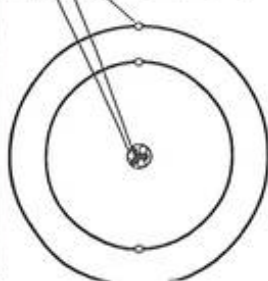


ATOMS and REACTIONS

ATOMIC STRUCTURE

Particle	Location	Charge (relative values)	Mass
Proton	nucleus	+1	1
Neutron	nucleus	0	1
Electron	shells	-1	1/1839



An element has all atoms with the same number of protons

Isotopes have same number of protons but different numbers of neutrons

Atoms have equal numbers of protons and electrons and so have no overall charge

Ions have different numbers of protons and electrons and so have an overall charge

mass number
= number of protons + neutrons

atomic number = number of protons

charge
= number of protons - number of electrons

CHANGING MODELS OF THE ATOM

Over time, the way we think about atoms has changed. Scientists used to believe that atoms were the smallest particles of matter and could not be broken apart into anything simpler. At the end of the 19th century, it was discovered that atoms contained electrons, and that these had a negative charge. Ideas about how the atom remained neutral overall changed. At first, it was thought that positive charge was spread throughout the atom; then in the early part of the 20th century, experiments proved that the positive charge was in the nucleus.

TOF MASS SPECTROMETRY

Mass spectra can tell us about the relative isotopic mass and the abundance of the isotopes of an element. This information can be used to identify elements and to calculate their relative atomic mass.

Mass spectrometry can also measure the relative molecular mass of molecules.

Time of flight mass spectrometry works like this:

- The particles (atoms or molecules) enter the machine and are turned into 1+ ions (either by firing electrons at them to 'knock out' other electrons, or by attaching protons to them).
- These ions are then accelerated by an electric field. All ions end up with the same kinetic energy (KE). Since this is related to mass (m) and velocity (v) by $v = \sqrt{\frac{2KE}{m}}$, lighter ions (with less mass) move faster than heavier ones.
- The ions all move down a long tube. At the end of the tube is a metal plate. When ions hit the plate, they cause an electric current. The size of the current is related to the number of ions that are detected.
- The time taken for ions to travel down the tube is used to calculate the mass of the ion. Time (t), length of the tube (d) and velocity (v) are related by $t = d/v$, combining this with the previous equation gives $t = d \sqrt{\frac{m}{2KE}}$ or $m = \frac{2t^2 KE}{d^2}$

ATOM ECONOMY

This is calculated using the formula: $\% \text{ atom economy} = \frac{\text{Molecular mass of desired product}}{\text{Sum of molecular masses of all products}} \times 100$ and helps to evaluate the economic and environmental impact of reactions. When atom economy is low, it indicates that a reaction is wasteful. As well as making their products more expensive, reactions with low atom economies use up more resources and produce more waste.

e.g. for the reaction $C_2H_4 + HBr \rightarrow C_2H_5Br$, the desired product is ethene and the atom economy is calculated as:

$$\% \text{ atom economy} = \frac{28.0}{108.9} \times 100 = 25.7\%$$

VOLUMES OF GAS IN BALANCED EQUATIONS

One mole of all gases occupies the same volume (under the same conditions), so the numbers in a balanced equation give the ratio of volumes as well as moles, e.g. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

In this reaction, 1 dm³ of CH₄ requires 2 dm³ of O₂ to burn, producing 1 dm³ of CO₂ and 2 dm³ of H₂O vapour.

MOLES

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Relative molecular mass (M_r) or relative formula mass is found by adding up the relative atomic masses for every atom in a molecule or formula unit.

M_r for ethanol, C_2H_5OH
 $= [2 \times 12.0] + [5 \times 1.0] + 16.0 + 1.0 = 46.0$

Relative formula mass for aluminium hydroxide, $Al(OH)_3$
 $= 27.0 + [(16.0 + 1.0) \times 3] = 78.0$

Magnesium hydroxide: $Mg(OH)_2$

1	2
H	He
Li	Be
B	C
N	O
F	Ne
Na	Mg

One Mg^{2+} ion (you can tell the charge is 2+ as Mg is in group 2 of the periodic table)

Two OH^- ions. You need to remember some ions:

Ammonium: NH_4^+	nitrate: NO_3^-
Zinc: Zn^{2+}	carbonate: CO_3^{2-}
Silver: Ag^+	sulfate: SO_4^{2-}
	hydroxide: OH^-

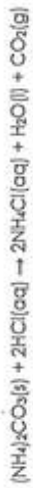
State symbols

(s) solid	(l) liquid	(g) gas
(aq) dissolved in water (aqueous)		

BALANCING CHEMICAL EQUATIONS

Both sides of the arrow must have the same:

- number of atoms of each element
- total charge



2 nitrogen atoms	2 nitrogen atoms
10 hydrogen atoms	10 hydrogen atoms
1 carbon atom	1 carbon atom
3 oxygen atoms	3 oxygen atoms
1 chlorine atom	1 chlorine atom

DIFFERENT TYPES OF CHEMICAL FORMULA

- Empirical formulae give the simplest, integer ratio of atoms of all the elements present in a compound
- Molecular formulae tell you exactly how many atoms of each element are in a molecule (e.g. $C_6H_{12}O_6$)

This empirical formula tells you there are twice as many H atoms as C atoms – but not how many C or H atoms there actually are. Many possible molecular formulae correspond to this empirical formula: $C_6H_{12}O_6$, $C_{12}H_{24}O_{12}$, etc.

CALCULATING EMPIRICAL AND MOLECULAR FORMULAE

Divide percentages by the relative atomic masses of the elements and round to the nearest whole number ratio

Compare the M_r to the relative formula mass for the empirical formula

A compound with $M_r = 92$ contains 30.43% N and 69.57% O by mass.
 Ratio $N : O = \frac{30.43}{14.0} : \frac{69.57}{16.0} = 2.17 : 4.35 = 1 : 2$, so empirical formula is NO_2 .
 Since $M_r = 92$, and $14 + (2 \times 16) = 46$, then molecular formula = N_2O_4 .