DELHI PUBLIC SCHOOL BANGALORE - EAST
CHEMISTRY NOTES
Class-IX
Ch-3 Atoms & Molecules

LAWS OF CHEMICAL COMBINATION

Dalton explained about atom on the basis of Laws of Chemical Combination.
There are three laws of chemical combination.

1. Law of Conservation of Mass
2. Law of Constant Proportions
3. Law of Multiple Proportions

LAW OF CONSERVATION OF MASS

Antoine L. Lavoisier, a French scientist, established the theory of Law of Conservation of Mass. The law of conservation of mass states, "**Mass can neither be created nor destroyed in a chemical reaction**".

All matters in the universe exist in three states. There are two ways of classification of matter.
1. According to physical state as solid, liquid or gas.
2. According to its composition as element, compound or mixture.

According to this law mass of an isolated system will remain constant over time. This means when mass is enclosed in a system and none is allowed in or out, its quantity will never change. That is mass will be conserved, and hence this is called Law of Conservation of Mass. This means total mass of products is always equal to the total mass of reactants.

REACTANTS AND PRODUCTS:

In a chemical reaction the substances that combine or react are known as reactants and the new substance/substances formed are called product or products.
A chemical reaction can be represented in general as follows:

$$\text{Reactant} + \text{Reactant} \longrightarrow \text{Product}$$

Example: When calcium oxide is dissolved in water calcium hydroxide is formed. The reaction involve in this can be written as:

$$\underbrace{\text{Calcium Oxide} + \text{Water}}_{\text{Reactants}} \longrightarrow \underbrace{\text{Calcium hydroxide}}_{\text{Product}}$$

In this reaction calcium oxide and water are reactants while calcium hydroxide is product.
In this reaction 74 g of calcium hydroxide is obtained when 56 g of calcium oxide reacts with 18 g of water, which is proved by experiment.

$$\underset{56g}{\text{Calcium Oxide}} + \underset{18g}{\text{Water}} \longrightarrow \underset{74g}{\text{Calcium hydroxide}}$$

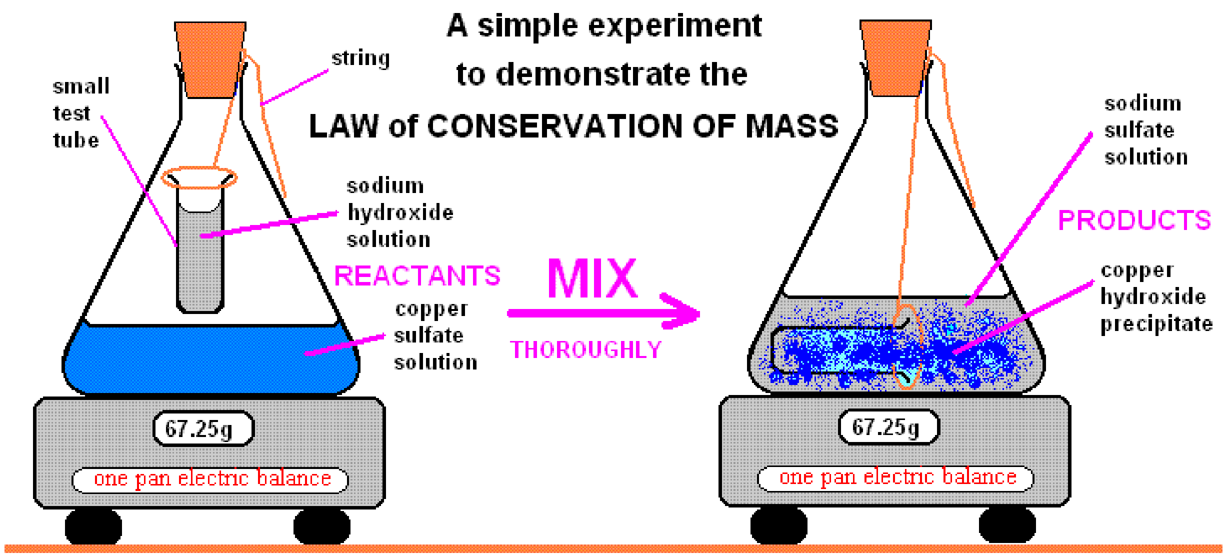
56g + 18g = 74g

Here the total mass of reactants, i.e. calcium oxide and water is equal to 74 g. And the mass of product, i.e. calcium hydroxide is also equal to 74g. This proves that the total mass of reactantsis

$$\underset{56g}{\text{Calcium Oxide}} + \underset{18g}{\text{Water}} \longrightarrow \underset{74g}{\text{Calcium hydroxide}}$$

$$56g + 18g = 74g$$

always equal to the total mass of product, which proves the Law of Conservation of Mass.



LAW OF CONSTANT PROPORTIONS

Law of Constant Proportion states that **a chemical compound always contains exactly the same proportion of elements by mass.**
This law is also known as Law of definite proportions. Joseph Louis Proust gave this law hence, this law is also known as Proust's Law.

Explanation of the law:-

Compounds are formed by the combination of two or more elements. In a compound the ratio of the atoms or element by mass remains always same irrespective of the source of compound. This means a certain compound always formed by the combination of atoms in same ratio by mass. If the ratio of mass of constituent atoms will be altered the new compound is formed.

Examples:-

Water is formed by the combination of hydrogen and oxygen. The ratio of masses of hydrogen and oxygen is always in 1:8 in water irrespective of source of water. Whether you collect the water from a well, river, pond or from anywhere the ratio of their constituent atoms by mass will always same.

$$\begin{array}{lcll} 2H_2 & + & O_2 & \longrightarrow \quad 2H_2O \\ \downarrow & & \downarrow & \\ 4 & & 32 & \\ \downarrow & & \downarrow & \\ 1 & : & 8 & \text{(By Mass)} \end{array}$$

Nitrogen dioxide is a compound, which is formed by the combination of nitrogen and oxygen. The ratio of nitrogen and oxygen by mass in nitrogen dioxide is in 7:16.
Nitrous oxide is a compound which is also formed by the combination of nitrogen and oxygen. The ratio of nitrogen and oxygen in nitrous oxide is in 28:16.
From the above examples it is clear that if the ratio of the atoms by mass is altered then the new compound is formed, such as in the case of nitrogen dioxide, nitrous oxide. These compounds are formed by the combination of same atoms but because of combination of the constituent atoms in different ratios by mass new compound are formed.

DALTON'S ATOMIC THEORY

John Dalton, a British Chemists and scientists gave the Atomic Theory in 1808. This theory is popularly known as Dalton's Atomic Theory. He gave the theory on the basis of Laws of Chemical combination and explains them properly.

- Every matter is made up of very small or tiny particles called atoms.
- Atoms are not divisible and cannot be created or destroyed in a chemical reaction.
- All atoms of a given element are same in size, mass and chemical properties.
- Atoms of different elements are different in size, mass and chemical properties.
- Atoms combine in the ratio of a small whole number to form compounds.
- The relative number and kinds of atoms are constant in a given compound .

ATOM

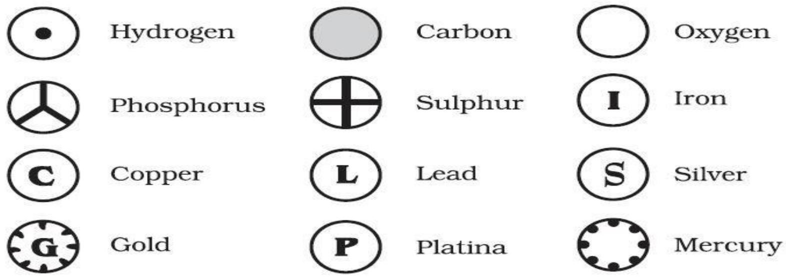
On the basis of Dalton's Atomic Theory , atom can be definedas the smallest particle of matter.

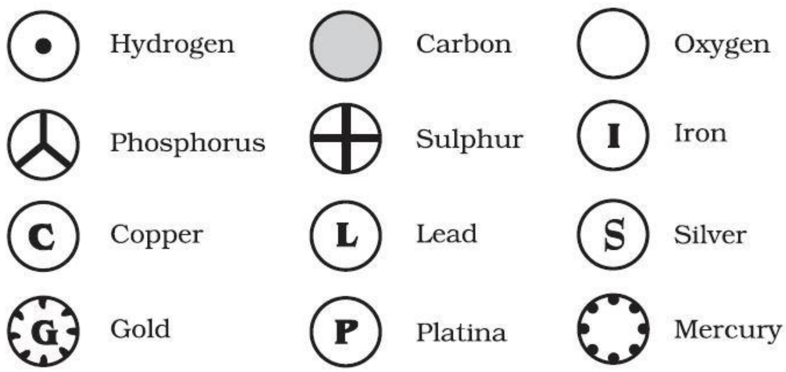
Characteristics of atoms:

- Atom is the smallest particle of matter.
- All elements are made of tiny particles called atom.
- Atoms are very small in size and cannot be seen through naked eyes.
- Atom does not exist in free-state in nature. But atom takes part in a chemical reaction.
- The properties of a matter depend upon the characteristics of atoms.
- Atoms are the building block of an element similar to a brick which combine togetherto make a building.
- The size of atoms is indicated by its radius.
- In ancient time atoms was considered indivisible.

SYMBOLS OF ATOMS OF ELEMENTS

Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element. Berzilius suggested that the symbols of elements be made from one or two letters of the name of the element.





Many of the symbols are the first one or two letters of the element's name in English. The first letter of a symbol is always written as a capital letter (uppercase) and the second letter as a small letter (lowercase).

Symbol and Name of some elements					
Element	**Symbol**	**Element**	**Symbol**	**Element**	**Symbol**
Hydrogen	H	Sodium	Na	Cromium	Cr
Helium	He	Magnesium	Mg	Mangese	Mn
Lithium	Li	Aluminium	Al	Iron	Fe
Beryllium	Be	Silicon	Si	Cobalt	Co
Boron	B	Phosphorous	P	Nickel	Ni
Carbon	C	Sulphur	S	Copper	Cu
Nitrogen	N	Chlorine	Cl	Zinc	Zn
Oxygen	O	Argon	Ar	Silver	Ag
Fluorine	F	Potassium	K	Gold	Au
Neon	Ne	Calcium	Ca	Mercury	Hg

For convenience elements are represented by unique symbols. For example: Hydrogen is represented by 'H'. Oxygen is represented 'O'. Nitrogen is represented by 'N'. Iron is represented by 'Fe'. Elements are represented by unique symbols. For example: Hydrogen is represented by 'H'. Oxygen is represented 'O'. Nitrogen is represented by 'N'. Iron is represented by 'Fe'.

ATOMIC MASS

Mass of atom is called atomic mass. Since, atoms are very small consequently actual mass of an atom is very small. For example the actual mass of one atom of hydrogen is equal to 1.673×10^{-24} g. This is equal to 0.000000000000000000000001673 gram. To deal with such small number is very difficult. Thus for convenience relative atomic mass is used.

Carbon-12 is considered as unit to calculate atomic mass. Carbon-12 is an isotope of carbon.The relative mass of all atoms are found with respect to C-12.
One atomic mass = 1/12 of the mass of one atom of C-12.

$$This\ means\ atomic\ mass\ unit = \frac{1}{12}th\ of\ Carbon - 12$$

Atomic Mass of some elements					
Element	**Symbol**	**Atomic Mass**	**Element**	**Symbol**	**Atomic Mass**
Hydrogen	H	1u	Sodium	Na	23u
Helium	He	4u	Magnesium	Mg	24u
Lithium	Li	7u	Aluminium	Al	27u
Beryllium	Be	9u	Silicon	Si	28u
Boron	B	11u	Phosphorous	P	31u
Carbon	C	12u	Sulphur	S	32u
Nitrogen	N	14u	Chlorine	Cl	35u
Oxygen	O	16u	Potassium	K	39u
Fluorine	F	19u	Calcium	Ca	40u
Neon	Ne	20u	Iron	Fe	56

Thus atomic mass is the relative atomic mass of an atom with respect to 1/12 th of the mass ofcarbon-12 atom. 'amu' is the abbreviation of Atomic mass unit, but now it is denoted just by 'u'.
The atomic mass of hydrogen atom = 1u.
This means one hydrogen atom is 1 times heavier than $1/12^{th}$ of the carbon atom.
The atomic mass of oxygen is 16u, this means one atom of oxygen is 16 times heavier than$1/12^{th}$of carbon atom.

EXISTENCE OF ATOMS

Atoms of most of the elements exist in the form of molecule or ion, since they are most reactive. For example, hydrogen, oxygen, chlorine, etc. However, atoms of some elements, which are non-reactive, exist in free-state in nature. For example helium, neon, argon, etc.
Usually atoms exist in following two forms -
• In the form of molecules
• In the form of ions

MOLECULE

Molecule is the smallest particle of compound

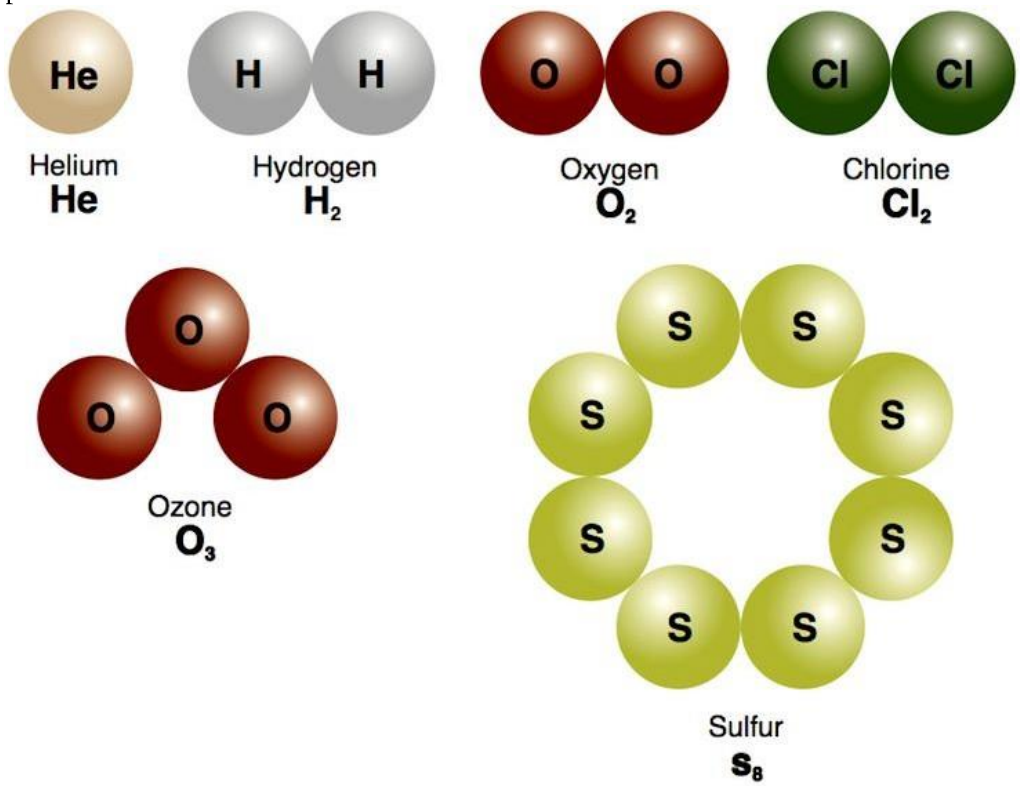
- A molecule may be formed by the combination of two or more similar atoms of an element, such as oxygen molecule is formed by the combination of two oxygen atoms, molecule of hydrogen which is formed by the combination of two hydrogen atoms. These are called molecule of elements
- Molecules may be formed by the combination of atoms of two or more different elements. These are called molecule of compounds. For example molecule of water, formed by the

combination of two atomsof hydrogen and one atom of oxygen. Molecule of Nitric oxide or nitrogen monoxide, formed by the combination of one nitrogen atom and one oxygen atom.

- A molecule takes part in chemical reaction.

MOLECULES OF ELEMENTS

When two or more atoms of same element combine to form a molecule these are called molecules of element.
Example:



ATOMICITY

Monoatomic:
When molecule is formed by single atom only, it is called monoatomic molecule. Generally noble gas forms monoatomic molecules. For example: Helium (He), Neon (Ne), Argon (Ar),Kr (Krypton), Xenon (Xe), Radon (Rn).

Diatomic
When molecule is formed by the combination of two atoms of it is called diatomic molecule. For example: Hydrogen (H_2), Oxygen (O_2)Nitrogen (N_2), Chlorine (Cl_2), etc.

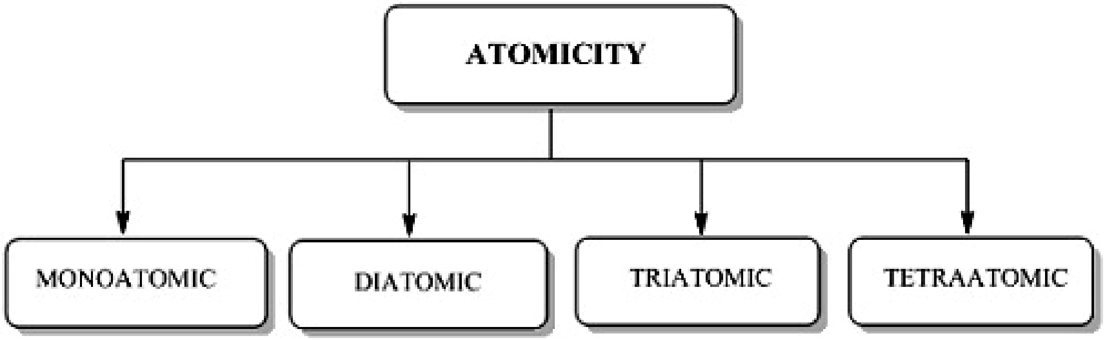
Triatomic
When molecule is formed by the combination of three atoms it is called triatomic molecule. For example: molecule of ozone (O_3)

Tetra-atomic
When molecule is formed by the combination of four atoms it is called tetra-atomic molecule.For

example: Phosphorous molecule (P_4)

Polyatomic

When molecule is formed by the combination of more than two atoms, it is called polyatomic molecule. For example: Sulphur molecule (S_8)



Atomicity of some elements :-

Type of element	Name		Atomicity
Non metal	Argon	Ar	1 – Monatomic
Non metal	Helium	He	1 – Monatomic
Non metal	Oxygen	O_2	2 – Diatomic
Non metal	Hydrogen	H_2	2 – Diatomic
Non metal	Nitrogen	N_2	2 – Diatomic
Non metal	Chlorine	Cl_2	2 – Diatomic
Non metal	Phosphorus	P_4	4 – Phosphorus
Non metal	Sulphur	S_8	Poly atomic
Metal	Sodium	Na	1 – Monatomic
Metal	Iron	Fe	1 – Monatomic
Metal	Aluminum	Al	1 – Monatomic
Metal	Copper	Cu	1 – Monatomic

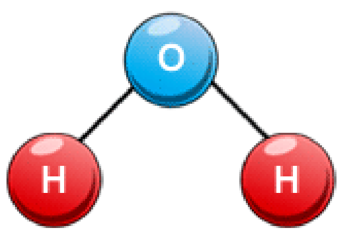
MOLECULES OF COMPOUNDS

When molecule is formed by the combination of two or more atoms of different elements, it is called the molecule of compound.

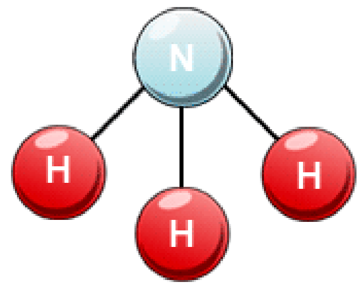
Example: Molecule of water (H_2O), molecule of water is formed by the combination of two hydrogen atoms and one oxygen atom.

Molecules of some compounds	
Compound	**Combining Elements**
Water (H_2O)	Hydrogen, Oxygen
Ammonia (NH_3)	Nitrogen, hydrogen
Carbon dioxide(CO_2)	Carbon, oxygen
Hydrogen Chloride (HCl)	Hydrogen, Chlorine
Methane (CH_4)	Carbon, Hydrogen
Ehtane (C_2H_6)	Carbon, hydrogen
Sodium chloride (NaCl)	Sodium, chlorine.
Copper oxide (CuO)	Copper and oxygen

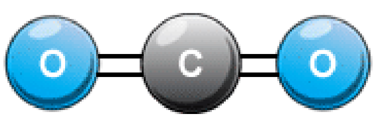
water



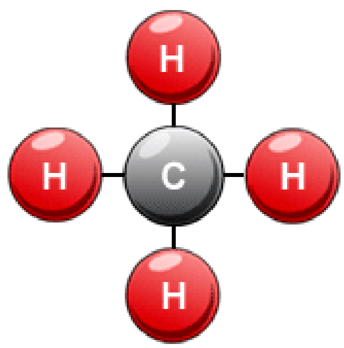
ammonia



carbon dioxide



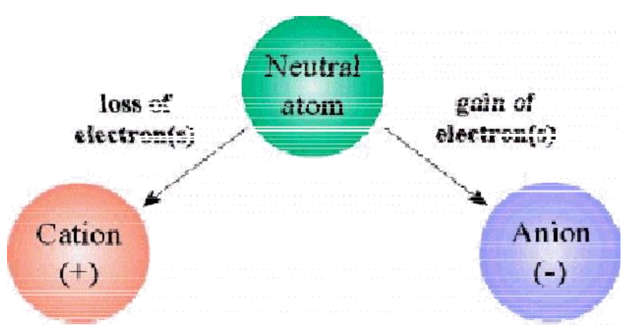
methane



IONS

Atoms of several elements exist in the form of ion. Atoms or molecules with positive or negative charge over them are called ions.

For example: Sodium ion (Na^+), postassiun ion (K^+), Chlorine ion (Cl^-), Fluoride ion (F^-)etc.



Cations:
Ions having positive charge over them are called cations.For example: sodium ion (Na^+), potassium ion (K^+), etc
Anions:
Ions having negative charge over them are called anions. For example: Chloride ion (Cl^-), Fluoride ion (F^-), etc

Monoatomic ions:
Ions formed by one atom are called monoatomic ions.
For example: sodium ion (Na^+), potassium ion (K^+), Chloride ion (Cl^-), Fluoride ion (F^-), etc.

Polyatomic ions:
Ions formed by two or more atoms are called polyatomic ions. These are group of atoms ofdifferent elements which behave as single units, and are known as polyatomic ions.
For example: Ammonium ion (NH_4^+), Hydroxide ion (OH^-), etc

Some common ions and their valencies

Valency	Name of ion	Symbol	Name of ion	Symbol	Name of ion	Symbol
1	Sodium	Na^+	Hydrogen	H^+	Ammonium	NH_4^+
1	Potassium	K^+	Hydride	H^-	Hydroxide	OH^-
1	Silver	Ag^+	Chloride	Cl^-	Nitrate	NO_3^-
1	Copper (I)	Cu^+	Bromide	Br^-	Hydrogen carbonate	HCO_3^-
2	Magnesium	Mg^{2+}	Iodide	I^-		
2	Calcium	Ca^{2+}	Oxide	O^{2-}	Carbonate	CO_3^{2-}
2	Zinc	Zn^{2+}			Sulphite	SO_3^{2-}
2	Iron (II)	Fe^{2+}			Sulphate	SO_4^{2-}
2	Copper (II)	Cu^{2+}				
3	Aluminum(III)	Al^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}
3	Iron (III)	Fe^{3+}				

WRITING CHEMICAL FORMULA
Chemical formula of the compound is the symbolic representation of its composition. To write chemical formula of a compound, symbols and valencies of constituent elements must be known.

Points to remember
- The symbols or formulas of the component radicals of the compound are written side by side.
- Positive radicals are written left and negative radicals on the right.
- The valencies of the radicals are written below the respective symbols.
- The criss-cross method is applied to exchange the numerical value of valency of each radical. It is written as subscript of the other radical.
- The radical is enclosed in a bracket and the subscript is placed outside the lower right corner.
- The common factor is removed.
- If the subscript of the radical is one, it is omitted.

The rules that you have to follow while writing a chemical formula are as follows:
- the valencies or charges on the ion 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), iron sulphide (FeS), copper oxide (CuO) etc., where oxygen, chlorine, sulphur are non-metals and are written on the right, whereas calcium, sodium, iron and copper

are metals, and are writtenon the left.

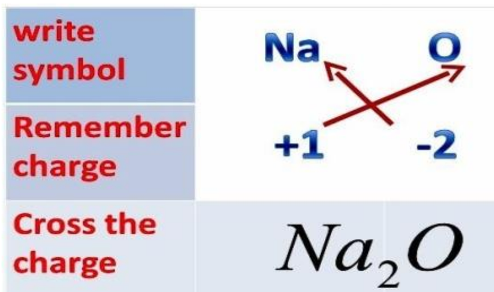
- in compounds formed with polyatomic ions, the ion is enclosed in a bracket before writing the number to indicate the ratio.

While writing the chemical formulae for compounds, we write the constituent elements and their valencies as shown below. Then we must crossover the valencies of the combining atoms.

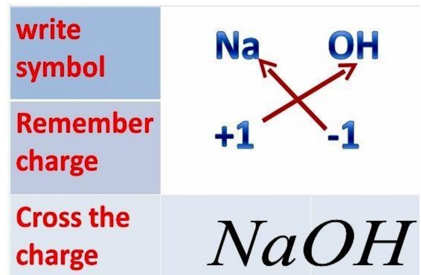
The formulae of ionic compounds are simply the whole number ratio of the positive to negative ions in the structure. For magnesium chloride, we write the symbol of cation (Mg^{2+}) first followed by the symbol of anion (Cl^{-}). Then their charges are criss-crossed to get the formula.

EXAMPLES

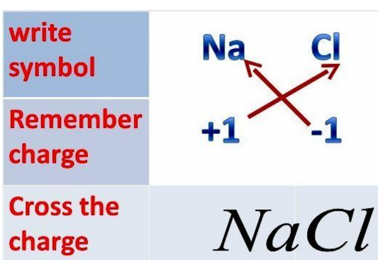
Formula of Sodium oxide



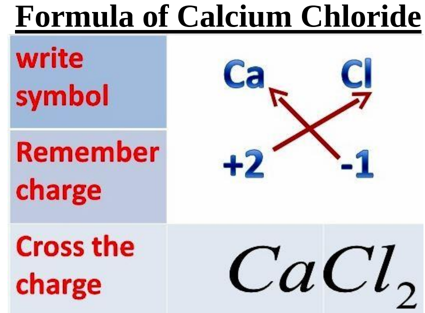
Formula of Sodium hydroxide



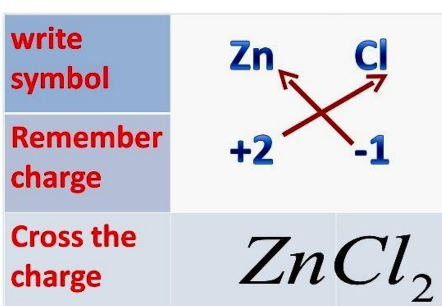
Formula of Sodium chloride



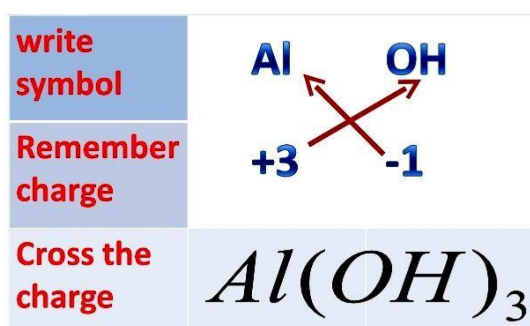
Formula of Calcium Chloride



Formula of Zinc chloride



Formula of Aluminium hydroxide



Formula of Calcium oxide

write symbol	Ca O
Remember charge	+2 -2
Cross the charge	CaO

Formula of Aluminium oxide

write symbol	Al O
Remember charge	+3 -2
Cross the charge	Al_2O_3

Formula of Silver oxide

write symbol	Ag O
Remember charge	+1 -2
Cross the charge	Ag_2O

Formula of Silver chloride

write symbol	Ag Cl
Remember charge	+1 -1
Cross the charge	$AgCl$

Formula of Ammonium Chloride

write symbol	NH_4 Cl
Remember charge	+1 -1
Cross the charge	NH_4Cl

Formula of Ammonium carbonate

write symbol	NH_4 CO_3
Remember charge	+1 -2
Cross the charge	$(NH_4)_2CO_3$

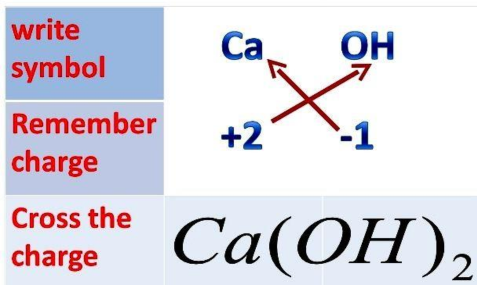
Formula of Silver Carbonate

write symbol	Ag CO_3
Remember charge	+1 -2
Cross the charge	Ag_2CO_3

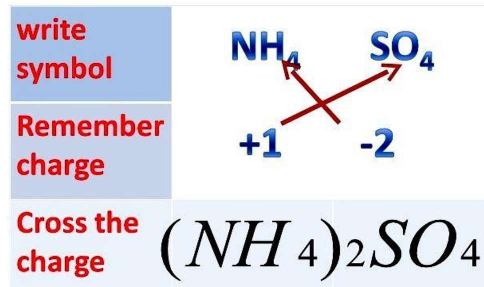
Formula of Silver Sulphate

write symbol	Ag SO_4
Remember charge	+1 -2
Cross the charge	Ag_2SO_4

Formula of Calcium hydroxide



Formula of Ammonium sulphate



MOLECULAR MASS

Atomic mass: The atomic mass of an element is the mass of one atom of that element in atomic mass units or (u).

Atomic mass unit (amu): 1/12th of the mass of an atom of carbon-12 is called atomic mass unit. It is a unit of mass used to express atomic masses and molecular masses.

Molar mass: The molar mass of an element is equal to the numerical value of the atomic mass. However, in case of molar mass, the units change from 'u' to 'g'. The molar mass of an atom is also known as gram atomic mass.

For example, the atomic mass of carbon =12 atomic mass units. So, the gram atomic mass of carbon = 12 grams.

Molecular mass of the molecule: The sum of the atomic masses of all the atoms in a molecule of a substance is called the molecular mass of the molecule.

Molecular mass - calculation: Generally we use relative atomic masses of atoms forcalculating the molecular mass of 1 mole of any molecular or ionic substances.

Example: Molecular mass of H_2SO_4 Atomic mass of Hydrogen = 1u Atomic mass of sulphur = 32u Atomic mass of oxygen = 16u

Molecular mass of H_2SO4 = 2(Atomic mass of Hydrogen) + 1 (Atomic mass of sulphur) + 4 (Atomic mass of oxygen) = 2×1 + 32 + 4× 16 = 98 u.

Calculation of molecular mass of hydrogen chloride:

Atomic mass of hydrogen + Atomic mass of chlorine = 1 + 35.5 = 36.5 u.

FORMULA UNIT MASS

The formula unit mass of a substance is the sum of the atomic masses of all atoms in a formula unit of a compound. The term 'formula unit' is used for those substances which are made up of ions.

Formula unit mass of NaCl:
=1 x Atomic mass of Na + 1 x Atomic mass of Cl
=1 x 23 +1 x 35.5 = 58.5 u

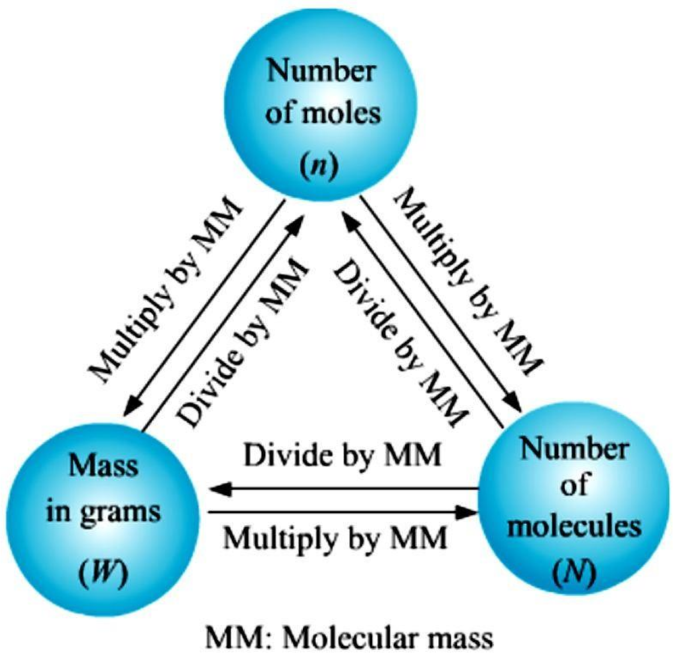
Formula unit mass of ZnO:
= 1 x Atomic mass of Zn + 1 x Atomic mass O
= 1 x 65 + 1 x 16 = 81 u.

MOLE CONCEPT

Mole: Mole is the measurement in chemistry. It is used to express the amount of a chemical substance.
One mole is defined as the amount of substance of a system which contains as many entities like, atoms, molecules and ions as there are atoms in 12 grams of C-12 isotope.

Avogadro number: The number of the particles present in one mole of any substance is equal to 6.022×10^{23}. This is called avogadro's number or avogadro's constant.

Number of particles in 1 mole:
1 mole of hydrogen atoms represents 6.022×10^{23} hydrogen atoms.
1 mole of hydrogen molecules represents 6.022×10^{23} hydrogen molecules.
1 mole of water molecules represents 6.022×10^{23} water molecules.



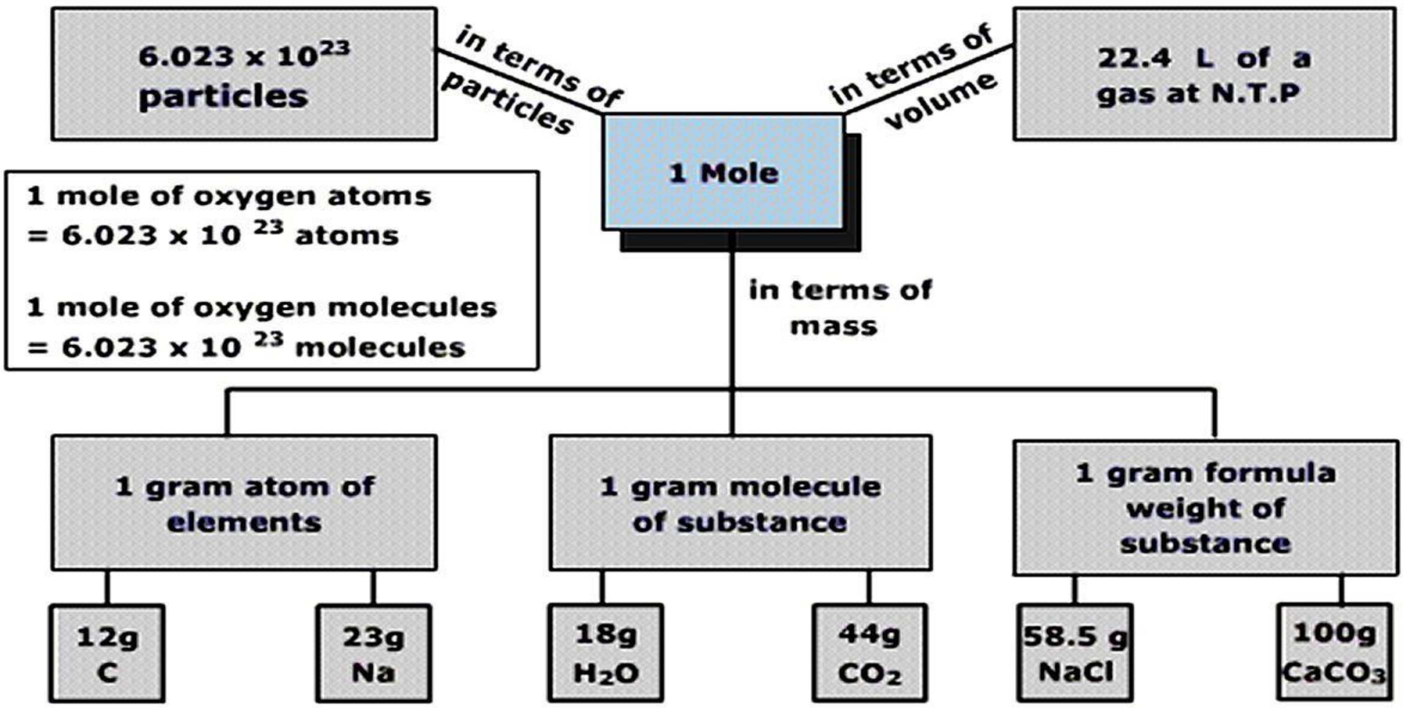
The key concept used in these kind of problems is that a mole of any substance contains gram formula mass or molecular mass of that substance i.e. molecular mass of Hydrogen is 2 a.m.u. So mass of 1 mole of hydrogen which is also known as molar mass will be 2 gram. Similarly if we have 2 moles of hydrogen, it will weigh 2*2 grams which is equal to 4 grams.

MOLE CONCEPT CALCULATION

Most of the times, moles or number of atoms or molecules are given in the question and the mass is needed to be calculated. In that case proceed as shown in the above example. In rest of the cases, mass will be given and moles or number will be needed to be calculated. In those questions also, proceed by:

STEP 1:- Establishing relationship between molar mass and the number (N_A) or moles of that particular entity (atom, molecule or ion).
STEP 2:- Use unitary method to calculate what is asked in the question.

NOTE: – When we say oxygen gas weighs 32 gram then we mean to say that 1 mole of oxygen molecule (O_2) weighs 32 grams and not 1 mole of oxygen atom which is O. This is because in natural form, oxygen exists as O_2 molecule.



Problems (based on mole concept)

1.When the mass of the substance is given

No. of moles= Given mass/atomic mass

Example1: Calculate the number of moles in 81g of aluminium.

No. of moles= Given mass/atomic mass= 81/27=3 moles of aluminium

Example 2. Calculate the mass of 0.5 mole of iron

Solution: mass = atomic mass x number of moles

= 55.9 x 0.5 = 27.95 g

2. Calculation of number of particles when the mass of the substance is given:

No. of particles= Avogadro no.x given mass/gram molecular mass

Example1: Calculate the number of molecules in 11g of CO_2.

Solution: No. of molecules = $6.022 \times 10^{23} \times 11/44 = 1.51 \times 10^{23}$ molecules

3.Calculation of mass when number of particles are given

Mass of substance= gram molecular mass x number of particles/6.022×10^{23}

Example1: Calculate the mass of glucose in 2×10^{24} molecules

Solution: Gram molecular mass of glucose=180g

Mass of glucose =180 x 2 x 10^{24}/6.022 x 10^{23} = 597.8g

4.Calculation of number of moles when number of molecules are given
No. of moles of atom= No. of molecules/Avogadro no.
Example1: Calculate the number of moles in 12.046x 10^{22} molecules
Solution: No. of moles of atom=12.046x10^{22} / 6.022x10^{23}=0.2 moles

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