# Stoichiometry

## Laws of chemical combinations

**Important laws of chemical combinations are**

a) The law of conservation of mass

b) The law of definite proportions

c) The law of multiple proportions

d) The law of reciprocal proportions

e) Gay-Lussac's law of combining volumes

**1. The law of conservation of mass**

It was proposed by Lavoisier. Law of conservation of mass states that "The matter can neither be created nor destroyed during a chemical change".i.e the total mass of the products formed during a chemical change is exactly equal to the total mass of the reactants.

**Eg:** The calculated amounts of solid Ammonium sulphate and solid Barium chloride are dissolved in water separately and their solutions are mixed. The following reaction takes place :

$$(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \longrightarrow BaSO_{4(s)} + 2NH_4Cl_{(aq)}$$

$BaSO_4$ is a white precipitate. It is separated from the solution by filtration and weighed. The filtrate is completely evaporated and the mass of the residue $NH_4Cl$ is weighed. Total mass of $(NH_4)_2SO_4$ + $BaCl_2$ is equal to the total mass of $BaSO_4$ + $NH_4Cl$. Thus, the law of conservation of mass is verified.

**E.g.:** $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Mass before reaction = 2+71 = 73 gm

Mass after reaction = 2 ×36.5 = 73

*A chemical equation is balanced to obey law of conservation of mass.

*It is applicable for chemical reactions only but not for Nuclear reactions.

**2. The law of definite or constant or fixed proportions.**

It was proposed by the French chemist Joseph Proust.

It states that ‘A given chemical substance always contains the same elements combined in a fixed proportion by weight’.

**E.g.:** A sample of carbon dioxide may be prepared by different chemical methods

$C + O_2 \rightarrow CO_2$

$CaCO_3 \rightarrow CaO + CO_2$

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$

Irrespective of method of preparation carbon dioxide is made up of the same elements carbon and oxygen combined together in the same fixed ratio of 3: 8 by weight.

*The importance of law of definite proportions is that it is useful in deriving the chemical formulae of compounds.

**3. The law of multiple proportions**

It was proposed by John Dalton. It states that “ If two elements chemically combine to give two or more compounds, then the weights of one element that combine with fixed weight of the other element in those compounds are in a simple multiple ratio”.

Law of multiple proportions was derived from law of definite proportions and law of conservation of mass.

**E.g.**: Carbon and oxygen combine to form carbon monoxide (CO) and carbon dioxide ($CO_2$)12 grams of carbon combines with 16grams of oxygen In carbon monoxide and with 32 grams of oxygen In carbon dioxide.The weights of oxygen that combine with 12 grams of carbon in CO and $CO_2$ are in the ratio 16:32 or 1:2, which is a simple multiple ratio.

**E.g.**: Hydrogen combines with oxygen to form two compounds, water and hydrogen peroxide. The masses of oxygen which combine with 1gm of hydrogen bear a simple ratio 1: 2.

**E.g.**: The ratio of different weights of oxygen that combines with 14g of $N_2$ to form oxides i.e, $N_2O$, NO, $N_2O_3$, $NO_2$ and $N_2O_5$ is 1 : 2 : 3 : 4 : 5

Some other examples illustrating this law are

1.$S_2Cl_2$, $SCl_2$ & $SCl_4$

2.FeO& $Fe_2O_3$

3. $SO_2$&$SO_3$

**E.g.**: Two oxides of metal M have 27.6% and 30% oxygen by weight. If the formula of the first oxide is $M_3O_4$, what is the formula of second oxide?

**Solution:** Oxide (A): Oxygen 27.6%; 4'O' atoms

Metal 72.4%; 3 'M' atoms

Oxide (B): Oxygen 30%; Metal 70%

Number of 'O' atoms = 30/27.6 × 4 = 4.35

Number of 'M' atoms = 72.4/70× 3 = 2.9

Ratio of M and O atoms in oxide B = 2.9: 4.35 = 2: 3

Hence the Formula of the second oxide is $M_2O_3$

**4. Law of reciprocal proportions**

It was proposed by Ritcher and verified by Stass.

"The ratio of Weights of two different elements that are combining with a fixed weight of a third element is same in the compound formed when they combine with one another

**E.g.** i) NaC*l*, NaH, HC*l*

The ratio of weight's Cl and 'H'that combine with 35,5gm Na is 35.5:1 which is same in HCl

ii) $CH_4$, $CO_2$, $H_2O$ etc.

Law of reciprocal proportions can be used to obtain equivalent weights of the elements. Hence it is also called law of equivalent weights.

According to law of equivalent weights elements always combine in the ratio of their equivalent weights.

**5. Gay-Lussac's law of combining volumes**

It was proposed by Gay Lussac. It states that "when gases under similar conditions of temperature and pressure chemically combine they bear a simple ratio in their volumes. If the product is also a gas, the ratio of the volumes can be extended to its volume also".

**E.g.** Hydrogen chloride gas is produced from its gaseous elements in 1: 1 volume ratio

$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$

1vol 1vol 2 vol

The simple ratio between the volumes of $H_2$, $Cl_2$ and HC*l* in the reaction is 1: 1: 2.

**6. Avogadro's Law**

It states that "Equal volumes of all gases under similar conditions of temperature and pressure contain equal number of moles or molecules".

It is useful in obtaing the mass of a single atom or a molecule.

**Significant figures**

1.In a number all the digits except the last digit are certain but the last digit is doubtful.

2.The number of certain digits along with the last doubtful digit present in a number is called significant figures

3.The number of certain digits depends upon the precision of scale used.

Rules for determining the number of significant figures:

i. All non-zero digits as well as the zeros between the non-zero digits are significant.

ii.Zeros to the left of the first non-zero digit in a number are not significant.

iii.If a number ends in zeros but these zeros are to the right of the decimal point, then these zeros are significant.

iv. If a number ends in zeros but these zeros are not to the right of a decimal point, these zeros may or may not be significant.

For example in Counting numbers of objects, 2 bags (or) 5 books's have infinite significant figures as these are exact Numbers and can be represented by writing infinite numbers of zeros after placing a decimal.

i.e., 2 = 2.000000 (or) 5=5.000000…

v. The results of a addition or subtraction should be reported to the same number of decimal places as that of the term with least number of decimal places.

vi. The result of multiplication or division should be reported to the same number of significant figures as is possessed by the least precise term.

vii. If calculation involves a number of steps, the result should contain the same number of significant figures as that of the least precise number involved, other than the exact numbers.

**Rounding off**

i. If the digit just next to the last digit to be retained is less than 5, the last digit is taken as such and all other digits to its right are dropped.

ii.If the last digit is greater than 5, the digit to be retained is increased by 1 and all other digits on its right are dropped.

iii.If the digit just next to the last digit to be retained is equal to 5, the last significant figure is left unchanged if it is even and is increased by 1 if it is odd.

**Precision:** It is the difference between measured value and the arithmetic mean value for a series of measurements.

i. Smaller the difference between the individual values of repeated measurement greater is precision.

ii. Precision refers how closely two or more measurements of the same quantity agree with one another.

**Accuracy:** It is a measure of the difference between experimental value or the mean value of a set of measurements and the true value. i.e. Mean value - true value.

i. Smaller the difference greater is the accuracy.

ii. Accuracy expresses the correctness of measurement.

iii. Accurate results are precise but precise result need not be accurate.

iv. Good precision does not assure good accuracy.