

CHAPTER – 4



Symbols, formulas and equations

Scientists use a shorthand notation to save both time and space when describing atoms and molecules. Each element is represented by a unique symbol. Dalton was the first scientist to use the symbols for elements in very specific sense, such as a *circle* [O] for an oxygen atom, a *circle with a dot* in its centre [⊙] for hydrogen etc.

4.1. Modern symbols of elements:

Berzelius suggested that the first letter of the name of the element in capital should represent a particular element, such as "O" for oxygen, "H" for hydrogen and so on. Examples of this convention include the following (Table 4.1).

Table 4.1. Elements having single letter symbols.

Name of element	Symbol	Name of element	Symbol
Boron	B	Oxygen	O
Carbon	C	Phosphorus	P
Fluorine	F	Sulphur	S
Hydrogen	H	Uranium	U
Iodine	I	Vanadium	V

There are a number of elements, whose names begin with the same letter, for example, barium, bromine, bismuth, beryllium etc. For such elements two-letter combinations are used. The first letter of the symbol is capital and the second letter which is a prominent letter of their English name is small. Examples include the following (Table 4.2).

Table 4.2. Elements having two letter symbols.

Name of element	Symbol	Name of element	Symbol
Aluminium	Al	Lithium	Li
Arsenic	As	Magnesium	Mg
Barium	Ba	Manganese	Mn
Bromine	Br	Nickel	Ni
Bismuth	Bi	Neon	Ne
Beryllium	Be	Calcium	Ca
Silicon	Si	Chlorine	Cl
Platinum	Pt	Cobalt	Co
Zinc	Zn	Chromium	Cr

Symbols of some elements are derived from their Latin or German names. A list of these elements are given below (Table 4.3).

Table 4.3. Elements with symbols derived from Latin names.

Name of element	Latin name	Symbol
Antimony	Stibium	Sb
Copper	Cuprum	Cu
Gold	Aurum	Au
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Potassium	Kalium	K
Silver	Argentum	Ag
Sodium	Natrium	Na
Tin	Stannum	Sn

Significance of the symbol of an Element:

A symbol of an element is not only an abbreviation. It also denotes one atom of that element as well as the mass of an atom. For example, the symbol "Na" represents:

- (A) the element sodium
- (B) an atom of sodium
- (C) the mass of an atom of sodium

Similarly, the symbol for hydrogen, H represents or stands for one atom of the element hydrogen. H also stands for the mass of one atom of hydrogen. H does not symbolise the molecule of hydrogen, because the molecule of hydrogen has two atoms of hydrogen combined together and so H means one atom only of the element.

4. 2. Chemical formula:

How can we symbolise the molecules of an element or of a compound?

We know that a molecule of an element is made up of atoms of the same kind. We have also learnt that atoms of different elements combine in simple numerical ratios to produce compounds. It is therefore, possible to represent the molecule of a substance (element or compound) with the help of symbols of elements present in it. The expression obtained by writing the symbols of the constituent elements side by side and indicating the number of each kind by a subscript figure (placed at the right hand bottom of each symbol) is called a *formula*. For example, a molecule of water contains two atoms of hydrogen and one atom of oxygen. Therefore the formula of water is H_2O . It must be noted that for one atom of an element, no subscript is required as the symbol of an element itself represent one atom of the element.

In the case of molecule of an element, the number of atoms constituting the

molecule (atomicity) is written as a subscript after the symbol of that element. For example, a molecule of oxygen is written as O_2 . It shows that the molecule contains two atoms of oxygen in combination.

Thus a *chemical formula* is a symbolic representation of the composition of the molecule of a substance.

The molecular formula of some common elements and compounds are given in the following table (Table 4.4).

Table 4.4 Formula of some common substances.

Element	Chemical formula	Compound	Chemical formula
Helium	He	Water	H_2O
Hydrogen	H_2	Common salt	
Oxygen	O_2	(Sodium Chloride)	NaCl
Neon	Ne	Methane	CH_4
Nitrogen	N_2	Ammonia	NH_3
Phosphorous	P_4	Hydrogen Chloride	HCl
Ozone	O_3	Sulphuric acid	H_2SO_4
Chlorine	Cl_2	Nitric acid	HNO_3
Bromine	Br_2	Carbon dioxide	CO_2
Iodine	I_2		
Sulphur	S		

Carbon (C), Sodium (Na), Copper (Cu), Aluminium (Al), Iron (Fe) and all other metals exist as collection of atoms. Such elements are represented by the symbol of their atoms.

4.2.1. Valency:

Atoms combine to form molecules. The combining capacity of an atom of an element to form a molecule is termed valency.

Valency can be used to find out how the atoms of an element will combine with the atoms of other elements to form compounds. Valency can be thought of as hands or arms of that atom. For example, human beings have two arms and an octopus has eight. If one octopus has to catch hold of a few people by their hands so that all the eight arms of the octopus and the two arms of all human beings are locked, how many humans will be held by the octopus? If the octopus is represented by "T" and humans by "M", how can we represent this combination? It comes out to be TM_4 . The subscript 4 indicates the number of humans held by octopus.

It is interesting to note that some elements show variable valency. For example, iron combines with chlorine to form two compounds, ferrous chloride ($FeCl_2$) and ferric chloride ($FeCl_3$). In $FeCl_2$, valency of iron is 2 and in $FeCl_3$, the valency of iron is 3.

When a metallic element forms two compounds with another element, the name of the metal in its lower valency state ends with a suffix, "ous" and that in the compound of its higher valency state ends with a suffix "ic", or the valency of the metal is shown within brackets.

Thus

Ferrous chloride or Iron (II) Chloride = FeCl_2

Ferric Chloride or Iron (III) Chloride = FeCl_3

Valency of some common metals and non-metals are given in Table 4.5 and 4.6 respectively.

Table 4.5. Valencies of some common Metals

Element	Symbol	Valency	Element	Symbol	Valency
Aluminium	Al	3	Magnesium	Mg	2
Calcium	Ca	2	Mercury	Hg	1,2
Copper	Cu	1,2	Potassium	K	1
Iron	Fe	2,3	Silver	Ag	1
Lead	Pb	2,4	Sodium	Na	1
Zinc	Zn	2			

Table 4.6. Valencies of some common non-metals

Element	Symbol	Valency.
Hydrogen	H	1
Fluorine	F	1
Chlorine	Cl	1
Bromine	Br	1
Iodine	I	1
Oxygen	O	2
Sulphur	S	2(4,6)
Nitrogen	N	3 (1,2, 4,5)
Phosphorous	P	3,5
Carbon	C	4

Valencies shown within brackets are not common.

4.2.3. Ions:

Compounds made up of metals and non-metals generally consists of charged species. *The charged species are known as ions.* The charge of the ion may be positive or negative. The positively charged ions are called *cations* and the negatively charged ions *anions*. For example, the compound sodium chloride consists of positively charged sodium ions (Na^+) and negatively charged chloride (Cl^-) ions. Ions may consist of a charged atom or a group of atoms having a net charge on them. A group of atoms carrying a charge is also known as a *polyatomic ion*. *Thus an ion may be defined as atom or group of atoms having either positive or negative charge.* The compounds which are made up of ions are known as *ionic compounds*. The valency of an ion is equal to the charge on the ion. The valencies of some simple and polyatomic ions are given in Table 4.7.

Table 4.7. Some common, simple and polyatomic ions

Positively charged ions (CATIONS)			Negatively charged ions (ANIONS)		
Valency	Name of ion	Symbol	Valency	Name of ion	Symbol
1 (Monovalent cation)	Sodium	Na ⁺	1 (monovalent)	Hydride	H ⁻
	Potassium	K ⁺		Chloride	Cl ⁻
	Silver	Ag ⁺		Bromide	Br ⁻
	Cuprous or Copper (I)	Cu ⁺		Hydroxide	OH ⁻
	Ammonium	NH ₄ ⁺			
2 (Divalent cation)	Magnesium	Mg ²⁺		Nitrate	NO ₃ ⁻
	Calcium	Ca ²⁺		Nitrite	NO ₂ ⁻
	Zinc	Zn ²⁺		Bicarbonate (Hydrogen carbonate)	HCO ₃ ⁻
	Ferrous or Iron (II)	Fe ²⁺			
	Cupric or Copper (II)	Cu ²⁺			
3 (Trivalent cation) or Iron (III)	Aluminium	Al ³⁺	2 Bivalent Anion)	Oxide	O ²⁻
	Ferric	Fe ³⁺		Sulphide	S ²⁻
			Sulphate	Sulphite	SO ₃ ²⁻
				SO ₄ ²⁻	
				Carbonate	CO ₃ ²⁻
			3 (Trivalent anion)	Nitride	N ³⁻
				Phosphate	PO ₄ ³⁻
				Phosphide	P ³⁻

4.2.4. Writing chemical formulae:

Knowing the valencies of elements, we can write the formula of their compounds by balancing the valencies of the different atoms which form the compound. The general rules are as follows:

- The valencies of the elements (atoms) or the charges of the ions must balance.
- When a compound consists of a metal and a non-metal the name or symbol of the metal is written first. For example, calcium oxide (CaO), sodium chloride (NaCl), zinc sulphide (ZnS) etc, calcium, sodium and zinc are metals and are written on the left, whereas, oxygen, chlorine and sulphur are non-metals, and are written on the right.

- (iii) In compounds formed with polyatomic ions, the ion is enclosed in a bracket before writing the number to indicate the ratio.

While writing the chemical formula of compounds, we write the symbols of the constituent elements and their valencies below the symbol. Then we must cross over the valencies of the combining atoms to balance their valencies. The common factor, if there is any, is cancelled out to get a simple whole number ratio.

Example 1.

Formula of hydrogen chloride

Symbols: H $\swarrow \nearrow$ Cl

Valency: 1 $\swarrow \nearrow$ 1

Formula of the compound is HCl

Example 2.

Formula of hydrogen sulphide

Symbol: H $\swarrow \nearrow$ S

Valency: 1 $\swarrow \nearrow$ 2

Formula: H₂S

Example 3.

Formula of ammonia

Symbol: N $\swarrow \nearrow$ H

Valency: 3 $\swarrow \nearrow$ 1

Formula : NH₃

Example 4. Formula of carbon dioxide.

Symbol: C $\swarrow \nearrow$ O

Valency: 4 $\swarrow \nearrow$ 2

Formula : C₂O₄, dividing the formula by common factor 2, we get formula of carbon dioxide as CO₂

Example 5.

Formula of aluminium oxide.

Symbol: Al $\swarrow \nearrow$ O

Valency: 3 $\swarrow \nearrow$ 2

Formula : Al₂O₃

In the formation of an ionic compound, combination takes place between the positive and negative ions in such a way that the resulting molecule as a whole is electrically neutral. In other words, the product of the valency and the number of ions must be the same for both the ions (cations and anions). For this we criss-crossed the charges to get the formula.

Example 6.

Formula of Calcium chloride

Symbol: Ca $\swarrow \nearrow$ ClCharge (Valency): 2^+ 1^- Formula: CaCl_2 **Example 7.**

Formula of Magnesium nitrate

Symbol: Mg $\swarrow \nearrow$ NO_3 Charge: 2^+ 1^- Formula $\text{Mg}(\text{NO}_3)_2$

It is to be noted that we use brackets when we have two or more of the same polyatomic ions in the formula. Here the bracket around NO_3 with a subscript 2 indicates that there are two nitrate groups joined to one magnesium ion.

Example 8.

Formula of ammonium sulphate

Symbol: NH_4 $\swarrow \nearrow$ SO_4 Charge: 1^+ 2^- Formula: $(\text{NH}_4)_2\text{SO}_4$ **Let us answer these:**

1. Write down the formula of

(i) Aluminium nitrate (ii) Zinc sulphide (iii) Calcium hydroxide

(iv) Aluminium sulphate (v) Iron (II) carbonate

2. Name the following compounds:

 $\text{Cu}(\text{OH})_2$, FeS , $\text{Mg}_3(\text{PO}_4)_2$, AgNO_3 , PbCO_3 , HgBr_2

3. How many atoms are present in a

(i) $\text{Al}_2(\text{SO}_4)_3$ molecule (ii) CO_3^{2-} ion?**4.3. Molecular mass and mole concept:****4.3.1. Molecular mass:**

We have discussed the concept of atomic mass in section 3.2.3. Since a molecule is made up of atoms, the concept can be extended to calculate molecular masses. *The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance.* The molecular mass is therefore the relative mass of a molecule expressed in atomic mass units (u). It may be defined as the relative mass of the molecule as compared with the mass of one atom of carbon (C-12) taken as 12 u.

Example 4.1.

Find the molecular mass of water (H_2O)

Solution:

Atomic mass of hydrogen (H) = 1u

“ “ “ oxygen (O) = 16u

A water molecule (H_2O) contains two atoms of hydrogen and one atom of oxygen.

$$\begin{aligned}\therefore \text{Molecular mass of water } (\text{H}_2\text{O}) &= (1 \times 2) + (1 \times 16) \\ &= 2 + 16 \\ &= 18\text{u}.\end{aligned}$$

Example 4.2.

Calculate the molecular mass of sodium carbonate (Na_2CO_3)

Solution:

Atomic mass of sodium (Na) = 23

“ “ “ Carbon (C) = 12

“ “ “ Oxygen (O) = 16

$$\begin{aligned}\therefore \text{Molecular mass of } \text{Na}_2\text{CO}_3 &= (23 \times 2) + 12 + (16 \times 3) \\ &= 46 + 12 + 48 \\ &= 106.\end{aligned}$$

4.3.2. Calculation of percentage composition from molecular formula:

Can we find out the percentage content of elements present in a compound?

Since a molecular formula gives us the number of atoms of elements which constitute the substance (compound) and also parts by mass of the elements present in the substance, we can calculate the percentage composition of those elements provided the molecular formula of the substance is known.

Example: 4.3

Calculate the percentage composition by mass of the constituents of water.

Solution:

The molecular formula of water is H_2O .

$$\begin{aligned}\text{Molecular mass of } \text{H}_2\text{O} &= 2 \times \text{atomic mass of H atom} + \text{atomic mass of 1 O atom} \\ &= 2 + 16 = 18 \text{ u}\end{aligned}$$

$$\therefore \% \text{ of hydrogen} = \frac{2}{18} \times 100 = 11.11$$

$$\% \text{ of oxygen} = \frac{16}{18} \times 100 = 88.89.$$

Example 4.4

Calculate the % composition by mass of oxygen in nitric acid.

Solution:

The molecule formula of nitric acid is HNO_3 .

$$\begin{aligned}\text{Molecular mass of } \text{HNO}_3 &= (1 \times \text{H}) + (1 \times \text{N}) + (3 \times \text{O}) \\ &= 1 + 14 + 48 \\ &= 63 \text{ u.}\end{aligned}$$

$$\begin{aligned}\therefore \% \text{ composition by mass of oxygen} &= \frac{\text{Parts by mass of oxygen}}{\text{Molecular mass of } \text{HNO}_3} \times 100 \\ &= \frac{48}{63} \times 100 \\ &= 76.12.\end{aligned}$$

Example 4.5

Calculate the mass of aluminium present in 34 g of aluminium oxide, Al_2O_3 (atomic mass of Al = 27)

Solution:

$$\begin{aligned}\text{Molecular mass of } \text{Al}_2\text{O}_3 &= \text{mass of 2 Al atoms} + \text{mass of 3 O atoms} \\ &= (2 \times 27) + (3 \times 16) \\ &= 54 + 48 \\ &= 102 \text{ u.}\end{aligned}$$

$$\begin{aligned}\therefore \text{Mass of Aluminium present in 34g of } \text{Al}_2\text{O}_3 &= \frac{54 \text{ u}}{102 \text{ u}} \times 34 \text{ g} \\ &= 18 \text{ g.}\end{aligned}$$

4.3.3 Formula Mass:

The formula unit mass of a substance can be calculated in the same manner as we calculate the molecular mass. The formula unit mass is the sum of the atomic masses of all atoms in a formula unit of a compound. The only difference between the formula unit mass and molecular mass is that we use the word formula unit for those substances whose constituent particles are ions. For example, sodium chloride consists of sodium ion and chloride ions. Its formula unit is NaCl. Hence, the formula unit mass of

$$\text{NaCl} = 23 + 35.5 = 58.5 \text{ u.}$$

Example: 4.6

Calculate the formula unit mass of sodium nitrate (NaNO_3)

Solution:

$$\begin{aligned}\text{Formula unit mass of } \text{NaNO}_3 &= 23 + 14 + (16 \times 3) \\ &= 23 + 14 + 48 \\ &= 85 \text{ u.}\end{aligned}$$

Gram Molecular Mass:

The molecular mass of a substance (element or compound) expressed in grams is called the gram-molecular mass of the substance. For example, the molecular mass of water (H_2O) is 18 u. Hence, the gram-molecular mass of water (H_2O) is 18 g.

Example 4.7

Calculate gram-molecular mass of methane (CH_4)

Solution:

$$\begin{aligned}\text{Molecular mass of methane (CH}_4\text{)} &= \text{Atomic mass of C} + 4 \times \text{atomic mass of H} \\ &= 12 + 4 \\ &= 16 \text{ u}\end{aligned}$$

$$\therefore \text{ gram-molecular mass of CH}_4 = 16 \text{ g.}$$

Let us answer these:

1. Calculate the molecular masses of Cl_2 , CO_2 , CH_4 , NH_3 , C_2H_6
2. Calculate the formula masses of CaO , K_2CO_3 , NaHCO_3 , H_2SO_4
3. Calculate the gram molecular mass of $\text{Al}_2(\text{SO}_4)_3$ (atomic mass of Al = 27, S = 32)

4.3.4 Mole Concept:

Atomic, molecular and formula masses are just numbers. They are relative numbers and carry no units such as gram (g) or kilogram (kg). They are expressed as numbers and as atomic mass unit (u). In practice and in everyday use, we want to handle substances in grams or kg quantities.

What is the relation between the mass of a substance and those of the atoms or molecules it is made up of ?

The basic unit is the atom or the molecule. We have to find a way to connect the masses of the materials we use everyday with the numbers of atoms or molecules in them. The connection between the everyday world (macroscopic) and the atomic and molecular (microscopic) world is made by the concept of *mole*.

We know that the mass of a hydrogen molecule is 2 a. m. u (u) and that of an oxygen molecule is 32 a. m. u. This means that 2 units of mass of H_2 contain the same number of molecules (one) of H_2 as 32 units of mass of O_2 (also one). If we take two samples, one containing H_2 gas and the other O_2 gas in the mass ratio 2:32, then the first sample must contain exactly as many H_2 molecules as the second contain O_2 molecules.

If the first contains "L" molecules in 2g of H_2 , then there must be the same L molecules of O_2 in 32 g of oxygen gas. This also means that the number of grams of any substance equal to its molecular mass (gram molecular mass) must contain "L"

molecules. The number of molecules of a substance contained in one gram molecular mass of it will be this fixed number "L". This magic number "L" is experimentally determined and found to be 6.022×10^{23} and is called the *Avogadro number* or *Avogadro constant* or the *mole*. A mole is thus just a collection of 6.022×10^{23} of the same object. It is thus like the atomic or molecular dozen (12 nos) or gross (144 nos), except that it is just a huge number. One gram of hydrogen is such a large collection of atoms, in fact it has precisely 6.022×10^{23} atoms in it.

A mole of any substance contains the number of elementary particles equal to Avogadro's constant.

It does not matter whether we talk about a mole of atoms, a mole of molecules, a mole of electrons, or a mole of ions, by definition, a mole always contains 6.022×10^{23} elementary particles.

There are 6.022×10^{23} oxygen atoms in a mole of oxygen atoms.

There are 6.022×10^{23} oxygen molecules in a mole of oxygen molecules.

There are 6.022×10^{23} H_2O molecules in a mole of water

There are 6.022×10^{23} Na^+ ions in a mole of sodium ions.

There are 6.022×10^{23} Cl^- ions in a mole of chlorine ions.

There are 6.022×10^{23} electrons in a mole of electrons.

Why is mole so significant?

Besides being related to a number, a mole has one more advantage over other number like dozen or gross. The advantage is that mass of 1 mole of a particular substance is also fixed.

The mass of 1 mole of a substance (element or compound) is equal to its relative atomic or molecular mass in grams (gram atomic or gram molecular mass).

Example 4.7

Relative atomic mass of hydrogen (H) = 1u

gram atomic mass of H = 1 g.

1 u hydrogen has only 1 atom of hydrogen

1 g hydrogen has 1 mole atoms, that is 6.022×10^{23} atoms of hydrogen.

Example 4.8

If 12 g of carbon contains 1 mole of carbon atoms, what is the actual mass of one atom of carbon?

Solution:

$$\begin{aligned} \text{Mass of 1 atom of carbon} &= \frac{12\text{g}}{6.022 \times 10^{23}} \\ &= 1.99 \times 10^{-23} \text{ g.} \end{aligned}$$

Example 4.9

How many moles are in 20 g of copper metal?

Solution:

The atomic mass of copper is 63.5u

1 mole copper (Cu) = 63.5g.

$$\begin{aligned}\therefore \text{Number of moles} &= \frac{20\text{g}}{63.5\text{g/mol}} \\ &= 0.31\text{mole (nearly)}\end{aligned}$$

Example 4.10

How many molecules of oxygen (O_2) are there in 4 g of O_2 ?

Solution:

Molecular mass of $\text{O}_2 = 32 \text{ u}$

Gram molecular mass (molar mass) of $\text{O}_2 = 32 \text{ g}$.

32 g O_2 contains 6.022×10^{23} molecules of O_2

$$\begin{aligned}\therefore 4\text{g } \text{O}_2 \text{ contains} &= \frac{6.022 \times 10^{23} \times 4}{32} \\ &= 7.5 \times 10^{22} \text{ molecules (nearly)}\end{aligned}$$

Example 4.11

How many molecules of water (H_2O) are there in 1 g of H_2O ?

Solution:

Molecular mass of $\text{H}_2\text{O} = 18 \text{ u}$

18g H_2O contains 6.022×10^{23} molecules.

$$\begin{aligned}\therefore 1 \text{ g } \text{H}_2\text{O} \text{ will have} &= \frac{6.022 \times 10^{23}}{18} \text{ molecules} \\ &= 3.346 \times 10^{22} \text{ molecules.}\end{aligned}$$

The relationship between mole, Avogadro number and mass is given in the following Table (Table 4.8).

Table 4.8. Relationship between mole, Avogadro number and mass.

Mole	No. of particles	Mass
1 mole carbon atoms	6.022×10^{23} atoms of C	12 g Carbon
1 mole of water	6.022×10^{23} molecules of H_2O	18 g water
1 mole of any particle (atoms, molecules, ion)	6.022×10^{23} number of that particle.	Relative mass of those particles in grams
1 mole of molecules	6.022×10^{23} number of molecules	Molecular mass in grams.

4.3.5 Significance of a Formula

A formula of a substance has both *qualitative* as well as *quantitative* meaning. In general, a chemical formula conveys the following information:

- (a) *Qualitatively*, it represents:
 - (i) The name of the compound.
 - (ii) The elements present in the compound.
- (b) *Quantitatively*, it represents:
 - (i) One molecule of the substance.
 - (ii) The number of atoms of various elements which constitute one molecule.
 - (iii) The molecular mass of the substance.
 - (iv) The number of parts by mass of the elements present in the molecule.
 - (v) One mole of the substance.

Let us take the example of CO_2

- (a) *Qualitatively*, it represents:
 - (i) Carbon dioxide.
 - (ii) Carbon dioxide is made up of carbon and oxygen elements.
- (b) *Quantitatively*, it represents:
 - (i) One molecule of carbon dioxide.
 - (ii) One molecule of carbon dioxide consists of one atom of carbon and two atoms of oxygen.
 - (iii) Molecular mass of carbon dioxide is $12 + 16 \times 2 = 44\text{u}$.
 - (iv) 44 parts by mass of carbon dioxide contains 12 parts by mass of carbon and 32 parts by mass of oxygen.
 - (v) One mole of carbon dioxide i.e. 6.022×10^{23} molecules of CO_2 .

Let us answer these:

1. What mass in grams is represented by:
 - (a) 0.44 mole of CO_2
 - (b) 3 mole of NH_3
2. The mass of a single atom M is $3.05 \times 10^{-22}\text{ g}$. What is its atomic mass?
3. Which has more number of atoms, 50g of sodium or 50g of Ca?
(given atomic mass of Na = 23u, Ca = 40 u)?

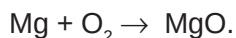
4. 4. Chemical equation:

We have learnt that chemical formulas are used in representing molecules and their composition. A chemical reaction also can be represented by chemical equation using symbols and formulas of respective reactants and products.

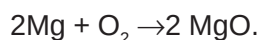
Let us take the reaction of burning magnesium in oxygen forming magnesium oxide as an example. In words, we can represent it as follows:

Magnesium + Oxygen $\rightarrow$ Magnesium oxide.

Using the symbols and formula, this can be written as,



Here, magnesium and oxygen are the *reactants* and magnesium oxide is the *product*. The number of atoms of magnesium in both the reactants and the product is the same. But the number of atoms of oxygen in the reactant and product is not the same. There are two oxygen atoms in O_2 . Only one oxygen atom combines with magnesium in MgO . The other atom of oxygen must have combined with another atom of magnesium to form two molecules of MgO . To represent this, we have to put the number 2 before MgO and Mg . Thus we get



Now the total number of atoms on both sides is equal and the equation is balanced.

A chemical equation is the symbolic representation of an actual chemical reaction with the help of symbols and formulas of respective reactants and products.

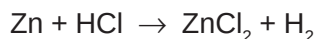
In writing a chemical equation, the reactants and the products are represented by their molecules. For example, elements like hydrogen, oxygen, nitrogen etc. are represented by their molecular formula H_2 , O_2 , N_2 etc. respectively. However elements such as carbon, sodium, copper, iron etc. are represented by their symbols because they take part in chemical reactions in the form of their atoms.

While writing chemical equations, the following points must be kept in mind:

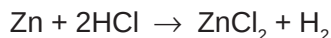
- (i) The reactants (symbols or formula) are placed on the left hand side separated by plus (+) sign which means "reacts with"
- (ii) The products are placed on the right hand side separated by plus (+) sign which means "along with"
- (iii) The reactants and products are separated by an arrow pointing towards the products ($\rightarrow$), or the sign of equality (=) which means 'to produce'.
- (iv) Above the arrow, reaction conditions such as catalyst, temperature, pressure etc. may be indicated.
- (v) If the product is a gas, it is indicated by an upward arrow ($\uparrow$) and if the product is a precipitate, it is indicated by a downward arrow ($\downarrow$).
- (vi) Sometimes the physical state of reactants and products are also indicated in a chemical equation.

We know that in a chemical reaction, atoms can neither be created nor destroyed as given by the law of conservation of mass. Hence all the atoms present in reactants must be found in products. The number of atoms present in reactants and products must be equal. Thus *all chemical equations must be balanced*.

Dilute hydrochloric acid reacts with zinc metal to produce zinc chloride and hydrogen gas. To write chemical equation for the reaction, we first write the skeleton equation as follows:

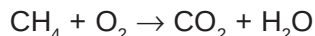


Here, we find that two chlorine and two hydrogen atoms on the product side but only one atom of chlorine and one atom of hydrogen on the reactant side. To balance, we put 2 before HCl.

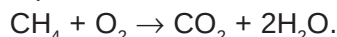


Now the equation is balanced.

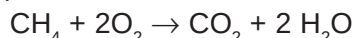
Let us take one more example, the reaction between methane and oxygen. Methane (CH_4) burns in oxygen to form water vapour and carbon dioxide (CO_2).



To balance hydrogen, we must put 2 as the coefficient of H_2O .



To balance oxygen atoms, we place 2 as the coefficient of O_2 on the reactant side



The equation is thus balanced.

4.4.1 Information conveyed by a chemical equation

Like symbols and formulas, a chemical equation has also both qualitative and quantitative significance.

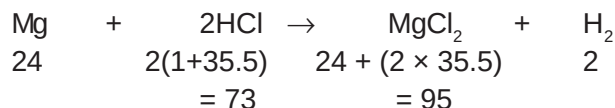
Qualitatively, it represents:

- (i) What are the reactants and what are the products,
- (ii) The composition of reactants and products.

Quantitatively, it represents:

- (i) the relative number of each kind of molecules and atoms;
- (ii) the relative masses of the reactants and products;
- (iii) the number of moles of the reactants and products;
- (iv) the volumes of gaseous substances involved.

For example, the chemical equation,



gives us the following information:

Qualitatively,

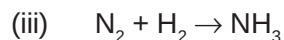
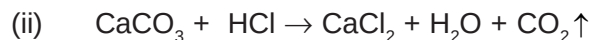
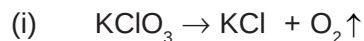
- (i) It shows that magnesium react with hydrogen chloride to produce magnesium chloride and hydrogen.

Quantitatively, it represents

- (i) Two molecules of hydrogen chloride reacts with one atom of magnesium to produce one molecule of magnesium chloride and one molecule of hydrogen.
- (ii) 73 parts by mass of hydrogen chloride react with 24 parts by mass of magnesium to produce 95 parts by mass of magnesium chloride and 2 parts by mass of hydrogen.
- (iii) Two moles of hydrogen chloride react with one mole of magnesium to produce one mole of magnesium chloride and one mole of hydrogen.

Let us answer these:

1. Verify whether the following equations are balanced or not? If not, balance it.



2. Sodium reacts with water to produce sodium hydroxide and hydrogen gas. Write a chemical equation for the reaction.

POINT TO REMEMBER

- * Symbol is the accepted abbreviation of the name of an element
- * A symbol represents the name, an atom and the atomic mass of an element.
- * A chemical formula is a symbolic representation of the composition of the molecule of a substance.
- * The combining capacity of an element is termed valency.
- * A charged atom or a group of atoms having a net charge is called an ion.
- * The valency of an ion is equal to the number of charges carried by the ion.
- * The chemical formula of a compound can be written by balancing the valencies of the elements (atoms) or the charges of the ions.
- * A chemical equation represents an actual chemical reaction using symbols and formulas of respective reactants and products.
- * The *molecular mass* of a substance can be determined by adding together the atomic masses of all the atoms in a molecule of the substance.
- * *Formula mass* is the sum of the masses of all the atoms in the formula of an ionic compound or others where discrete molecules do not exist.
- * The molecular mass expressed in grams is termed gram molecular mass.
- * The Avogadro constant (L) 6.022×10^{23} is defined as the number of atoms in 12 g of carbon-12.
- * The mole is the amount of substance of a system which contains as many elementary units as there are atoms in 12 g of carbon-12.
- * 1 mole of atoms has a mass equal to the gram atomic mass.
- * 1 mole of particles = 6.022×10^{23} particles of any substance.
- * Molar mass is the mass of one mole of a substance.

EXERCISES

1. What is meant by valency of an element?
2. What is meant by the symbol of an element? Explain with examples.
3. Give two symbols which have been derived from the Latin names of the elements.
4. What is molecule? Explain with an example.
5. What is meant by a chemical formula? Write the formula of three elements and two compounds.
6. Explain the difference between 2N and N_2 .
7. Define the molecular mass of a substance.
8. Calculate the molecular masses of the following:
 - (a) Ethane, C_2H_6
 - (b) Calcium carbonate CaCO_3
 - (c) Copper sulphate, CuSO_4
 - (d) Ethanol, $\text{C}_2\text{H}_5\text{OH}$
 - (e) Acetic acid, CH_3COOH (Atomic masses: $\text{Ca} = 40$, $\text{Cu} = 63.5$)
 - (f) Ferrous sulphate (hydrated) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
9. Translate the following statements into chemical equations and then balance the equations.
 - (a) Chlorine gas burns in hydrogen gas to give hydrogen chloride.
 - (b) Hydrogen sulphide gas burns in air to give water and sulphur dioxide.
 - (c) Hydrogen gas combines with nitrogen to give ammonia, NH_3
 - (d) Sodium metal reacts with water to give sodium hydroxide and hydrogen gas.
 - (e) Aluminium metal replaces iron from ferric oxide Fe_2O_3 , giving aluminium oxide and iron.
10. What is the difference between a cation and an anion? Give examples.
11. Name the following compounds. Also write the symbols/ formulas of the ions present in them
 - (a) CuSO_4
 - (b) Na_2SO_4
 - (c) NH_4NO_3
 - (d) Na_2CO_3
 - (e) CaCl_2
12. Calculate formula masses of the following compounds:
 - (a) Calcium chloride
 - (b) Sodium hydrogen carbonate.
13. If the valency of carbon is 4 and that of sulphur is 2, work out the formula of the compound of carbon and sulphur. Name the compound.
14. An element B shows valencies 2, and 3. Write the formula of its two oxides.
15. If the aluminium salt of an anion X is A_2X_3 , what is the valency of X? What will be the formula of the magnesium salt of X?
16. Define mole.
17. How many atoms are there in 0.24 mole of oxygen (O_2)?
18. Convert into mole.
 - (a) 12 g of nitrogen gas
 - (b) 15 g of water
 - (c) 22 g of carbon dioxide.
19. What is the mass of
 - (a) 0.2 mole of Chlorine (Cl_2) gas.
 - (b) 0.5 mole of water molecules.
20. Calculate the number of potassium ions present in 7.45 g of potassium oxide. (at.mass of $\text{K} = 39\text{u}$)