USEFUL DEFINITIONS

Element A substance which cannot be split into anything simpler by chemical means.

Atom The smallest part of an element that can take part in a chemical reaction.

Molecule The smallest particle of a compound (a combination of two or more elements).

It is also the name given to the smallest part of those elements which do not exist as atoms in the free state i.e. hydrogen H_2, oxygen O_2, nitrogen N_2, fluorine F_2, chlorine Cl_2, bromine Br_2 and iodine I_2.

N.B. *ionic compounds (e.g. sodium chloride) do not exist as molecules.*

Ion The name given to any electrically charged atom or molecule.

- positively charged ions are known as cations
- negatively charged ions are known as anions

Like charges repel but unlike (opposite) charges attract. If the sum of all the positive charges is equal and opposite to all the negative charges then the species will be neutral (no overall charge).

Symbol A symbol represents one atom, or one mole, of an element.

Formula A formula represents one molecule of a compound, or the simplest ratio of the ions present. As with symbols, a formula represents a single particle or one mole of particles.

The number of atoms or groups of atoms in a formula is given by putting a small number just below and behind the symbol(s). As the appearance of a symbol indicates one atom is present, a 1 isn't written (you put NaC*l* not Na_1Cl_1).

In some formulae brackets are used to avoid ambiguity. Aluminium sulphate has the formula $Al_2(SO_4)_3$ to show that there are two Al's to every three SO_4's. Without the brackets it would appear as though there were forty three O's i.e. Al_2SO_{43}.

Valency A numerical measure of the **combining power** of an atom / ion.

Historically, it was the number of hydrogen atoms which will combine with one atom, or group of atoms.

It is also the number of positive (+) or negative (-) charges on an ion. A list of common valencies appears below to help you construct formulae.

Atom	*Valency*	*Compound*
C	4	CH_4
N	3	NH_3
O	2	H_2O
C*l*	1	HC*l*

VALENCY TABLE

	POSITIVE IONS		NEGATIVE IONS	
1	hydrogen	H^+	chloride	Cl^-
	sodium	Na^+	bromide	Br^-
	potassium	K^+	iodide	I^-
	lithium	Li^+	**hydroxide**	$\mathbf{OH^-}$
	rubidium	Rb^+	**nitrate**	$\mathbf{NO_3^-}$
	caesium	Cs^+	**nitrite**	$\mathbf{NO_2^-}$
	copper(I)	Cu^+	**hydrogencarbonate**	$\mathbf{HCO_3^-}$
	silver(I)	Ag^+	**hydrogensulphate**	$\mathbf{HSO_4^-}$
	ammonium	$\mathbf{NH_4^+}$		
2	calcium	Ca^{2+}	**sulphate**	$\mathbf{SO_4^{2-}}$
	barium	Ba^{2+}	**sulphite**	$\mathbf{SO_3^{2-}}$
	magnesium	Mg^{2+}	sulphide	S^{2-}
	zinc	Zn^{2+}	oxide	O^{2-}
	iron(II)	Fe^{2+}	**carbonate**	$\mathbf{CO_3^{2-}}$
	cobalt	Co^{2+}	copper(II)	Cu^{2+}
	manganese(II)	Mn^{2+}		
3	aluminium	Al^{3+}	**phosphate**	$\mathbf{PO_4^{3-}}$
	iron(III)	Fe^{3+}		

ions in bold contain more than one element

Many elements (e.g. iron) have more than one valency. To avoid ambiguity, a number appears in brackets after the name e.g. iron(III); this is the oxidation number and can be used to give you the valency.

Q.

- *Name the following* Sn^{2+}

  Sn^{4+}

  Sb^{3+}

- *Give the symbol of* *lead(IV)*

  scandium(III)

- *What do you notice about the valency of elements in...* *Group I*

  Group II

  Group VII

CONSTRUCTION OF FORMULAE

Method The table lists a selection of valencies of some common ions and atoms. It is not complete but there are enough for you to appreciate the basic principles of formulae construction. Several methods are available, choose the one which suits you, or the situation, best. Magnesium chloride is used as an example.

1. Balance the number of ionic charges. All compounds are electrically neutral so the number of positive and negative charges must balance.

   Magnesium ions are Mg^{2+}, chloride ions Cl^-. You need two Cl^- ions to balance the 2+ ion of magnesium. Therefore the formula will be $MgCl_2$.

2. Use “hooks”. The valency is the number of “hooks” an element or group has. All hooks must be joined up so there are no spares.

   Magnesium has two “hooks”, — Mg — , chlorine has one, Cl — . Join up all “hooks”; this gives you Cl — Mg — Cl . The formula is thus $MgCl_2$.

3. Switching the valency numbers if two valencies are different. Don’t write in a 1 and cancel any combination of numbers which can be reduced (e.g. Mg_2O_2 will become MgO).

   The valency of magnesium is two so multiply chlorine by two and the valency of chlorine is one, so multiply magnesium by one to give Mg_1Cl_2 ; the formula will be $MgCl_2$.

   example: aluminium sulphate
   - *the valency of aluminium is 3 and that of sulphate is 2*
   - *they will combine in the ratio of 2 aluminiums to 3 sulphates [i.e. 2x3 = 3x2]*
   - *the formula will be $Al_2(SO_4)_3$. [Notice the use of brackets]*

It is useful to learn some formulae...

Acids	hydrochloric acid	HC*l*	nitric acid	HNO_3
	sulphuric acid	H_2SO_4	ethanoic acid	CH_3COOH
Gases	ammonia	NH_3	carbon dioxide	CO_2
	carbon monoxide	CO	methane	CH_4
	sulphur dioxide	SO_2		

Equations
- show the formulae of the reactants and the products.
- can show in which state the substances exist.
- show the relationship between the numbers of each substance involved; this is known as the **STOICHIOMETRY** of the reaction

BALANCING EQUATIONS

1 Work out what has reacted and what has been formed. A word equation can help.

2 Get the correct formula for each species. Include the state symbols if necessary. Once you have obtained the correct formula of a species you must not change it to help balance an equation.

3 Having written out the initial equation, check to see if it is balanced. An equation balances if the same number of each type of atom appears on either side of the arrow.

4 Place large numbers in front of any formula to indicate if more than one of it is required. This multiplies everything in the formula immediately behind it. Continue until the equation balances.

5 Finally, check the equation to see that you have balanced it correctly.

Worked example

Step 1 *sodium + water ——> sodium hydroxide + hydrogen*

Step 2 Na(s) + H_2O(l) ——> $NaOH$(aq) + H_2(g)

Step 3 *Count up the atoms :* *LHS ... 1 x Na, 2 x H, 1 x O*
RHS ... 1 x Na, 3 x H, 1 x O.

The equation doesn't balance; an extra H is needed on the LHS. However we must not change any formulae. One can only get extra H's by having two waters; multiply H_2O *by two.*

Step 4 Na(s) + **2** H_2O(l) ——> $NaOH$(aq) + H_2(g)

This doesn't solve the problem as we now have too many O's (2) and H's (4) on the LHS; multiplying the NaOH by two will solve this problem.

Na(s) + 2 H_2O(l) ——> **2** $NaOH$(aq) + H_2(g)

However, it creates yet another problem because it has introduced an extra Na on the RHS; multiply the Na on the LHS by two.

2 Na(s) + 2 H_2O(l) ——> **2** $NaOH$(aq) + H_2(g)

Step 5 *Check the equation; it balances. As you can see it can take time but with a little effort a balanced equation can be achieved.*

FORMULAE AND EQUATIONS - Test questions

Q.1 Write out the correct formula for each of the following compounds.

a) sodium chloride
b) magnesium sulphate
c) calcium oxide
d) calcium chloride
e) copper(II) nitrate
f) potassium sulphate
g) manganese(IV) oxide
h) zinc carbonate
i) aluminium oxide
j) aluminium sulphate
k) aluminium bromide
l) calcium hydroxide

Q.2 Write out the correct formulae under the names in these word equations.
Do not attempt to balance the equations at this stage.

a) hydrogen + oxygen ——> water

b) zinc + sulphuric acid ——> zinc sulphate + hydrogen

c) copper(II) oxide + sulphuric acid ——> copper(II) sulphate + water

d) nitrogen + hydrogen ——> ammonia

e) magnesium + oxygen ——> magnesium oxide

Q.3 How many atoms of each type are in the following ?

a) H_2O	H =	O =			
b) H_2SO_4	H =	O =	S =		
c) $(NH_4)_2SO_4$	H =	N =	O =	S =	
d) $CuSO_4.5H_2O$	H =	O =	S =	Cu =	
e) 2 NaOH	H =	O =	Na =		
f) 3 $Ca(OH)_2$	H =	O =	Ca =		
g) 2 Na_2HPO_4	H =	O =	Na =	P =	
h) 2 $NH_4Al(SO_4)_2.12H_2O$	H =	N =	O =	A*l* =	S =

Q.4 Are the equations balanced ?

a) $2H_2 + O_2 \longrightarrow 2H_2O$ Y / N

b) $CH_4 + O_2 \longrightarrow CO_2 + H_2O$ Y / N

c) $H_2 + Cl_2 \longrightarrow 2HCl$ Y / N

d) $NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$ Y / N

e) $Ag_2CO_3 + 2HNO_3 \longrightarrow 2AgNO_3 + CO_2 + H_2O$ Y / N

Q.5 Balance the following equations.

a) $Mg + HCl \longrightarrow MgCl_2 + H_2$

b) $Na + O_2 \longrightarrow Na_2O$

c) $Ca(OH)_2 + HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$

d) $Ca + H_2O \longrightarrow Ca(OH)_2 + H_2$

e) $NaNO_3 \longrightarrow NaNO_2 + O_2$

f) $Mg(NO_3)_2 \longrightarrow MgO + NO_2 + O_2$

g) $Cu + H_2SO_4 \longrightarrow CuSO_4 + SO_2 + H_2O$

h) $Al + O_2 \longrightarrow Al_2O_3$

i) $Fe + Cl_2 \longrightarrow FeCl_3$

j) $C_2H_6 + O_2 \longrightarrow CO_2 + H_2O$

k) $Al_2O_3 + NaOH + H_2O \longrightarrow NaAl(OH)_4$

l) $Cu + HNO_3 \longrightarrow Cu(NO_3)_2 + H_2O + NO$

m) $KOH + F_2 \longrightarrow KF + F_2O + H_2O$

n) $KOH + Cl_2 \longrightarrow KCl + KClO_3 + H_2O$

ANSWERS TO QUESTIONS

Q.1 Write out the correct formula for each of the following compounds.

a) $NaCl$	b) $MgSO_4$	c) CaO	d) $CaCl_2$
e) $Cu(NO_3)_2$	f) K_2SO_4	g) MnO_2	h) $ZnCO_3$
i) Al_2O_3	j) $Al_2(SO_4)_3$	k) $AlBr_3$	l) $Ca(OH)_2$

Q.2

a) hydrogen + oxygen ——> water
H_2 O_2 H_2O

b) zinc + sulphuric acid ——> zinc sulphate + hydrogen
Zn H_2SO_4 $ZnSO_4$ H_2

c) copper(II) oxide + sulphuric acid ——> copper(II) sulphate + water
CuO H_2SO_4 $CuSO_4$ H_2O

d) nitrogen + hydrogen ——> ammonia
N_2 H_2 NH_3

e) magnesium + oxygen ——> magnesium oxide
Mg O_2 MgO

Q.3 How many atoms of each type are in the following ?

a) H_2O	H = 2	O = 1			
b) H_2SO_4	H = 2	O = 4	S = 1		
c) $(NH_4)_2SO_4$	H = 8	N = 2	O = 4	S = 1	
d) $CuSO_4.5H_2O$	H = 14	O = 9	S = 1	Cu = 1	
e) 2 $NaOH$	H = 2	O = 2	Na = 2		
f) 3 $Ca(OH)_2$	H = 6	O = 6	Ca = 3		
g) 2 Na_2HPO_4	H = 2	O = 8	Na = 4	P = 2	
h) 2 $NH_4Al(SO_4)_2.12H_2O$	H = 56	N = 2	O = 40	Al = 2	S = 4

Q.4 Are the equations balanced ?

a) $2H_2 + O_2 \longrightarrow 2H_2O$	Y
b) $CH_4 + O_2 \longrightarrow CO_2 + H_2O$	N
c) $H_2 + Cl_2 \longrightarrow 2HCl$	Y
d) $NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$	N
e) $Ag_2CO_3 + 2HNO_3 \longrightarrow 2AgNO_3 + CO_2 + H_2O$	Y

Q.5 Balance the following equations.

a) $Mg + \mathbf{2}HCl \longrightarrow MgCl_2 + H_2$
b) $\mathbf{4}Na + O_2 \longrightarrow \mathbf{2}Na_2O$
c) $Ca(OH)_2 + \mathbf{2}HNO_3 \longrightarrow Ca(NO_3)_2 + \mathbf{2}H_2O$
d) $Ca + \mathbf{2}H_2O \longrightarrow Ca(OH)_2 + H_2$
e) $\mathbf{2}NaNO_3 \longrightarrow \mathbf{2}NaNO_2 + O_2$
f) $\mathbf{2}Mg(NO_3)_2 \longrightarrow \mathbf{2}MgO + \mathbf{4}NO_2 + O_2$
g) $Cu + \mathbf{2}H_2SO_4 \longrightarrow CuSO_4 + SO_2 + \mathbf{2}H_2O$
h) $\mathbf{4}Al + \mathbf{3}O_2 \longrightarrow \mathbf{2}Al_2O_3$
i) $\mathbf{2}Fe + \mathbf{3}Cl_2 \longrightarrow \mathbf{2}FeCl_3$
j) $\mathbf{2}C_2H_6 + \mathbf{7}O_2 \longrightarrow \mathbf{4}CO_2 + \mathbf{6}H_2O$
k) $Al_2O_3 + \mathbf{2}NaOH + \mathbf{3}H_2O \longrightarrow \mathbf{2}NaAl(OH)_4$
l) $\mathbf{3}Cu + \mathbf{8}HNO_3 \longrightarrow \mathbf{3}Cu(NO_3)_2 + \mathbf{4}H_2O + \mathbf{2}NO$
m) $\mathbf{2}KOH + \mathbf{2}F_2 \longrightarrow \mathbf{2}KF + F_2O + H_2O$
n) $\mathbf{6}KOH + \mathbf{3}Cl_2 \longrightarrow \mathbf{5}KCl + KClO_3 + \mathbf{3}H_2O$