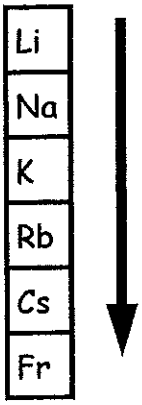
Chemists have classified elements and arranged them in the Periodic Table of Elements

A **PERIOD** is a row across the table

A **GROUP** is a column down the table.

Elements from the same group in the Periodic Table show similar chemical properties and are often given 'family' names.

Group 1 Alkali Metals



MOST REACTIVE

When group 1 metals react with water an alkali is formed. The alkali metals are stared under oil to prevent them from reacting with oxygen and water vapours in the air. Alkali metals have low densities for metals (floating on water) and they can be cut with a knife.

Group 8 Noble Gases

Unreactive by nature, the noble gases exist as separate single atoms- MONATOMIC. Until 1962 no compounds of the noble gases were known. Nowadays, several compounds are known and the name INERT has replaced noble.

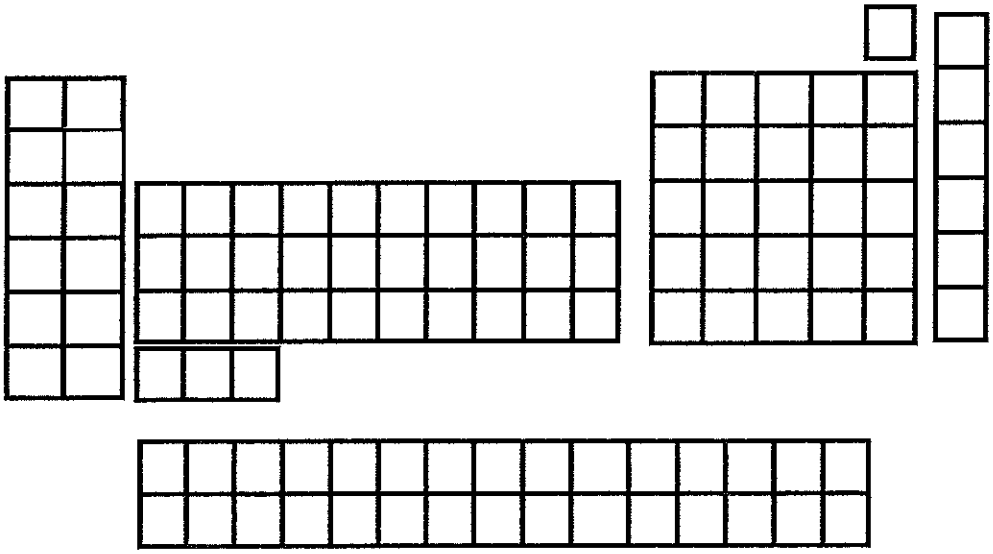
Group 7 The Halogens

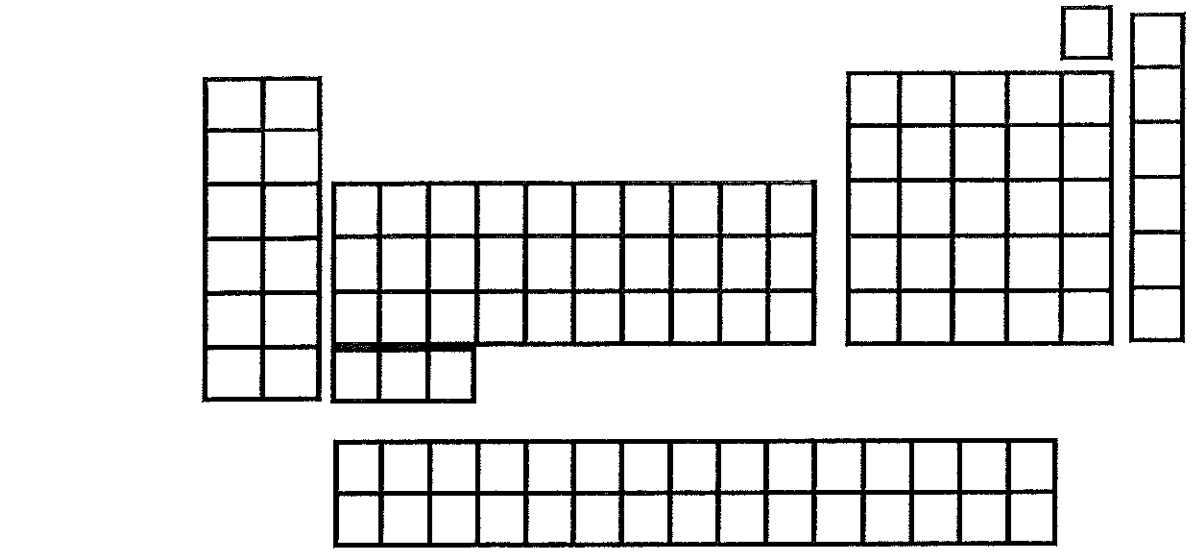
F
Cl
Br
I
At

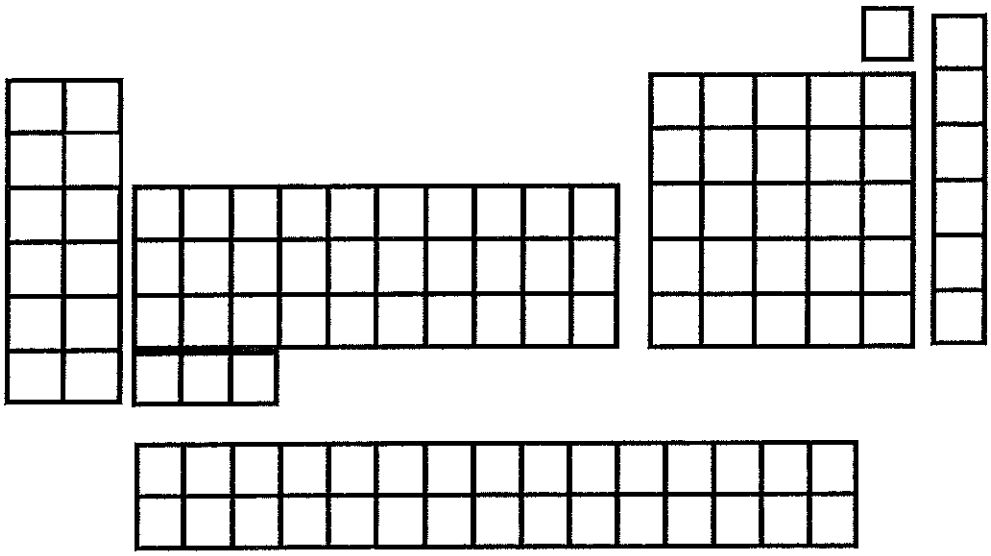
The elements of group 7 are DIATOMIC MOLECULES (ie molecules containing only two atoms) They are very reactive elements and as a result are rarely found uncombined in nature.

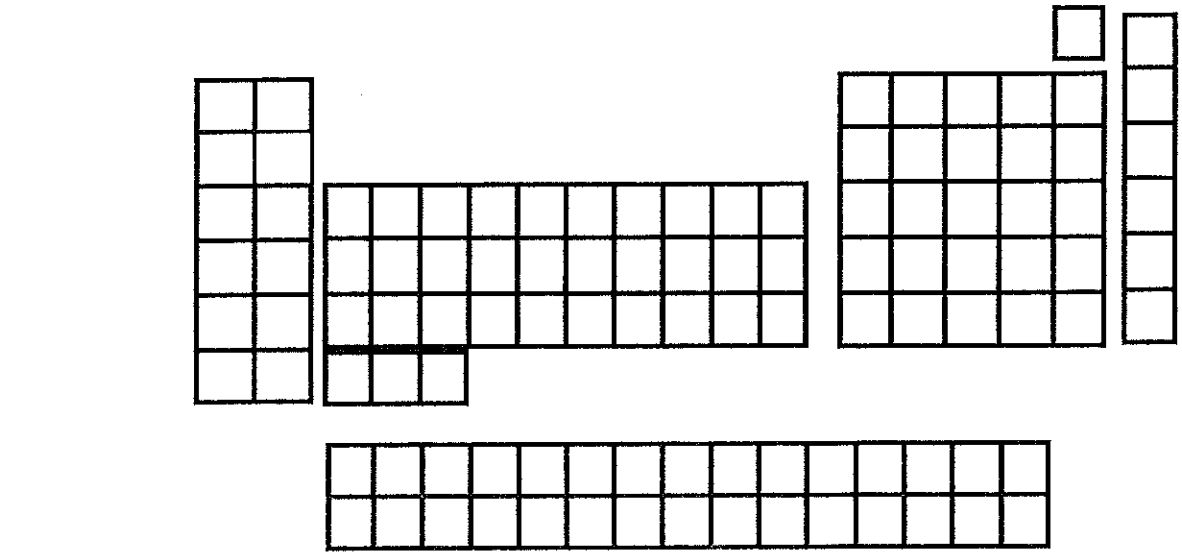
The Transition Metals

These metals form the central block of the periodic table and have very many important uses. Many catalysts are transition metals, eg Pt/Rh in catalytic converters. They can have variable valencies and when writing formula the roman numeral given after the metals name indicates it's valency for that compound.









Classification

When scientists group elements according to a specific characteristic or property, we say they are being classified.

The test that chemists use to classify an element as a metal or non metal is electrical conductivity.

Experiment

Result

Name of substance	Does Bulb light?

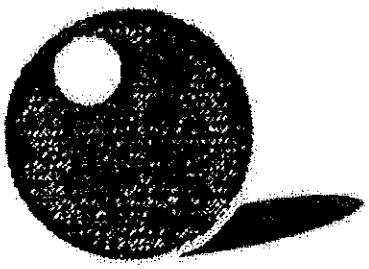
ALL METALS CONDUCT ELECTRICITY

Non metals do not conduct electricity and are said to be electrical insulators.
EXCEPT- Carbon (in the form of graphite)

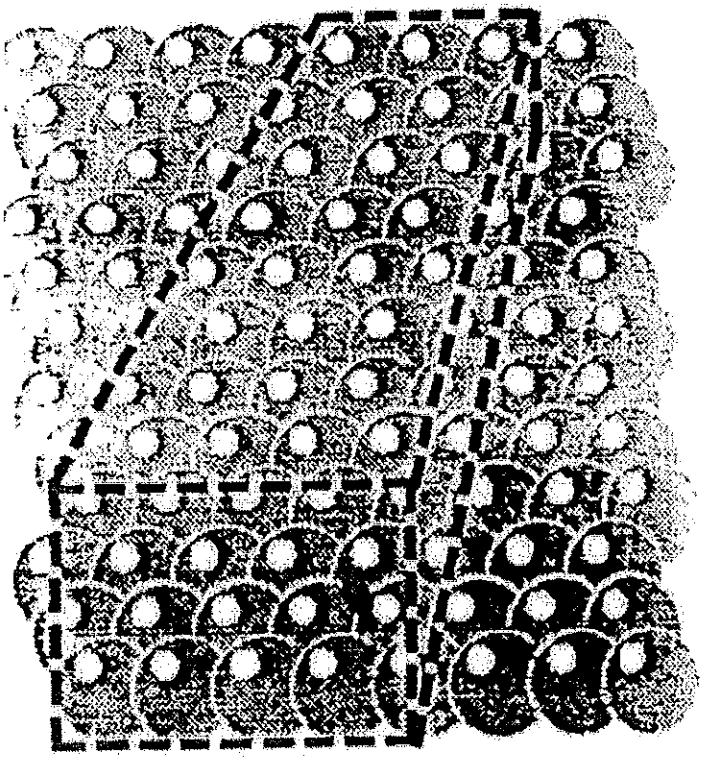
PICTURES OF THE ATOM

1800

In 1803 John Dalton put forward a theory that atoms were tiny, solid, spherical balls - like the one shown below.

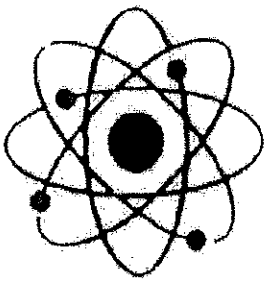


He suggested that a lump of substance would be made from millions of these tiny atoms and would be mostly SOLID.

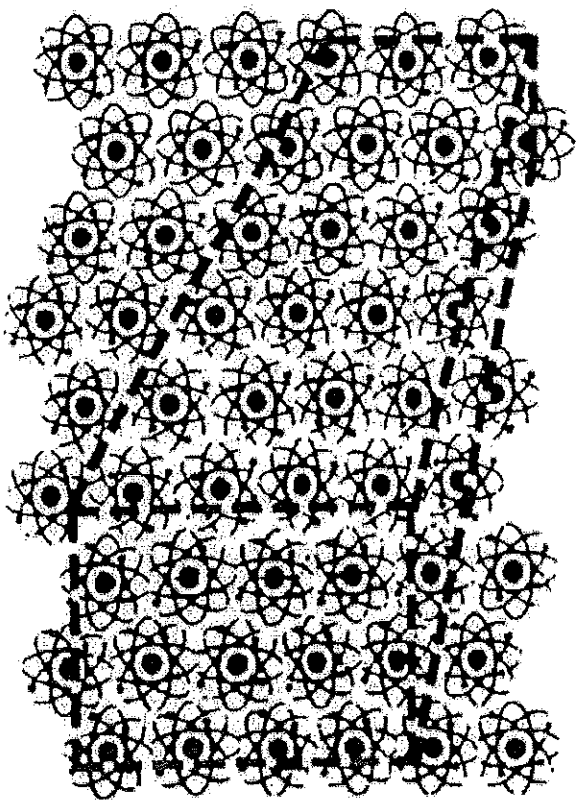


1900

In 1911 Lord Ernest Rutherford wrote a paper suggesting that atoms were not tiny, solid, spherical balls but were in fact made up of very small sub-atomic particles which were separate from each other.



He suggested that a lump of a substance would be made from millions of these tiny atoms and would be mostly SPACE.



What are atoms made up of?

The word atom comes from the Greek word 'atom' meaning indivisible. However, in the last 100 years scientists have shown that atoms are made up of even smaller particles. The way in which the particles are arranged is referred to as the **structure** of the atom.

Atoms can contain three particles. **Protons** and **neutrons** are found in a small "core" at the centre of the atom. This is called the **nucleus**. The nucleus is very small compared to the size of the rest of the atom - if atoms were magnified to the size of a football park, then the nucleus would be about the size of a pin-head. **Electrons** move through space outside the nucleus.

Protons have a charge of one-positive. This gives the nucleus a positive charge. Electrons have a negative charge which is equal and opposite to that on protons. Neutrons have no charge; they are neutral.

The atomic mass scale is used to measure the mass of protons and neutrons. On the atomic mass scale, protons and neutrons have an approximate mass of one atomic mass unit (amu). Even on this scale, the mass of an electron is so small that it is not significant.

Atomic number

There are over 100 different elements. All the atoms in the one element are the same. Since atoms of different elements are not the same there are over 100 different kinds of atom. Each different kind of atom has a "number". This is called the **atomic number**. All atoms of the one element have the same atomic number. Atoms of different elements cannot have the same atomic number. Therefore, an element can be defined as a collection of atoms all with the same atomic number.

The atomic number of atoms of all the elements is given on page ..... of the data booklet.

The atomic number is important. It gives the number of protons in an atom of an element. Since atoms are neutral and the charge on an electron is equal and opposite to the charge on a proton, the atomic number also gives the number of electrons in an atom.

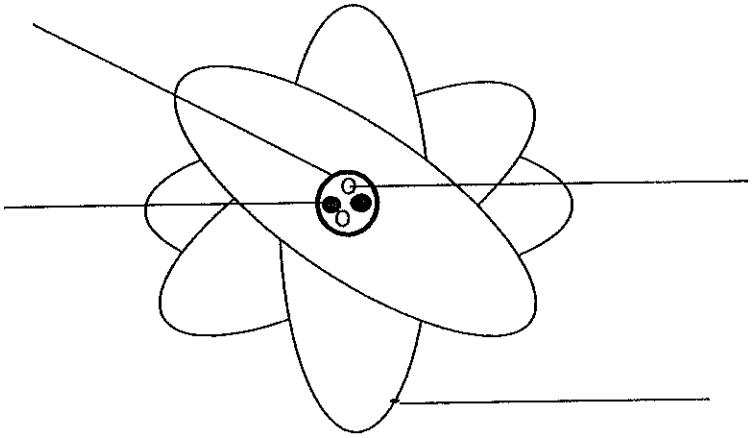
Therfore, an element can also be defined as a collection of atoms all with the same number of protons and electrons.

Modern Atomic Theory

All modern Periodic Tables use the atomic number of the elements to put them in order. Every element has a different atomic number and the atoms of each element will be different in SIZE and MASS from the atoms of other elements.

Structure of the Atom

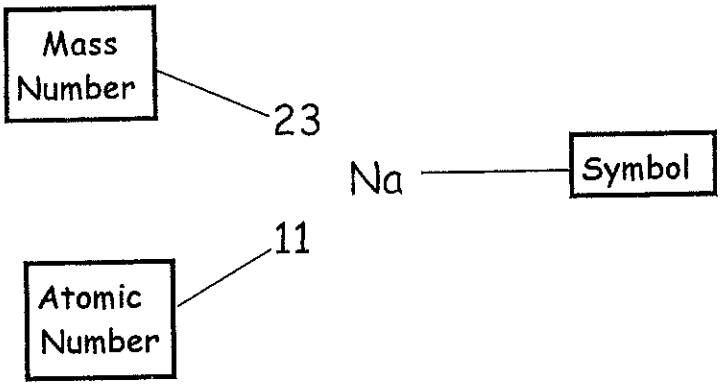
Before 1900 the atom had been thought to be like a little round ball. As a result of several important experiments, our knowledge of the structure of an atom is now more detailed. The atom consists of **3 subatomic particles**:-



Name of particle	Electrical Charge	Mass	Position

NB. (i) Most of the atom is **empty space**
(ii) Atoms have NO OVERALL CHARGE
(No of Protons = No of Electrons)

Representing an Element



Definitions

The **Atomic Number** is the number of **PROTONS** in the nucleus of an atom, ie. all sodium atoms have 11 protons in their nucleus

The **Mass Number** is the **total number of protons and neutrons** in the nucleus of an atom. When both the atomic and the mass numbers ore known we can calculate the number of neutrons in the atomic nucleus of the atom. Eg. for sodium above, mass number of 23 **minus** atomic number of 11 gives 12 neutrons.

Electron Arrangement

The electrons of an atom are arranged in 'shells' or 'orbitals' or 'levels', which surround the nucleus in a very organised way. Each level can hold a maximum number of electrons as shown in the table below.

Energy Level	Maximum number of electrons
1	2
2	8
3	8
4	2 (only up to 20)

Each level of an atom must be full before the electrons will start to move into the next energy level. The number of electrons present in each energy level is called the electron arrangement. Some electron arrangements are shown in the table below:-

Element	No of Electrons	Electron Arrangement
Hydrogen	1	1
Lithium	3	2,1
Sodium	11	2,8,1
Potassium	19	2,8,8,1

NB. 1. The group number is the same as the number of electrons in the outer level.

2. Elements in the same group have **similar chemical properties**

Energy of Electrons

The electrons in an atom have varying amounts of energy. Those **nearest** the nucleus have the **lowest energy**, while those farthest away from the nucleus have the highest energy.

Information from Representation

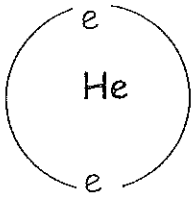
Atomic Number	=	12
Element Name	=	Magnesium
Mass Number	=	23
Number of protons	=	12
Number of Neutrons	=	11
Number of Electrons	=	12
Electron Arrangement	=	2,8,2
Group number	=	2

$$^{23}_{12}Mg$$

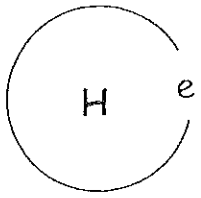
The First Energy Level

The first energy level of an at can only hold a maximum of two electrons in order to be full and hence stable. An atom of Helium has two outer electron in this first level and hence is stable and does not need to bond. However, an atom of Hydrogen only has one outer electron and will therefore require another to achieve a stable arrangement.

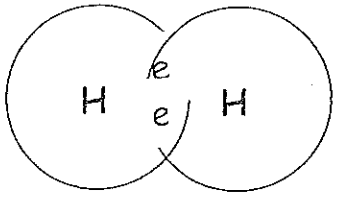
An atom of Helium



An atom of Hydrogen



Two atoms of hydrogen could however 'appear' to achieve stability if they SHARED their outer electron.



This is a **covalent bond** and can be represented by " - "

We can therefore show a hydrogen molecule as H-H. This is an example of a **DIATOMIC MOLECULE**, ie a molecule containing only 2 atoms.

NB. There are other examples of other diatomic molecule elements in the periodic table, eg. Oxygen, Nitrogen and all of the Halogens.

The Second/Third Energy Level

8 electrons are needed to fill the outer energy level for an atom in the 2nd or 3rd row of the Periodic Table. Draw a diagram of the arrangement of the electrons in the outer energy level for the following elements:

NEON

CHLORINE

OXYGEN

NITROGEN

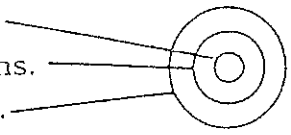
Some other Diatomic Molecules

When 2 chlorine atoms come close, their ELECTRON CLOUDS OVERLAP to share a pair of electrons(see diagram below). Each atom would now appear to have the same electron arrangement as the noble gas Argon.

Electron arrangement

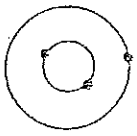
Most of the atom is empty space. Electrons move through this space. The electrons do not however move in a haphazard fashion - they are arranged in **energy levels (shells)**. There is a limit to the number of electrons each energy level can hold.

The first energy level can hold 2 electrons.
The second energy level can hold 8 electrons.
The third energy level can hold 8 electrons.

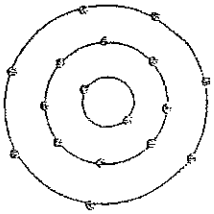


Electrons always enter the lowest energy level in which there is space.
This is the energy level nearest the nucleus,

lithium (atomic number 3) has 3 electrons arranged 2,1



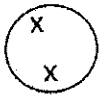
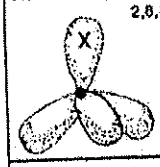
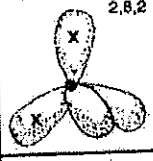
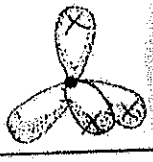
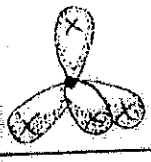
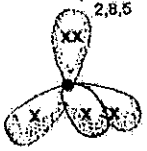
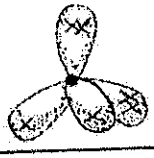
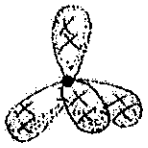
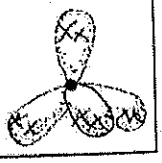
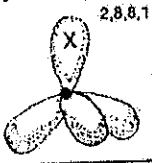
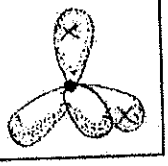
chlorine (atomic number 17) has 17 electrons arranged 2,8,7.



Electron arrangements are given on page ..... of the data booklet.

The chemical reaction of an element depends on the number of electrons in the outer energy level of its atoms. Elements with atoms having the same number of outer electrons are chemically similar.

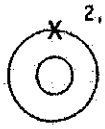
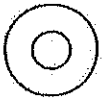
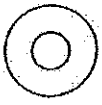
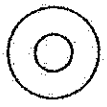
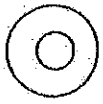
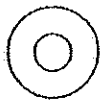
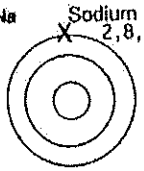
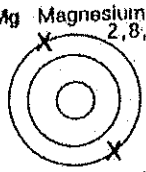
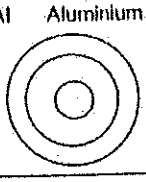
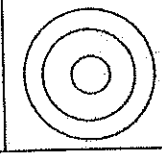
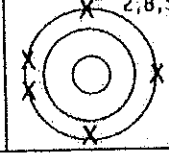
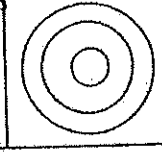
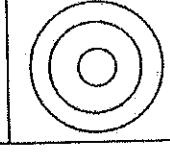
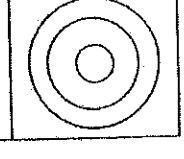
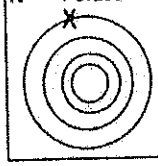
ELECTRON ARRANGEMENT

H Hydrogen 1 							He Helium 2 
Li Lithium 2,1 	Be Beryllium 	B Boron 	C Carbon 	N Nitrogen 	O Oxygen 	F Fluorine 	Ne Neon 
Na Sodium 2,8,1 	Mg Magnesium 2,8,2 	Al Aluminium 	Si Silicon 	P Phosphorus 2,8,5 	S Sulphur 	Cl Chlorine 	Ar Argon 
K Potassium 2,8,8,1 	Ca Calcium 						

Mark only the outermost electronswith an "X". Hydrogen, helium, lithium, sodium, magnesium phosphorus and potassium have been completed for you.

Remember, because electrons repel each other, each orbital is half filled before pairing occurs.

ELECTRON ARRANGEMENT

H Hydrogen 1 							He Helium 
Li Lithium 2,1 	Be Beryllium 	B Boron 	C Carbon 	N Nitrogen 	O Oxygen 	F Fluorine 	Ne Neon 
Na Sodium 2,8,1 	Mg Magnesium 2,8,2 	Al Aluminium 	Si Silicon 	P Phosphorus 2,8,5 	S Sulphur 	Cl Chlorine 	Ar Argon 
K Potassium 	Ca Calcium 						

Mass number

Since both the proton and the neutron have a mass of 1 amu and electrons have insignificant mass, the mass of an atom is concentrated in the nucleus.

The **mass number** is the number of protons plus the number of neutrons in an atom.

The atomic number and the mass number provide all the information necessary to calculate the number of protons, neutrons and electrons in an atom.

Number of protons = number of electrons = atomic number

Number of neutrons = mass number - atomic number

Note that the mass number of an atom of an element can **not** be found in the data booklet.

Chemical symbols again

The atomic number and the mass number can be written with the symbol of the element in the following way.

$$\begin{matrix}\text{Mass number} = 35 \\ \text{Atomic number} = 17\end{matrix}\ \mathrm{Cl}$$

For this atom of chlorine:

number of protons = 17 (atomic number)

number of electrons = 17 (number of protons = number of electrons)

number of neutrons = 18 (mass number - atomic number)

Different mass numbers

Atoms of the same element can have different numbers of neutrons. This means that the mass numbers will **not** be the same. Atoms of the same element (same atomic number) with different mass numbers (different numbers of neutrons) are called **isotopes.**

Most elements exist as a mixture of isotopes, each with atoms of a different mass. The relative proportion of each isotope is always the same. This allows the mass of an "average" atom to be calculated. This is what is given under **relative atomic mass** in the data booklet.

The relative proportions of isotopes of four different elements are shown below.

^{35}Cl	75%	^{1}H	99.98%
^{37}Cl	25%	^{2}H	0.015%
		^{3}H	Trace

^{12}C	98.89%	^{16}O	99.76%
^{13}C	1.11%	^{17}O	0.037%
^{14}C	Trace	^{18}O	0.204%

Because of the different isotopes, the mass of an "average" atom of each of the elements is not a whole number.
However, with hydrogen, carbon and oxygen, one of the isotopes is much more plentiful than the others and so the calculated average is very close to a whole number and the whole number is listed in the data booklet. The relative atomic mass is not listed as a whole number if both isotopes are relatively plentiful, e.g. the relative atomic mass of chlorine is listed as 35.5.

Relative formula mass

The mass of an atom is measured on the relative atomic mass scale.
The mass of a 'unit' of a compound is called the relative formula mass. This is obtained by adding together all the relative masses of the atoms or ions in the formula.

Example 1:
carbon tetrachloride

formula	CCl_4		
elements	C	Cl	
number of each element	1	4	
relative atomic mass of each element	12	35.5	
total relative mass of each element			
relative formula mass	154		

Example 2:
magnesium nitrate

formula	$Mg(NO_3)_2$		
elements	Mg	N	O
number of each element	1	2	6
relative atomic mass of each element	24	14	16
total relative mass of each element	24	28	92
relative formula mass	148		

Elements

Atoms are very small particles from which all substances are made. An element is the **simplest substance** known to man and is the building block for all substances you see around you.

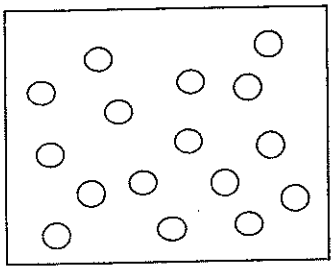
An element contains ONLY ATOMS OF THE SAME KIND. ie. The element sodium will contain ONLY sodium atoms.

Compound

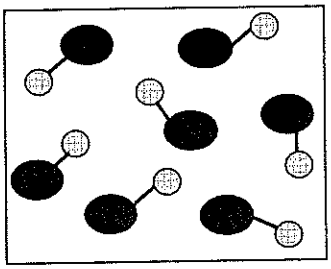
A compound is a substance made up of **two or more elements *joined together chemically***. ie for a compound to be formed a chemical reaction has to take place.

Mixtures

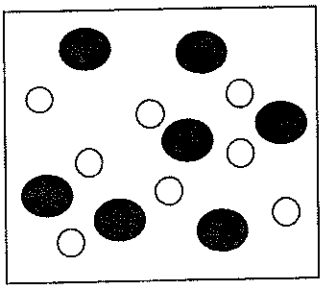
A PURE substance to a chemist is one which only contains a single substance ie it is not a mixture. If a substance is a mixture then the separation process is a relatively simple process.
If a chemical reaction has taken place then it is much more difficult (sometimes impossible) to get back the original elements.



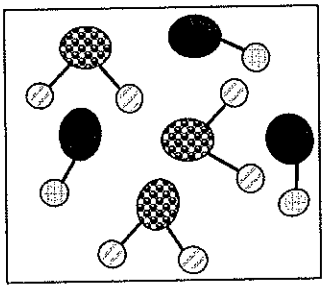
An Element



A Compound



A Mixture of elements



A mixture of compounds

Why do Atoms Bond?

You found out that the noble gases have a complete/full outer energy level of electrons. This arrangement of electrons is **VERY STABLE** and that is why they are very unreactive and do not form many compounds.

He **2** Ne 2,**8** Ar 2,8,**8**

The atoms of all other elements will try to achieve this stable electron arrangement by combining with other atoms. Elements will combine in a predictable way according to their position in the periodic table.

When a **metal and a non metal element** combine the outer electrons are **TRANSFERRED** and **charged particles** called IONS are formed. These particles are attracted to each other and form an **IONIC BOND**.

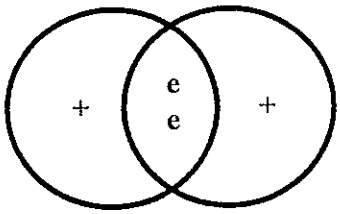
When **two non metal elements** combine the outer electrons are SHARED and this leads to the formation of a **COVALENT BOND**. The resulting particle is called a **MOLECULE**.

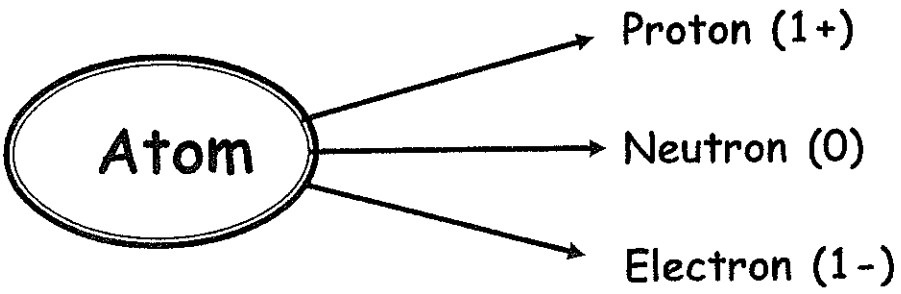
A molecule is the name given to a group of two or more atoms joined by covalent bonds.

The Covalent Bond

When two atoms collide, we would expect the negatively charged electron clouds to repel each other. However, if the collision has enough energy, the positive nucleus of one atom will 'pull' on the electron cloud of the other and vice versa. This allows a very strong attraction to develop between the two atoms which is called a **COVALENT BOND**.

- Positive nuclei of each atom is attracted to negatively charged shared pair of electrons





No Overall Charge

\+ protons = − electrons

Covalent Bond

- Non metal + Non metal
- Molecule
- <u>SHARING</u> electrons

Metal + Non metal

Loss of electrons

<u>transfer electrons</u>

Gain of electrons

\+ ion

<u>Ionic bond</u>

− ion

Ions

When atoms combine during a chemical reaction the outer electrons can be **TRANSFERRED**, ie. Atoms can either lose or gain electrons. When this happens electrically **charged particles called IONS** are formed.

An atom has a neutral charge because the number of **POSITVELY charged protons** is **EQUAL** to the number of **NEGATIVELY charged electrons.**

When atoms **gain electrons** we get an ion formed with an overall negative charge. This is because we no longer have equal numbers of protons and electrons (positive and negative charges). Since electrons now are in greater numbers than protons the particle has an overall negative charge.

Similarly, when an atom **loses electrons** it becomes an ion with an overall positive charge since it now has more protons than electrons.

NB. Electrons can only be **TRANSFERRED**. An atom will only 'lose' electrons if there is another atom waiting to 'gain' them.