THE INSTITUTE OF EDUCATION

Chemistry

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Higher Level

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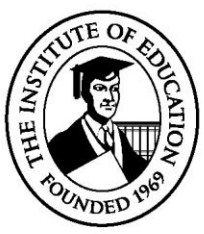
Atomic Theory



THE PERIODIC TABLE

The periodic table is a list of elements arranged in such a way to show trends in the physical and chemical properties of the elements. (Page 79 Maths tables)

ELEMENT

Defn- a substance that cannot be broken down into simpler substances by chemical means or produced by combining simpler substances.

- Elements are arranged horizontally in **periods**. Each element in a period *has the same number of electron shells. First period is H and He, second is Li to Ne, third is Na to Ar.* e.g. first period = 1 shell, second period = 2 shells, potassium has 4 shells as it is in the fourth period…..etc

- Elements are arranged vertically in **groups**. Each element in a group *has the same number of electrons in their outermost shell* (valence shell).
  e.g. group 1 = 1 electron in outer shell, group 5 = 5 electrons in outer shell. For example, sulfur has 6 electrons in outer shell as it is in group 6. Mg has 2 electrons in outer shell as its in group 2.

- The number of electrons in the outer shell gives rise to the **valency** – which means the number of chemical bonds an element can make. E.g. An element having a valency of 1 means that an atom of this element can form one bond with another atom.
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Valency is linked to the 'octet rule' you may have learned for your junior cert – it is no longer a rule but a useful guide. It states that most atoms try to attain eight electrons in their outermost shell when they bond. We will meet atoms that do not obey this 'rule' in due course.

GROUP 1;	1 electron in outer shell ; valency 1	**ALKALI METALS**
GROUP 2;	2 electrons in outer shell ; valency 2	**ALKALINE EARTH METALS**
GROUP 3;	3 electrons in outer shell ; valency 3	
GROUP 4;	4 electrons in outer shell ; valency 4	
GROUP 5;	5 electrons in outer shell ; valency 3	
GROUP 6;	6 electrons in outer shell ; valency 2	
GROUP 7;	7 electrons in outer shell ; valency 1	**HALOGENS**
GROUP 0;	8 electrons in outer shell ; valency 0	**NOBLE GASES**

ALKALI METALS – EXTREMELY REACTIVE / SOFT METALS / LOW DENSITIES / SHINY WHEN FRESHLY CUT BUT TARNISH RAPIDLY DUE TO REACTION WITH AIR / STORED UNDER OIL / BURN IN AIR TO FORM THE METAL OXIDE / REACT VIGOROUSLY WITH WATER TO FORM METAL HYDROXIDE AND HYDROGEN GAS

Metal + oxygen gas $\rightarrow$ metal oxide

Reactive metal + water $\rightarrow$ metal hydroxide + hydrogen gas

ALKALINE EARTH METALS – VERY REACTIVE BUT LESS REACTIVE THAN THE ALKALI METALS / MAGNESIUM REACTS SLOWLY WITH WATER.

HALOGENS – VERY REACTIVE NON-METALS / LOW MELTING AND BOILING POINTS / FLOURINE AND CHLORINE ARE YELLOW-GREEN GASES, BROMINE A RED LIQUID, IODINE A DARK SOLID AT R.T.

NOBLE GASES – GASEOUS AT R.T. / B.P. INCREASES DOWN GROUP / LEAST REACTIVE OF ALL ELEMENTS as have 8 electrons in outer shell (except He which has 2 electrons in its only shell).

Note – for now and for all classes in future it is important that you write down the name of every formula you come across in your notes. You must then learn how to write their names. This WILL be helpful in your understanding of chemistry.

ATOMIC STRUCTURE

All matter is composed of particles. These particles may be atoms, molecules or ions. Anytime the term 'particles' is mentioned in a question we should think of these.

E.g.atoms – Na, Mg, Fe which are single neutral units.

E.g.molecules – $H_2, O_2, NaOH, Cu(NO_3)_2$, which consist of two or more atoms: molecules are also neutral.

E.g.ions – Mg^{2+} , SO_4^{2-}, which are either single units (simple ions) or groups (complex ions) with a charge (+or -).

The atom

- An atom of any element is made up of the following three sub-atomic particles:

Protons - positively charged
Neutrons - neutral
Electrons - negatively charged

- The mass of an atom is concentrated in a very small central nucleus consisting of protons and neutrons.
- Around the nucleus are the electrons. The mass of an electron is so small that it can often be ignored.
- ***In an ATOM the number of electrons always equals the number of protons in the nucleus. So, the total negative charge equals the total positive charge, hence ALL atoms are neutral.***

Remember:

1. **Protons and neutrons are found in the nucleus of an atom and electrons in orbitals (sub-levels) around the nucleus.**
2. **Atoms and molecules are neutral but ions have a charge.**
3. **You must understand that atoms and ions are completely different so these words are not interchangeable.**

When we examine the periodic table we see the following information - The whole number above the symbol for the element is called the **atomic number (Z)** and the decimal number below each element is called the **relative atomic mass number (Ar). Note the example of potassium below -**

19
K
39.0983

The **atomic number** tells us the number of protons an atom of the element will have. This will equal the number of electrons in the atom also. The atomic number is always a whole number, as you cannot have a fraction of a proton or electron.

Atomic number of K is 19 so K has 19 protons and 19 electrons.

The Ar of K is 30.0983 (we will round it to 39 when carrying out calculations)
The **relative atomic mass number (Ar)** gives an average mass of all known isotopes of that element. As it is an average it is usually decimalised. Isotopes are different types of the same atom due to having different number of neutrons in the nucleus. The relative abundances of the isotopes are taken into account.

On going from left to right across the periodic table the elements get less metallic in nature and more gaseous. (**N. B. metals – left non-metals – right)**
H_2, N_2, O_2, F_2, Cl_2 are gaseous and diatomic at or near room temperature. These elements cannot be found on their own in nature.
Hg is the only metal that is liquid at room temperature: Br_2 is a non-metal that is liquid at room temperature, also exists diatomically.
I_2 is a non-metal that is solid at or near room temperature, also exists diatomically.
C, Si, P, S are non-metals and solids at room temperature and they exist mono-atomically.
All the noble gases are gaseous at room temperature and exist mono-atomically.

METAL
Defn – any element that loses electrons to form a positive ion (cation).

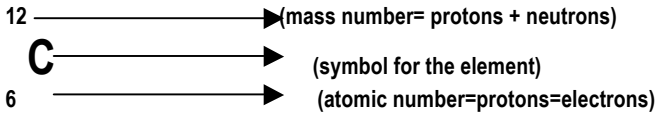
ATOMIC NUMBER
Defn – the number of protons present in the nucleus of an atom.
This number is always a whole number, as you cannot have a fraction of a proton or electron.

MASS NUMBER (not in the periodic table)
Defn - the mass number is the number of protons plus neutrons in the nucleus of an atom.

This is not in the periodic table. It will appear in questions written above the symbol for the element as shown below the next definition or after as in Carbon-12, Polonium-210.

ISOTOPES
Defn - isotopes are atoms of the same element that have the same atomic number but different mass numbers due to the different numbers of neutrons present in the nucleus.

Carbon has three isotopes $^{12}_{6}C$, $^{13}_{6}C$, $^{14}_{6}C$ and hydrogen also has three isotopes $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$. Isotopes are atoms that are the same on the outside but differ in the make up of the nucleus as they have different numbers of neutrons. As the number and arrangement of electrons are the same so they have the same chemical properties.



RELATIVE ATOMIC MASS NUMBER (Ar)
Defn- the average mass of an atom of an element compared to 1/12 the mass of the carbon – 12 isotope, taking relative abundances of the naturally occurring isotopes into account.

- This number is rarely a whole number as it is the *average* of all the known isotopes of an element.

RELATIVE MOLECULAR MASS NUMBER (Mr)
Defn – the average mass of a molecule of a compound compared to 1/12 the mass of the carbon – 12 isotope, taking relative abundances of the naturally occurring isotopes into account.

- Adding together the relative atomic masses present in a molecule will give you the Mr. You must know **the formula** of the compound to do this correctly! Please refer to hand out 7 of atomic theory AGAIN and learn!!

A brief introduction to ions –
Atoms gain or lose electrons to form ions. Remember atoms are always neutral so if you lose an (negative) electron the ion that forms will be positive and vice versa. Metal atoms tend to lose electrons to form cations (positive ions). Non-metal atoms tend to gain electrons to form anions (negative ions).

% Isotope questions
When you examine a sample of an element there is usually more than one isotope present. When we have the percentage of each isotope we can use this information to help us calculate the relative atomic mass of the element.

Naturally occurring chlorine consists of 75.5% of $^{35}_{17}Cl$ and 24.5% of $^{37}_{17}Cl$. Calculate the relative atomic mass (Ar) of chlorine. (LCH 1995)
Solution –

- Multiply the % by the mass number (top number) for each isotope.
- Get the total mass for 100 atoms.
- Divide this total by 100 to get the mass of one atom.

75.5 X 35 = 2642.5
24.5 X 37 = 906.5

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100 atoms = 3549
1 atom = 35.49 (Ar)

EQUATIONS TO KNOW FROM THIS CHAPTER

METAL + OXYGEN →METAL OXIDE

$Na + O_2 \rightarrow$

$Ca + O_2 \rightarrow$

METAL* + WATER→METAL HYDROXIDE + HYDROGEN GAS

$K + H_2O \rightarrow$

$Mg + H_2O \rightarrow$

(*metals usually coming from group 1 and 2)

LEAVING CERT 2016

(*a*) A dipositive ion, $\mathbf{M^{2+}}$, has 25 electrons and 32 neutrons. What is (*i*) the atomic number, (*ii*) the mass number, of **M**? (6)

What are isotopes? (4)

LEAVING CERT 2015

(*a*) How many (*i*) electrons, (*ii*) neutrons, has the aluminium ion, $_{13}^{27}\mathbf{Al^{3+}}$? (6)

(*b*) Explain why relative atomic masses are rarely whole numbers. (6)

LEAVING CERT 2014

Define (*i*) mass number, (*ii*) relative atomic mass. (9)

A sample of the element gallium is composed of 60.1% gallium–69 and 39.9% gallium–71. Calculate the relative atomic mass of gallium from this information. (7)

LEAVING CERT 2013

Define relative atomic mass. (6)

LEAVING CERT 2012

Define *relative atomic mass*.

LEAVING CERT 2011

Define (a) atomic number, (b) relative atomic mass. (11)

What are isotopes? (5)

LEAVING CERT 2009

In 1922, Francis Aston, pictured below, was awarded the Nobel Prize in chemistry for detecting the existence of isotopes using the first mass spectrometer.

(*i*) What are isotopes? (7)
(*ii*) What is the principle of the mass spectrometer? (9)
(*iii*) Calculate, to two decimal places, the relative atomic mass of a sample of neon shown by mass spectrometer to be composed of 90.50% of neon–20 and 9.50% of neon–22. (9)

LEAVING CERT 2006

(i) What are isotopes? (4)
(ii) Define relative atomic mass, Ar. (6)
(iii) What is the principle on which the mass spectrometer is based? (9)
(iv) Calculate the relative atomic mass of a sample of lithium, given that a mass spectrometer shows it consists of 7.4% ^{6}Li and 92.6% ^{7}Li. (6)

ANSWERS IN MARKING SCHEMES……. ALWAYS CHECK!!

Questions

1. Identify the following as atoms, molecules, simple ions or complex ions (also try to name each one!) –

$Na^+ =$ .....

$K =$ .....

$SO_4^{2-} =$ .....

$I_2 =$ .....

$F^- =$ .....

$Fe =$ .....

$KMnO_4 =$ .....

$O_2^{2-} =$ .....

2. What is the atomic number of the following elements –
sulfur =……..
calcium =……..
vanadium = ……..
bromine = ……

3. What is the relative atomic mass number of the following elements –
sulfur =……..
calcium =……..
vanadium = ……..
bromine = ……

4. How many (i) protons, (ii) neutrons and (iii) electrons in $^{35}_{17}Cl$?

5. Identify the element that has 60.4% of atoms with a mass of 69 and the remainder with a mass of 71.

6. What is the relative atomic mass of magnesium which normally consists of 78.6% magnesium-24, 10.1% magnesium-25 and 11.3% magnesium-26?

7. Identify an element that –
Is a non-metal and is liquid at room temperature = ……..
Is a divalent metal = …….
Exists in both diatomic and triatomic states =……
Has an atomic number of 26 = ……..

ANSWERS ON NEXT PAGE…. TRY NOT TO CHEAT!!!

ANSWERS

1. Identify the following as atoms, molecules, simple ions or complex ions (also try to name each one!) –

sodium ion (simple ion)
potassium atom (atom)
sulfate ion (complex ion)
iodine (molecule)
fluoride ion (simple ion)
iron (atom)
potassium manganate (VII) (molecule)
peroxide ion (complex ion)

2. What is the atomic number of the following elements –
sulfur = 16
calcium = 20
iron = 26
bromine = 35

3. What is the relative atomic mass number of the following elements –
sulfur = 32
calcium = 40
iron = 56
iodine = 154

4. How many (i) protons, (ii) neutrons and (iii) electrons in $^{35}_{17}Cl^-$? (i) 17p (ii) 18n (iii) 18e

5. Identify the element that has 60.4% of atoms with a mass of 69 and the remainder with a mass of 71. (answer = gallium)

6. What is the relative atomic mass of magnesium which normally consists of 78.6% magnesium-24, 10.1% magnesium-25 and 11.3% magnesium-26?

7. Identify an element that –
Is a non-metal and is liquid at room temperature = Br
Is a divalent metal = anyone from group 2 (Be, Mg, Ca….)
Exists in both diatomic and triatomic states =oxygen
Has an atomic number of 26 = Fe