(A) PHYSICAL AND CHEMICAL CHANGES

A large number of changes are ever taking place all around us. Evaporation of water, melting of ice, glowing of bulb filament, rusting of iron, spoiling of food materials, burning of fuels, etc. are some commonly observed changes. In these changes, matter changes its properties and energy contents.

These changes are classified in two types –

1. Physical Changes
2. Chemical Changes

1. Physical Changes

A physical change has following characteristics –

a) In a physical change **no new substance** is formed.
b) The chemical properties of the substance remain almost **unchanged**.
c) Physical changes are generally associated with **small changes in energy** contents.
d) Physical changes are generally **reversible**.
e) In physical changes the chemical **compositions** of substances remain **unchanged**.
f) Normally **no chemical bond is broken or formed** in physical changes.

Some of the common physical changes are –

1. Evaporation 2. Melting or fusion 3. Boiling 4. Sublimation 5. Freezing 6. Condensation 7. Distillation 8. Filtration 9. Absorption 10. Dissolution 11.Alloy formation 12. Grinding 13. Diffusion 14. Mixing of non-reactive gases 15. Flow of electric current through metallic conductor. 16. Drying

2. Chemical Changes

A chemical change has following characteristics –

a) In a physical change **new substance/s** is/are formed.
b) The chemical properties of the substance are **changed**.
c) Chemical changes are generally associated with **large changes in energy contents**.
d) Chemical changes are generally irreversible.
e) In chemical change the chemical **compositions** of substances **changes**.
f) Existing chemical bonds break and new chemical bonds are formed.

Some of the common chemical changes are –

1. Oxidation 2. Reduction 3. Burning/ignition of fuels 4. Corrosion/Rusting 5. Destructive distillation 6. Smelting 7. Hydrogenation 8. Halogenations 9. Respiration 10. Metabolism (catabolism or anabolism) 11. Photosynthesis 12. Souring of milk 13. Curd formation 14. Drying of paint 15. Drying of whitewash 16. Precipitation 17. Dropping of sodium metal in water 18. Passing of electric current through some electrolyte. 19. Setting of cement 20. Hydrolysis 21. Decomposition 22.Polymerisation 23. Isomerisation 24. Protein synthesis 25. Carbonisation

It may be noted that chemical properties of substances may change a little even during a physical change. For example, water almost does not react with iron but steam reacts.

(B) ELEMENTS, COMPOUNDS AND MIXTURES

All the matter in this universe can be chemically classified into –

1. **Elements**
2. **Compounds**
3. **Mixtures**

1. Elements

An element a pure substance made up of only one type of atoms. It has following characteristics –

1. An element is a pure matter (substance).
2. An element is made up of one type of constituting units, which in turn are made of only one type of atoms.
3. All the atoms in an element have same number of protons and electrons. The number of neutrons however can differ.
4. An element is the simplest form of matter and hence can not be decomposed to simpler substances.
5. An element is characterized by a definite atomic number and symbol.

Elements are basic constituents of all the matter. There are 116 elements discovered up to now. Out of these 92 are natural and remaining are man made. Hydrogen is most abundant element of universe, oxygen is most abundant element in earth crust and aluminium is most abundant metal in earth crust. Broadly elements can be classified as metals, non-metals and metalloids.

i) **Metals** - These are electropositive elements that form cations. For example - sodium, copper, iron, gold, uranium, etc. Out of 116 elements discovered 92 (about 80%) are metals. Metals generally have 1, 2 or 3 electrons in the valence shell. Metals are sonorous (produce sound on hitting), malleable (can be beaten into sheets), ductile (can be drawn into wires) and generally good conductors of heat and electricity. At room temperature (25 ºC) all metals except mercury are solids. However, francium, cesium and gallium may also be found in liquid at ordinary temperatures because of their low melting points. Metals present in s-block of periodic table are called light metals (1st group – alkali metals and 2nd group – alkaline earth metals), metals present in d- and f-block are called heavy metals (d-block – transition metals and f-block – inner transition metals) and those present in p-block are called poor metals due to their low electropositivity.

ii) **Non-metals** – These are electronegative elements that form anions. For example – hydrogen, oxygen, sulpher, chlorine, etc. Inert gases, although do not form anions but still considered as non-metals. There are 19 non-metals. Non-metals generally have more than 3 electrons in their valence shell. Non-metals are non-sonorous, non-malleable, non-ductile and generally bad conductor of heat and electricity (Graphite i.e. carbon although non-metal but is a good conductor of electricity). Non-metals may be gaseous, liquids (only bromine) and solids.

iii) **Metalloids** – These have properties that are intermediate of metals and non-metals. For example – silicon, germanium, arsenic, antimony and tellurium.

Some of the elements like carbon, sulpher and phosphorous exist in more than one elemental form. This phenomenon is referred to as Allotropy.

2. Compounds : A compound is a pure substance made up of two or more elements combined together in a fixed ratio by their mass (more truly by number of atoms because ratio of masses can vary due to isotopes). It has following characteristics –

1. A compound is a pure matter (substance).
2. A compound is made up of only one type of constituting units, which in turn are made up of more than one type of atoms/ions (i.e. more than one element).
3. The ratio of elements in a compound is fixed.
4. The composition of compound does not differ with source.
5. A compound does not exhibit properties of its constituents i.e. elements.
6. A compound can be broken into its constituting elements only by chemical means.
7. Considerable amount of energy is absorbed or released during forming or breaking of a compound.
8. Formation of a compound or its breaking is a chemical change.

There are millions of compounds discovered or synthesized up to now. Compounds can be mainly classified into organic and inorganic compounds.

i) **Organic compounds** - These generally originate from living world. These are essentially compounds of carbon and hydrogen (CCl_4 however does not contain hydrogen still an organic compound). Beside these elements they may also contain oxygen, nitrogen, halogens, sulpher, phosphorous, etc. Almost all the organic compounds are combustible. Number of organic compounds is much higher than inorganic compounds. This is mainly attributed to catenation, isomerism, multiple bonding and tetravalency of carbon. The complexity of organic compounds is much higher than inorganic compounds. Organic compounds specifically biomolecules form basis of life. Cellulose is most abundant organic compound found on earth.

ii) **Inorganic compounds –** These originate mainly from non-living world. These are mostly obtained from earth crust and oceans. Salts and minerals are generally inorganic in nature. These are generally non-combustible. Much less in number and complexity than organic compounds. A few inorganic compounds like co-ordination compounds show isomerism.

3. Mixtures

A mixture is combination of two or more substances (elements/compounds). The components of a mixture are not chemically combined to each other and only weak forces exist among the components. A mixture has following characteristics –

1. Mixture is not pure matter.
2. A mixture is made of more than one type of constituting units.
3. The ratio of components of a mixture is not fixed but variable with in certain limits.
4. The components of a mixture do not lose their properties in the mixture.
5. The components of a mixture can be easily separated by simple methods of separation and separation involves only physical change.
6. Only little amount of energy is exchanged in formation/ separation of a mixture.
7. The composition of a mixture may differ with source.

There can be millions of mixtures. New mixture can be made easily by mixing two or more non-reacting substances. Mixtures can be broadly classified into two broad classes –

i) **Homogenous Mixtures –** These are the mixtures in which the composition is uniform throughout the sample. The components can not be observed separately even under microscope i.e. even under microscope the material seems to be a single substance. All true solutions (solute size less than 1 nm) are homogenous mixtures. E.g. Sugar solution, salt solution, Alloys and Air.

ii) **Heterogeneous Mixtures –** These are the mixtures in which the composition is not uniform and differ from one part to another part of the sample. The components are distinctly visible either to naked eyes or under microscope. Colloidal solutions (solute size between 1 nm to 100 nm) seem to be homogenous but are heterogeneous e.g. Blood, milk, smoke. All suspensions are heterogeneous e.g. paint, muddy water, dusty stroms.

(C) LIST OF ELEMENTS

Element	**Symbol**	**At.NO.**	**Element**	**Symbol**	**At.NO.**
Actinium	**Ac**	89	**Helium**	**He**	2
Aluminum	**Al**	13	**Holmium**	**Ho**	67
Americium	**Am**	95	**Hydrogen**	**H**	1
Antimony	**Sb**	51	**Indium**	**In**	49
Argon	**Ar**	18	**Iodine**	**I**	53
Arsenic	**As**	33	**Iridium**	**Ir**	77
Astatine	**At**	85	**Iron**	**Fe**	26
Barium	**Ba**	56	**Krypton**	**Kr**	36
Berkelium	**Bk**	97	**Lanthanum**	**La**	57
Beryllium	**Be**	4	**Lawrencium**	**Lr**	103
Bismuth	**Bi**	83	**Lead**	**Pb**	82
Bohrium	**Bh**	107	**Lithium**	**Li**	3
Boron	**B**	5	**Lutetium**	**Lu**	71
Bromine	**Br**	35	**Magnesium**	**Mg**	12
Cadmium	**Cd**	48	**Manganese**	**Mn**	25
Calcium	**Ca**	20	**Meitnerium**	**Mt**	109
Californium	**Cf**	98	**Mendelevium**	**Md**	101
Carbon	**C**	6	**Mercury**	**Hg**	80
Cerium	**Ce**	58	**Molybdenum**	**Mo**	42
Cesium	**Cs**	55	**Neodymium**	**Nd**	60
Chlorine	**Cl**	17	**Neon**	**Ne**	10
Chromium	**Cr**	24	**Neptunium**	**Np**	93
Cobalt	**Co**	27	**Nickel**	**Ni**	28
Copper	**Cu**	29	**Niobium**	**Nb**	41
Curium	**Cm**	96	**Nitrogen**	**N**	7
Darmstadtium	**Ds**	110	**Nobelium**	**No**	102
Dubnium	**Db**	105	**Osmium**	**Os**	76
Dysprosium	**Dy**	66	**Oxygen**	**O**	8
Einsteinium	**Es**	99	**Palladium**	**Pd**	46
Erbium	**Er**	68	**Phosphorus**	**P**	15
Europium	**Eu**	63	**Platinum**	**Pt**	78
Fermium	**Fm**	100	**Plutonium**	**Pu**	94
Fluorine	**F**	9	**Polonium**	**Po**	84
Francium	**Fr**	87	**Potassium**	**K**	19
Gadolinium	**Gd**	64	**Praseodymium**	**Pr**	59
Gallium	**Ga**	31	**Promethium**	**Pm**	61
Germanium	**Ge**	32	**Protactinium**	**Pa**	91

Gold	Au	79	Radium	Ra	88
Hafnium	Hf	72	Radon	Rn	86
Hassium	Hs	108	Rhenium	Re	75

Rhodium	Rh	45	Thulium	Tm	69
Rubidium	Rb	37	Tin	Sn	50
Ruthenium	Ru	44	Titanium	Ti	22
Rutherfordium	Rf	104	Tungsten	W	74
Samarium	Sm	62	Ununbium	Uub	112
Scandium	Sc	21	Ununhexium	Uuh	116
Seaborgium	Sg	106	Ununoctium	Uuo	118
Selenium	Se	34	Ununpentium	Uup	115
Silicon	Si	14	Ununquadium	Uuq	114
Silver	Ag	47	Ununseptium	Uus	117
Sodium	Na	11	Ununtrium	Uut	113
Strontium	Sr	38	Unununium	Uuu	111
Sulfur	S	16	Uranium	U	92
Tantalum	Ta	73	Vanadium	V	23
Technetium	Tc	43	Xenon	Xe	54
Tellurium	Te	52	Ytterbium	Yb	70
Terbium	Tb	65	Yttrium	Y	39
Thallium	Tl	81	Zinc	Zn	30
Thorium	Th	90	Zirconium	Zr	40

SOME COMMON NAMES

Sl.No	**Common name**	**Chemical name**	**Formula/composition**
1.	Aqua fortis	Nitric acid	HNO_3
2.	Aqua Regia	A mixture of 3 parts of Hydrochloric acid and 1 part of Nitric acid	$HCl + HNO_3$ in the ratio 3:1
3.	Alumina	Aluminum Oxide	Al_2O_3
4.	Black ash	--	A mixture of carbon, sodium carbonate and calcium sulphate
5.	Borax	--	$Na_2B_4O_7.10\ H_2O$
6.	Black oxide of Copper	Copper Oxide	CuO
7.	Bleaching Powder	--	$CaOCl_2$
8.	Baryata	Barium Oxide	BaO
9.	Boric Acid	--	H_3BO_3
10.	Borazole (Inorganic benzene)	--	$B_3N_3H_6$
11.	Bauxite	--	$Al_2O_3.\ 2H_2O$
12.	Black Lead or Plumbgo or Graphite	Carbon	C
13.	Blue vitriol	Hydrated copper sulphate	$CuSO_4.\ 5H_2O$
14.	Bone ash	Calcium phosphate	$Ca_3(PO_4)_2$
15.	Baking soda	Sodium bicarbonate	$NaHCO_3$
16.	Black Jack	Zinc sulphide	ZnS
17.	Black gold	Petroleum	Complex mixture of hydrocarbons
18.	Chile saltpeter	Sodium nitrate	$NaNO_3$
19.	Caustic soda	Sodium hydroxide	$NaOH$
20.	Caustic potash	Potassium hydroxide	KOH
21.	Common Salt	Sodium Chloride	$NaCl$
22.	Cinnabar	Mercury Sulphide	HgS
23.	Cryolite	Sodium Aluminum Fluoride	Na_3AlF_6
24.	Carbonic acid	Hydrogen carbonate	H_2CO_3
25.	Carbonic anhydride	Carbon dioxide	CO_2
26.	Carbolic acid	Phenol	C_6H_5OH
27.	Carborandum	Silicon carbide	SiC
28.	Correndum	Aluminum oxide	Al_2O_3
29.	Caro’s acid	--	H_2SO_5
30.	Cyanogen	--	C_2N_2
31.	Diborane	Boron hydride	B_2H_6
32.	Dead burnt Plaster of Paris	Calcium sulphate	$CaSO_4$
33.	Dry ice or Dricold	Solid carbon dioxide	$CO_2(s)$
34.	Diamond	Carbon	C
35.	Dutch liquid	Ethylene chloride	$C_2H_4Cl_2$
36.	Dutch metal	--	An alloy of Cu and Zn
37.	Epsom salt	Magnesium sulphate heptahydrate	$MgSO_4.7H_2O$
38.	Feldspar	--	$KAlSi_3O_8$
39.	Green vitriol	Hydrated ferrous sulphate	$FeSO_4\ .\ 7H_2O$

40.	Gypsum	Calcium sulphate	$CaSO_4 . 2H_2O$
41.	Glauber's salt	Sodium sulphate	$Na_2SO_4 . 10H_2O$
42.	Grahm's salt	--	$(NaPO_3)_n$
43.	Gun-cotton (An explosive)	Cellulose nitrate	
44.	Gamexene or BHC or Lindane	Benzene hexachloride	$C_6H_6Cl_6$
45.	Hypo	Sodium thiosulphate	$Na_2S_2O_3$
46.	Hydrolith	Calcium hydride	CaH_2
47.	Horn Silver	Silver chloride	AgCl

Sl.No	**Common name**	**Chemical name**	**Formula/composition**
48.	Indian Salt petre or Nitre	Potassium nitrate	KNO_3
49.	King of Chemicals	Sulphuric acid	H_2SO_4
50.	Lithia	Lithium bicarbonate	$LiHCO_3$
51.	Lime	Calcium oxide	CaO
52.	Lime stone	Calcium carbonate	$CaCO_3$
53.	Lunar caustic	Silver nitrate	$AgNO_3$

54.	Laughing gas	Nitrous oxide or Nitrogen monoxide	N_2O
55.	Litharge	Lead monoxide	PbO
56.	Marsh gas	Methane	CH_4
57.	Massicot	Lead monoxide	PbO
58.	Marshall's acid	--	$H_2S_2O_8$
59.	Microcosmic salt	--	$Na(NH_4)HPO_4.4H_2O$
60.	Milk-of-sulphur (δ-sulphur)	--	An amorphous form of sulphur
61.	Milk-of-lime	--	A suspension of calcium hydroxide in water
62.	Milk-of-magnesia	--	A suspension of Magnesium hydroxide in water.
63.	Mosaic gold	Stannic sulphide	SnS_2
64.	Muriatic acid (Spirits of salt)	Hydrochloric acid	HCl
65.	Mustard gas	--	$Cl\text{-}CH_2\text{-}CH_2\text{-}S\text{-}CH_2\text{-}CH_2\text{-}Cl$
66.	Norwegian saltpeter	Calcium nitrate	$Ca(NO_3)_2$
67.	Nitre cake	Sodium bisulphate	$NaHSO_4$
68.	Oil of Vitriol	Sulphuric acid	H_2SO_4
69.	Olefiant gas	Ethylene	C_2H_2
70.	Pyrene (a fire extinguisher)	Carbon tetrachloride	CCl_4
71.	Phosgene	--	$COCl_2$
72.	Phosphine	--	PH_3
73.	Perchloron	--	$Ca(OCl_2)_2$
74.	Producer gas	--	A mixture of carbon monoxide and Nitrogen
75.	Pearl ash	Potassium carbonate	K_2CO_3
76.	Plaster of Paris	--	$(CaSO_4)_2.\ H_2O$
77.	Quick lime	Calcium oxide	CaO
78.	Quick silver	Mercury	Hg
79.	Red lead	Triplumbic tetraoxide	Pb_3O_4 or $2PbO.\ PbO_2$

80.	Soda lime	A mixture of sodium hydroxide and calcium oxide	NaOH + CaO
81.	Soda ash	Anhydrous Sodium Carbonate	Na_2CO_3
82.	Slaked lime	Calcium hydroxide	$Ca(OH)_2$
83.	Venation white	--	A mixture of white lead and barium sulphate
84.	Venation red	Ferric oxide	Fe_2O_3
85.	Washing soda	Sodium Carbonate Decahydrate	$Na_2CO_3 . 10H_2O$
86.	Water gas	--	A mixture of carbon monoxide and hydrogen
87.	White lead	Basic carbonate of lead	$2PbCO_3 . Pb(OH)_2$
88.	Zinc white	Zinc oxide	ZnO

PERIODIC TABLE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
						1 H 1.01											2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 15.99	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 25.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (270)	109 Mt (268)	110 Ds (281)	111 Rg (272)							

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

(D) LAWS OF CHEMICAL COMBINATION

It is well known that the diversity of matter is not restricted to elements only. A wide variety of substance is formed by combination of elements. Such substances are known as 'Compounds'. Scientists have studied these compounds quantativly to obtain large amount of data and made certain generalizations by studying this data. Such generalizations are known as 'Laws of Chemical Combination'. As these laws are based on experimental data, there is no exception to these. The important laws of chemical combination are discussed below –

1. Law of Conservation of Mass or Law of conservation of Matter

(Given by French chemist A. Lavoisier in 1774)

' In a chemical reaction, the sum of masses of all the products is equal to sum of masses of all the reactants.'

Example – 1

If hydrogen gas is burnt in presence of oxygen gas mass of water produced is equal to sum of masses of hydrogen gas and oxygen gas consumed -

$$2H_2 + O_2 \rightarrow 2H_2O$$

$$4g + 32g = 36g$$

Example –2

If carbon is burnt in presence of oxygen gas mass of carbon dioxide is equal to sum of masses of carbon and oxygen gas consumed -

$$C + O_2 \rightarrow CO_2$$

$$12g + 32g = 44g$$

It should be noted however that if due to less than required amount of one of the reactant (limiting reagent) or due to some other reason the reaction does not undergo completion the masses of unreacted reactant/reactants should be added to mass of product. For example, if 4 g hydrogen is reacted only with 24 g oxygen, only 27 g of water will be produced and 1 g hydrogen will remain unreacted due to shortage of oxygen (limiting reagent).

2. Law of definite proportions or Law of constant Composition

(Given by French chemist, Louis Proust in 1799)

'A compound is always made up of same elements combined together in same proportion (ratio) by their mass irrespective of the source from where it is obtained.'

Example-1

From whatever source water is obtained, in its pure form it always contains 11.11% hydrogen and 88.8% oxygen by mass i.e. in ratio of 1:8.

Example-2

Whatever may be source of carbon dioxide gas (heating of calcium carbonate or burning of coke or neutralization of sodium carbonate using hydrochloric acid), it always consists of carbon and oxygen combined in ratio of 3:8 by their mass.

3. Law of Multiple proportions

(Given by British scientist John Dalton in 1804)

'*When two or more elements combine together to form two or more different compounds, then the ratio of the masses of one of the elements, which combine, with a fixed mass of the other element will be in a simple whole number ratio'.*

Example-1

In carbon monoxide, 16 g oxygen combine with 12 g carbon and in carbon dioxide 32 g oxygen combine with 12 g carbon. Here, the masses of carbon is same, where as the ratio of the masses of oxygen are 16 g and 32 g and these bear a simple ratio of 1:2.

Example-2

In water, 16 g oxygen is combined with 2 g hydrogen and in hydrogen peroxide 32 g of oxygen is combined with 2 g hydrogen. Here, the masses of hydrogen is same, where as the ratio of the masses of oxygen are 16 g and 32 g and these bear a simple ratio of 1:2.

4. Law of Reciprocal or Equivalent Proportions

(Given by Richter in 1792)

' When two elements (say A and B) combine separately with a third element (say C), then the ratio of the masses of these elements (A and B), which combine with a fixed mass of the third element(C) will be the same or a simple multiple or division of the ratio in which the two elements (A and B) combine directly with each other.'

Example -1

In CCl_4, 12 g carbon combines with 142 g chlorine. In CH_4, 12 g carbon combines with 4 g of hydrogen and in HCl, 142 g chlorine combines with same 4 g of hydrogen. So ratio of masses in which they combine with each other is 12:142 or 6:71 and the ratio of their masses which combine with fix mass of hydrogen is also **same** i.e. 12:142 or 6:71.

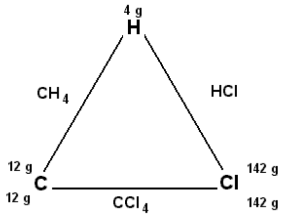
Example - 2

In CH_4, 12 g carbon combines with 4 g hydrogen. In CO_2, 12 g carbon combines with 32 g of oxygen and in H_2O; 2 g hydrogen combines with same

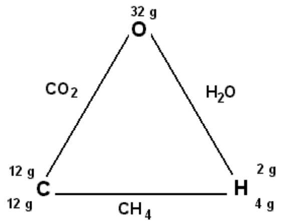
32 g of oxygen. So the ratio of masses in which they combine with each other is 12:4 or 3:1 and the ratio of their masses which combine with fix mass of oxygen is its **half** i.e. 12:2 or 3:0.5.

Example - 3

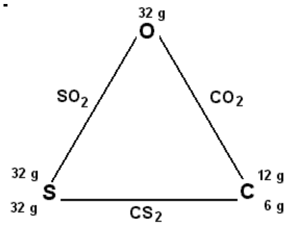
In CS_2, 32 g sulphur combines with 6 g carbon. In SO_2, 32 g sulphur combines with 32 g of oxygen and in CO_2, 12 g carbon combines with same 32 g of oxygen. So the ratio of masses in which they combine with each other is 32:6 or 16:3 and the ratio of their masses which combine with fix mass of oxygen is its **double** i.e. 32:12 or 16:6.



Example - 1



Example - 2



Example - 3

5. Gay Lussac's law of combining volumes –

(Given by Gay Lussac in 1808)

'Whenever gases react together, the volumes of the reacting gases and gases produced, if measured under similar conditions of temperature and pressure gases bear a simple whole number ratio.'

Example – 1

When nitrogen and hydrogen react together to form ammonia, the volumes (measured under same conditions) of nitrogen and hydrogen reacting together and ammonia produced are in ratio of 1:3:2.

$$N_2(g) + H_2(g) \rightarrow NH_3(g)$$

Example – 2

When hydrogen and chlorine react together to form hydrogen chloride, the volumes (measured under same conditions) of hydrogen and chlorine reacting together and hydrogen chloride produced are in ratio of 1:1:2.

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

(E) AIR

Air is the Earth's atmosphere. Air around us is a mixture of many gases and dust particles. It is the clear gas in which living things live and breathe. It has an indefinite shape and volume. It has no colour or smell. It has mass and weight, because it is matter. The weight of air creates atmospheric pressure. There is no air in outer space.

Air is a mixture of about 78% of nitrogen, 21% of oxygen, 0.9% of argon, 0.04% of carbon dioxide, and very small amounts of other gases.[1][2] There is an average of about 1% water vapour.

Animals live and need to breathe the oxygen in the air. In breathing, the lungs put oxygen into the blood, and send back carbon dioxide to the air. Plants need the carbon dioxide in the air to live. They give off the oxygen that we breathe. Without it we die of asphyxia.

Wind is moving air. This causes weather.

Air can be polluted by some gases (such as carbon monoxide), smoke, and ash. This air pollution causes various problems including smog, acid rain and global warming. It can damage people's health.

Air pollution is a type of environmental pollution that affects the air and is usually caused by smoke or other harmful gases, mainly oxides of carbon, sulphur and nitrogen.

In other words, air pollution is the contamination of air due to the presence or introduction of a substance which has a poisonous effect

Air pollution is usually described as either *primary pollutants* or *secondary pollutants*.Primary pollutants are pollutants that are put directly into the air by humans or natural sources. Examples of primary pollutants are exhaust fumes (gas) from cars, soot from smoke, dust storms and ash from volcanic eruptions (as seen in the picture on the left).[1]

Secondary pollutants are pollutants that are made from chemical reactions when pollutants mix with other primary pollutants or natural substances like water vapor.[1] Many secondary pollutants are made when a primary pollutant reacts with sunlight. Ozone and smog are secondary pollutants. Ozone is a gas that stops harmful ultraviolet rays from the sun. When it is near the ground, though, it can poison people and other organisms.[1]

There are many problems caused by air pollution, like greenhouse effect and acid rain

Human-made air pollution comes from many things. Most air pollution made by humans today is because of transportation. Automobiles , for instance, make about 60% of the human-made air pollution. The gases inside car exhaust, like nitrogen oxide, make smog and acid rain.

Farmlands and forests sometimes burn in wildfires producing soot (a black powder composed mainly of carbon, produced when coal, grasses, wood etc. is burned) from smoke. Soot can affect people and other life. People start many of those fires.

Industrial air pollution

Many industrial power plants burn fossil fuels to get their energy. However, burning fossil fuels can make a lot of oxides (chemical compounds that have oxygen and other elements inside). In fact, the burning of fossil fuels makes 96% of the sulphur oxides in the atmosphere. Some industries also make chemicals that make poisonous fumes (smoke).

Indoor air pollution

Air pollution is not only on the outside. Homes, schools, and buildings can also have air pollution. Sometimes the air inside a building is even worse than the air outside.[1] Many things which humans use every day can pollute the air. Compounds inside carpets, paints, building materials and furniture also pollute the air, especially when they are new.

In buildings where the windows are tightly shut to stop air leaks, the air inside can be polluted more than the air outside.[1]

Acid precipitation

Acid precipitation is precipitation, like rain, sleet, or snow, that contains acids from air pollution. When fossil fuels are burned, they let out oxides into the air. When these oxides mix with water in the atmosphere, they make acid, which fall as precipitation.[1] Acid precipitation can kill living things like fish and trees, by making the place where they live too acidic. Acid rain can also damage buildings made of limestone and concrete.

Ozone hole

A global concern is the hole in the ozone layer in the stratosphere. The Earth's ozone layer protects life from the Sun's harmful ultraviolet rays, but in the 1970s, scientists found out that some chemicals let out into the atmosphere makes the ozone turn into oxygen. This lets more ultraviolet rays reach the Earth. During the 1980s, scientists found that the ozone layer above the South Pole had thinned by 50 to 98%.

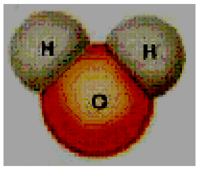
(F) WATER

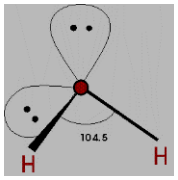
INTRODUCTION

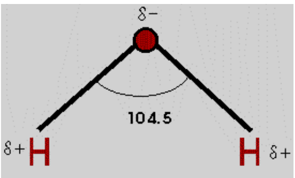
Water is a commonly known compound of hydrogen and oxygen. It has many unique properties due to which it plays a great role. Water is the most important compound for existence of life. It is widely distributed in nature and is found almost everywhere, in oceans, in rivers, on mountain tops, below earth surface, in hydrated salts, in living organisms and even in air.

STRUCTURE OF WATER

Water is made up of extremely small units called molecules. Every water molecule is made up of one oxygen atom and two hydrogen atoms. Each hydrogen atom is bonded to the oxygen atom by a single-covalent bond. The central oxygen atom is sp^3 hybridised. Two orbitals have lone pair of electrons.



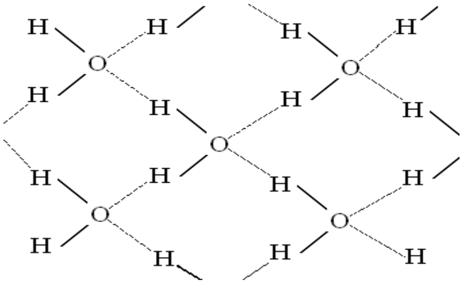




Due to difference in electronegativity of H and O , the O-H bond is polar. O-H bond length is 95.7 pm , H-O-H bond angle is 104.5(less than tetrahedral because of greater lone pair – lone pair repulsion) and dipole moment is 1.84 Debey. The mass ratio of H and O is 1:8.

H-BONDING IN WATER AND ICE

Liquid water consists of large number of molecules associated together by H-bond. With decrease in temperature extent of H-bonding increase and water become denser. Water acquires maximum density at 3.98 ^{0}C. Below 3.98 ^{0}C, water molecules undergo extensive H-bonding to form three-dimensional network in which each oxygen atom is tetrahedrally bonded to four hydrogen atoms, two by covalent bonds and two by H-bonds.



The three dimensional network has open spaces resulting in decrease in density. Thus ice has lower density than water and floats over it. This property of ice helps in survival of aquatic animals during winter below ice in frozen water bodies as floating over water it act as a thermal insulation.

PHYSICAL PROPERTIES OF WATER

1. Exists as solid, liquid and gas.
2. Liquid at room temperature.
3. Colourless, odourless, tasteless and transparent.
4. High freezing/melting point (273.15 K at 1 atmosphere) and boiling point (373.15 K at 1 atmosphere)
5. High heat of fusion and vaporization.
6. High specific heat (4.186 j/g/^{0}C)
7. Polar. Become non-polar at high temperature and pressure and dissolve organic substances.
8. High dielectric constant.
9. An excellent solvent.
10. Density at 298 K is 1.0000 g/cc.

CHEMICAL PROPERTIES OF WATER

1. Amphoteric nature- Water act as Bronsted acid as well as base-

H_2O (l) + NH_3 (aq) → OH^- (aq) + NH_4^+ (aq)

H_2O (l) + H_2S (g) → H_3O^+ (aq) + HS^- (aq)

2. Oxidising and reducing nature-Water act as oxidizing as well as reducing agent-

$2H_2O$ (l) + $2e^-$ → $2OH^-$ (aq) + H_2 (g) $E^0 = -0.41$ V

$2H_2O$ → $4H^+$ (aq) + O_2 (g) + $4e^-$ $E^0 = -0.82$ V

3. Hydrolysis – Water hydrolyse large number of compounds like oxides, carbides, phosphides, nitrides etc.

$CaO + H_2O \rightarrow Ca(OH)_2$

$SO_2 + H_2O \rightarrow H_2SO_3$

$CaC_2 + 2\ H_2O \rightarrow Ca(OH)_2 + C_2H_2$

$Al_4C_3 + 12\ H_2O \rightarrow 4\ Al(OH)_3 + 3CH_4$

$Mg_3N_2 + 6 H_2O \rightarrow 3 Mg(OH)_2 + NH_3$

$Ca_3P_2 + 6 H_2O \rightarrow 3 Ca(OH)_2 + 2 PH_3$

4. Formation of hydrates – Water can form three types of hydrates-

a) Co-ordination hydrates. e.g. $[Ni (H_2O)_6] (NO_3)$

b) H-bonding hydrates. e.g. $CuSO_4.5H_2O$. Out of 5 water molecules four are bonded to central Cu^{2+}

ion and one is bonded with SO_4^{2-} ion.

c) Interstial hydrates. e.g. $BaCl_2.2H_2O$

HARD AND SOFT WATER

Hard water contains bicarbonates, chlorides and sulphates of calcium and magnesium. It does not produce lather with soaps because the soap molecules are precipitated as their calcium or magnesium salts.

$$2\ C_{17}H_{35}COONa + Ca^{2+} \rightarrow (C_{17}H_{35}COO)_2Ca \downarrow + 2Na^+$$

Soft water is free from bicarbonates, chlorides and sulphates of calcium and magnesium. It readily

produce lather with soaps.

The hardness of water is of two types- **1. Temporary hardness 2. Permanent hardness**.

1. Temporary hardness is due to bicarbonates of calcium or magnesium. It can be removed by -

<u>a) Boiling</u> – On boiling the bicarbonates are decomposed to carbonates which are

precipitated out.

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$

$Mg(HCO_3)_2 \rightarrow MgCO_3 + H_2O + CO_2$

<u>b) Clark's process</u>- In this method a calculated amount of $Ca(OH)_2$ is added.

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$

$Mg(HCO_3)_2 + 2\ Ca(OH)_2 \rightarrow 2CaCO_3 + Mg(OH)_2 + 2H_2O$

2. Permanent hardness of water is due to presence of soluble chlorides or sulphates of calcium and

magnesium. Permanent hardness can be removed by Na_2CO_3.

$MgSO4 + Na_2CO_3 \rightarrow MgCO_3 \downarrow + Na_2SO_4$

$CaCl2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + NaCl$

Both temporary and permanent hardness can be removed –

a) By zeolites (Permutit Method) – A zeolite, hydrated sodium aluminum silicate called permutit is used as ion exchanger. When water passes through a column of permutit, calcium

and magnesium ions are exchanged with sodium ions.

$2 NaAlSiO_4 + Ca^{2+} \rightarrow Ca(AlSiO_4)_2 + 2Na^+$

The permutit is regenerated by using NaCl.

b) By ion-exchange resins- Ion exchange resins are of two types-

The water sample becomes acidic on passing through cation- exchangers.

These exchangers can be regenerated using HCl.

$R_2Ca + 2 HCl \rightarrow 2 R\text{-}SO_3H + CaCl_2$

ii) Anion-exchangers(OH^-resins) - Consist of large organic molecules having –OH

or $-NH_2$ group. These exchanges all anions present in the water sample.

$RNH_2 + H_2O \rightarrow RNH_3^+ + OH^-$

$RNH_3^+OH^- + X^- \rightarrow RNH_3^+ X^- + OH^-$

The water sample becomes basic on passing through anion- exchangers.

These can be regenerated using NaOH.

$RNH_3^+ X^- + NaOH \rightarrow RNH_3^+OH^- + NaX$

Water sample after passing through both type of exchangers is neutral.

c) By calgon – Hexametaphosphate $(NaPO_3)_6$ or $Na_2[Na_4(PO_3)_6]$ is known as calgon

(calcium gone). On treatment with water it exchange calcium ions with

magnesium ions.

$$Na_2[Na_4(PO_3)_6] + 2\,Ca^{2+} \rightarrow Na_2[Ca_2(PO_3)_6] + 4\,Na^{+}$$

HEAVY WATER

Water made up of deuterium isotopes of hydrogen is known as heavy water. It was first discovered by Urey. It's relative abundance in ordinary water is 6000:1.It's molecular mass is 20.028. It is generally denoted as D_2O.Oxygen and hydrogen are in ratio of 1:4.It is produced by repeated electrolysis of ordinary water and is used as moderator and coolant in nuclear power plants and in tracer technique.

All physical constants of heavy water are higher than ordinary water. The dielectric constant of heavy water is little less than ordinary water.

The chemical properties of heavy water are same as of ordinary water. The rate of reactions, however, is less.

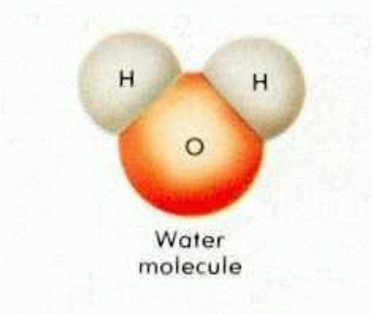
Heavy water has germicidic and bactricidic properties. High concentration retards animal and plant growth. In low concentrations it act as tonic and stimulate vegetative growth.

Water chemistry FAQ
Frequently Asked Questions

What is water?

Water is a very important substance, as it makes up the larger part of an organism's body. But what exactly is water? Inside the body of a human being there is a skeleton, which makes your body solid and makes sure you can stand up without falling apart. Water is also a kind of skeleton. It consists of tiny particles, the atoms, just like every other substance on earth. One of these atoms is called hydrogen and the other is called oxygen. As you probably know the air that we breathe also contains oxygen. One particle of water is called a molecule. When lots of water molecules melt together we can see the water and drink it or use it, for instance to flush a toilet.

How is a water molecule built up?



A water molecule consists of three atoms; an oxygen atom and two hydrogen atoms, which are bond together like little magnets. The atoms consist of matter that has a nucleus in the centre.
The difference between atoms is expressed by atomic numbers. The atomic number of an atom depends on the number of protons in the nucleus of the atom. Protons are small positively charged particles. Hydrogen has one proton in the nucleus and oxygen has eight. There are also uncharged particles in the nucleus, called neutrons.
Next to protons and neutrons, atoms also consist of negatively charged electrons, which can be found in the electron cloud around the nucleus. The number of electrons in an atom equals the number of protons in the nucleus. The attraction between the protons and electrons is what keeps an atom together.

How much does a water molecule weigh?

The weight of a molecule is determined by the atomic masses of the atoms that it is built of. The atomic mass of an atom is determined by the addition of the number of protons and neutrons in the nucleus, because the electrons hardly weigh anything. When the atomic masses of the separate atoms are known, one simply has to add them up to find the total atomic mass of a molecule, expressed in grams per mol. A mol is an expression of the molair weight of a molecule, derived from the weight of a hydrogen molecule, which is 1 mol.
Hydrogen has a relative atomic mass of 1 g/ mol and oxygen has a relative atomic mass of 16 g/ mol. Water consists of one oxygen atom and two hydrogen atoms. This means that the mass of a water molecule is 1g + 1g + 16g = 18 g/ mol.
When the number of moles of water is known, one can calculate how many grams of weight this is, by using the molar weight of water.

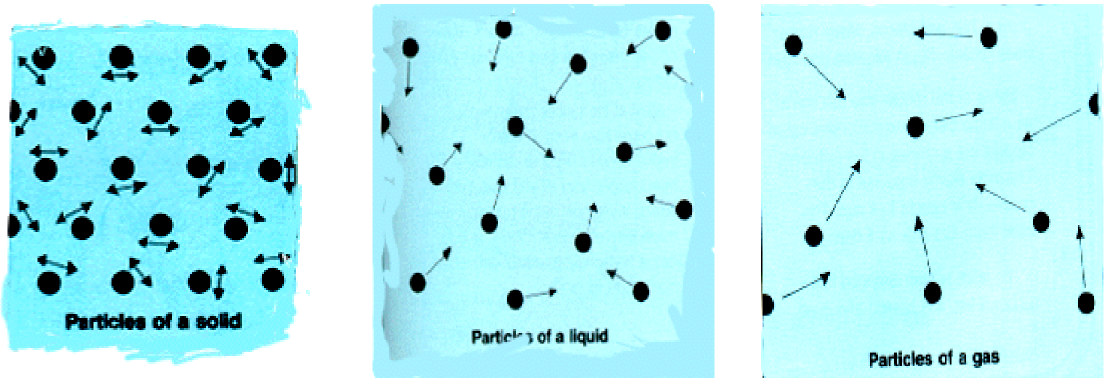
The molair weight of separate atoms can be found in the periodic table of Mendelejef.

In what states (phases) can water be found?

Water exists in three states: solid, liquid and gaseous. At a normal temperature of about 25ºC it is liquid, but below 0ºC it will freeze and turn to ice. Water can be found in the gaseous state above 100ºC, this is called the boiling point of water, at which water starts to evaporate. The water turns to gas and is then odourless and colourless.

How fast water evaporates depends on the temperature; if the temperature is high, water will evaporate sooner.

What happens if water changes phase?



The phase changes of water

The changes from a liquid to a solid or to a gas are called phase changes. When a substance such as water changes phase, its physical appearance changes, but not its chemical properties. This is because the chemical structure remains the same, but the molecules of which it consists will float a little further apart. In the solid state the water molecules are fairly close together, but in the liquid state they are a bit further apart. The water becomes liquid as a result of parting molecules. When water changes from liquid to gas the molecules will part even further, that is why we cannot detect it.

Why does ice float on water?

When substances freeze, usually the molecules come closer together. Water has an abnormality there: it freezes below 0ºC, but when temperatures fall to 4ºC, water starts to expand and as a result the density is lower. Density of a substance means the weight in kilograms of a cubic metre of a substance. When two substances are mixed but do not dissolve in one another, the substance with the lowest density floats on the other substance. In this case that substance is ice, due to the increased density of water.

How come not all substances are water-soluble?

Polarity determines if a substance is water-soluble. A polair substance is a substance that has two kinds of 'poles', as in a magnet. When another substance is also polair the poles of the substances attract each other and as a result the substances mix. A substance then dissolves in water.
Substances that contain no 'poles' are called apolair substances. Oil for instance is an apolair substance, which is why oil does not dissolve in water. In fact it floats on water, just like ice, due to its smaller density.

What is hard water?

When water is referred to as 'hard' this simply means, that it contains more minerals than ordinary water. These are especially the minerals calcium and magnesium. The degree of hardness of the water exceeds, when more calcium and magnesium dissolve.
Magnesium and calcium are positively charged ions. Because of their presence, other positively charged substances will dissolve less easy in hard water than in water that does not contain calcium and magnesium.

This is the cause of the fact that soap doesn't really dissolve in hard water.

What are physical and chemical properties?

Physical properties of a substance are properties that have everything to do with the substance's appearance. Chemical properties are properties that are often used in chemistry, to address the state of a substance. Physical and chemical properties can tell us something about the behaviour of a substance in certain circumstances.

Which physical and chemical properties does water have?

There are several different physical and chemical properties, which are often used alternately. We can name the following:
- Density. The density of water means the weight of a certain amount of water. It is usually expressed in kilograms per cubic metre. (physical)
- Thermal properties. This refers to what happens to water when it is heated; at which temperature it becomes gaseous and that sort of thing. (physical)
- Conductivity. This means the amount of electricity that water can conduct. It is expressed in a chemical magnitude. (physical)
- Light absorption. This is the amount of light a certain amount of water can absorb over time. (chemical)
- Viscosity. This means the syrupiness of water and it determines the mobility of water. When the temperature rises, the viscosity degrades; this means that water will be more mobile at higher temperatures. (physical)
- The pH. The pH has its own scale, running up from 1 to 14. The pH shows whether a substance is acid (pH 1-6), neutral (pH 7) or basic (pH 8-14). The number of hydrogen atoms in the substance determines the pH. The more hydrogen atoms a substance contains, the lower the pH will be. A substance that contains many hydrogen atoms is acid. We can measure the pH by dipping a special colouring paper in the substance, the colours shows which pH the substance has. (chemical)
- Alkalinity. This is the capacity of water to neutralize an acid or a base, so that the pH of the water will not change. (chemical)

(G) HYDROGEN

Hydrogen element was first discovered by Henery Cavendish in 1766. It name was given by Lavoisier who is also known as father of chemistry (hydro means water and gen means producing).

Position in Periodic Table

The position of hydrogen in periodic table is anomalous. This is because Hydrogen resembles with both Alkali metals and Halogens in its properties. So hydrogen can neither be kept with alkali metals nor with halogens. It has been given a separate place in periodic table.

Occurrence of Hydrogen

Hydrogen is most abundant element of universe (more than 50% of mass of stars is hydrogen). On earth, it is found in Free State only in traces. However in combined form it is widely distributed as water. It is third most abundant element on the surface of globe (15.4% mass of earth crust and oceans). Ninth element in order of abudence in earth crust alone.

Isotopes of Hydrogen

Hydrogen has three isotopes –

1. Protium – $^{1}H_{1}$ → 99.985 %
2. Deuterium – $^{1}H_{2}$ → 0.015 %
   1p+1n
3. Tritium – $^{1}H_{3}$ → 10^{-15} % (β-emiter $t_{1/2}$12.33 years)

The chemical properties of all three isotopes of hydrogen are same. The three isotopes however differ in the rate of chemical reactions due to difference in mass number. The difference in properties of isotopes due to difference in mass number is known as <u>Isotopic Effect</u>. Isotopes also differ in their physical properties like m.p., b.p., heat of fusion, bond energy etc. Most of the physical parameters of deuterium are higher than protium.

Dihydrogen (A mixture of H_2, HD and D_2. H_2 is diprotium and D_2 is dideuterium)

Hydrogen exists as diatomic molecule. Hydrogen in its molecular form is thus called <u>DIHYDROGEN</u>

Preparation of Dihydrogen

1. <u>By action of water on metals</u>

$2Na + 2H_2O \rightarrow 2NaOH + H_2$ $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

The reactions are highly vigorous.

2. <u>By action of acids on metals</u>

$Fe + 2HCl\ (dil) \rightarrow FeCl_2 + H_2$ $Mg + 2HCl\ (dil) \rightarrow MgCl_2 + H_2$ $Zn + H_2SO_4\ (dil) \rightarrow ZnSO_4 + H_2$

3. <u>By action of strong alkalies on metals</u>

$2\ Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$

$Sn + 2NaOH + H_2O \rightarrow Na_2SnO_3 + H_2$

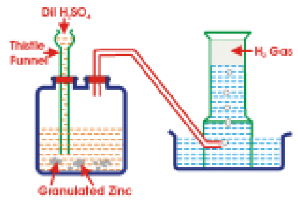
4. <u>By electrolysis of water</u>

$$2H_2O \xrightarrow{\text{Electrolysis}} 2H_2 + O_2$$

In laboratory DIHYDROGEN is prepared by action of dilute sulphuric acid on granulated zinc - $Zn + H_2SO_4\ (dil) \rightarrow ZnSO_4 + H_2$

1.Conc. H_2SO_4 is not used, as it is an oxidising agent.

2.Pure zinc is not used, as it is non-porous in nature.



Laboratory Preparation Of Dihydrogen

Methods of preparing pure hydrogen

1. <u>By action of pure dil. H_2SO_4 on magnesium ribbon</u> -
   $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

2. <u>By electrolysis of warm solution of Barium hydroxide using nickel electrodes</u>

Manufacture

Hydrogen is manufactured by Lane process, Bosch,s process, electrolysis of water or from methanol.

Physical Properties of Dihydrogen

1. Dihydrogen is a colourless, odourless and tasteless gas.2. It has very low solubility in water. 3. Density 1/14th of air. 4. It is highly combustible. 5. Can be liquefied at very high pressure and low temperature. 5. It is highly adsorbable on Ni, Pt and Pd.

Chemical Properties of Dihydrogen

1. It is neutral to litmus.
2. It is highly combustible and burns in presence of oxygen with blue flame.
   $2H_2 + O_2 \rightarrow 2\ H_2O + 572\ kJ\ heat$
3. <u>Reaction with metals-</u> It reacts with metals like Na, Ca etc. to form corresponding metal hydrides.
   $2Na + H_2 \rightarrow 2\ NaH$ $Ca + H_2 \rightarrow CaH_2$
4. <u>Reactions with non metals</u> – It reacts with large number of non-metals at elevated temperature to form corresponding hydrides.
   $N_2 + 3H_2 \rightarrow 2NH_3$ $C + 2H_2 \rightarrow CH_4$ $1/8\ S_8 + H_2 \rightarrow H_2S$

$H_2 + Cl_2 \rightarrow 2HCl$

5. Reaction with metal- oxides- It reduces metal oxides.
   $PbO + H_2 \rightarrow Pb + H_2O$

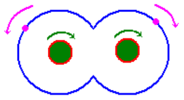
6. Reactions with unsaturated Hydrocarbons –
   $C_2H_4 + H_2 \rightarrow C_2H_6$ Oil + H_2 (in presence of Ni catalyst) → Fats

Uses of Hydrogen

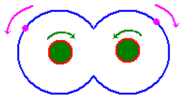
Used in preparation of NH_3, hydrogenation of oils, synthetic petrol, hydrogen-oxygen welding torch, atomic hydrogen torch, rocket fuel and as fuel.

Nuclear Spin Isomers of Hydrogen

There exist two nuclear spin isomers of hydrogen – i) ortho with parallel spin and ii) para with opposite spin of two nuclei.



ORTHO HYDROGEN



PARA HYDROGEN

1. Ordinary dihydrogen contains 75% ortho and 25% para hydrogen.
2. Decrease in temperature decrease percentage of ortho hydrogen. For example at 20 K ortho hydrogen is just 0.18%.
3. Pure para hydrogen can be obtained at low temperature but a sample containing more than 75% ortho hydrogen can not be obtained.
4. The Chemical Properties of two forms are same.
5. The two forms differ in physical properties like specific heat, thermal conductivity, boiling point, etc. For example thermal conductivity of para-hydrogen is 50% higher than that of ortho.

Hydrides

The binary compounds of hydrogen are called HYDRIDES.

There are three types of Hydrides –

1. Saline or Ionic Hydrides
2. Metallic or Interstitial Hydrides
3. Molecular or Covalent Hydrides

1. Saline or Ionic Hydrides

Compounds of hydrogen with most of s-Block elements are called saline hydrides.

They are non-volatile, non-conducting crystalline solids.

Examples – NaH, KH, CaH_2, etc.

The thermal stability of these halides decrease down the group –

LiH > NaH > KH > RbH > CsH

$CaH_2 > SrH_2 > BaH_2$

Electrolysis of solution of saline hydrides in molten alkali halide gives hydrogen gas at anode.

This confirms existence of H- ion in saline hydrides.

$$2H^- \rightarrow H_2 + 2e^-$$

Saline hydrides react explosively with water -

$$NaH + H_2O \rightarrow H_2 + NaOH$$

The fire produced can not be extinguished using carbon dioxide.

Alkali metal hydrides are used in preparation of complex metal hydrides like $LiAlH_4$ and $NaBH_4$.

2. Metallic or Interstitial Hydrides

Hydrogen forms non-stoichiometric interstitial hydrides with d- and f-Block metals.

These hydrides show appreciable electric conductivity.

Metal hydrides of gp. 3,4 and 5 are common.

In group 6, only Cr forms hydride i.e. CrH.

Metals of gp. 7, 8, 9 do not form hydrides. This is referred as HYDRIDE GAP.

Examples – ScH_2, YH_2, YH_3, LaH_2, LaH_3, TiH_2,

ZrH_2, HfH_2, NbH, NbH_2, TaH, etc.

3. Molecular or Covalent hydrides

Most of the p-Block elements forms covalent hydrides. These are volatile hydrides and exist as molecules.

Examples – CH_4, NH_3, H_2S, H_2O, B_2H_6, SiH_4, HCl, PH_3,etc.

Molecular hydrides are further classified into three classes depending on relative number of electrons and bonds in their Lewis structures -

a) Electron-deficient e.g. B_2H_6 (b)Electron-precise e.g. CH_4 c) Electron-rich e.g. NH_3, H_2O

(H) OXYGEN

Oxygen is the most abundant element in the earth's crust (46.6%). In normal conditions, it exists in molecular form O_2. It is in the 2nd period and 16th group of the periodic table.

Occurrence

It occurs in water (88.8% by weight) and in atmosphere (21% by volume) other than in the earth's crust as oxides.

Preparation

1. **By the decomposition of oxygen rich compounds**

$$2KMnO_4 \xrightarrow{\text{Heat}} K_2MnO_4 + MnO_2 + O_2$$

2. **Laboratory preparation**

a. $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$

b. $2Na_2O2 + 2H_2O \xrightarrow{MnO2} 4NaOH + O_2$

3. **Industrial Preparation**

a. From air - Air is liquefied under very high pressure and at low temperature. The liquid air is then allowed to distil when dinitrogen with lower boiling point (78K) distils as vapours while dioxygen with higher boiling point (90K) remains in the liquid state and can be separated.

b. From water - When water containing acid or alkali is electrolyzed, oxygen is obtained at anode.

Properties

Physical properties

a. Dioxygen is colourless, odourless and tasteless gas.

b. It is slightly heavier than air.

c. It is slightly soluble in water.

Chemical properties

a. Action with litmus – neutral towards litmus

b. Supporter of combustion but not combustible

c. Action with non-metals -

(i) $2H_2 + O_2 \xrightarrow{1073K} 2H_2O$ (ii) $N_2 + O_2 \xrightarrow[3273\ K]{\text{Electric discharge}} 2NO$ Nitric oxide

d. Action with metals

(i) $4Na + O_2 \xrightarrow{\Delta} 2Na_2O$

ii) $2Mg + O_2 \xrightarrow{\Delta} 2MgO$

(Noble metals like gold and platinum do not combine with oxygen.)

e. Action with compounds -

(i) $4NH_3 + 5O_2 \xrightarrow[Pt]{1073K} 4NO + 6H_2O$

(ii) $4HCl + O_2 \xrightarrow[CuCl2]{700K} 2Cl_2 + 2H_2O$

(iii) $2SO_2 + O_2 \xrightarrow[\text{Pt or V2O5}]{723K} 2SO_3$

f. With hydrocarbon

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Uses

1. For artificial respiration
2. As a rocket fuel oxidiser in the liquid form.
3. In the manufacture of large number of compounds.

(I) NITROGEN

Nitrogen is the most abundant gas in atmosphere. In normal conditions, it exists in molecular form N_2. It is in the 2nd period and15th group of the periodic table.

Occurrence

i. In Free State, it is present in the atmosphere to the extent of 78% by volume.
ii. In combined state, it is present in many compounds such as potassium nitrate (Nitre) and sodium nitrate (Chile Salt Petre), proteins and nucleic acid.

Preparation

1. Laboratory Method

i) $$\underset{\text{Amm. chloride}}{NH_4Cl} + \underset{\text{Sod. Nitrite}}{NaNO_2} \xrightarrow{\text{Heat}} NH_4NO_2 + NaCl$$

$$\underset{\text{Amm. nitrite}}{NH_4NO_2} \xrightarrow{\text{Heat}} N_2 + 2H_2O$$

ii) $$\underset{\text{Amm. dichromate}}{(NH_4)_2Cr_2O_7} \xrightarrow{\text{Heat}} Cr_2O_3 + N_2 + 4H_2O$$

2. Manufacture of Dinitrogen

It is manufactured by the fractional distillation of the liquid air. When the liquid air is allowed to boil, dinitrogen with lesser boiling point (77K) gets distilled first leaving behind dioxygen with higher boiling point (90K).

Properties

Physical Properties

I. It is a colourless, odourless and tasteless gas.

II. It is slightly lighter than air.

III. It is very slightly soluble in water.

Chemical Properties

1. Action with litmus - Neutral towards litmus.

2. <u>Combustibility</u> - It is neither combustible nor supports combustion.

3. <u>Action with metals</u> - it reacts with active metals to form nitrides.

$$6Li + N_2 \rightarrow 2Li_3N$$

$$3Mg + N_2 \rightarrow Mg_3N_2$$

4. <u>Action with non-metals</u>

$$N2 + O_2 \xrightarrow{3273K} 2NO$$

(Nitric oxide)

$$2NO + O_2 \rightarrow 2NO_2$$

(Nitrogen dioxide)

5. <u>Action with compounds</u>

$$CaC_2 + N_2 \rightarrow CaCN_2 + C$$ (Calcium cyanamide)

$$CaCN_2 + 2H_2O \rightarrow CaCO_3 + 2NH_3$$

6. <u>Natural fixation of nitrogen</u>

$$N_2 + O_2 \xrightarrow[3273K]{Lighting} 2NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$$

$$CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$$

Uses

1. It moderates the combustion of substances in air.
2. It is used in the manufacture of compounds like ammonia, Nitric acid, calcium cyanamide etc.
3. In providing inert atmosphere in iron and steel industries.

(J) CARBON DIOXIDE

Occurrence

It is present in the atmosphere to the extent of 0.03% by volume.

Preparation

i. It is prepared by burning carbon, a hydrocarbon or carbon monoxide in excess of air.

$C + O_2 \rightarrow CO_2$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

$2CO + O_2 \rightarrow 2CO_2$

ii. On action of dilute hydrochloric acid on calcium carbonate -

$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Marble chips

iii. Manufacture

a. $\underset{\text{Limestone}}{CaCO_3} \xrightarrow[\text{1600 K}]{\text{Heat}} CaO + CO_2$

b. $\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Yeast}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2$

Properties

Physical

I. It is colourless, odourless and tasteless gas.

II. It is about 1.5 times heavier than air.

III It can be readily liquefied under a pressure 50-60 atmosphere at room temperature.

Chemical Properties

1. It turns moist blue litmus red and hence acidic in nature.

$$CO_2 + H_2O \leftrightarrow \underset{\text{Carbonic acid}}{H_2CO_3}$$

2. Action with lime water

$$\underset{\text{Lime water}}{Ca(OH)_2} + CO_2 \rightarrow \underset{\text{Milky}}{CaCO_3} + H_2O$$

$$CaCO_3 + H_2O + \underset{\text{Excess}}{CO_2} \dashrightarrow \underset{\text{Colourless}}{Ca(HCO_3)_2}$$

3. Photosynthesis by plants

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

Uses

i. In the preparation of aerated drinks like soda water.
ii. As a fire extinguisher.
iii. In the manufacture of washing soda by Solvay's process.
iv. As a refrigerant in the form of dry ice (solid carbon dioxide)
v. By plants, during photosynthesis.

(K) OXIDATION AND REDUCTION

There are three concepts regarding oxidation and reduction.

1. Classical concept
2. Electronic concept
3. Oxidation number concept

1. Classical concept of oxidation and reduction

According to classical concept,

‘Gain of oxygen or loss of hydrogen by a species is known as its **oxidation**.’

For example-

$C + O_2 \rightarrow CO_2$ (addition of oxygen – carbon oxidised)

$H_2S + Br_2 \rightarrow 2HBr + S$ (removal of hydrogen – sulpher oxidised)

‘**Oxidising agent** is a substance which brings about oxidation of other substance.’

In first reaction O_2 is oxidising agent whereas in second reaction Br_2 is oxidising agent.

Similarly,

‘Gain of hydrogen or loss of oxygen by a species is known as its reduction.’

For example –

$N_2 + 3H_2 \rightarrow 2NH_3$ (addition of hydrogen – nitrogen reduced)

$ZnO + C \rightarrow Zn + CO$ (removal of oxygen – zinc reduced)

‘**Reducing agent** is the substance which brings about reduction of other substance.’

In first reaction H2 is reducing agent whereas in second reaction C is reducing agent.

2. Electronic concept of oxidation and reduction

According to electronic concept,

‘Loss of electron/s by a species is known as its **oxidation**.’

The loss of electrons is also called de-electronation. For example –

$Na \rightarrow Na^{+} + e^{-}$ (Na oxidized)

$Fe^{2+} \rightarrow Fe^{3+} + e^{-}$ (Fe^{2+} oxidized)

‘**Oxidising agent** is the substance which brings about oxidation of other species by taking electron/s and getting reduced itself.’

Similarly,

‘Gain of electron/s by a species is known as its reduction.’

The gain of electrons is also called electronation. For example –

$Cl + e^{-} \rightarrow Cl^{-}$ (Cl reduced)

$Sn^{4+} + 2e^{-} \rightarrow Sn^{2+}$ (Sn^{4+} reduced)

‘**Reducing agent** is the substance which brings about reduction of other species by losing electron/s and getting oxidised itself.’

3. Oxidation number concept of oxidation and reduction

According to oxidation number concept,

‘Increase in oxidation number of a species is known as its **oxidation**.’

and

‘Decrease in oxidation number of a species is known as its **reduction**.’

For example in the reaction –

$$10\,FeSO_4 + 2KMnO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 5Fe_2(SO_4)_3 + 2MnSO_4 + 8H_2O$$

oxidation number of Fe increases from +2 to +3 hence it is undergoing oxidation and the oxidation number of Mn decreases from +7 to +2 hence it is under going reduction.

According to this concept,

‘**Oxidising agent** is the species which increases the oxidation number of other species and its own oxidation number decreases.

and

‘**Reducing agent** is the species which decreases the oxidation number of other species and its own oxidation number increases.’

Oxidation number

“The oxidation number of an element in any species is the charge which must develop on it when all other atoms in the species are hypothetically removed as their most common ions.”

The oxidation number of an element may be different in different species i.e. an element can show variable oxidation state. The oxidation number of an element can be positive, negative, zero or even fractional depending upon the state of combination in the species.

Rules for calculating oxidation number or oxidation state of an atom in a species

Following rules are used to determine the oxidation number of an atom in a species.

1. The sum of oxidation number of all atoms in a species is equal to charge on that species. For example the sum of oxidation numbers of four oxygen atoms and one sulpher atom in SO_4^{2-} is –2.
2. Oxidation number of an atom in its elemental form is always zero. For example, the oxidation number of oxygen in O_3 is zero.
3. The oxidation number of alkali metals and alkaline earth metals in their compounds is always +1 and +2 respectively. For example oxidation number of Na in NaCl is +1 and that of Ca in $CaCO_3$ is +2.
4. The oxidation number of fluorine in its compounds is always –1. For example the oxidation number of fluorine in OF_2, HF and IF_2 is –1.
5. The oxidation number of hydrogen in its compounds is always +1 except metal hydrides where it is –1. For example in HCl, H_2SO_4, C_2H_4, etc. oxidation number of hydrogen is +1 but in LiH, NaH, CaH_2, etc. oxidation number of hydrogen is –1.

6. The oxidation number of oxygen in the combined form is always –2 except in superoxides, peroxides and oxyfluoride where it is -½, -1 and +2 respectively. For example in H_2O, Fe_2O_3, SO_3, etc. oxidation number of oxygen is –2 but in KO_2, H_2O_2 and OF_2 it is -½, -1 and +2 respectively.
7. The oxidation number of halogens in their compounds is always –1 except the compounds like their oxides and interhalogen compounds where these are joined to more electronegative element. In such cases the more electronegative element is assigned its normal oxidation number. For example, the oxidation number of Br in KBr, CH_2Br_2, $AlBr_3$, etc. is –1 but in HOBr and BrF_3 is +1 and +3 respectively.

Determination of oxidation number in a neutral molecule or ion.

i) Oxidation number of Mn in $KMnO_4$: Let the oxidation number of Mn in $KMnO_4$ be x .

$\therefore$ (+1 × 1) + (x × 1) + (-2 × 4) = 0 **or** 1 + x - 8 = 0 or x = 8 – 1 or x = 7

Hence the oxidation number of Mn in $KMnO_4$ is +7

ii) Oxidation number of Cr in $K_2Cr_2O_7$: Let the oxidation number of Cr in $K_2Cr_2O_7$ be x

$\therefore$ (+1 × 2) + (2 × x) + (-2 × 7) = 0 **or** 2x - 12 = 0 **or** 2x = 12 **or** x = 6

Hence the oxidation number of Cr in $K_2Cr_2O_7$ is +6.

It must be noted, however, that different atoms of same element in a species may have different oxidation number. For example in H_2SO_5 two oxygen atoms and in CrO_5 four oxygen atoms are peroxides oxygen and have oxidation number of –1 and not-2. In H2S2O3, the oxidation number of one of the S is –2 whereas that of other is +6. Similarly, in NH_4 NO_3, oxidation number of N of NH_4^+ is –3 but that of N of NO_3^- is +5.

It must also be noted that some substances are actually stoichiometric combination of two or more substances. For example, Fe_3O_4 is combination of FeO (oxidation number of Fe = +2) and Fe_2O_3 (oxidation number of Fe = +3).

Oxidation number of an element in its compounds may be zero. For example, oxidation number of carbon in $C_6H_{12}O_6$ is zero. Similarly, oxidation number of Fe in $Fe(CO)_5$ and Ni in $Ni(CO)_4$ is zero.

The highest oxidation state of +8 is shown by Osmium. Oxidation state of +8 is sometimes also shown by Rhodium.

NOTE – If in a complete reaction reduction of one or more species is taking place oxidation of some species must be taking place and vice-versa. ***There can be no reduction without oxidation and vice-versa***. Any half reaction showing oxidation only is known as **Oxidation Half Reaction** and that showing reduction only is known as **Reduction Half Reaction**. All reactions, however, are not redox reactions. In a redox reaction oxidation number of at least two species definitely changes.

(L) ACIDS,BASES AND SALTS

The Arrhenius Theory of acids and bases

- Acids are substances that produce hydrogen ions in solution.
- Bases are substances that produce hydroxide ions in solution.

Neutralization happens because hydrogen ions and hydroxide ions react to produce water.

$$H^+(aq)+OH^-(aq) \rightarrow H_2O(l) \qquad (1)$$

Hydrochloric acid is neutralized by both sodium hydroxide solution and ammonia solution. In both cases, you get a colorless solution which you can crystallize to get a white salt - either sodium chloride or ammonium chloride. These are clearly very similar reactions. The full equations are:

$$NaOH(aq)+HCl(aq) \rightarrow NaCl(aq)+H_2O(l) \qquad (2)$$

$$NH_3(aq)+HCl(aq) \rightarrow NH_4Cl(aq) \qquad (3)$$

In the sodium hydroxide case, hydrogen ions from the acid are reacting with hydroxide ions from the sodium hydroxide - in line with the Arrhenius theory. However, in the ammonia case, there do not appear to be any hydroxide ions! You can get around this by saying that the ammonia reacts with the water it is dissolved in to produce ammonium ions and hydroxide ions:

$$NH_3(aq)+H_2O(l) \rightarrow NH^+_4(aq)+OH^-(aq) \qquad (4)$$

This is a reversible reaction, and in a typical dilute ammonia solution, about 99% of the ammonia remains as ammonia molecules. Nevertheless, there are hydroxide ions there, and we can squeeze this into the Arrhenius theory. However, this same reaction also happens between ammonia gas and hydrogen chloride gas.

$$NH_3(g)+HCl(g) \rightarrow NH_4Cl(s) \qquad (5)$$

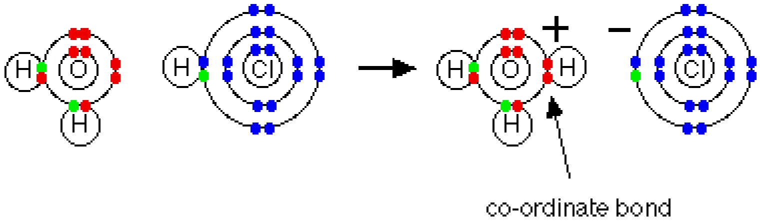
In this case, there are no hydrogen ions or hydroxide ions in solution - because there is not any solution. The Arrhenius theory would not count this as an acid-base reaction, despite the fact that it is producing the same product as when the two substances were in solution.

The Brønsted-Lowry Theory of acids and bases

- An acid is a proton (hydrogen ion) donor.
- A base is a proton (hydrogen ion) acceptor.

The Brønsted-Lowry theory does not go against the Arrhenius theory in any way - it just adds to it. Hydroxide ions are still bases because they accept hydrogen ions from acids and form water. An acid produces hydrogen ions in solution because it reacts with the water molecules by giving a proton to them.

When hydrogen chloride gas dissolves in water to produce hydrochloric acid, the hydrogen chloride molecule gives a proton (a hydrogen ion) to a water molecule. A coordinate (dative covalent) bond is formed between one of the lone pairs on the oxygen and the hydrogen from the HCl. Hydronium ions, $H_3O^+(aq)$ are produced.

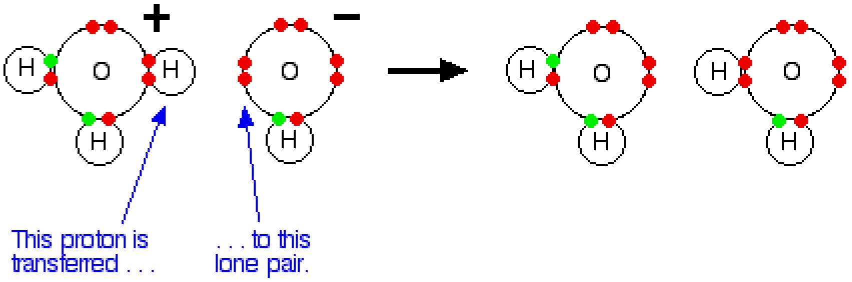


$$H_2O + HCl \rightarrow H_3O^+ + Cl^- \tag{6}$$

When an acid in solution reacts with a base, what is actually functioning as the acid is the hydronium ion. For example, a proton is transferred from a hydronium ion to a hydroxide ion to make water.

$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l) \tag{7}$$

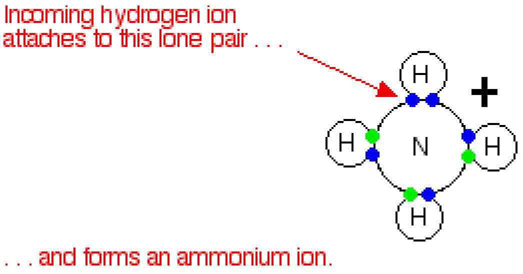
Showing the electrons, but leaving out the inner ones:



It is important to realize that whenever you talk about hydrogen ions in solution, $H^+(aq)$, what you are actually talking about are hydronium ions.

The hydrogen chloride / ammonia problem:

This is no longer a problem using the Brønsted-Lowry theory. Whether you are talking about the reaction in solution or in the gas state, ammonia is a base because it accepts a proton (a hydrogen ion). The hydrogen becomes attached to the lone pair on the nitrogen of the ammonia via a co-ordinate bond.



If it is in solution, the ammonia accepts a proton from a hydronium ion:

$$NH_3(aq)+H_3O^+(aq) \rightarrow NH^+_4(aq)+H_2O(l) \qquad (8)$$

If the reaction occurs in the gas state, the ammonia accepts a proton directly from the hydrogen chloride:

$$NH_3(g)+HCl(g) \rightarrow NH_4Cl(s) \qquad (9)$$

Either way, the ammonia acts as a base by accepting a hydrogen ion from an acid.

Conjugate pairs

When hydrogen chloride dissolves in water, almost 100% of it reacts with the water to produce hydronium ions and chloride ions. Hydrogen chloride is a strong acid, and we tend to write this as a one-way reaction:

$$H_2O+HCl \rightarrow H_3O^++Cl^- \qquad (10)$$

In fact, the reaction between HCl and water is reversible, but only to a very minor extent. To generalize, consider an acid HA, and think of the reaction as being reversible.

$$HA+H_2O\rightarrow H_3O^++A^- \qquad (11)$$

Thinking about the forward reaction:

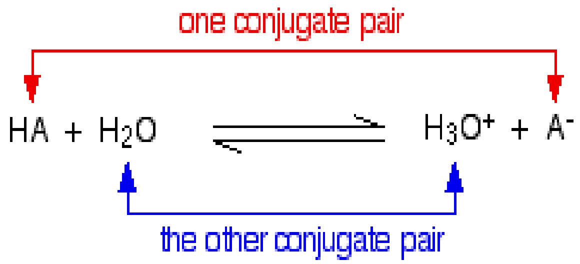
- The HA is an acid because it is donating a proton (hydrogen ion) to the water.

- The water is a base because it is accepting a proton from the HA.

However, there is also a back reaction between the hydronium ion and the A^- ion:

- The H_3O^+ is an acid because it is donating a proton (hydrogen ion) to the A^- ion.
- The A^- ion is a base because it is accepting a proton from the H_3O+.

The reversible reaction contains two acids and two bases. We think of them in pairs, called *conjugate pairs*.



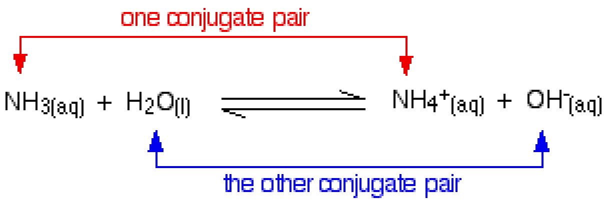
When the acid, HA, loses a proton it forms a base, A^-, which can accept a proton back again to refom the acid, HA. These two are a *conjugate pair*. Members of a conjugate pair differ from each other by the presence or absence of the transferable hydrogen ion.

- If you are thinking about HA as the acid, then A^- is its conjugate base.
- If you are thinking about A^- as the base, then HA is its conjugate acid.

The water and the hydronium ion are also a conjugate pair. Thinking of the water as a base, the hydronium ion is its conjugate acid because it has the extra hydrogen ion which can give away again. Thinking about the hydronium ion as an acid, then water is its conjugate base. The water can accept a hydrogen ion back again to reform the hydronium ion.

A second example of conjugate pairs

This is the reaction between ammonia and water that we looked at earlier:

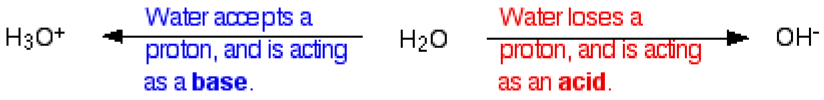


Think first about the forward reaction. Ammonia is a base because it is accepting hydrogen ions from the water. The ammonium ion is its conjugate acid - it can release that hydrogen ion again to reform the ammonia.

The water is acting as an acid, and its conjugate base is the hydroxide ion. The hydroxide ion can accept a hydrogen ion to reform the water. Looking at it from the other side, the ammonium ion is an acid, and ammonia is its conjugate base. The hydroxide ion is a base and water is its conjugate acid.

Amphoteric substances

You may possibly have noticed (although probably not!) that in one of the last two examples, water was acting as a base, whereas in the other one it was acting as an acid. A substance which can act as either an acid or a base is described as being amphoteric.



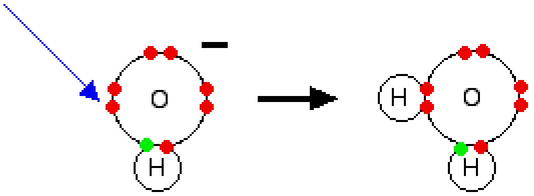
The Lewis Theory of acids and bases

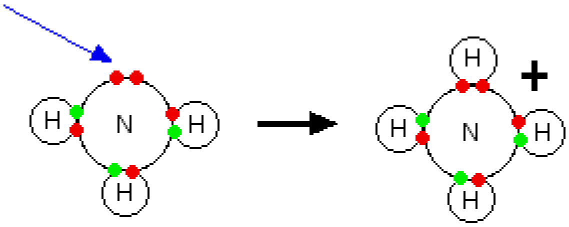
This theory extends well beyond the things you normally think of as acids and bases.

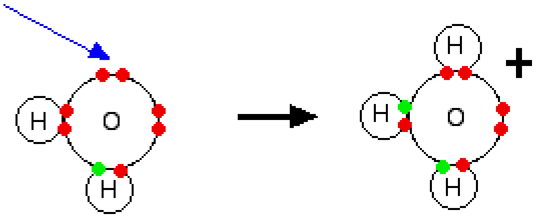
- An acid is an electron pair acceptor.
- A base is an electron pair donor.

Lewis bases

It is easiest to see the relationship by looking at exactly what Brønsted-Lowry bases do when they accept hydrogen ions. Three Brønsted-Lowry bases we've looked at are hydroxide ions, ammonia and water, and they are typical of all the rest.

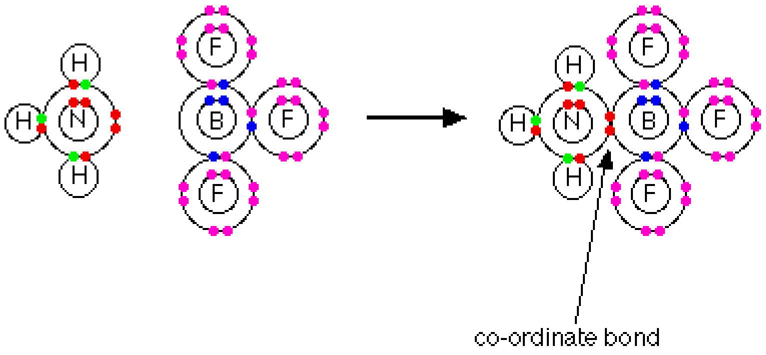

A hydroxide ion picks up a hydrogen ion by attaching it to one of the lone pairs on the oxygen.


Ammonia picks up a hydrogen ion by attaching it to the lone pair on the nitrogen.


Water picks up a hydrogen ion by attaching it to one of the lone pairs on the oxygen.

The Brønsted-Lowry theory says that they are acting as bases because they are combining with hydrogen ions. The reason they are combining with hydrogen ions is that they have lone pairs of electrons - which is what the Lewis theory says. The two are entirely consistent. So how does this extend the concept of a base? At the moment it doesn't - it just looks at it from a different angle.

But what about other similar reactions of ammonia or water, for example? On the Lewis theory, any reaction in which the ammonia or water used their lone pairs of electrons to form a co-ordinate bond would be counted as them acting as a base. Here is a reaction which you will find talked about on the page dealing with co-ordinate bonding. Ammonia reacts with BF_3 by using its lone pair to form a co-ordinate bond with the empty orbital on the boron.



As far as the ammonia is concerned, it is behaving exactly the same as when it reacts with a hydrogen ion - it is using its lone pair to form a co-ordinate bond. If you are going to describe it as a base in one case, it makes sense to describe it as one in the other case as well.

Lewis acids

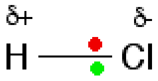
Lewis acids are electron pair acceptors. In the above example, the BF_3 is acting as the Lewis acid by accepting the nitrogen's lone pair. On the Brønsted-Lowry theory, the BF_3 has nothing remotely acidic about it. This is an extension of the term acid well beyond any common use.

What about more obviously acid-base reactions - like, for example, the reaction between ammonia and hydrogen chloride gas?

$$NH_3(g)+HClg) \rightarrow NH^{+}{}_{4}(s)+Cl^{-}(s) \qquad (12)$$

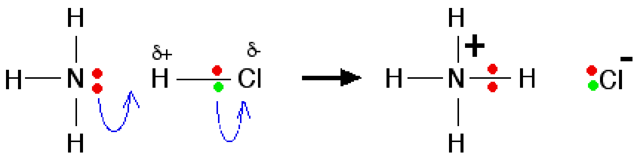
What exactly is accepting the lone pair of electrons on the nitrogen. Textbooks often write this as if the ammonia is donating its lone pair to a hydrogen ion - a simple proton with no electrons around it. That is misleading! You don't usually get free hydrogen ions in chemical systems. They are so reactive that they are always attached to something else. There aren't any uncombined hydrogen ions in HCl.

There isn't an empty orbital anywhere on the HCl which can accept a pair of electrons. Why, then, is the HCl a Lewis acid? Chlorine is more electronegative than hydrogen, and that means that the hydrogen chloride will be a polar molecule. The electrons in the hydrogen-chlorine bond will be attracted towards the chlorine end, leaving the hydrogen slightly positive and the chlorine slightly negative.



The lone pair on the nitrogen of an ammonia molecule is attracted to the slightly positive hydrogen atom in the HCl. As it approaches it, the electrons in the hydrogen-chlorine bond are repelled still further towards the chlorine. Eventually, a coordinate bond is formed between the nitrogen and the hydrogen, and the chlorine breaks away as a chloride ion.

This is best shown using the "curly arrow" notation commonly used in organic reaction mechanisms.



The whole HCl molecule is acting as a Lewis acid. It is accepting a pair of electrons from the ammonia, and in the process it breaks up. Lewis acids don't necessarily have to have an existing empty orbital.

Properties of Acids:

– Sour taste.
– Turn blue litmus red.
– Act as electrolytes in Solution.
– Neutralize solutions carrying hydroxide ions.
– React with several metals releasing Hydrogen gas.
– React with carbonates releasing CO_2 (g)
– Destroy body tissues.
– corrode metal surface quickly.

On the basis of origin, acids are classified as :

a. Organic acids: Acids derived from living organisms like plants and animals . For example: citric acid is present in fruits, acetic acid present in vinegar, oxalic acid present in tomato, tartaric acid present in tamarind, lactic acid present in sour milk and curd.

b. Mineral acids: They are also called inorganic acids. They are dangerous Example sulphuric acid (H_2SO_4), hydrochloric acid (HCl) etc.

➢ **On the basis of their strength, acids are classified as :**

a. Strong acids: Completely dissociate into its ions in aqueous solutions.
Example: Nitric acid (HNO_3), sulphuric acid (H_2SO_4), hydrochloric acid (HCl).

b. Weak acids: Weak acids are those acids which do not completely dissociate into its ions in aqueous solutions. For example: carbonic acid (H_2CO), acetic acid (CH_3COOH).

➢ **On the basis of their concentration, acids are classified as :**

a. Dilute acids: Have a low concentration of acids in aqueous solutions.
b. Concentrated acids: Have a high concentration of acids in aqueous solutions.

➢ **On the basis of number of hydrogen ion, acids can be classified as :**

Monoprotic acid – Such type of acid produces one mole of H^+ ions per mole of acid, e.g., HCl , HNO_3
Diprotic acid – They can produce two moles of H^+ ions per mole of acid, e.g., H_2SO_4.

Triprotic acid – They produce three moles of H^+ ions per mole of acid, e.g., H_3PO_4.

Polyprotic – They can produce more than three H+ ions per mole of acid.

Properties of Base:

– Water soluble bases are called alkalies.
– Bitter Taste
– Turn Red Litmus blue.
– Act as electrolytes in Solution.
– Neutralize solutions containing H^+ ions.
– Have a slippery, 'soapy' feel.
– Dissolve fatty material.

On the basis of their strength, bases are classified as:

a. Strong bases: Strong bases are those bases which completely dissociate into its ions in aqueous solutions. Example: sodium hydroxide (NaOH), potassium hydroxide (KOH).

b. Weak bases: Weak bases are those bases which do not completely dissociate into its ions in aqueous solutions. For example: ammonium hydroxide (NH_4OH).

On the basis of their concentration, bases are classified as:

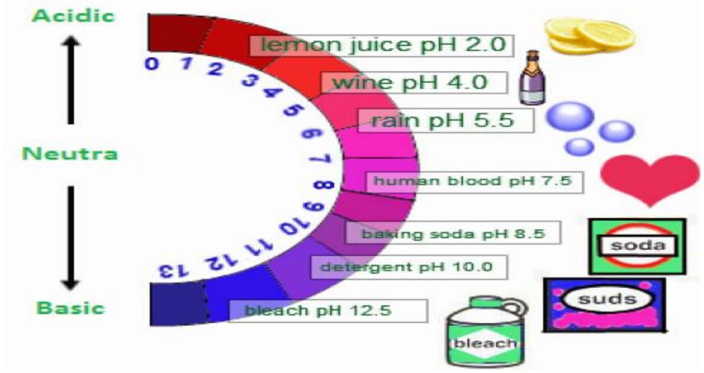
a. Dilute bases: Have a low concentration of alkali in aqueous solutions.
b. Concentrated bases: Have a high concentration of alkali in aqueous solutions.

Strength Of Acid Or Base Solutions:

A scale for measuring hydrogen ion concentration in a solution, called pH scale has been developed. The p in pH stands for 'potenz' in German, meaning power.
p= potential or Power H = Hydrogen

pH =7	Neutral Solution	$H_3O^+ = OH^-$
pH>7	Basic Solution	$H_3O^+ < OH^-$
pH<7	Acidic Solution	$H_3O^+ > OH^-$

Range of pH is from 1 to 14

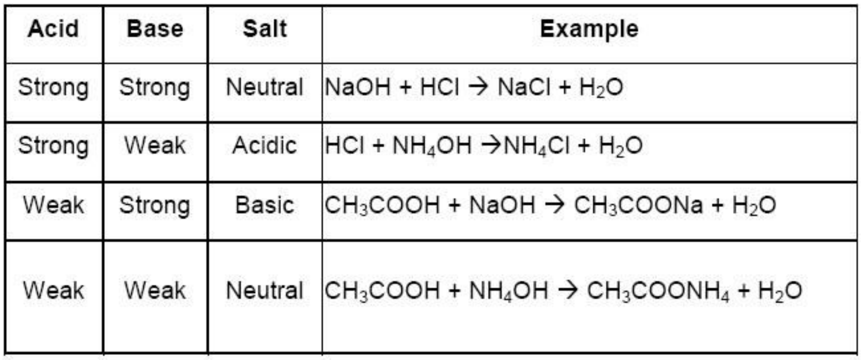


➢ pH Sensitivity of Plants & Animals:

- Human body works in a narrow range of pH 7 to 7.8. Acidity can be lethal for plants and animals.
- pH of Digestive System: Stomach secretes HCl to kill bacteria in the food. The inner lining of stomach protects vital cells from this acidic pH.
- pH and tooth decay: Lower pH because of sour food and sweet food can cause tooth decay. The pH of mouth should always be more than 5.5.
- pH as self defense mechanism in plants & animals: Certain animals like bee and plants like nettle secrete highly acidic substance for self defense.

➢ Properties of salts:

- Salts form by the combination of acid and base through neutralization reaction.
- The acidic and basic nature of salts depends on the acid and base combined in neutralization reaction.



Acid	Base	Salt	Example
Strong	Strong	Neutral	$NaOH + HCl \rightarrow NaCl + H_2O$
Strong	Weak	Acidic	$HCl + NH_4OH \rightarrow NH_4Cl + H_2O$
Weak	Strong	Basic	$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
Weak	Weak	Neutral	$CH_3COOH + NH_4OH \rightarrow CH_3COONH_4 + H_2O$

- The most common salt is sodium chloride or table salt which forms by the combination of sodium hydroxide (base) and hydrochloric acid.
- Other examples include Epsom salts ($MgSO_4$) used in bath salts, ammonium nitrate (NH_4NO_3) used as fertilizer, and baking soda ($NaHCO_3$) used in cooking.
- The pH of salts solution depends on the strength of acids and base combined in neutralization reaction.
- Indicators – Indicators are substances which indicate the acidic or basic nature of the solution by their colour change.

The colour of some acid – base indicators in acidic and basic medium are given below :

S. No.	Indicators	Colour in	Colour in
		acidic medium	basic medium
1	Litmus solution	Red	Blue
2	Methyl Orange	Pink	Orange
3	Phenolphthalein	Colourless	Pink
4	Methyl red	Yellow	Red

Chemical properties of acids:

i) Acids react with active metals to give hydrogen gas.
$Zn + H_2SO_3 \rightarrow ZnSO_4 + H_2$

ii) Acids react with metal carbonate and metal hydrogen carbonate to give carbon dioxide.
$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$
iii) Acids react with bases to give salt and water. This reaction is called as neutralization reaction.$NaOH + HCl \rightarrow NaCl + H_2O$
iv) Acids react with metals oxides to give salt and water.
$CuO + H2SO4 \rightarrow CuSO_4 + H_2O$

Addition of Acids or Bases to Water

The process of dissolving an acid, specially nitric acid or sulfuric acid or a base in water is a highly exothermic one. As a rule: Always add acid to water and never the other way! The acid must be added slowly to water with constant stirring. If one mixes the other way by adding water to a concentrated acid, the heat generated causes the mixture to splash out and cause burns.

- **Chemical properties of Bases:**

i) Reaction with Metals - Certain reactive metals such as Zinc, Aluminium, and Tin react with alkali solutions on heating and hydrogen gas is evolved. $2NaOH + Zn \rightarrow Na_2ZnO_2 + H_2$

ii) Reaction with acids -Bases react with acids to form salt and water. $KOH + HCl \rightarrow KCl + H_2O$

iii) Reaction with Non -metallic oxides – These oxides are generally acidic in nature. They react with bases to form salt and water. $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

- **Some Important Chemical Compounds:•**

• Common Salt (NaCl)

Sodium chloride is known as common salt. Its main source is sea water. It is also exists in the form of rocks and is called rock salt.
Common salt is an important component of our food. It is also used for preparing sodium hydroxide, baking soda, washing soda etc.

• Sodium hydroxide (NaOH)

Prepared by Chlor Alkali process :Electricity is passed through an aqueous solution of Sodium chloride (called brine). Sodium chloride decomposes to form sodium hydroxide. Chlorine gas is formed at the anode, and hydrogen gas at the cathode. Sodium hydroxide solution is formed near the cathode.
$2NaCl(aq) + 2\,H_2O\,(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$

- **Bleaching powder**:

Bleaching powder is represented as $CaOCl_2$, though the actual composition is quite complex. Bleaching powder is produced by the action of chlorine on dry slaked lime.
$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$

- **Baking soda: Sodium hydrogen carbonate ($NaHCO_3$)**

Preparation: $NaCl + H_2O + CO_2 + NH3 \rightarrow NH_4Cl + NaHCO_3$

- **Washing soda:** Sodium carbonate $N_2CO_3.10H_2O$

In the first step, sodium carbonate is obtained by heating baking soda.
$2\ NaHCO_3(heat) \rightarrow Na_2CO_3 + H_2O + CO_2$

Then washing soda is produced by recrystallisation of sodium carbonate
$Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3\ .10H_2O$

- **Plaster of Paris:**

Calcium sulphate hemihydrate $CaSO_4.\ ½\ H_2O$ Prepared by heating Gypsum at 373K.
$CaSO_4.\ 2H_2O(Heat\ at\ 373K) \rightarrow CaSO_4.\ ½\ H_2O + 1½\ H_2O$

➢ **[KEY POINTS]**

- Acid is a compound which yields hydrogen ion (H^+), when dissolved in water.
- Acid is sour to the taste and corrosive in nature. The pH value for acids is less than 7.
- Generally, all acids readily react with metal to release hydrogen gas. For example, metal zinc reacts with hydrochloric acid to form zinc chloride and hydrogen gas.
- Acid react with limestone ($CaCO_3$) to produce carbon dioxide. For example, hydrochloric acid reacts with limestone to produce carbonic acid and calcium chloride.
- Acid can be classified in organic and inorganic acids. Acetic acid (CH_3COOH) is the best example of organic acid, while acid produced from minerals are termed as inorganic acids like sulfuric acid (H_2SO_4), hydrochloric acid (HCl).
- Acid converts blue litmus paper to red in color.
- Acids have tendency to corrode metal surface quickly.
- Acids and bases conduct electricity because they produce ions in water. There is a flow of electric current through the solution by ions.
- Indicators are those chemical substances which behave differently in acidic and basic medium and help in determining the chemical nature of the substance.
- Acid base indicators indicate the presence of an acid or a base by a change in their colour or smell.

Strong bases: They are completely ionized in water to produce hydroxide ions, e.g,

- **Weak bases:** Partially ionize and equilibrium lies mostly towards reactants side, e.g, ammonia in water: $NH3(aq) + H2O(l)\quad NH4\ (aq) + OH\ (aq)$

- A salt is defined as a compound formed by the complete or incomplete replacement of the hydrogen ion of an acid by a basic radical.
- A normal salt is formed by the **complete** replacement of the hydrogen ion of an acid by a basic radical whereas an **acid** salt is formed by the **incomplete** replacement of the hydrogen ion of an acid by a basic radical.

- Phenolphthalein solution turns pink in color in basic solution. Bases turn methyl orange to yellow. Red cabbage juice which is purple in color changes to yellow in basic medium.

- **Strong bases:** They are completely ionized in water to produce hydroxide ions, e.g,

- **Weak bases:** Partially ionize and equilibrium lies mostly towards reactants side, e.g, $NaOH_{(s)}$

Na+(aq)+ OH(aq) ammonia in water: NH3(aq) + H2O(l) NH4 (aq) + OH (aq)

- A salt is defined as a compound formed by the complete or incomplete replacement of the hydrogen ion of an acid by a basic radical.
- A normal salt is formed by the **complete** replacement of the hydrogen ion of an acid by a basic radical whereas an **acid** salt is formed by the **incomplete** replacement of the hydrogen ion of an acid by a basic radical.

(M) CARBON – DIFFERENT FORMS

Introduction

Carbon is an element. Its name has been derived from term 'Carbos' which means coal. Symbol of carbon is C. Its atomic number is 6 and mass number of most common isotope is 12. It is represented as $_6C^{12}$.

Position in Periodic Table

In periodic table, it is in 2nd period and 14th group.

Electronic Configuration

$1s^2, 2s^2, 2p^2$.

Valency

Valency of carbon in almost all of its compounds is four. Hence carbon is tetravalent.

Isotopes of carbon

Naturally occurring carbon has two stable isotopes i.e. C-12 (98.9%) and C-13 (1.1%). Beside this there are traces of radioactive isotope, C-14 with half-life period of 5770 years. Amounts of C-14 in archeological objects are studied to determine their age. This is known as **Carbon Dating**.

Occurrence

Carbon is widely distributed in nature in elemental as well as combined form. In elemental form it exist as many allotropes. Carbon forms very large number of compounds. It forms largest number of compounds, next only to hydrogen. It is essential component of all organic compounds. There can be no life without carbon as carbon is necessarily present in all biomolecules. 18% of human body is carbon. Carbon is seventeenth most abundant element in earth crust.

Allotropes of carbon

Different forms of an element are known as Allotropes. Elemental carbon exists in many forms. The allotropes of carbon may be crystalline or amorphous.

Crystalline allotropes of carbon – There are three crystalline allotropes of carbon namely

a) Diamond b) Graphite and c) Fullerenes

Diamond

Diamond is an extremely hard naturally occurring allotrope of carbon with extra ordinary brilliance. It is hardest known natural substance. Diamond is almost pure form of carbon with only traces of impurities, which impart colour to diamond. In diamond, each carbon atom is sp^3 hybridised and is bound tetrahedraly to four other carbon atoms with single covalent bond (bond length = 154 pm and bond angle = 109.5º). This gives a highly rigid three-dimensional network. This explains its extra ordinary hardness and high melting point (3600 ºC). Diamond is a bad conductor of electricity due to the fact that all valence electrons of carbon in diamond are involved in bond formation.

Diamond is highly useful substance. It is used in jewellery, for cutting and grinding tools, for making dies, for drilling rocks, for making surgical instruments, for high precision thermometers and for windows in spacecrafts.

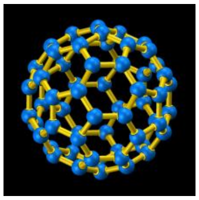
Graphite

Graphite is grey coloured, slippery, crystalline, thermodynamically most stable allotrope of carbon. In graphite, each carbon atom is sp^2 hybridised and is bound to three other carbon atoms lying in the same plain with covalent bonds giving rise to a two dimensional sheet like structure. Each layer is like a fused system of benzene rings. The distance between two carbon atoms of a sheet is 142 pm. A large number of such layers are staked over each other to give a three dimensional structure. The distance between two layers is 340 pm. These layers are bound only by weak forces, hence can slip over each other. This explains why graphite is slippery and leaves black mark on paper. This also explains why melting point (3500 ºC) and density of graphite is somewhat lower than diamond. Graphite is a good conductor of electricity because one of the valence electron of each carbon is not involved in bonding and is free to conduct electricity.

Like diamond, graphite is also used for a number of purposes. It is used in making lead pencils, crucibles for melting metals, electrodes, in nuclear reactors as moderator and as lubricant in heavy machinery.

Fullerenes

Fullerenes are recently discovered purest allotropic form of carbon. These large spheroidal molecules having hollow cage like structures. They have a general formula of C_{2n}. H W Kroto, R F Curl and R E Smalley discovered Fullerenes and they received NOBEL PRIZE for this in 1996. These were originally prepared by evaporation of graphite using LASER. C_{60} and C_{70} are most common Fullerenes. C_{60} is spherical like soccer ball whereas C_{70} is like rugby ball. C_{60} is known as Buckminister Fullerenes in honour of American architect Buckminister Fullere because its shape resembles domes constructed by him. C_{60} consist of 12 five-membered rings and 20 six-membered rings.



Five-membered rings are joined to six-membered rings only while six-membered rings are joined to both six-membered rings and five-membered rings. Both single and double bonds exist with bond length of 145.3 and 138.3 pm respectively.

C_{60} is an excellent lubricant. It itself is bad conductor of electricity but its alkali metal compounds are superconductors. For example K_3C_{60} act as superconductor below 18 K. Fullerenes give coloured solutions in organic solvents.

Amorphous allotropes of carbon – There are many amorphous allotropes of carbon like coal, coke, charcoal, gas carbon and carbon black.

Coal

Coal is an impure form of amorphous carbon. It was formed deep under the earth crust due to carbonisation of vegetable matter buried millions of years ago. Depending on the extent of carbonisation, coal has been classified as anthracite, bituminous, lignite and peat. Anthracite is oldest and best coal with highest %age of carbon whereas peat is cheapest quality of coal with lowest carbon contents. Coal is mainly used as fuel.

Coke

Coke is a greyish black hard amorphous allotrope of carbon. It is obtained by destructive distillation (heating in absence of air) of coal. It is used as fuel and reducing agent in metallurgical operations.

Charcoal

It is a black, soft and highly porous allotrope of carbon. It is obtained in different forms by different methods.

i) Wood Charcoal- It is obtained by heating wood or saw dust in limited supply of air. It is used as adsorbent for gases, for making gas-masks and as a domestic fuel.

ii) Animal Charcoal- It is also known as Bone Charcoal and is obtained destructive distillation of bone powder. It contains only about 10% carbon and rest is calcium phosphate. It is mainly used to decolourise organic solutions such as sugar-cane juice in sugar industry.

iii) Sugar charcoal- Sugar charcoal is purest amorphous allotrope of carbon. It is obtained by action of conc sulphuric acid on sugar. It is used as black pigment.

All forms of charcoal are excellent adsorbents and adsorbs many times of their own volume of gases. Adsorption capacity of charcoal can be increased by heating in absence of air. Charcoal thus obtained is called *Activated Charcoal*.

Gas carbon

Gas carbon is obtained during formation of coke from coal. Gas carbon is deposited on roof and sides of the retort. Being a good conductor of electricity, gas carbon is used for making electrodes.

Lamp black or Carbon black

Carbon black is obtained by burning carbon rich materials like natural gas, kerosene oil, turpentine oil, etc. in limited supply of air. The soot obtained is made to stick on wet blankets. After drying, the soot is removed from the blankets. It contains about 98-99% of carbon. Carbon black is used for making black ink, boot polish and black paints. It is also used as filler in rubber to make it hard, strong and cheap.

Oxides of Carbon

Carbon forms two important oxides- i) carbon monoxide and ii) carbon dioxide

Carbon monoxide

Carbon monoxide is formed by incomplete combustion of carbon or carbon rich substances in limited supply of air or oxygen. It is an important constituent of water gas ($CO + H_2$), producer gas ($2CO + 4N_2$). In laboratory, pure CO is obtained by dehydration of formic acid by conc H_2SO_4.

Carbon monoxide is a colourless, odourless, tasteless and highly poisonous gas. It combines readily with haemoglobin to form carboxyhaemoglobin which is unable to transport oxygen. Air containing even 1% CO proves fatal if inhaled for long time. It is neutral towards litmus and burns with pale blue flame. It is a good reducing agent for extraction of iron and nickel from their oxides. It is also used for manufacture of methyl alcohol, synthetic petrol, phosgene (a war gas) and metal carbonyls.

Carbon dioxide (Already discussed in detail separately)

(N) FERTILIZERS

Beside water, carbon dioxide and sunlight, plants require compounds of more than a dozen different elements for their healthy growth. Such elements are thus called '**Nutrients**'. The required amount of these elements, however, varies. Depending on amount required, these may be classified into three classes-

(i) **Elements needed in small quantities (Minor Nutrients)** – Calcium, Magnesium and Sulphur

(ii) **Elements needed in traces –** Iron, manganese, boron, Iodine, copper, zinc etc.

Nutrients required in small quantities and nutrients required in traces are sufficiently present in soil but soil become deficient of major nutrients over period of time. Hence these nutrients must be added to soil from time to time in order to maintain its fertility.

'A fertilizer is a substance which make up deficiency of a nutrient (essential element) in soil.'

Requisites of a good fertilizer

(i) It should have sufficient amount of essential elements.
(ii) It should be moisture soluble.
(iii) It should not drastically change the pH of the soil.
(iv) The fertilizer must be stable so that the nutrients are available over a period of time.

Types of fertilizers

There are two types of fertilizers

(i) Natural fertilizers
(ii) Artificial fertilizers

(i) Natural fertilizers - Fertilizers, which are, derived from natural sources, are called natural fertilizers. These are more commonly known as 'Manures'. There are various types of natural fertilizers-

(a) Animal manures - These are derived from animal waste from slaughterhouse such as blood, bones, hoofs, hairs etc.
(b) Farm yard and animal manures: Solid and liquid excreta of live stock mixed with straw leaves in stored in pits for several months till it decay properly. Compost is prepared by anaerobic decomposition of animal dung and agricultural waste. Earthworms are very helpful in converting raw manure into compost. It supplies all major nutrients (N, P and K).
(c) Plant manures – They are obtained from decayed plants, woods etc. Green plants are buried under soil to serve as green manures.

Human excreta, kitchen waste and waste from sewage disposal plants also form excellent manure after proper decomposition. Ash is also a rich source of nutrients.

(ii) Artificial fertilizers (Chemical manures)

Man-made fertilizers are called as artificial fertilizers. These are industrially prepared from other simple chemicals and are also called 'Chemical fertilizers'.

Types of chemical fertilizers

There are various types of chemical fertilizers depending on the nutrients provided by them-

A. **Nitrogenous fertilizers-** Nitrogenous fertilizers provide 'Nitrogen' to plants. Their power is expressed in terms of N_2 or NH_3. Some of important nitrogenous fertilizers are discussed below-
   1. Ammonium sulphate, $(NH_4)_2SO_4$ – Contains aprox.20% nitrogen. In India it is produced in Sindri and Trivancore.
   2. Calcium cynamide, $CaCN_2$- Contain 35% nitrogen and is produced from calcium carbide

      $CaC_2 + N_2 \rightarrow CaCN_2 + C$ (Nitrolim)

      It acts as fertilizer by reacting with water and carbon dioxide

      $CaCN_2 + H_2O + CO_2 \rightarrow CaCO_3 + H_2NCN$

      $H_2NCN + H_2O \rightarrow NH_2CONH_2$

      $NH_2CONH_2 + H_2O \rightarrow CO_2 + 2\,NH_3$

      $NH_3 \rightarrow$ Nitrates

   3. Calcium ammonium nitrate (CAN), $Ca\,(NO_3)_2.NH_4NO_3$ – Contain 22.95 % nitrogen.

   4. Basic calcium nitrate (Norwegian salt petre), $Ca\,(NO_3)_2.\,CaO$ – Contain 12.73 % nitrogen. It is produced by reaction of calcium carbonate and nitric acid-

      $2\,CaCO_3 + 2\,HNO_3 \xrightarrow{\text{Evaporation}} Ca\,(NO_3)_2.CaO$

   5. Urea, (H_2NCONH_2) – Contain 46.67 % nitrogen. Produced from carbon dioxide and ammonia –

      $CO_2 + 2NH_3 \rightarrow NH_2COONH_4$

      $NH_2COONH_4 \rightarrow NH_2CONH_2$

      In India it is produced in Sindri, Nangal and Kota. It is best nitrogenous fertilizer as it has maximum percentage of nitrogen and leaves no residue in soil.

      Note – Ammonium nitrate, NH_4NO_3 is not used as fertilizer as it is explosive in nature.

B. **Phosphatic fertilizers -** Phosphatic fertilizers provide 'phosphorous' to plants. Strength of phosphatic fertilizers is expressed in terms of P_2O_5. Some important phosphatic fertilizers are discussed below –

1. Superphosphate of lime, Ca $(H_2PO_4)_2.H_2O + CaSO_4.2H_2O$ – Contain 23.82 % P_2O_5.Prepared by action of calculated amount of conc. H_2SO_4 on phosphorite or rock phosphate ($Ca_3(PO_4)_2$) or bone ash or apatite (3 $Ca_3(PO_4)_2.CaF_2$).

   $$Ca_3(PO_4)_2 + 2H_2SO_4 \rightarrow Ca(H_2PO_4)_2 + 2CaSO_4$$

   A sufficient amount of water is than added to convert $CaSO_4$ to gypsum.

2. Triple superphosphate, Ca $(H_2PO_4)_2.H_2O$ – Contain 56.35 % P_2O_5. It is prepared by action of phosphoric acid on rock phosphate –

   $$Ca_3(PO_4)_2 + 4H_3PO_4 \rightarrow 3Ca(H_2PO_4)_2$$

   It is considered to be best phosphatic fertilizer as it contains 56.35 % P_2O_5.

3. Phosphatic slag or Thomas slag, $Ca_3(PO_4)_2 + CaSiO_3$ – Produced as by-product of steel industry.

Rock phosphate as such is not used as fertilizer because it is insoluble in water.

C. Potash fertilizers – Potash fertilizers provide potassium to plants. These are specially required for cultivation of tobacco, corn, cotton, coffee etc. Their strength is expressed in terms of K_2O. A few important potash fertilizers are discussed below –

1. Potassium chloride or Muriate of potash, KCl – Contain 63.8 % K_2O. However it produces high melting ash.
2. Potassium sulphate, K_2SO_4 - Contain 54.02 % K_2O.

3. Potassium nitrate or Indian salt petre,KNO_3 - Contain 46.5 % K_2O.

D. **Mixed fertilizers –** Mixed fertilizers provide more than one nutrient to plants. These are generally mixtures of nitrogenous, phosphatic and potash fertilizers and are called N, P, K fertilizers. e.g. NH_4SO_4 or CAN + Calcium super phosphate + KCl or K_2SO_4 .

Gypsum, lime and NaCl are called Stimulant fertilizers as they do not provide any nutrient but increase fertility of soil by maintaining pH of soil or otherwise.

Calculation of percentage of elements in the given fertilizer

Percentage of an element in a fertilizer is calculated by using the formula -

$$\textbf{Percentage of element in fertilizer} = \frac{\textbf{No. of atoms x At. wt. x 100}}{\textbf{Molecular wt. of fertilizer}}$$

E.g.:

$$\% \text{ of Nitrogen in Urea, } (NH_2–CO–NH_2) = \frac{2 \times 14 \times 100}{60} = 46.6\%$$

(O) **SOAPS**

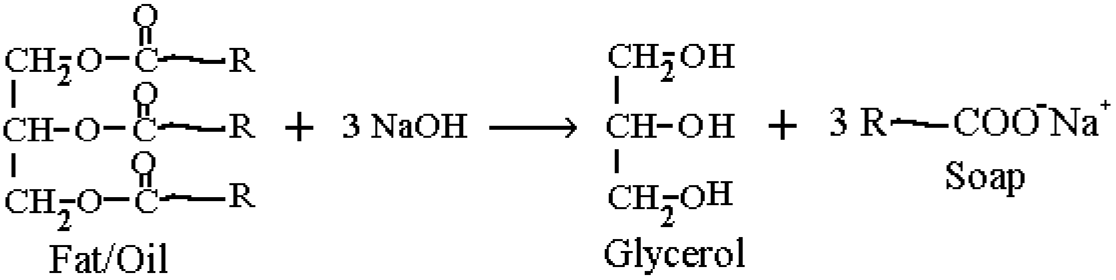
Soaps are commonly used cleaning agents. Chemically soaps are –

'Sodium or potassium salts of long chain fatty acids.'

Soaps are represented by general formula $R\sim COO^{-}Na^{+}$, where R~ is long chain of fatty acid (monocarboxylic acid). R~ has a variable structure.

PREPARATION OF SOAPS (SAPONIFICATION)

Soaps are prepared by alkaline hydrolysis of fats and oils. Chemically fats and oils are trimesters of long chain fatty acids with glycerol (glycerin). On hydrolysis each fat or oil molecule produce three molecules of soap and one molecule of glycerol. Thus glycerol is produced as a by-product of soap industry.



CLEANING ACTION OF SOAPS

When dissolved in water soap molecule dissociate into ions –

$$R\sim COONa \rightarrow R\sim COO^{-} + Na^{+}$$

The soap anion has non-polar lyophillic (hydrophobic) hydrocarbon end and polar hydrophilic carboxylate $-COO^{-}$ end. When these anions come in contact with some greasy particle on fabric their lyophillic (hydrophobic) ends attach to the greasy particle to form clusters called '*Micelles*'. The hydrophilic ends remain spread out due to –ve charge on them. These micelles remain suspended in water and dirt is removed from the fabric.

NOTE – Sodium soaps are called hard soaps and are used for washing whereas potassium soaps are called soft soaps and are used for bathing.

DEMERITS OF SOAPS

i) Less cleaning action.
ii) Do not work in hard water due to its precipitation by Ca^{2+} or Mg^{2+} ions.

DETERGENTS

Detergents are sodium or potassium salts of long chain benzene sulphonic acids. These have better cleaning action and can work even in hard water. Most of detergents, however are non-biodegradable unlike soaps.

(P) GLASS

INTRODUCTION

Glass is an amorphous, transparent or translucent super cooled liquid of infinite viscosity. It is not a true solid, as it seems to be but acquires characteristics of solid by great increase in viscosity on cooling.

Chemically glass is-

‘A mixture of silicates of different metals one of which is always Na or K. Beside this Ca, Pb, Al, Ce and B may also be present depending on variety of glass.’

No fixed chemical formula can be assigned to glass, as it is a mixture and not a substance. Its composition is variable. However, it is generally represented by general composition $xM_2O.M'O.6SiO_2$.

Glass is insoluble in almost all substances but soluble in HF. When it dissolve in HF it produce SiF_4 gas.

$$Na_2O.CaO.6SiO_2. + 28\ HF \rightarrow 2NaF + CaF_2 + 6SiF_4 + 14H_2O$$

Glass has no fixed melting point, it being an amorphous solid. It melts over a range of temperature. When heated it gradually softens and can be moulded into any desired shape.

MANUFACTURE

A large number of raw materials are used in preparation of different types of glass. A brief description of raw materials used is given below.

a) Silica in form of sand with uniform particle size and free from iron and organic matter, otherwise it will produce colour.
b) Compounds of alkali metals e.g. Na_2CO_3, Na_2SO_4, $NaNO_3$, K_2CO_3 and KNO_3.
c) Compounds of alkaline earth metals e.g. $CaCO_3$, CaO and $BaCO_3$ (for glass of high refractive index).
d) Oxides of heavy metals e.g. PbO and Pb_3O_4.
e) Calcium phosphate (for opalescent glass).
f) Colouring material (to make coloured glass)-

i) CoO – Blue
ii) Cu_2O – Red
iii) Fe_2O_3 – Yellow
iv) CdS – Lemon yellow
v) Cr_2O_3 – Green
vi) $Na_2Cr_2O_7$ – Green
vii) MnO_2 – Purple
viii) $AuCl_3$ – Ruby

PROCEDURE

Glass is prepared by fusing together a mixture of raw materials in proper proportions in a furnace. Some pieces of broken glass are also added to initiate fusion. The main chemical changes taking place during the fusion are –

$$Na_2CO_3 + SiO_2 \xrightarrow{1700\ K} Na_2SiO_3 + CO_2\uparrow$$

$$CaO + SiO_2 \xrightarrow{1700\ K} CaSiO_3$$

The hot molten mass of glass is cooled very slowly on slow moving conveyer belts. The process is known as '*Annealing*'. On cooling the glass obtained has a general composition Na_2SiO_3. $CaSiO_3.4SiO_2$ or $Na_2O.CaO.6SiO_2$ and is called '*Soda Glass*'. Glass is also prepared by *Sol-Gel Process*.

TYPES OF GLASS

Glass has been used for a variety of purposes so there are various types of glass. A few important types of glass are discussed below.

a) Soda/Soda lime/Soft/Ordinary Glass – ($Na_2O.CaO.6SiO_2$) It is a mixture of sodium and calcium silicates. It is prepared by sand, $CaCO_3$ and Na_2CO_3. It is cheap and is used for making bottles, glass panes, etc.
b) Potash/Hard Glass – ($K_2O.CaO.6SiO_2$) It can withstand high temperature and used to make combustion tubes.
c) Lead/Lead Potash/Flint Glass – ($K_2O.PbO.6SiO_2$) It has high refractive index and is used to make high quality optical instruments like lenses, prisms, etc.
d) Borosil/Pyrex/Corning Glass – ($Na_2O.B_2O_3.Al_2O_3.SiO_2$) It is prepared by adding borax (or boron oxide) and aluminum oxide. It is heat resistant and has low coefficient of thermal expansion and thus can withstand sudden temperature changes. Borosil glass is used to make lab equipments, thermometers, kitchenwares, etc.
e) Crook's Glass – It is a special type of glass containing CeO_2. It cuts off harmful UV radiations and used to make spectacle lenses.
f) Quartz Glass – It is obtained from pure silica. It has very low coefficient of thermal expansion and dopes not break even when plunged red hot in water.
g) Jena Glass – It is a mixture of zinc and barium borosilicates. It is heat resistant and shock resistant.
h) Ground Glass – It is ordinary glass grinded by emery and turpentine oil. It is used in bathroom fittings.
i) Reinforced Glass – In this type of glass a network of wires is embedded in ordinary glass so that it does not shatter easily.
j) Safety/Shatterproof Glass – Safety glass is obtained by joining two layers of glass on transparent layer of vinyl acetate resin by a suitable adhesive. It is used to make windscreens of automobiles, aeroplanes, trains, etc.
k) Bulletproof Glass – In bulletproof glass a large number of thin glass sheets are joined by suitable adhesive.

NOTE – 'Water Glass' is not a glass but an aqueous solution of Na_2SiO_3 used in making Chemical Garden.

(Q) INK

Major constituents of Ink are gallic acid, Materials used for blue-black ink are – (a) Gallic acid. (b) Ferrous sulphate (c) Tannic acid (Tannic acid is presentation, Babool, Gall nuts and Triphla (amla, harra & Bahera)

Red Ink - Gum arabic and eosin.

(R) GUN POWDER

Gun powder is a mixture of Potassium Nitrate, wood charcoal and Sulpher. These substances are separately powdered and mixed.

(S) PAPER

Chemically paper is cellulose, $(C_6H_{10}O_5)_n$. Fibrous materials such as wood, straw, bagase, bamboo etc. are used as raw materials for the preparation of paper. Various inorganic substances like Clay, $CaCO_3.CaSO_4$, TiO_2, ZnS etc. are used as fillers and loading materials. Substances like starch, glue casin are added to prevent spreading of ink. NaOH and bleaching powder is used to make the paper white.

(T) MATCH INDUSTRY

Matches are mainly of two types – 1. Lucifer Match 2. Safety Match

LUCIFER MATCH

Preparation of Match Stick

Lucifer matches are also known as Friction matches or Strike anywhere matches. The stick of Lucifer match is prepared by dipping the splinter (made of soft wood like simbal wood) in three different baths.

a) First Dip – In molten sulpher or paraffin to about half inch length.
b) Second Dip – The tip of the splinter is dipped in a paste of (i) Readily combustible substance like antimony trisulphide Sb_2S_3 (ii) A low kindling substance like red P (Note – Earlier white phosphorous was used but has been replaced due to poisonous nature) or phosphorous trisulphide (P_2S_3) (iii) An oxidizing agent like $KClO_3$ or KNO_3 or Pb_3O_4 (iv) Inert substance like glass powder to produce friction and (v) A binding agent like glue.
c) Third Dip – The dried up matchstick is dipped in molten wax to provide protective coating to the tip.

Preparation of Friction Surface

A friction surface is made on the sides of matchbox by coating them with a mixture of sand/glass powder and glue. This surface is used to provide friction to the matchstick.

SAFETY MATCH: The only difference between Lucifer and safety match is that in safety match the low kindling material like red phosphorous or phosphorous trisulphide is present on side of matchbox (in friction surface) and not on tip of matchstick.

Note – To prevent afterglow of matchsticks, the wooden splinters are impregnated with borax or alum.

WORKING OF MATCH

When a matchstick is stroked on side of matchbox, red phosphorous or phosphorous trisulphide (low kindling material) catches fire. Due to this readily combustible substance like antimony sulphide catches fire which in turn ignite sulpher or paraffin and then wood splinter. The oxidizing agent readily provides oxygen for combustion.

Process of preparation of Match

Matchsticks
Raw materials – i) Potassium chlorate - 112 g ii) Antimony sulphide – 25 g iii) Sulpher – 25 g iv) Sand/Glass powder – 20 g v) Glue – 25 g

Make a paste of above materials. Soak some splinters of soft wood in dilute alum/borax solution and dry them completely. Dip half inch of splinter in molten sulpher/paraffin. Dip the tip of splinter in paste and let it dry. Protect the tip from moisture by dipping the tip in molten wax.

Striking surface
Raw materials – I) Red phosphorous/P_2S_3 – 6 g ii) Glass powder – 10 g iii) Glue – 15 g

Make a fine paste of these materials and apply on the sides of the matchbox with help of a brush.

Note – For making coloured matches copper sulphate/barium sulphate (for green) or strontium salts (for crimson red) are added.

(U) CEMENT

INTRODUCTION

First discovered by Joseph Aspdin in 1824. Chemically, cement is essentially a finely powdered mixture of calcium silicates and calcium aluminates with some amount of gypsum.

Approximate composition of cement is –

a) 50-60 % CaO b) 20-25 % SiO_2 c) 5-10 % Al_2O_3 d) 2-3 % MgO

e) 1-2 % Fe_2O_3 f) 1-2 % SO_3

For good quality cement the ratio of SiO_2 and Al_2O_3 should be between 2.5 and and 4 and ratio of CaO to total oxide mixture (SiO_2, Al_2O_3 and Fe_2O_3) should be as close to 2:1 as possible. Tricalcium silicate (Ca_3SiO_5) is most common (51%) and important silicate of cement.

MANUFACTURE

Cement is prepared from two main raw materials – a) Lime stone which provides CaO and b) Clay which provide SiO_2, Al_2O_3, Fe_2O_3, etc.

Cement can be prepared by Dry process or Wet process. Dry process is preferred when raw materials are hard and wet process is preferred when raw material is soft and fuel is cheap. The various steps in manufacture of cement are –

i) 3 parts of lime stone and one part of clay are mixed and powdered.

ii) The 'raw meal' (in case of dry process) or 'raw slurry' (in case of wet process) is passed through a slanting rotary kiln and known as 'Charge'. The temperature in kiln varies from 1000 K to 1873 K. The various changes which take place are –

   a) In upper part of kiln at 1000 – 1100 K - The charge loses all water.

   b) In middle part of kiln at 1100 – 1200 K – The lime stone undergo decomposition –

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$

   c) In lower part of kiln at 1773 to 1873 K – CaO, Al_2O_3 and SiO_2 react to form various silicates, aluminates and aluminosilicates.

$$2\,CaO + SiO_2 \rightarrow 2\,CaO.SiO_2$$

$$3\,CaO + Al_2O_3 \rightarrow 3\,CaO.Al_2O_3$$

Due to very high temperature 20-30% mass melts and combine with solid mass to form grey coloured pebbles called 'Clinkers'.

Hot clinkers coming out of kiln are cooled and mixed with 2-3% gypsum to slow down of setting of setting of cement. The mixture is finely powdered and is then known as 'Portland Cement' (because after setting it resembles a building stone found near Portland in England).

SETTING OF CEMENT

On mixing with water, calcium aluminates and silicates undergo hydration/hydrolysis to form a gelatinous mass which sets into hard mass having three dimensional network structure involving Si-O-Si and Si-O-Al chains. It is an exothermic process and cement structure should be cooled during setting by sprinkling water.

Fly ash contain a lot of calcium silicate and is used as additive to make cement cheap. Rice husk is also used to make cement as it is rich in SiO_2.

SOME IMPORTANT FACTS

1. White cement is completely free from Fe_2O_3.
2. Cement with excess of CaO cracks after setting but less amount make it weak.
3. Cement with excess SiO2 in slow in setting but having more Al_2O_3 sets quickly.

(V) PAINTS

Paints can be defined as: “A liquid solution of **pigment** (*coloring material*) and **solvent**, which is applied on different surfaces for decorative or protective reasons.”

OR

It can also be defined as: ” Dispersion of **pigment** (*coloring substance*) in a suitable drying oil in the presence of a **solvent** (*paint thinner*) is known as paint.”

Paints are applied on the surfaces of timber, metals and plastered surfaces as a protective layer and at the same time to get pleasant appearance. Paints are applied in liquid form and after sometime the volatile constituent evaporates and hardened coating acts as a protective layer.

Constituents of Paint

The essential constituents of paints are:
1. Base 2. A vehicle 3. A pigment 4. A drier 5. A thinner. 6. Extenders:

1. Bases: It is a principal constituent of paint. It also possesses the binding properties. It forms an opaque coating. Commonly used bases for paints are white lead, red lead, zinc oxide, iron oxide, titanium white, aluminium powder and lithophone. A lead paint is suitable for painting iron and steel works, as it sticks to them well. However it is affected by atmosphere action and hence should not be used as final coat. While zinc forms good base but is costly. Lithophone, which is a mixture of zinc sulphate and barytes, is cheap. It gives good appearance but is affected by day light. Hence it is used for interior works only.
2. Vehicles: The vehicles are the liquid substances which hold the ingredients of a paint in liquid suspension and allow them to be applied on the surface to be painted. Linseed oil, Tung oil and Nut oil are used as vehicles in paints. Of the above four oils, linseed oil is very commonly used vehicles. Boiling makes the oil thicker and darker. Linseed oil reacts with oxygen and hardens by forming a thin film.
3. Pigment: Pigments give required colour for paints. They are fine particles and have a reinforcing effect on thin film of the paint. The common pigments for different colours are:
Black—Lamp black, suit and charcoal black.
Red—venedion red, red lead and Indian red.
Brown—burned timber, raw and burned sienna
Green—chrome green, copper sulphate.
Blue—prussian blue and ultra marine
Yellow—ochre and chrome yellow.
4. The Drier: These are the compounds of metal like lead, manganese, cobalt. The function of a drier is to absorb oxygen from the air and supply it to the vehicle for hardening. The drier should not be added until the paint is about to be used. The excess drier is harmful because it destroys elasticity and causes flaking.
5. The Thinner: It is known as solvent also. It makes paint thinner and hence increases the

coverage. It helps in spreading paint uniformly over the surface Terpentine and neptha are commonly used thinners. After paint applied, thinner evaporates and paint dries.

6. Extenders:

They are also called **fillers**. A *Filler* is a substance which can be added to paints to increase its bulk volume without effecting its useful properties.
These materials (Fillers) are necessarily inert towards other components of paint.
Commonly used extenders are: Chalk, gypsum, barite, silica and magnesium silicate.

Properties of an Ideal Paint

1. It should be possible to apply easily and freely.
2. It should dry in reasonable time.
3. It should form hard and durable surface.
4. It should not be harmful to the health of workers.
5. It should not be easily affected by atmosphere.
6. It should possess attractive and pleasing appearance.
7. It should form a thin film of uniform nature i.e., it should not crack.
8. It should possess good spreading power.
9. It should be cheap.

Types of Paints

Depending upon their constituents there are various types of paints. A brief description of some of them
which are commonly used are given below:
1. **Oil Paint**: These paints are applied in three co
ats-primer, undercoat and finishing coat. The presence of dampness while applying the primer adversely affect the life of oil paint. This paint is cheap and easy to apply.

2. **Enamel Paint**: It contains white lead, oil, petroleum spirit and resinous material. The surface provided by it resists acids, alkalies and water very well. It is desirable to apply a coat of titanium white before the coat of enamel is applied. It can be used both for external and internal walls.

3. **Emulsion Paint**: It contains binding materials such as polyvinyl acetate, synthetic resins etc. It dries in 1,5 to 2 hours and it is easy to apply. It is more durable and can be cleaned with water. For plastered surfaces, first a coat of cement paint should be applied and then the emulsion point. Emulsion paint needs sound surfaces.

4. **Cement Paint**: It is available in powder form. It consists of white cement, pigment and other additives. It is durable and exhibits excellent decorative appearance. It should be applied on rough surfaces rather than on smooth surfaces. It is applied in two coats. First coat is applied on wet surface but free from excess water and allowed to dry for 24 hours. The second coat is then applied which gives good appearance.

5. **Bituminous Paints**: This type of paint is manufactured by dissolving asphalt or vegetable bitumen in oil or petroleum. It is black in colour. It is used for painting iron works under water.

6. **Synthetic Rubber Paint**: This paint is prepared from resins. It dries quickly and is little affected by weather and sunlight. It resists chemical attack well. This paint may be applied even on fresh concrete. Its cost is moderate and it can be applied easily.

7. **Aluminium Paint**: It contains finely ground aluminium in spirit or oil varnish. It is visible in darkness also. The surfaces of iron and steel are protected well with this paint. It is widely used for painting gas tanks, water pipes and oil tanks.

8. **Anti-corrossive Paint**: It consists essentially of oil, a strong dier, lead or zinc chrome and finely ground sand. It is cheap and resists corrossion well. It is black in colour.

Application of Paint

Preparation of surface for application of paint is the most important part in painting. The surface to be painted should not be oily and it should be from flakes of the old paint. Cracks in the surface should be filled with putty and then with sand paper. Then primer is applied. Painting work should be carried out in dry weather. The under coats and first coats must be allowed to dry before final coat is applied.

(W) ATOMIC STRUCTURE

The concept of atom was first put forward systematically by John Dalton in 1848, through in famous **"Dalton's Atomic Theory"** According to the theory all matter is made up of indivisible, tiny particles called atoms. All atoms of an element are identical and atoms of different elements differ in their masses, sizes and properties. Atoms of different elements combine to form complex matter (compounds).

However, the picture of atom has undergone a drastic change as a result of systematic work by many eminent scientists like J.J. Thomson, Goldstein, Rutherford, Chadwick, Bohr, de-Broglie, Heisenberg, Schrodinger etc. It has been proved beyond doubt that atom itself is made up of many sub-atomic particles and has a complex structure.

The presence of charged particles in atoms was expected on the basis of generation of charges when glass rod is rubbed with silk and ebonite rod is rubbed with fur. The quantitative relation between charge and matter was proved by Faraday (Faraday's laws of electrolysis).

Discovery of Electron

The first sub-atomic particle discovered was electron. Credit of its discovery goes to Sir J.J.Thomson. William Crooke, J. Plucker and E.Goldstein studied the passage of electricity through gases. During their experiments, it was found that when a high voltage current (approx. 10,000V) was passed through a gas at low pressure (10^{-4} atm.) taken in a discharge tube (A long glass tube fitted with two electrodes and connected to vacuum pump), some invisible rays emerged from cathode side and traveled towards anode. On striking with discharge tube, these rays produced a faint greenish glow. These rays were called 'Cathode Rays'.

Sir. J.J. Thomson studied cathode rays and found that -

a) Cathode rays travel in straight line (cast sharp shadow of objects placed in their path).
b) Cathode rays consist of particles (they produce mechanical effect).
c) Particles of cathode rays are negatively charged (bends towards +ve plate in electric field).
d) Cathode rays produce heating effect, fluorescence, penetrate through metallic sheets, effect photographic plate and produce X-rays on striking against hard metals like tungsten, copper etc.
e) The nature of cathode rays (charge to mass ratio of cathode ray particles) is independent of the nature of gas taken in discharge tube.

In view of the above observations, it was concluded that cathode rays consist of negatively charged particles called "Electrons". The name 'Electron' was first given by G.J.Stoney for particles of electricity (Electron in Greek meaning amber which become charged with rubbed with wool or silk). As the gas produced the cathode rays, electrons are considered as constituents of all atoms.

J.J. Thomson determined charge to mass ratio of electron by study of their deflection in electric and magnetic fields applied perpendicular to each other. The e/m ratio of electron was found to be 1.759×10^{8} coulombs per gram. Millikan determined charge of e- by oil-drop experiment. It was found to be 1.602×10^{-19} coulombs. On basis of charge to mass ratio and charge, mass of e^{-} was found to be 9.11×10^{-28} g or 9.11×10^{-31} kg.

Discovery of Proton

The presence of positively charged particle in atom was obviously expected after discovery of electron, as atom is neutral. Goldstein (1886) found that on taking a perforated cathode in discharge tube experiment, some positively charged rays were observed on the other side of cathode. These radiations actually traveled from anode to cathode, passed through cathode and went beyond. These rays were called ‘Anode Rays’ or ‘canal rays’. Anode rays were found to be made up of positively charged particles and traveling in straight line. Charge to mass ratio of anode ray particles was found to be much less than electrons and was found to be depending on nature of gas taken in discharge tube. The mass of anode ray particles was found to be equal to mass of atom of gas. The lightest particle (highest charge to mass ratio) was found in case of hydrogen gas and it was named as ‘Proton’. The charge to mass ratio was found to be 9.58×10^4 coulombs per gram and charge was found to be 1.602×10^{-19} coulombs of +ve (same as in electron but opposite in sign). On basis of e/m ratio and charge, mass of proton was found to be 1.67×10^{-24} g or 1.67×10^{-27} kg. This was approx. 1837 times of mass of electron.

Discovery of Neutron

English Physicist, James Chadwick discovered Neutron in 1932 on basis of bombarding α–particles on thin Be sheet. Neutron was found to have no charge and mass of 1.674×10^{-24}g or 1.674×10^{-27} kg (very slightly higher than proton).

Beside these three fundamental particles, many other (approx. 40) particles like positron (e^+), neutrino (ν) meson (π^+ or π^-) etc. have been found in atom.

Thomson model of atom (Water Melon or Plum - Pudding Model)

According to this model an atom consist of a field of positive charge in which electrons are embedded, like seeds in water melon or resins in pudding, to make it over all neutral. However, this model was discarded mainly because it could not explain the observations of Rutherford’s scattering experiment.

Rutherford’s Scattering Experiment - (Discovery of Nucleus)

In 1911, Rutherford bombarded a very thin (4×10^{-5} cm) gold foil with α–particles (Helium nuclei with 2 unit +ve charge and 4 unit mass) from a radioactive substance and studied their fate on fluorescent screen coated with zinc sulphide. It was observed by Rutherford that most of the α–particles passed straight, a few deflected through small angles and very few (approx. one out of 20,000) deflected back. These observations clearly indicated that (1) all the positive charge of atom is condensed in a very small region in atom and most of the atom is empty (only electrons occupied this space). The positive core of atom was called ‘Nucleus’. Radius of nucleus is of order of 10^{-15} m where that of atom is of order of 10^{-10} m. (2) Almost all the mass of atom is present in nucleus. Density of nucleus is of order of 10^{15} g/cc.

Composition of Nucleus

Nucleus consist of all protons and neutrons. Actually, all particles of atom except electrons are present in nucleus.

Rutherford Model of Atom

According to Rutherford model of atom, the entire mass and positive charge of atom is concentrated in a very small region called nucleus. The magnitude of positive charge is different for atoms of different elements. The nucleus is surrounded by electron revolving at high speed in order to balance force of attraction from nucleus. Most of the space in atom is empty.

Few important facts/terms related to atom / nucleus

a) **Atomic Number (Z) -** The number of protons (+ve charges) in nucleus of an atom is called its atomic number. It has a definite value for an element. For neutral atoms, the number of electrons are same as number of protons (atomic number).
b) **Mass Number (A) –** The total number of protons and neutrons in nucleus of an atom is called its mass number. So, Mass Number (A) = Atomic Number (Z) + Number of Neutrons (n) or Number of Neutrons = A – Z .
c) **Isotopes –** Atoms of an element (having some atomic number i.e. number of protons) with different mass number (due to difference in number of neutrons). Isotopes have same number of protons and different number of neutrons. E.g.. ${}_6C^{12}$ and ${}_6C^{14}$.
d) **Isotones –** Atoms of different elements (having different atomic number i.e. number of protons) but same number of neutrons. Isotones have same number of neutrons but different number of protons. E.g.. ${}_{11}Na^{23}$ and ${}_{12}Mg^{24}$.
e) **Isobars –** Atoms of different elements (having different atomic number i.e. number of protons) having same mass number. Isobars have different number of protons and neutrons but total number of protons and neutrons are same. E.g. ${}_6C^{14}$ and ${}_7N^{14}$
f) **Isodiapheres –** Atoms of different elements having same difference in number of neutrons and protons (isotopic excess). E.g. ${}_{11}Na^{23}$ and ${}_{13}Al^{27}$.
g) **Nuclear Isomers –** Atoms of same element having same number of protons and neutrons but differ in their arrangement with in the nucleus. E.g. uranium has two nuclear isomers one with half-life period of 1.4 minute and other with half-life period of 6.7 hours.
h) **Nucleons –** Protons and neutrons are collectively known as nucleons.
i) **Mass Defect –** The mass of nucleus is slightly less than the sum of masses of all particles in it. Actually some of mass converts into energy according to Einstein equation, $E = MC^2$. This mass is called mass defect.
j) **Binding Energy -** The energy equivalent of mass defect responsible for holding together all constituents of nucleus is called 'Binding Energy'.
k) **Radioactivity –** The spontaneous emission of certain invisible radiations from certain substances like uranium, Thorium, Radium etc. due to disintegration of their nuclei is called Radioactivity. Henry Becquerel first observed the phenomenon in 1896 in a salt of Uranium. Radioactive radiations consist of three types of rays i.e. α–rays (consisting of α–particles i.e. He nuclei) β-rays (consisting of electrons) and γ-rays (electromagnetic radiations).
l) **Half-life period of radioactive substance –** Radioactive disintegration leads to change in composition of nucleus i.e. emission of one α–particles decrease atomic number by two and mass number by four and emission of one β–particles increase atomic number by one but mass number remain unchanged. Radioactive disintegration is a first order reaction and takes a definite time for disintegration of a definite fraction of initial amount. The time taken by a radioactive substance to disintegrate half of its original amount is called its 'half-life period'. E.g. $t_{1/2}$ of ${}_6C^{14}$ is 5770 years. It means that if initially we have 100 g C-14, in first 5770 years, 50 g will disintegrate, in next 5770 years, 25 g will disintegrate, in next 5770 years 12.5 g will disintegrate and so on. This concept can be used to determine age of fossils, minerals, rocks etc.
m) **Fermi –** A unit of length, generally used to express diameter of nucleus (1 Fermi = 10^{-15} m)
n) **Nuclear Fission –** The breaking of nucleus in fragments of comparable masses by use of slow moving neutrons is called 'Nuclear Fission'. This process is associated with liberation

of huge amount of energy. The nuclear fission is carried out in controlled manner in nuclear reactors using U-235 (in form of U_3O_8 having 2-3% U-235), Cadmium or Boron as control rods (Control rods control number of neutrons hence rate of fission), heavy water or graphite as moderator (slow down neutrons) and heavy water or liquid sodium as coolant (takes out heat produced). The process is carried out in a thick heavy steel or concrete dome called Shield. In a nuclear bomb, the nuclear fission is carried out in an uncontrolled manner.

o) **Nuclear fusion –** The combining of smaller nuclei at very high temperature (order of 10^6 K) to produce larger nuclei with liberation of large amount of energy is called nuclear fusion. A huge amount of energy is produced in all stars including sun due to nuclear fusion. In Hydrogen bomb (Thermonuclear bomb), nuclear fusion is carried out by first carrying out nuclear fission to create high temperature.

p) During any chemical reaction, composition of nucleus remains unchanged.

Failure of Rutherford Model

1. Rutherford model could not explain stability of atom. If negatively charged electrons revolve around positively charged nucleus they should loss energy continuously in form of radiations, according to electrodynamics and should acquire a spiral path ultimately falling in nucleus and atom should collapse but atom is quite stable.
2. According to the Rutherford model the atomic spectra of atoms should be continuous but spectrum of all elements is discontinuous.

Bohr's Model of Atom

On basis of study of Hydrogen spectra, Neils Bohr proposed a new model in 1913. Acc. to this model-

1. Electrons revolve around nucleus in certain fixed circular paths called orbits or shells. Starting from nucleus these are numbered as 1, 2, 3, 4, 5 … or designated as K, L, M, N, O, ect.
2. Only those orbits are allowed in which angular momentum of electron is natural number multiple of $h/2\pi$(h is Planck's constant).
3. As long as an electron is in a particular orbit, its energy is constant. It means electron is energetically stationary in an orbit. The orbits are thus also called energy levels.
4. An electron can jump to higher orbits by absorbing radiations of exactly required energies. For this it absorbs radiations of definite wavelengths or frequencies. When an electron falls back to lower orbits it liberates radiations of exactly desired energies (i.e. wavelengths or frequencies).

It should be noted that higher is orbit, more is its energy and radius. Energy of electron in atom is quantised (have only certain values) and is negative.

The energy of electron in nth orbit of Hydrogen atom

$$= -1312/n^2 \text{ kJ/mol}$$

Hence in first orbit it is -1312 kJ/ mol, in second orbit it is -1312/4 = -328 kJ/mol, in third orbit it is -1312/9 = -145.8 kJ/mol and so on. At infinity when n = ∞, it become zero.

The maximum number of electron that can be present in nth orbit of an atom is $2n^2$. So maximum number of electrons that can be present in various orbits or shells are as follows-

1st Orbit Or K - Shell – 2 , 2nd Orbit Or L - Shell – 8, 3rd Orbit Or M - Shell – 18 and 4th Orbit Or N - Shell – 32 and so on.

However it is not necessary that electron goes in higher orbits only when lower orbit is fully filled up to its capacity e.g. after Argon (2,8,8) the 19th electron enter 4th orbit although 3rd orbit can have up to 18 electrons.

The distribution of electron in various orbits in an atom is called its electronic configuration. Electronic configuration of some elements is given below-

H – 1 → 1
He – 2 → 2
Li – 3 → 2,1
Be – 4 → 2,2
B – 5 → 2,3
C – 6 → 2,4
N – 7 → 2,5
O – 8 → 2,6
F – 9 → 2,7
Ne – 10 → 2,8
Na – 11 → 2,8,1
Mg – 12 → 2,8,2
Al – 13 → 2,8,3
Si – 14 → 2,8,4
P – 15 → 2,8,5
S – 16 → 2,8,6
Cl – 17 → 2,8,7
Ar – 18 → 2,8,8
K – 19 → 2,8,8,1
Ca – 20 → 2,8,8,2
Sc – 21 → 2,8,9,2
Ti – 22 → 2,8,10,2
V – 23 → 2,8,11,2
Cr – 24 → 2,8,13,1
Mn – 25 → 2,8,13,2
Fe – 26 → 2,8,14,2
Co – 27 → 2,8,15,2
Ni – 28 → 2,8,16,2
Cu – 29 → 2,8,18,1
Zn – 30 → 2,8,18,2

Bohr model was successful in explaining a number of facts and observations-

a) It could explain stability of atom.
b) It could explain spectra of Hydrogen and other single electron systems.
c) It could explain valency of many simple atoms on basis of number of electrons in outermost shell (valence shell).

Failure of Bohr's Model

1. Bohr's model could not explain splitting of Hydrogen spectra in presence of electric (Stark effect) and magnetic (Zeeman effect) fields.
2. Bohr model could not explain spectra of multi-electron systems.
3. Bohr model could not explain three-dimensional nature of atom.
4. Bohr model could not justify the relation between angular momentum and $h/2\pi$.
5. The major failure of Bohr's model is that it is not in harmony with modern concepts such as de Borglie concept and Heisenberg's uncertainty principle.

de Broglie Concept

Every moving particle is associated with a wave character. Hence it has dual character i.e. both particle and wave. The wavelength associated with it is given by formula -

$$\lambda = \mathbf{h/mv}$$

Where, λ = wavelength, h = Planck's constant = 6.25×10^{-34} Kg M^2S^{-1}
M = mass of particle and v = velocity of particle

Heisenberg's Uncertainty Principle

It is impossible to determine simultaneously the position and momentum of a moving particle with desired accuracy. Mathematically,

$$\Delta x \,.\, \Delta p \geq h/4\pi \quad \text{or} \quad \Delta x \,.\, m\Delta v \geq h/4\pi$$

Where, Δx = uncertainty in determination of position
Δp = uncertainty in determination of momentum
m = mass of particle
Δv = uncertainty in determination of velocity
h = Planck's constant

In view of de-Broglie concept and Heisenberg's uncertainty principle, no definite position or path can be assigned to electron as in Bohr model.

Quantum Mechanical Model of Atom

The behavior of electron in atom can be expressed in terms of mathematical equation. This approach has resulted in development of 'Quantum Mechanical Model' of atom.

The probability of finding an electron at a point around nucleus can be calculated by a complex mathematical equation called Schrodinger wave equation. It involved a function ψ. ψ itself has no significance but ψ^2 gives probability of finding the electron.

Orbital – The space around nucleus with in which there is maximum (say 95%) probability of finding an electron is known as orbital of the electron.
Depending on the energy of electron, there are various types of orbitals.

Shapes of Orbitals –

1. **s– Orbital** - Spherical around nucleus. Size – 1s<2s<3s … so on.
2. **p – Orbital** - Dumb-bell shape with two lobes on opposite side of nucleus. Size – 2p<3p<4p… so on.
3. **d – Orbital** - Four lobes at right angles in same plane.
4. **f – Orbital** - Complex structure.

Quantum Numbers - Various orbitals in atom are designated by use of a set three numbers called quantum numbers. An additional quantum number is required to designate electron. A brief account of quantum numbers is given below -

a) **Principal Quantum Number (n) –** Refers to main energy level (same as in Bohr's model). It can have values 1, 2, 3, 4 and so on.
b) **Azimuthal or Secondary or Subsidiary Quantum Number (l) –** Refers to sub-shell for any value of n, l, has n values starting from 0 to (n-1). If l = 0 orbital is s-type, if l=1 orbital is p-type, if l=2 orbital is d-type and if l=3 orbital is of f-type.
c) **Magnetic Quantum Number (m) –** Refers to the orientation of orbital in space. For any value of l, m has (2l+1) values starting from –l to +l via 0.
d) **Spin Quantum Number (s) –** Refers to the spin of electron. For any value of m, s has two values +½ (clockwise spin) and –½ (anticlockwise spin).

Filling of electrons in orbitals

The requisite numbers of electron are filled in orbitals in accordance with Aufbau's Principle, Pauli's Exclusion Principle and Hund's Rule of Maximum Multiplicity.

Aufbau's Principle – Electrons are filled in various orbitals in increasing order of energy. The increasing order of energy is -
1s<2s<2p<3s<3p<4s<4p<5s<4d<5p<6s<4f<5d<6p<7s<5f<6d<7p ect.
Pauli's Exclusion Principle - No two electrons in an atom can have same set of four quantum number or An orbital can have maximum two electrons that too with opposite spin.

Hund's Rule of Maximum Multiplicity – The pairing of electrons in an orbital does not take place until each orbital of degenerate set (same energy) is singly occupied.

On basis of Pauli's exclusion principal, it can be concluded that maximum number of electrons in any shell is $2n^2$, in any sub-shell is 2(2l+1) and maximum number of orbitals in a shell is n^2.

There are certain exceptions to these rules. Two are most commonly given as examples -

	Expected	Real
Cr – 24	[Ar] $3d^4 4s^2$	[Ar] $3d^5\ 4s^1$
Cu – 29	[Ar] $3d^9\ 4s^2$	[Ar] $3d^{10}\ 4s^1$

(X) Atoms and Molecules

The smallest particle of an element, which may or may not have independent existence is called an atom, while the smallest particle of a substance which is capable of independent existence is called a molecule.
Molecules are classified as homoatomic and heteroatomic. Homoatomic molecules are made up of the atoms of the same element and heteroatomic molecules are made up of the atoms of the different element have different atomicity (number of atoms in a molecule of an element) like monoatomic, diatomic, triatomic and polyatomic.

Atomic Mass Unit

One atomic mass unit is defined as a mass exactly equal to one twelfth the mass of one carbon -12 atom. And 1 amu = 1.66056×10^{-24} g.
Today, 'amu' has been replaced by 'u' which is known as unified mass.

Atomic Mass: Atomic mass of an element is defined as the average relative mass of an atom of an element as compared to the mass of an atom of carbon -12 taken as 12.

$$\text{Atomic mass} = \frac{\text{mass of an atom}}{1/12\ \text{massofacarbon atom}(^{12}\text{C})}$$

Gram Atomic Mass

The quantity of an element whose mass in grams is numerically equal to its atomic mass. In simple terms, atomic mass of an element expressed in grams is the gram atomic mass or gram atom. For example, the atomic mass of oxygen = 16 amu Therefore gram atomic mass of oxygen = 16 g

Molecular Mass

Molecular mass of a substance is defined as the average relative mass of its molecule as compared to the mass of an atom of C-12 taken as 12. It expresses as to how many times the molecule of a substance is heavier than 1/12th of the mass of an atom of carbon.
For example, a molecule of carbon dioxide is 44 times heavier than 1/12th of the mass of an atom of carbon. Therefore the molecular mass of CO_2 is 44 amu.
It is obtained by adding the atomic masses of all the atoms present in one molecule.

Gram Molecular Mass

A quantity of substance whose mass in grams is numerically equal to its molecular mass is called gram molecular mass. In simple terms, molecular mass of a substance expressed in grams is called gram molecular mass.
e.g., the molecular mass of oxygen = 32 amu
Therefore, gram molecular mass of oxygen = 32 g

Formula Mass-

Sum of atomic masses of the elements present in one formula unit of a compound. It is used for the ionic compounds.

Mole Concept.

Mole is defined as the amount of a substance, which contains the same number of chemical units (atoms, molecules, ions or electrons) as there are atoms in exactly 12 grams of pure carbon-12.
A mole represents a collection of 6.022×10^{23}(Avogadro's number) chemical units..**The mass of one mole of a substance in grams is called its molar mass.**

Molar Volume

The volume occupied by one mole of any substance is called its molar volume. It is denoted by Vm. One mole of all gaseous substances at 273 K and 1 atm pressure occupies a volume equal to 22.4 litre or 22,400 mL. The unit of molar volume is litre per mol or millilitre per mol

PERCENTAGE COMPOSITION

The mass percentage of each constituent element present in any compound is called its percentage composition

$$\text{Mass \% of the element} = \frac{\text{Mass of element in 1 molecule of the compound}}{\text{Molecular mass of the compound}} \times 100$$

Empirical Formula and Molecular Formula—

An **empirical formula** represents the simplest whole number ratio of various atoms present in a compound. E.g. CH is the empirical formula of benzene.
The **molecular formula** shows the exact number of different types of atoms present in a molecule of a compound. E.g. C_6H_6 is the molecular formula of benzene.

Relationship between empirical and molecular formulae

The two formulas are related as Molecular formula = n x empirical formula

$$n = \frac{\text{Molecular mass}}{\text{empirical formula mass}}$$

Chemical Equation-

Shorthand representation of a chemical change in terms ofsymbols and formulae of the substances involved in the reaction is called chemical equation..
The substances that react among themselves to bring about the chemical changes are known as reactants, whereas the substances that are produced as a result of the chemical change, are known as products

Limiting Reagent- The reactant which gets consumed first or limits the amount of product formed is known as **limiting reagent**

Reactions in Solutions-- The concentration of a solution can be expressed in any of the following ways.

1. Mass Percent is the mass of the solute in grams per 100 grams of the solution.

$$\text{Mass \% of the solute} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$$

A 5 % solution of sodium chloride means that 5 g of NaCl is present in 100g of the solution.

2. Volume percent is the number of units of volume of the solute per 100 units of the volume of solution.

$$\text{Volume \% of the solute} = \frac{\text{Volume of the solute}}{\text{Volume of the solution}} \times 100$$

A 5 % (v/v) solution of ethyl alcohol contains 5 cm^3 of alcohol in 100 cm^3 of the solution

3. Molarity of the solution is defined as the number of moles of solute dissolved per litre (dm^3) of the solution. It is denoted by the symbol M. Measurements in Molarity can change with the change in temperature because solutions expand or contract accordingly.

$$\text{Molarity of the solution} = \frac{\text{No. of moles of the solute}}{\text{Volume of the solution in litre}} = \frac{n}{V}$$

The Molarity of the solution can also be expressed in terms of mass and molar mass

$$\text{Molarity of the solution} = \frac{\text{Mass of the solute}}{\text{Molar mass of the solute X volume of the solution in liter}}$$

In terms of weight, molarity of the substance can be expressed as:

$$\text{Molarity} = \frac{W g}{M \text{ g mol}^{-1} \times V \text{ litre}} = \frac{W}{M \times V} \text{ mol/L}$$

Molarity equation

To calculate the volume of a definite solution required to prepare solution of other molarity, the following equation is used:
$M_1V_1 = M_2V_2$, where M_1= initial molarity, M_2 = molarity of the new solution,

V_1= initial volume and V_2 = volume of the new solution.

4. Molality- Molality is defined as the number of moles of solute dissolved per 1000 g (1 kg) of solvent. Molality is expressed as 'm'.

$$\text{Molality} = \frac{\text{Moles of the solute}}{\text{Wt. of Solvent (in gm)}} \times 1000$$

5. Mole Fraction is the ratio of number of moles of one component to the total number of moles (solute and solvents) present in the solution. It is expressed as 'x'.

$$\text{Mole fraction of the solute} = \frac{\text{Moles of the solute}}{\text{Moles of solute} + \text{Moles of solvent}}$$

$$\text{Mole fraction of the solvent} = \frac{\text{Moles of the solvent}}{\text{Moles of solute} + \text{Moles of solvent}}$$

Mole fraction of the solute + Mole fraction of solvent = 1

(X) Equivalent Weights

1. Equivalent Weights of Elements

The weight of an element which can combine with or displace 1.008 parts by weight of Hydrogen or 8 parts by weight of oxygen or 35.5 parts by weight of chlorine.

From the formula of $MgCl_2$ we can see that 24 parts by weight of Mg combine with 70.1 parts by weight of chlorine. Thus the weight of Mg which can combine with 35.5 parts by weight of chlorine is 12. Therefore the equivalent weight of Mg is 12.

From the formula CaO, weight of Calcium combine with 16 parts by weight of oxygen is 40. Therefore the weight of Ca which can combine with 8 parts by weight of oxygen is 20. Thus the equivalent weight of Calcium is 20.

From the formula NaH, we see that 23 parts by weight of Na combine with 1.008 parts by weight of Hydrogen. Thus the equivalent weight of Sodium is 23.

Alternate Method of find equivalent weight of elements

$$\text{Equivalent weight of an element} = \frac{\text{Atomic weight}}{\text{Valency}}$$

Equivalent weight has no units, as such **Gram equivalent weight.**

Equivalent weight expressed in gram is called gram equivalent weight

Element	At weight	Equivalent weight	Gram equivalent weight
H	1.008	1.008	1.008g
Na	23	23.	23g
Mg	24	12	12g
Ca	40	20	20g

Equivalent Weights of Acids

It is the weight of an acid which can produce 1.008 parts by weight of Hydrogen

$$\text{Equivalent weight of Acids} = \frac{\text{Molecular weight}}{\text{Basicity of the acids}}$$

Basicity = Number of displaceable hydrogen atom in a molecule of the acid. HCl, HNO_3, CH_3COOH are Monobasic acids H_2SO_4, H_2CO_3 are dibasic acids where as H_3PO_4 is a tribasic acid.

$$\textit{Equivalent weight of Acids} = \frac{\textit{Molecular weight}}{\textit{Basicity of the acid}}$$

Acid	Molecular weight	Basicity	Equivalent weight	Gram equivalent weight
HCl	36.5	1	36.5	36.5g
H_2SO_4	98	2	49	49g
HNO_3	63	1	63	63g

Equivalent weight of Bases (NaOH, KOH, $Ca(OH)_2$ etc…)

It is the weight of a base which can combine with 1.008 parts by weight of Hydrogen ions or one gram equivalent of an acid.

$$\text{Equivalent weight of Base} = \frac{\text{Molecular weight}}{\text{Acidicity of the Base}}$$

Acidicity is the number of OH groups per molecule of the base or metal hydroxide.

Base	Molecular weight	Acidicity	Equivalent weight	Gram equivalent weight
NaOH	40	1	40	40g
$Mg(OH)_2$	58	2	29	29g

One Gram Equivalent of an Acid or Base

It is the weight expressed in gram of one equivalent of an acid or base

One gram equivalent HCl is 36.5g and one gram equivalent of NaOH is 40g.

Normality (N)

It is the number of gram equivalents of an acid, base or a salt in a solution. This is a way of expressing the concentration of solutions like molarity.

$$\text{Normality} = \frac{\text{Weight of solute per L of solution}}{\text{Gram Equivalent weight of the compound}}$$

Equivalent weight of Oxidising Agents and Reducing Agents

Equivalent weights of an oxidising agent is the weight of that compound which can produce 8 parts by weight of oxygen or which can accept one electron.

For example in the case of KmnO4, its equivalent weight is molecular weight divided by 5, because one KmnO4 accepts 5 electrons

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

Equivalent Weights of Salts

It is the molecular weight divided by the total number of charges on the cation.

For example the equivalent weight of $Al_2(SO_4)_3$ is molecular weight of $Al_2(SO_4)_3$ divided by 2 x 3 = 6.

(Y) VALENCY

The valency of an element is a measure of its ***combining capacity*** and can be defined as the number of electrons that must be lost or gained by an atom to obtain a stable electron configuration.
Electrons that are found in the outermost shell are generally known as valence electrons and the number of valence electrons determines the valency (or valence) of an atom.

- The valencies of the elements belonging to the s-block and the p-block of the periodic table are generally calculated as the number of valence electron or eight minus the number of valence electrons.
- For the d-block and f-block elements, valency is determined not only on the basis of valence electrons but also on d and f orbital electrons. However, the general valencies of these d and f block elements are 2 and 3.

- **Valency of First 30 Elements**
- The valency of the first 30 elements of the periodic table is given below.

Element	Atomic Number	Valency
Valency of Hydrogen	**1**	**1**
Valency of Helium	**2**	**0**
Valency of Lithium	**3**	**1**
Valency of Beryllium	**4**	**2**
Valency of Boron	**5**	**3**
Valency of Carbon	**6**	**4**
Valency of Nitrogen	**7**	**3**
Valency of Oxygen	**8**	**2**
Valency of Fluorine	**9**	**1**
Valency of Neon	**10**	**0**
Valency of Sodium (Na)	**11**	**1**
Valency of Magnesium (Mg)	**12**	**2**

Valency of Aluminium	**13**	**3**
Valency of Silicon	**14**	**4**
Valency of Phosphorus	**15**	**3**
Valency of Sulphur	**16**	**2**
Valency of Chlorine	**17**	**1**
Valency of Argon	**18**	**0**
Valency of Potassium (K)	**19**	**1**
Valency of Calcium	**20**	**2**
Valency of Scandium	**21**	**3**
Valency of Titanium	**22**	**4**
Valency of Vanadium	**23**	**5,4**
Valency of Chromium	**24**	**2**
Valency of Manganese	**25**	**7, 4, 2**
Valency of Iron (Fe)	**26**	**2, 3**
Valency of Nickel	**27**	**3, 2**
Valency of Cobalt	**28**	**2**
Valency of Copper (Cu)	**29**	**2, 1**
Valency of Zinc	**30**	**2**