ATOMS AND MOLECULES

Introduction

We know that matter is made up of small particles . In matter the smallest particle may be an atom or molecule.Different particles process different properties , so different types of matter possess different properties. .

Matter consists of two types of pure substances i.e., elements and compounds. Compounds are formed when elements combine together. Experimental studies were carried out to understand the laws according to which elements combine to form a compound; these laws are known as laws of chemical combination.

Laws of chemical combination

As mentioned above elements combine together to form a compound this is done as per certain last known as laws of chemical combination

there are two laws of chemical combination

1.Law of conservation of mass

2. law of Definite proportions

Law of conservation of mass

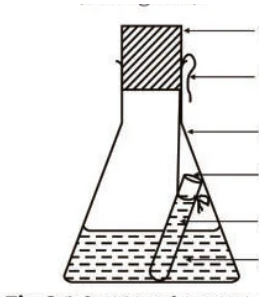
According to this law, mass is neither created nor destroyed in a chemical reaction.The mass of reactants (The substances before the reaction) equal to the mass of products(The substances formed in the reaction).

Experimental verification of law of conservation of mass :

Take a clean conical flask fitted with a rubber cork, also take a small test tube and tie thread to its neck so that it can lie suspended in the conical flask.Weigh the whole apparatus.Let it be w1.

Prepare 5 % solution of barium chloride by dissolving 5 grams of barium chloride in 100 ml of water.

Take small Amount of Barium Chloride solution in the conical flask and small amount of sodium sulphate solution the test tube .Suspend the test tube in the conical flask with the thread as shown in the figure, such that both the solutions do not mix with each other.



Now weigh the whole apparatus. Let it be w2.The weight of the reactants = w2 - w1.

Now loosen the cork so that the thread is loose and the test tube falls into the conical flask then both the solutions mix together.Then we observe the formation of a precipitate due to the following reaction.

$BaCl_2+Na_2SO_4$---->$BaSO_4+2NaCl$

Now weigh the whole apparatus. Let it be w3. The weight of the products formed is w3 - w1.Experimentally the weight of reactants taken is found to be equal to the weight of the

products formed i.e., w2-w1=w3-w1. From the above, the law of conservation of mass is set to be verified.

Law of definite proportion

This law was proposed by J.L.Proust.It states that “a chemical compound is always made up of same kind of elements combined together in the fixed proportion by their mass”

Examples to illustrate the law of constant proportion

Ex1:

Water : Water is obtained from different sources like river, well, by the reaction of hydrogen with oxygen by passing of hydrogen gas over the heated copper oxide etc.

$CuO+H_2$----------> $Cu+H_2O$

In all these different sources , the water obtained is made up of the same elements ,i.e., hydrogen and oxygen and the hydrogen and oxygen combine together in the fixed ratio 1:8 by their masses. This can be checked by the electrolysis of water. When 9 grams of water is subjected to electrolysis you always get one gram of hydrogen gas and 8 grams of Oxygen gas.

Ex2:

Carbon dioxide: Carbon dioxide can be prepared from different methods

a)By burning of coal in air

$C+O_2$----->CO_2

b)By heating of limestone

$CaCO_3$------>$CaO+CO_2$

c)By adding dilute Hydrochloric acid to any carbonate salt

Na_2CO_3+2HCl------>$2NaCl+H_2O+CO_2$

It is found that carbon dioxide is obtained from different methods but is made up of same kind of elements Carbon and oxygen combined together in the ratio of 3:8 by their masses.As the law of constant proportion is true, this helps us to calculate the percentage of any element in the given compound.

% of element in compound =(mass of element X100)/Mass of compound.

Dalton's atomic theory

After the proposal of two laws of chemical combination , the next task for the scientist was to give a suitable explanation for this laws.This lead John Dalton to put forward a Theory known as Dalton's atomic theory.

Postulates of Dalton's atomic theory

1.All the matter either element or compound or mixture is made up of extremely tiny particles known as atoms .

2.Atoms of the same element are identical in their size mass and properties

3.Atoms of different elements have different size,mass and properties.

4.Atoms of different elements combine together to form a compound.

5.When atoms of different elements combine to form a compound, it is done in the form of simple whole number ratio

Ex1 : 1:1 , 2:7 , etc.

6.The number and the kind of atoms are fixed in given compound though it is obtained from different methods.

7.Atom is the smallest particle which takes place in a chemical reaction.

8.Atoms cannot be created nor destroyed.

Atom

Atoms are the tiny particles which further cannot be divided into pieces.It may or may not be capable of existing independently.In elements like Helium, Neon, Argon, krypton, Xenon and Radon atoms exist independently. In elements like Hydrogen, Oxygen or the compounds like carbon dioxide and Nitrogen dioxide atoms exist in the combined form, with same or different kinds of atoms known as molecule.In elements like sodium, copper, iron etc,atoms exist by linking to other atom.

How bigger the atoms ? Can we see them ?

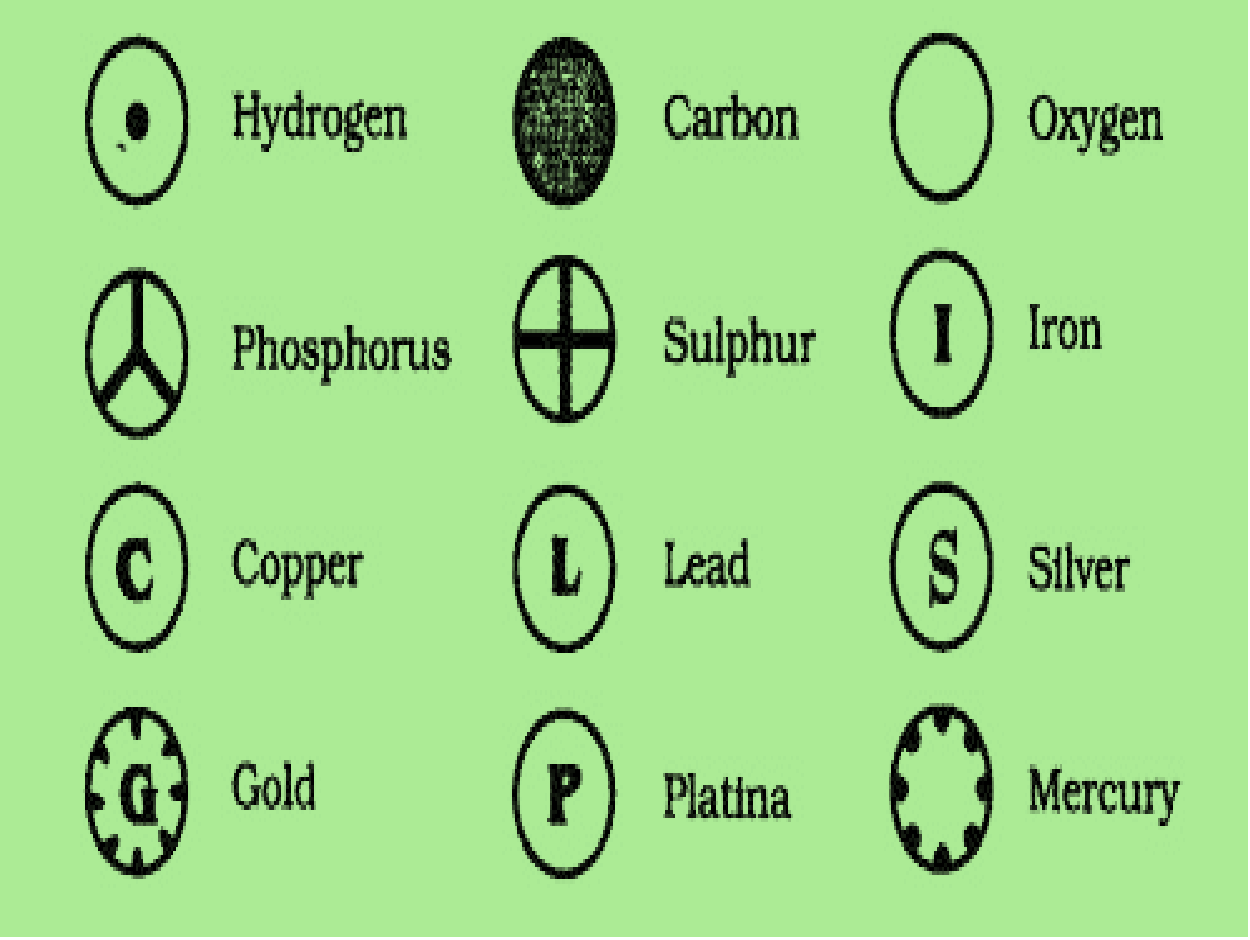
The atoms are very small particles.They are so small such that even by using a very powerful microscope we cannot see them.However, recently a highly sophisticated microscope known as scanning tunneling microscope has made possible to take the photograph of an atom.

Atomic radius

Atoms are generally considered to be spherical in shape.The size of an atom is measured in terms of its radius known as atomic radius.Atomic radius is measured in terms of A^o .(One $A^o = 10^{-10}$nm)

Symbol

Symbol is the shorthand notation of the full name of an element and was the first scientist to suggest specific symbol for the name of the elements in the form of figure.



However they are inconvenient to draw and were not popular.

Berzelius suggestion for the symbol of elements

Berzelius,a swedish Scientist suggested a method to represent the full name of the element by using one or two letters from the name of the element.

the symbol of an element is the first letter or the first letter and another letter of the English name or Latin name of the element.

however in all cases first letter is always capital and other letter is always small.

Hydrogen- H,Aluminium Al, Cobalt - Co, etc.

Few elements have their symbols based on their Latin name.

1. Sodium- natrium-Na
2. Potassium- kalium - K
3. Iron- Ferrum - Fe
4. Copper- cuprum- Cu
5. Tin- stannum-Sn
6. Lead- plumbum-Pb
7. Tungsten- Wolfram- W
8. Gold - Aurum - Au
9. silver- Argentum- Ag
10. Mercury- hydagerum - Hg
11. Antimony- Stibium - Sb

Subatomic particles

The particles which are present inside an atom are known as sub atomic particles. There are more than hundred subatomic particles ,three are important among them .They are electron ,proton and neutron .Electron is a massless charged particle . Proton has charge and mass .Neutron is a particle which has mass but no charge .Electron and proton contribute charge to atom .Proton and neutron contribute mass to atom .The mass of proton and neutron is same ,(mass of proton equals to 1 U,mass of neutron is equal to 1 U)

Atomic mass

The mass of an atom is known as atomic mass and atomic mass is measured by using unit unified mass (U) / atomic mass unit(amu).

Carbon-12 isotope is taken as the standard reference for measuring atomic mass.

1 Unified mass

Unified mass is defined as one by twelfth part of mass of a single carbon atom.

Element	No. of protons	No. of neutrons	No. of electrons	Atomic mass
Hydrogen(H)	1	0	1	1
Helium	2	2	2	4
Lithium	3	4	3	7
Beryllium	4	5	4	9
Boron	5	6	5	11

Carbon	6	6	6	12
Nitrogen	7	7	7	14
Oxygen	8	8	8	16
Fluorine	9	10	9	19
Neon	10	10	10	20
Sodium	11	12	11	23
Magnesium	12	12	12	24
Aluminium	13	14	13	27
Silicon	14	14	14	28
Phosphorus	15	16	15	31
Sulphur	16	16	16	32
Chlorine	17	18	17	35.5
Argon	18	22	18	40
Potassium	19	20	19	39
Calcium	20	20	20	40

Formula

Formula is the representation of the smallest particle of an element or compound. In an element the smallest particle may be an atom or molecule. In the compound, the smallest particle is a molecule.

Atomicity

The number of atoms present in a molecule is known as atomicity.

Example:

Atomicity of Hydrogen is 2 ----------H_2
Atomicity of Oxygen is 2 ----------O_2
Atomicity of Ozone is 3 ----------O_3
Atomicity of Phosphorus is 4 ---------P_4
Atomicity of Sulphur is 8 ----------S_8
Atomicity of Carbon dioxide is 3 -----CO_2
Atomicity of Sulphuric acid is 7 ------H_2SO_4

Formula of elements

S.No	Name of the element	Symbol	Formula	Atomicity	Metal/Nonmetal

1	Hydrogen	H	H_2	2	Non metal
2	Oxygen	O	O_2	2	Non metal
3	Nitrogen	N	N_2	2	Non metal
4	Ozone	O	O_3	3	Non metal
5	Chlorine	Cl	Cl_2	2	Non metal
6	Fluorine	F	F_2	2	Non metal
7	Iodine	I	I_2	2	Non metal
8	Phosphorus	P	P_4	4	Non metal
9	Sulphur	S	S_8	8	Non metal
10	Carbon	C	C	1	Non metal
11	Heluim	He	He	1	Non metal
12	Neon	Ne	Ne	1	Non metal
13	Argon	Ar	Ar	1	Non metal
14	Krypton	Kr	Kr	1	Non metal
15	Radon	Rn	Rn	1	Non metal
16	Xenon	Xe	Xe	1	Non metal
17	Potassium	K	K	1	Metal
18	Magnesium	Mg	Mg	1	Metal
19	Sodium	Na	Na	1	Metal
20	Calcium	Ca	Ca	1	Metal
21	Zinc	Zn	Zn	1	Metal
22	Barium	Ba	Ba	1	Metal
23	Aluminium	Al	Al	1	Metal
24	Manganese	Mn	Mn	1	Metal
25	Iron	Fe	Fe	1	Metal
26	Copper	Cu	Cu	1	Metal
27	Silver	Ag	Ag	1	Metal

28	Gold	Au	Au	1	Metal
29	Platinum	Pt	Pt	1	Metal
30	Lead	Pb	Pb	1	Metal
31	Mercury	Hg	Hg	1	Metal
32	Tin	Sn	Sn	1	Metal

Formula of compounds

We know that Compounds are formed on combining of two or more elements.

1. compounds formed by the combining of element with a non metal element are known as ionic compounds.
   In this process metal elements lose the electrons and become positively charged ions(Cations).
   and nonmetal gains electrons and becomes negatively charged ions (Anions).
   both of them are held Together by the electrostatic forces of attraction
2. The compounds which are formed by combining of a non metal element with a non metal element are known as covalent compounds.
   This occurs by sharing of electrons between two combining non metal elements.
   To write the formula of ionic compounds it is essential to know their valencies of cations and anions present in the compound.
   To write the formula of covalent compounds we should know the valency of the elements in the compound.

Formula of ionic compounds

Some cations

S.No	Name of the ion	Symbol/Formula of ion	Valency
1	Sodium ion	Na	1
2	Potassium ion	K	1
3	Hydrogen ion	H	1
4	Silver ion	Ag	1
5	Cuprous ion	Cu	1
6	Ammonium ion	NH_4	1
7	Magnesium ion	Mg	2
8	Calcium ion	Ca	2

9	Zinc ion	Zn	2
10	Barium ion	Ba	2
11	Ferrous ion	Fe	2
12	Aluminium ion	Al	3
13	Ferric ion	Fe	3
14	Chromium ion	Cr	3
15	Cupric ion	Cu	2

Some anions

S.No	Name of the ion	Symbol/Formula of ion	Valency
1	Chloride ion	Cl	1
2	Bromide ion	Br	1
3	Iodide ion	I	1
4	Hydride ion	H	1
5	Hydroxide ion	OH	1
6	Nitrate ion	NO_3	1
7	Bicarbonate ion	HCO_3	2
8	Permanganate ion	MnO_4	1
9	Chlorate ion	ClO_3	1
10	Carbonate ion	CO_3	2
11	Sulphate ion	SO_4	2
12	Sulphite ion	SO_3	3
13	Sulphide ion	S	3
14	Chromate ion	CrO_4	2
15	Dichromate ion	Cr_2O_7	2
16	Phosphate ion	PO_4	3

17	Nitride ion	N	3
18	Phosphide ion	P	3
19	Oxide ion	O	2
20	Nitrite ion	NO_2	1

Polyatomic ion

A group of atoms which carries the charge is called polyatomic ion.

Ex: NH_4^{+1} , NO_2^{-1},SO_4^{-2}

Total number of atoms present in Phosphate ion is 5 ---------PO_4^{-3}

Total number of atoms present in Sulphate ion is 5 ----------SO_4^{-2}

Total number of atoms present in Ammonium ion is 5 --------NH_4^{+1}

Total number of atoms present in Hydroxide ion is 1 ----------OH^{-1}

Total number of atoms present in Nitrate ion is 4 ----------NO_3^{-1}

Sodium chloride — Na^{+1} Cl^{-1} → $NaCl$

Aluminium sulphate — Al^{+3} SO_4^{-2} → $Al_2(SO_4)_3$

Sodium oxide — Na^{+1} O^{-2} → Na_2O

Ammonium phosphate — NH_4^{+1} PO_4^{-3} → $(NH_4)_3PO_4$

Sodium sulphate — Na^{+1} SO_4^{-2} → Na_2SO_4

Potassium nitrate — K^{+1} NO_3^{-1} → KNO_3

Calcium nitrate — Ca^{+2} NO_3^{-1} → $Ca(NO_3)_2$

Calcium carbonate — Ca^{+2} CO_3^{-2} → $CaCO_3$

Sodium carbonate — Na^{+1} CO_3^{-2} → Na_2CO_3

Calcium bicarbonate	$Ca^{+2}\ HCO_3^{-1}$ $Ca(HCO_3)_2$
Ammonium sulphate	$NH_4^{+1}\ \ SO_4^{-2}$ $(NH_4)_2SO_4$
Cupric sulphate	$Cu^{+2}\ \ SO_4^{-2}$ $CuSO_4$
Cuprous oxide	$Cu^{+1}\ \ O^{-2}$ Cu_2O
Cupric oxide	$Cu^{+2}\ \ O^{-2}$ CuO
Ferric chloride	$Fe^{+3}\ Cl^{-1}$ $FeCl_3$
Ferrous sulphate	$Fe^{+2}\ \ SO_4^{-2}$ $FeSO_4$
Aluminium phosphate	$Al^{+3}\ \ PO_4^{-3}$ $AlPO_4$
Potassium permanganate	$K^{+1}\ \ MnO_4^{-1}$ $KMnO_4$
Potassium dichromate	$K^{+1}\ \ Cr_2O_7^{-2}$ $K_2Cr_2O_7$
Calcium hydroxide	$Ca^{+2}\ \ OH^{-1}$ $Ca(OH)_2$
Sodium hydroxide	$Na^{+1}\ \ OH^{-1}$ $NaOH$
Ammonium carbonate	$NH_4^{+1}\ \ CO_3^{-2}$ $(NH_4)_2CO_3$

Molecular mass

The mass of a molecule is known as the molecular mass.It is measured by the units unified mass.

Calculate the Molecular mass of hydrogen

formula of hydrogen=H_2

molecular mass of hydrogen=2X atomic mass of hydrogen

=2X1

=2 U

Calculate the Molecular mass of oxygen

formula of hydrogen=O_2

molecular mass of oxygen=2X atomic mass of oxygen

=2X16

=32 U

Calculate the Molecular mass of carbon dioxide

Formula of carbon dioxide = CO_2

Molecular mass of carbon dioxide = (1X12)+(2X16)

=12+32

=44 U

Calculate the Molecular mass of nitrogen

formula of nitrogen=N_2

molecular mass of nitrogen=2X atomic mass of nitrogen

=2X14

=28 U

Calculate the Molecular mass of Calcium carbonate

formula of hydrogen=$CaCO_3$

molecular mass of oxygen=(1X40)+(1X12)+(3X16)

=40+12+48

=100 U

Calculate the Molecular mass of nitrogen dioxide

formula of hydrogen=NO_2

molecular mass of nitrogen dioxide=(1X14)+(2X16)

=14+32

=46 U

Calculate the Molecular mass of water

formula of hydrogen=H_2O

molecular mass of water=(2X1)+(1X16)

=2+16

=18 U

MOLE CONCEPT

Mole : The amount of a substance that contains exactly $6.022X10^{23}$ particles of the given substance.

A mole of a substance is referred to as the mass of a substance containing the same number of fundamental units as there are atoms in exactly 12 g of C^{12}

A mole of hydrogen atoms contains $6.022X10^{23}$ Hydrogen atoms.

A mole of Oxygen atoms contains $6.022X10^{23}$ Oxygen atoms.

A mole of sulphur atoms contains $6.022X10^{23}$ Sulphur atoms.
A mole of Hydrogen gas contains $6.022X10^{23}$ Hydrogen molecules.
A mole of Oxygen gas contains $6.022X10^{23}$ Oxygen molecules.
A mole of Carbon dioxide gas contains $6.022X10^{23}$ Carbon dioxide molecules.
A mole of electrons contains $6.022X10^{23}$ electrons.

Gram Atomic Mass : Mass of one mole of atoms of a particular element is known as gram atomic mass. It is measured in grams.

1 amu = $1.67X10^{-24}$ grams.

Mass of one mole of hydrogen atoms =$6.022X10^{23}$ amu
= $6.022X10^{23}$ X$1.67X10^{24}$
= 1 gram.

Therefore Gram Atomic Mass of hydrogen atoms is 1 gram.
Gram atomic mass of sulphur atoms is 32 grams.
Gram atomic mass of sulphur atoms is 32 grams.
Gram atomic mass of sulphur atoms is 32 grams.

Gram Molecular Mass : Mass of one mole of molecules of a particular element is known as gram molecular mass. It is measured in grams.

Gram molecular mass of hydrogen gas is 2 grams.
Gram molecular mass of water is 18 grams.
Gram molecular mass of carbon dioxide is 44 grams.
Gram molecular mass of oxygen gas is 32 grams.
Gram molecular mass of sulphuric acid is 98 grams.
Gram molecular mass of Sodium hydroxide is 40 grams.

Numerical problems in Mole concept:

1. What is the total number of moles present in 52 grams helium?
2. What is the total number of moles present in $12.044X10^{23}$ Helium atoms?
3. What is the mass of 0.5 moles of nitrogen atoms?
4. What is the mass of $6.022X10^{23}$ nitrogen atoms
5. What is the mass of 0.5 moles of Nitrogen gas?
6. What is the number of particles present in 46 grams of sodium atoms ?
7. What is the total number of particles present in 8 grams Oxygen gas?
8. What is the number of particles present in 0.1 mole of carbon atoms?
9. If one mole of carbon atoms weighs 12 grams , what is the mass of one atom of carbon?
10. Which has more number of atoms hundred grams of sodium or 100 grams of iron?
11. Which of the following would weigh the highest? 0.2 moles sucrose ,2 moles carbon dioxide,2 miles calcium carbonate ,10 moles water.
12. Which of the following has maximum number of atoms ?18 grams water ,18 grams of oxygen, 18 grams carbon dioxide 18 grams methane

13. Which has maximum molecules ?1 gram carbon dioxide ,1 gram nitrogen, 1 gram hydrogen ,1 gram methane?
14. 3.42 grams of sucrose is dissolved in 18 grams of water. What is the total number of oxygen atoms present in the solution ?

BBlue box questions

Pg. 35

1. Define atomic mass unit.
2. Why is it not possible to see an atom with naked eyes?

pg. 39

1. Write down the formulae of (i)sodium oxide (ii)aluminium chloride (iii)sodium sulphide (iv)magnesium hydroxide
2. Write down the names of the compounds represented by the following formula a l 2 S o4 taken price
3. What is meant by the term chemical formula?
4. How many atoms are present in hydrogen sulphide molecule and phosphate ion

Pg. 40

1. Calculate the molecular mass of hydrogen gas Oxygen gas chlorine gas carbon dioxide gas Methane Gas Ethane ethylene Ammonia methyl alcohol
2. Calculate the formula unit mass of zinc oxide sodium oxide Sodium Potassium carbonate given the atomic masses of zinc 65 you sodium 23 you potassium 39 carbon 12 you and oxygen 16 you

Pg. 42

1. If one mole of carbon atoms weight 12 grams what is the mass of one atom of carbon
2. Which has more number of atoms and G of sodium or 100 grams of iron atomic mass of sodium is 23 you iron is 56 U