St Ninian's High School

Chemistry Department

National 5

Unit 1

Chemical Changes & Structure

Section 1.4/1.6

Formulae and Reaction Quantities

Summary Notes

Name _____

Learning Outcomes

After completing this section you should be able to :

1	state that the chemical formula for a covalent molecular substance gives the number of each type of atom present in the molecule
2	state the chemical formula for substances with meaningful names (mono, di, tri, tetra)
3	state the meaning of diatomic
4	state the seven diatomic elements
5	state that the chemical formulae for covalent network and ionic compounds gives the simplest ratio of atoms/ions in the substance
6	write a chemical formula for a substance using the valency method
7	use roman numerals to write a chemical formulae for a substance
8	write a chemical formula using group atoms/ions
9	write an ionic formulae
10	write a chemical equation given the reactants and products including state symbols
11	balance a chemical equation.

What is Chemical Formulae?

Covalent Networks and Ionic Substances.

The chemical formulae for covalent network and ionic compounds gives the simplest ratio of atoms/ions in the substance.

Examples:

Silicon dioxide has the chemical formula SiO_2, this means that for every 1 silicon atom in the covalent network there are 2 oxygen atoms. A ratio of 1:2.

Sodium chloride has the chemical formula NaCl since there is one sodium ion for every chloride ion.

Diatomic Elements

Molecules made up of only two atoms are called **diatomic** molecules, e.g. hydrogen chloride, HCl, (one carbon atom and one chlorine atom), and carbon monoxide, CO, (one carbon atom and one oxygen atom).
Certain elements normally exist as diatomic molecules. Normally the formula of an uncombined element is just its symbol, for example, the formula of carbon is C. For the diatomic elements, however, the symbol is followed by a "2", for example, O_2, N_2, etc.

The full list of diatomic elements is hydrogen (H_2), nitrogen (N_2), oxygen (O_2), and the group 7 elements (F_2, Cl_2, Br_2, I_2).

Writing Chemical Formula

Meaningful Names

Some compounds have meaningful names which contain indicate what the chemical formula is by using one or more of the following prefixes; **mono-, di-, tri-, or tetra.**

The name of the compound gives its chemical formula, for example carbon **di**oxide has the formula CO_2.

Prefix	Meaning	Name of Compound	Formula
mono-	one	Carbon monoxide	CO
di-	two	Sulfur dioxide	SO_2
tri-	three	Sulfur trioxide	SO_3
tetra-	four	Silicon tetrachloride	$SiCl_4$
penta-	five	Phosphorous pentaiodide	PI_5
hexa-	six	Tungsten hexachloride	WCl_6

Valency Method

(i) Simple two element compounds

The formula for compounds whose names do not have prefixes are worked out by, first of all, giving each element a valency number.

The **valency number** depends on the **Group** where the element is found in the Periodic Table and directly relates to the **number of bonds** the element can make.

Group	1	2	3	4	5	6	7	0
Valency	1	2	3	4	3	2	1	0

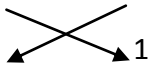
Magnesium has a valency of 2, because it is in Group 2 while oxygen also has a valency of 2, because it is in Group 6.

Writing Chemical Formula

(i) Simple two element compounds examples.

1. Sodium chloride.

1. Symbols Na Cl
2. Valency 1 1
3. Swap 1 1



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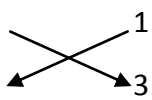
5. Formula NaCl

2. Nitrogen chloride

1. Symbols N Cl
2. Valency 3 1
3. Swap 1 3



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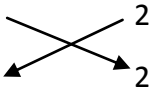
5. Formula NCl_3

3. Calcium oxide

1. Symbols Ca O
2. Valency 2 2
3. Swap 2 2



4. Cancel 1 1
5. Formula CaO

(ii) Using roman numerals

Some elements, like the transition metals and some of the metals in Group 4 onwards, can have **more than** one valency number. This is given in the compound's name by a **Roman Numeral.**

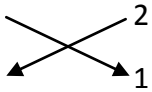
Roman Numeral	(I)	(II)	(III)	(IV)	(V)
Valency	1	2	3	4	5

The chemical formula is then worked out using the valency method as described for simple two element compounds.

Example

Copper(I) oxide

1. Symbols Cu O
2. Valency 1 2
3. Swap 2 1



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5. Formula Cu_2O

Writing Chemical Formula

Valency Method

(iii) Group ions (Compounds with more than two elements)

Compounds with more than two elements contain **group ions.**

Recap: An ion is an atom or group of chemically combined atoms which carry an electric charge, either positive or negative.

Some ions, like sulfate ions, are made up of group atoms which stay together during chemical reactions. These are known as group ions. The sulfate ion is written;

$$SO_4^{2-}$$

Group ions have a valency number which covers the whole ion. This is equal to the **size** of its charge. So the valency of the sulfate ion is **2**.

The valencies of the group ions can be found on page 4 of your Data Booklet.

Group ion	Formula	Valency
Carbonate	CO_3	2
Nitrate	NO_3	1
Sulfate	SO_4	2
Hydroxide	OH	1
Sulfite	SO_3	2
Ammonium	NH_4	1

(iii) Group ions (Compounds with more than two elements)

The chemical formula is then worked out using the valency method as described for simple two element compounds.

Example

Sodium sulfate

1. Symbols Na SO_4
2. Valency 1 2
3. Swap 2 1

(4. Cancel - not needed here)

5. Formula Na_2SO_4

When there is more than one of the same group ion in a compound we must put the group ion inside brackets.

Example

Magnesium hydroxide

1. Symbols Mg OH
2. Valency 2 1
3. Swap 1 2

(4. Cancel - not needed here)

5. Formula $Mg(OH)_2$ Brackets needed to show 2 hydroxide ions.

Ionic Formulae

An **ionic formula** shows the charges of the ions as well as the proportion of each.

The **total charge** in an ionic formula should be **'zero'**.

Examples

1. Sodium Chloride:

1. Symbols Na^+ Cl^-
2. Valency 1 2
3. Swap 2 1

(4. Cancel - not needed here)

5. Formula Na^+Cl^-

Double check that the overall charge is zero: (+1) + (-1) = 0

2. Potassium Oxide

1. Symbols K^+ O^{2-}
2. Valency 1 2
3. Swap 2 1

(4. Cancel - not needed here)

5. Formula $(K^+)_2O^{2-}$

Double check that the overall charge is zero: 2 x (+1) + (-2) = 0

Writing Chemical Equations

Chemical Equations.

(i) Writing chemical equations

Recap : Word Equations.

A word equation is used to show the chemicals being used in a reaction (**reactants**) and the new substances being made ore produced in a reaction (**products**).

Example:

When calcium carbonate reacts with hydrochloric acid, calcium chloride, carbon dioxide and water are produced.

Written as a word equation this would be:

Calcium carbonate + hydrochloric acid ⟶ calcium chloride + carbon dioxide + water

Reactants **Products**

If the names of the chemicals in a word equation are replaced with their formulae, the word equation becomes a **chemical equation.**

The above word equation would become:

calcium carbonate + hydrochloric acid ⟶ calcium chloride + carbon dioxide + water

$CaCO_3$ + HCl ⟶ $CaCl_2$ + CO_2 + H_2O

The same elements must appear on both sides of the chemical equation.

State Symbols.

State symbols are used in chemical equations to indicate the physical state of the chemicals being used.

State	Symbol
Solid	s
Liquid	*l*
Gas	g
Solution	aq

E.g. calcium carbonate + hydrochloric acid ⟶ calcium chloride + carbon dioxide + water

$CaCO_3(s)$ + HCl(aq) ⟶ $CaCl_2(aq)$ + $CO_2(g)$ + $H_2O(l)$

Chemical Equations

(ii) Balancing chemical equations

A chemical equation must have the same elements on each side.
A **balanced** chemical equation must have the same number of atoms of each element on each side.

Example

Methane + Oxygen → Carbon dioxide + Water

CH_4 + O_2 → CO_2 + H_2O

1 C atom	1 C atom
4 H atoms	2 H atoms
2 O atoms	3 O atoms.

This equation is not balanced, there are more hydrogen atoms on the left hand side and more oxygen atoms on the right hand side.

An extra oxygen molecule must be added to the left hand side, and an extra water molecule to the right:

CH_4 + **2**O_2 → CO_2 + **2**H_2O

1 C atom	1 C atom
4 H atoms	**4** H atoms (2 x 2 = 4)
4 O atoms (2 x 2 = 4)	**4** O atoms (2 + (2 x 1) = 4)

The equation is now said to be balanced.

Formula Mass

The formula mass of a substance can be calculated using the Relative Atomic Masses given on P 4 of the data book

EXAMPLES

Calculate **the formula mass** for the following element:

Magnesium Mg

1 x 24 =24 amu

AMU stands for Atomic Mass Units.

Calculate the formula mass for the following compound:

Sodium Chloride Na Cl

1 x 35.5 = 35.5

1 x 23 = 23

58.5 amu

The Mole

Mole Definition!!

A mole is the formula mass of a substance expressed in grams.

1 mole of carbon = 12g

2 moles of carbon = 24g

1 mole of sodium = 23g

4 moles of sodium = 23g

Relative Atomic Masses are found on **p4** of the data book

The Mole

When we are looking at compounds we need to add up the masses of all the elements in the chemical formula. This gives us the **gram formula mass or GFM, where the GFM is the mass of one mole of a substance expressed in grams.**

Examples

H_2O

1 x 16 = 16

2 x 1 = 2

18g

$Mg(NO_3)_2$

6x 16 = 96

2 x 14 = 28

1 24.5 = 24.5

148.5g

Calculating Numbers of Moles

What is the mass of the following:

2 moles of H_2O

Calculate the mass of 1 mole of H_2O

H_2O

1 x 16 = 16

2 x 1 = 2

18g

2 moles = 2 x 18 = 36g

3 moles of HCl

Calculate the mass of 1 mole of HCl

HCl

1 x 35.5 = 35.5

1 x 1 = 1

= 36.5g

3 moles = 3 x 36.5= 109.5g

Changing Moles to Mass/ Mass to Moles

To calculate the **mass** of a substance we have simply multiplied the **number of moles** by the GFM, this leads to the expression:

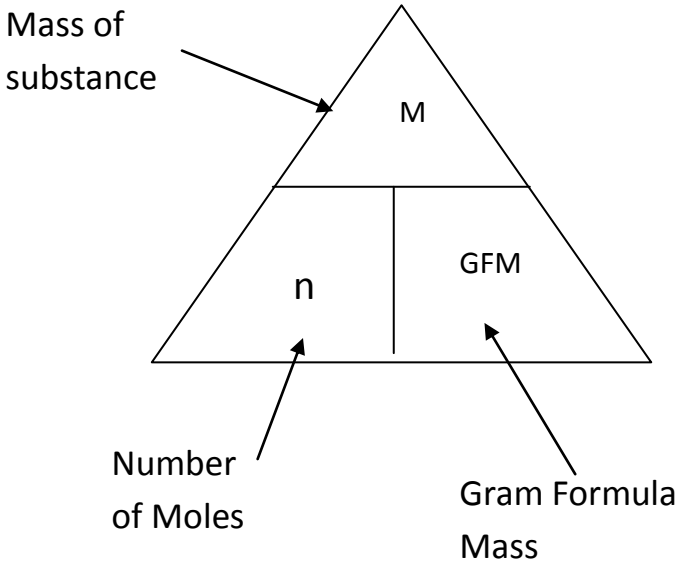
mass = number of moles x GFM

Or **m = n x GFM**

We can rearrange the formula to find the number of **moles** of a substance if we know its mass:

number of moles = $\frac{\text{mass}}{\text{GFM}}$

Or **$n = \frac{m}{GFM}$**



What is the mass of the following?

a. **2 moles of Na Cl**

M = n x GFM

M = 2 x 58.5

= 117g

b. **0.2 moles of CaF_2**

M = n x GFM

M = 3 x 78

= 234g

Solution Chemistry

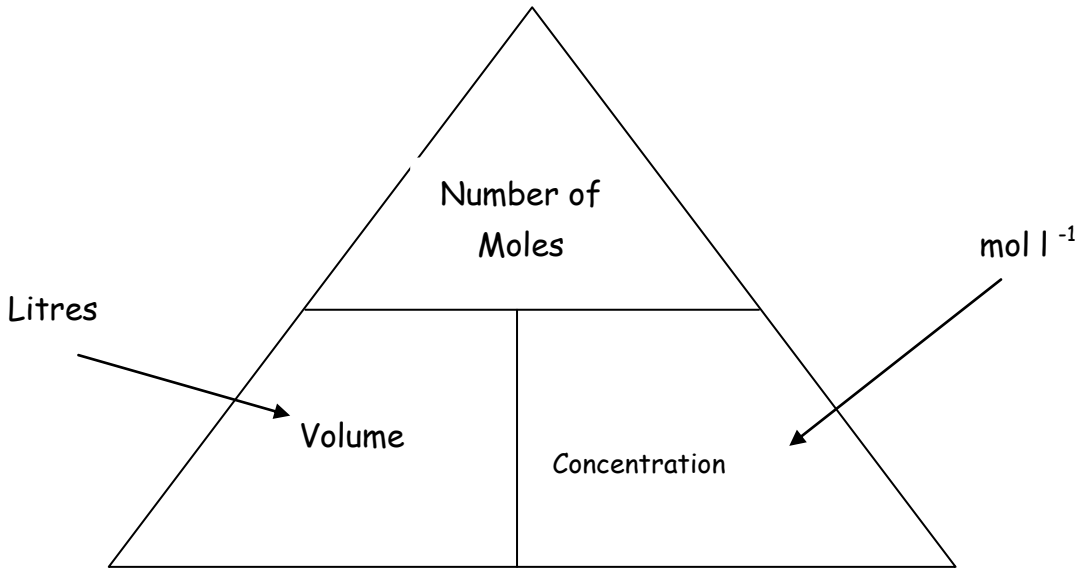
When you make up a solution you are dissolving a substance (**solute**) in water (**solvent**). The more substance you dissolve the more concentrated the **solution**. Alternatively we could dissolve the same mass of solid but reduce the volume of water used which would also make the solution more concentrated.

So **Concentration** depends on the **mass of solid** dissolved and the **volume of water** used.

The following formula is used to calculate the concentration of a solution :-

Number of Moles = Volume x Concentration
(litres) (mol l^{-1})

Remember! Always change volume to **litres** before putting it in this formula.



The units of concentration are **moles per litre** written as:

moll^{-1} or **mol/l**

Solution Chemistry

In order to calculate the **concentration** of a solution you need to know two things:

- **How many moles are dissolved in the solution**
- **What the volume of the solution is**

Example

Calculate the **concentration** of a solution if 5 moles of solute are dissolved in 2 litres of water?

$$\text{Concentration} = \frac{\text{Moles}}{\text{Volume}}$$

$$C = \frac{5}{2}$$

$$C = \mathbf{2.5\ moll\text{-}1}$$

The relationship between concentration, moles and volume allows you to calculate any of the three if you know the other two values.

Example

Calculate the number of **moles** of sodium chloride in 500 cm^3 of a 0.2 moll-1 solution?

$$\text{Moles} = \text{Volume} \times \text{Concentrtion}$$

$$= 0.5 \times 0.2$$

$$= \mathbf{0.1\ moles}$$

Calcualte the volume of solution required to dissolve 4 moles of sodium chloride to obtain a concentration of 0.1 moll-1?

$$\text{Volume} = \frac{\text{Moles}}{\text{Concentration}}$$

$$= \frac{4}{0.1}$$

$$= \mathbf{40\ litres}$$

Standard Solutions

To make a standard solution the following method should be followed:

1. Calculate the mass of solute you require.
2. Weigh this out accurately using a mass balance
3. Dissolve in a small volume of water in a beaker.
4. Pour into a standard flask.
5. Rinse the beaker and the stirring rod. Add the rinsings to the standard flask.
6. Fill up to the calibration mark with water (deionised).
7. Stopper the standard flask and invert a few times to ensure mixing.
8. Label with correct concentration.

Calculating Mass of Solute required

To calculate the mass of solute required to make up a solution the following method should be used:

How many grams of solute are required to make the following solution?

500 cm^3 of 0.1 $moll^{-1}$ copper chloride solution.

moles = volume x concentration

0.5 x 0.1

= 0.05 moles

Formula for solute

Cu Cl_2

2_x 35.5 = 71

1 x 63.5 =63.5

Calculating mass required.

134.5 g

0.05 X 134.5 =**6.725g**

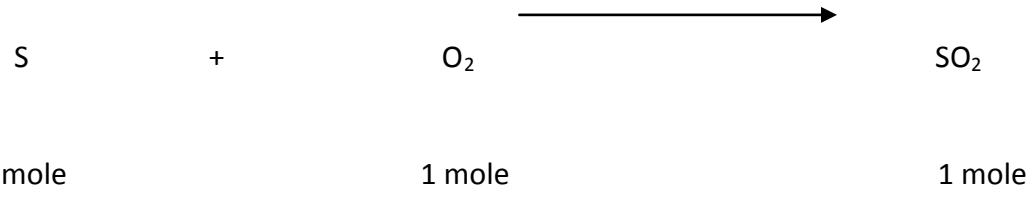
Calculations from Equations

It is possible to use a balanced chemical equation to work out how much product is produced during a chemical reaction or how much reactant is needed to produce a certain amount of product.

Step 1 – Ensure equation is balanced
Step 2 -Write down the mole to mole relationship between the reactant you have been given information about and the product you want to know about.
Step 3 – Work out how many moles of reactant you have by dividing the mass by the mass of 1 mole.
Step 4 - Use proportion to work out how many moles of product would form.
Step 5 – Change the number of moles of product into a mass.

EXAMPLE

Find the mass of sulphur dioxide produced when 4 g of sulphur are burned?



Calculate number of moles of sulphur reacting:

Mass to moles

4 g ⟶ 4/ 32

⟶ 0.25 moles

0.25 moles ⟶ 0.25 moles

0.25 moles of SO_2 formed

Mass = Moles x GFM
= 0.25 x 64g
= **16g**