REDOX REACTIONS

1. **Stock notations** Expressing the oxidation state of a metal by Roman numbers like. I ,II, III etc. within parenthesis is called stock notation e.g., $FeSO_4$ = Iron (II) sulphate; Na_2CrO_4 = Sodium chromate (VI) etc.

2. **Valency** of an element is only a number and as such there is no postive or negative sign attached to it. It can neither be zero nor fractional. Oxidation number, on the other hand, refers to charge and hence has either postive or negative sign. It can also be zero or fractional. For example oxidation state of C in CH_2Cl_2 is zero while that of Fe in Fe_3O_4 is $\frac{8}{3}$ and of S in $Na_2S_2O_3$ is 2.0.

3. **Calculation of oxidation state :**

Rules I :

The oxidation state of any atom in its elemental state is zero.

Rules II:

The maximum oxidation state of any atom will be equal to (+group number) and minimum oxidation state will be equal to (group number –8), where group numbers are in roman numerals. For example, Sulphur (S) is member of group VI A and hence its maximum oxidation state is +6 and minimum is = (6–8) = –2

Exception : Cu(IB) : +1, +2
Au (IB) : 1, +3
Xe (0) : +2, +4, +6, +8. etc

Rule III:

The sum of oxidation state of all the atoms in a molecule is zero and for ions, it is equal to the ionic charge.

Rule IV:

The oxidation states of some elements are fixed in all their compounds.

+1: Alkali metals (Li, Na, K, Rb, Cs, Fr) and Ag
+2: Alkaline earth metals (Be. Mg, Ca, Sr, Ba, Ra) and Zn
+3: Al
–1 :F

Rule V:

Oxidation state of hydrogen is +1 in all of its compounds, except the metal hydrides, where it is –1.

Rule VI:

Oxidation state of oxygen is –2 in all of compounds except

(i) Peroxide like Na_2O_2, H_2O_2, BaO_2, etc, where it is –1.

(ii) Superoxides like KO_2, RbO_2, etc, where it is –1/2.

(iii) Some other binary compounds of alkali metals and oxygen like KO_3 (O.S. of O = –1/3), Rb_2O_3 (O.S. of O = –2/3), etc.

(iv) Oxides of fluorine, where it is positive states. For example: O.S. of O in OF_2, O_2F_2, O_3F_2 etc. are +2, +1, +2/3, respectively.

Rule VII:

The charges on different ions commonly used, should be known.

CO_3^{2-}	Carbonate ion	HCO_3^-	Hydrogen carbonate ion
SiO_4^{4-}	Silicate ion	PO_4^{3-}	Phosphate ion
HPO_4^{2-}	Hydrogen phosphate ion	$H_2PO_4^-$	Dihydrogen phosphate ion
HPO_3^{2-}	Phosphite ion	NO_3^-	Nitrate ion
NO_2^-	Nitrite ion	SO_4^{2-}	Sulphate ion
SO_3^{2-}	Sulphite ion	S^{2-}	Sulphide ion
S_2^{2-}	Pyrite ion	$S_2O_7^{2-}$	Disulphate ion
$S_2O_3^{2-}$	Thiosulphate ion	$S_2O_8^{2-}$	Peroxodisulphate ion
ClO^-	Hypochlorite ion	ClO_3^-	Chlorate ion
ClO_2^-	Chlorite ion	ClO_4^-	Perchlorate ion

Rule VIII :

In the complex compound, the overall charge on ligand should be considered in place of considering the charges on individual atoms.

4. Peroxy linkage calculation :

The linkage of the two oxygen atoms i.e. there are the oxygen-oxygen linkages.

(i) $(O.S)_{Cal.} > (O.S)_{max.}$; Peroxy linkage is present

(ii) $(O.S)_{Cal.} = (O.S)_{max.}$: Oxy linkage is present

(ii) $(O.S)_{Cal.} < (O.S)_{max.}$: M–M bond is persent

Calculation of no. of peroxy linkage :

$$n = \frac{(\text{Calculated oxidation state}) - (\text{Maximum oxidation state})}{1 \text{or} 2}$$

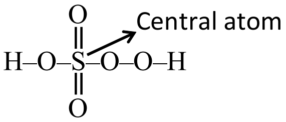
⇒ If two central atom present than divide it by 1

⇒ If one central atom present then divide it by 2

⇒ When ‘n’ comes out to be fractional then use below formula

$n = [O.S]_{cal.} - [0.S]_{max.} + 1$

Example : H_2SO_5



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-O-H$$

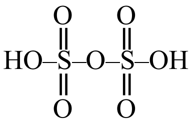
no. of peroxy linkage = $\frac{8-6}{2} = 1$

Calculated O.S. of S → (+8)

Maximum O.S. of S → (+6)

i.e. $(O.S.)_{Cal.} > (O.S.)_{max.}$ ⇒ Peroxy linkage is present

Example : $H_2S_2O_7$



$$HO-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OH$$

For sulphur $(O.S)_{max.} = +6$

$(O.S)_{cal.} = +6$

$+2 + 2x - 14 = 0$

$2x = 12$

$x = +6$

Therefore, no peroxy linkage is present.

Example : $H_4P_2O_6$

For phosphorus $(O.S)_{max.} = +5$

$4(+1) + 2x - 12 = 0$

$2x - 8 = 0$

$x = +4$

Therefore, no peroxy linkage is present

As $(O.S)_{max.} > (O.S)_{cal.}$ → M – M bond

5. **Redox reaction :**

Redox reaction are also called electron - transfer reactions since electron are transferred from the reductant to the oxidant.

Type of redox reaction :

These are the reactions involving oxidation as well as reduction.

Examples:

$$\overset{0}{Zn} + 2\overset{+1}{H}Cl \longrightarrow \overset{+2}{Zn}Cl_2 + \overset{0}{H_2}$$

(Oxidation = Zn, Reduction = HCl)

1. Disproportionation Reaction:

The redox reaction in which the atoms of same element belonging from the same molecule or ion are oxidised as well as reduced are called disproportionation reaction. Such reaction are also called autoredox or self-redox reaction.

Examples:

$$3\overset{0}{Cl_2} + 6NaOH \longrightarrow 5Na\overset{-1}{Cl} + Na\overset{+5}{Cl}O_3 + 3H_2O$$

Cl–atoms are oxiidised and reduced, both

2. Comproportionation Reaction

These are just the reverse of disproportionation. Atoms of the same element, belonging to the same molecule or ion, oxidise and reduce to give the element in the commom oxidation state.

Example:

$$2H_2\overset{-2}{S} + \overset{+4}{S}O_2 \longrightarrow \overset{0}{S} + 2H_2O$$

6. Methods of Balancing Chemical reactions

1. Oxidation number method

Step I: Select the species undergoing oxidation and reduction and write both the processes, separately

StepII: Balance the atoms of responsible elements (elements responsible for change in oxidation state) by simple counting.

StepIII: Determine the changes in oxidation state of both the process, due to the total number of atoms of responsible elements.

StepIV: Make the changes is oxidation state of both processes, equal by multiplying with suitable numbers. Add both the processes after multiplication.

StepV : If some reaction components are left, write them in proper side and balance them by simple counting.

StepVI: If the reaction is not balanced at step IV or V, add some molecule or ion in the proper side, The species added should be according to the reaction and it should not create a new change in oxidation state.

Example :

$$KMnO_4 + H_2SO_4 + HCl \longrightarrow K_2SO_4 + MnSO_4 + H_2O + Cl_2$$

Solution:

Step I: Oxidation: $H\overset{-1}{Cl} \longrightarrow \overset{0}{Cl_2}$

Reduction: $K\overset{+7}{Mn}O_4 \longrightarrow \overset{+2}{Mn}SO_4$

Step II: Oxidation: $2HCl \longrightarrow Cl_2$

Reduction: $KMnO_4 \longrightarrow MnSO_4$

Change is O.S.

Step III: Oxidation: $2H\overset{-1}{Cl} \longrightarrow \overset{0}{Cl_2}$ 2

Rediuction: $K\overset{+7}{Mn}O_4 \longrightarrow \overset{+2}{Mn}SO_4$ 5

Change is O.S.

Steep IV: Oxidation: $2HCl \longrightarrow Cl_2 \quad 2\,]\times 5$

Reduction: $KMnO_4 \longrightarrow MnSO_4 \; 5\,]\times 2$

$$2KMnO_4 + 10\,HCl \longrightarrow 2MnSO_4 + 5Cl_2$$

Step V: $2KMnO_4 + 10HCl + 3H_2SO_4 \longrightarrow 2MnSO_4 + 5Cl_2 + K_2SO_4 + 8H_2O$ is the balanced reaction.

2. Ion electron method :

Step I : If the reaction is given in molecular form, convert it in the ionic form. For it, write strong acids, strong bases and all water soluble salts in ionic form and then cancel out the spectator ions (ions common in both sides).

Step II: Select the species undergoing oxidation and reduction and write them separately.

Step III: Balance the atoms of responsible element by simple counting.

Step IV: Balance the atoms of all other elements by adding some molecule or ion in the proper side. The species added should be according to the reaction and it should not create not create any new change in the oxidation state. In most of the reaction, the other elements are hydrogen or oxygen. They are balanced according to medium of the reaction.

In acidic medium:

→ Add one water molecule in the opposite side for each excess of oxygen atom.

→ Add one H^+ ion in the opposite side for each excess of hydrogen atom.

In basic medium:

→ Add one water molecule in the same side and two OH^- ions in opposite side for each excess of oxygen atom.

→ Add one OH^- ion in the same side and one water molecule in the opposite side for each excess of hydrogen atom.

→ Hydrogen and oxygen atoms may also be balanced by balancing them first in acid medium and then replacing the H^+ ions suitably by OH^- ions. For it, add OH^- ions equal in number to the H^+ ions in both the sides and then write the combination of one OH^- ion and one H^+ ion ions as an H_2O molecule. It must be noted that the combination of one H^+ and one OH^- ions, in ionic form of a reaction.

Step V : Balance the charges in both process by addding proper number of electron in the proper side. The number of electrons added and the side, in which they are added, can be checked.

→ In oxidation, electrons will be added in the right side and in the reduction, left side.

→ The number of electrons lost or gained will always be equal to the change in oxidation state.

→ The number of elecrons lost or gained in a particular process in independent to the medium of reaction.

Step VI: Make the total number of electrons lost and gained equal by multiplying with suitable numbers. Add both the processes. It should be balanced reaction in ionic form.

Step VII: If the original reaction was in molecular form, convert the ionic form into molecular form.

Example :

$KMnO_4 + H_2SO_4 + HCl \rightarrow K_2SO_4 + MnSO_4 + Cl_2 + H_2O$

Solution:

Step I: Ionic form of the given reaction is

$K^+ + MnO_4^- + 2H^+ + SO_4^{2-} + H^+ + Cl^- \longrightarrow 2K^+ + SO_4^{2-} + Mn^{2+} + SO_4^{2-} + Cl_2 + H_2O$

or $MnO_4^- + H^+ + Cl^- \longrightarrow Mn^{2+} + Cl_2 + H_2O$

Step II: Oxidation: $Cl^- \longrightarrow \overset{0}{Cl_2}$

Reduction: $\overset{+7}{Mn}O_4^- \longrightarrow Mn^{2+}$

Step III: Oxidation: $2Cl^- \longrightarrow Cl_2$

Reduction: $MnO_4^- \longrightarrow Mn^{2+}$

Step IV: Oxidation: $2Cl^- \longrightarrow Cl_2$

Reduction: $MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 4H_2O$

Step V: Oxidation: $2Cl^- \longrightarrow Cl_2 + 2e^-$

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

Step VI: Oxidation: $2Cl^- \longrightarrow Cl_2 + 2e^-] \times 5$

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

$2MnO_4^- + 16H^+ + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$

It is balanced reaction in ionic form.

Step VII: $2KMnO_4 + 10\ HCl + 3H_2SO_4 \longrightarrow 2MnSO_4 + 8\ H_2O + 5Cl_2 + K_2SO_4$ is the balanced reaction.

7. Equivalence weight (E) :

In general, $\text{Eq. wt. (E)} = \dfrac{\text{Atomic weight or Molecular weight}}{\text{valency factor(v.f)}} = \dfrac{\text{Mol.wt.}}{\text{n}-\text{factor}} = \dfrac{M}{x}$

$\text{Number of Equivalents} = \dfrac{\text{mass of species}}{\text{eq. wt. of that species}}$

For a solution, Number of equivalents = N_1V_1, where N is the normality and V is the volume in litres

- Equivalent mass is a pure number which, when expressed in gram, is called gram equivalent mass.
- The equivalent mass of a substance may have different values under different conditions.
- There is no hard and fast rule that equivalent weight will be always less than the molecular mass.

(a) The equivalent weight of an element is that weight of the element that will combine with or replace directly or indirectly 1.0 gm of H, 35.5 gm of Cl or 8.0 gm. of O or 108 gm of Ag.

(b) In the reaction $Mg + Cl_2 \rightarrow MgCl_2$

1 atom of Mg loses 2 electrons to become Mg^{2+} ion. If we start with 1 mole or 24 gm of Mg, we have N_A (6.023×10^{23}) number of Mg atoms which would lose $2N_A$ number of electrons and form N_A number of Mg^{2+} ions. Therefore, we get $2N_A$ number of electrons from 24 gm of Mg.

So, N_A number of electrons can be obtained from $\dfrac{24}{2} = 12$ gm of Mg. Thus the equivalent weight of Mg = 12.

Thus equivalent weight of an element is that weight of the element which loses or gained Avogadro number (N_A) of electrons.

Valency factor/n-factor calculation :

For Elements : Valency factor = valency of the element.

For Acids : Valency factor = number of replaceable H^+ ions per acid molecule.

v. f. for acid is the number of OH^- replaced from the base by each molecule of acid.

Example :

n factor of HCl = 1

n factor of CH_3COOH = 1

n factor of H_2SO_4 = 2

For Bases :

Valency factor = number of replacable OH^- ions per base molecule.

Example :

n factor of NaOH = 1

n factor of $Ca(OH)_2$ = 2

n factor of $Al(OH)_3$ = 3

n factor of $B(OH)_3$ = 1 (because it is a mono basic acid)

Salts :

(i) When no atom undergoes change in oxidation state

The n-factor for such salts isdefined as the totalmoles of cationic/anionic charge present in 1 mole of the salt. For the reaction

$2Na_3PO_4 + 3BaCl_2 \rightarrow 6NaCl + Ba_3(PO_4)_2$

n-factor of Na_3PO_4 in this reaction is 3

n-factor of $BaCl_2$ in this reaction is 2

n-factor of NaCl in this reaction is 1

n-factor of $Ba_3(PO_4)_2$ in this reaction is 6

(ii) When only one atom undergoes change in oxidation state and goes in only one product

The n-factor of such salts is defined as the number of moles of electrons exchanged (lost or gained) by one mole of the salt.

For example, let us calculate the n-factor $KMnO_4$ for the given chemical change.

$KMn^{+7}O_4 \xrightarrow{H^+} Mn^{+2}$

In this reaction, oxidation state of Mn changes from +7 to +2. Thus, $KMnO_4$ is acting as oxidising agent, since it is reduced

$\therefore$ n-factor of $KMnO_4 = |1 \times (+7) - 1 \times (+2)| = 5$

Similarly

(a) $KMn^{+7}O_4 \xrightarrow{H_2O} Mn^{+4}$

n-factor of $KMnO_4 = |1 \times (+7) - 1 \times (+4)| = 3$

(b) $KMn^{+7}O_4 \xrightarrow{OH^-} Mn^{+6}$

n–factor of $KMnO_4 = |1 \times (+7) - 1 \times (+6)| = 1$

It can be seen that in all above chemical changes, $KMnO_4$ is acting as oxidising agent, yet its n-factor is not same in all reactions. Thus, the n-factor of a compound is not fixed, it depends on the type and the extent of reaction it undergoes.

(iii) When only one atom undergoes change in oxidation state but goes in two products with the same oxidation state

In such case, the n-factor is calculated in the same manner as in case (ii).

For example, let us calculate the n-factor of $K_2Cr_2O_7$ for the given chemical change.

$Cr_2O_7^{2-} \rightarrow Cr^{3+} + Cr^{3+}$

In this reaction, state of Cr changes from +6 to +3 in both products.
$\therefore$ n-factor of $K_2Cr_2O_7$ = $|2 \times (+6) - 2 \times (+3)| = 6$

(iv) When only one atom undergoes change in oxidation state but goes in two products with different oxidation state
Consider a chemical change, $2Mn^{7+} \rightarrow Mn^{4+} + Mn^{2}$
Out of the two moles of Mn^{7+}, one mole Mn^{7+} changes to Mn^{+4} bygaining 3 moles of electrons and the other mole of Mn^{7+} changes to Mn^{2+} by gaining 5 mole of electrons, so in all 8 mole of electrons are gained by 2 mole of Mn^{7+}. So each mole of Mn^{7+} has gained 8 / 2 = 4 mole of electrons. Thus, 4 would be the n-factor of Mn^{7+} in this reaction.

If the reaction would have been
$3Mn^{7+} \rightarrow 2Mn^{2+} + Mn^{4+}$

Out of 3 moles of Mn^{7+}, two moles of Mn^{7+} changes to Mn^{2+} by gaining 10 mole of electrons and one mole of Mn^{7+} changes to Mn^{4+} by gaining 3 mole of electrons. Thus each mole of Mn^{7+} have gained 13 / 3 mole of electrons. Therefore, the n-factor of Mn^{7+} in this reaction would be 13 / 3.

Note that n-factor can be a fraction because it is not the number of electrons exchanged but it is the number of moles of electrons exchanged which can be a fraction.

Now, if the reaction would have been $3Mn^{7+} \rightarrow Mn^{2+} + 2Mn^{4+}$. Thus, each mole of Mn^{7+} have gained 11 / 3 mole of electron. Therefore, n-factor of Mn^{7+} in this reaction would be 11 / 3.
Salts which react in a fashion that only one atom undergoes change in oxidation state but goes in two products with different state (in one product with same oxidation state and in other with different state than in the reactant).

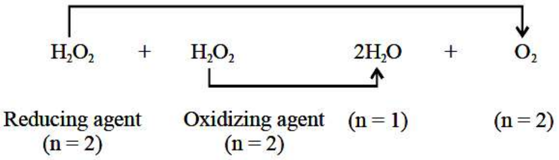
For such reactions also, the n-factor calculation is not possible without the knowledge of balanced chemical reaction because n-factor of reactant would depend on the fact that how much of reactant under went change to different oxidation state +y and how much of reactant remained in the same oxidation state +x.

(v) Salts or compounds which undergoes disproportionation reaction
Disproportionation reactions can be divided into two types.

(a) Disproportionation reactions in which moles of compound getting oxidised and reduced are same i.e. moles of oxidising agent and reducing agent are same. The n-factor for such compounds is calculated by either the number of mole of electrons lost or gained by one mole of the compound because in such a case, n-factor of the compound acting as oxidizing agent or as reducing agent would be same.

For example, $2H_2O_2 \rightarrow 2H_2O + O_2$
Out of 2 mole of H_2O_2 used in reaction, one mole of H_2O_2 gets oxidised to O_2 (oxidation state of O changes from –1 to –2). When 1 mole of H_2O_2 gets oxidised to O_2, the half - reaction would be $O_2^{2-} \rightarrow O_2^0 + 2e^-$ and when 1 mole of H_2O_2 gets reduced to H_2O, the half-reaction would be $O_2^{2-} + 2e^- \rightarrow 2O^{2-}$

Thus, it is evident that one mole of H_2O_2 (which is either getting oxidised or reduced) will lose or gain 2 mole of electrons. Therefore, n-factor of H_2O_2 as oxidizing as well as reducing agent in this reaction is 2. Thus



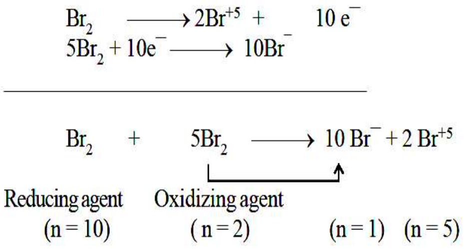
Or when the reaction iswritten as
$2H_2O_2 \rightarrow 2H_2O + O_2$
Where, H2O2 is not distinguished as howmuch of it functions as oxidizing agent and howmuch as reducing agent, then n-factor calculation can be done in the followingmanner. Find the number of electrons exchanged (lost or gained) using the balanced equation and divide it by the number ofmoles H_2O_2 involved in the reaction.Thus, then-factor of H_2O_2 when the reactioniswrittenwithout segregating

Oxidising and reducing agent is $\frac{2}{2}$

$$\underset{(n=1)}{2H_2O_2} \rightarrow \underset{(n=1)}{2H_2O} + \underset{(n=2)}{O_2}$$

(b) Disproportionation reactions inwhichmoles of compound getting oxidised and reduced are not same.
$6Br_2 + 12OH^- \rightarrow 10Br^- + 2BrO_3^- + 6H_2O$

In this reaction, themole of electrons lost by the oxidation of some of themoles of Br2 are same as the number ofmole of electrons gained by the reduction of rest of the moles of Br_2 of the 6 moles of Br_2 used, onemole is getting oxidized, loosing 10 electrons (as reducing agent) and 5 moles of Br_2 are getting reduced and accepts 10moles of electron (as oxidizing agent)



Thus, n-factor of Br_2 acting as oxidizing agent is 2 and that Br_2 acting as reducing agent has n-factor 10.

Or when the reaction is written as

$6Br_2 \rightarrow 10Br^- + 2Br^{5+}$

where, Br_2 is not distinguished as how much of it function as oxidizing agent and how much as reducing agent, then for calculating n-factor of compound in such reactions, first find the total number of electrons exchanged (lost or gained) using the balanced equation and divide it with the number of mole of Br2 involved in the reaction to get the number of mole electrons exchanged by one mole of Br_2. In the overall reaction, the number of mole of electrons exchanged (lost or gained) is 10 and the moles of Br_2 used in the reaction are 6.

Thus, each mole of Br_2 has exchanged 10/6 or 5/3 mole of electrons. Therefore , the n-factor of Br_2 when the reaction is written without segregation oxidising and reducing agent is 5/3.

$$\underset{(N = 5/3)}{6Br_2} \rightarrow \underset{(N = 1)}{10Br^-} + \underset{(N = 5)}{2Br^{5+}}$$

HYDROGEN AND ITS COMPOUND

⇒ Electronic confiuration of hydrogen : $1s^1$

Isotopes of hydrogen :

Isotope	%abundance	n, p, e^-
$_1H^1$ (H)	99%	0, 1, 1 (Ordinary hydrogen)
$_1H^2$ (D)	0.01%	1, 1, 1 (Heavy hydrogen)
$_1H^3$ (T)	Trace	2, 1, 1 (Radio active)

Preparation of di hydrogen (H_2) :

(A) Lab method :

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

(B) By the action of hydrolith on water :

$CaH_2 + 2H_2O \xrightarrow{Fe_2O_3 or Cr_2O_3} Ca(OH)_2 + 2H_2$.

(C) By electrolysis of water :

Water containing sulphuric acid - Ions are H^+, OH^- & SO_4^{-2}. On passing electricity H^+ ions move towards cathode while OH^- & SO_4^{-2} ions move towards anode.

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

At anode $OH^- \rightarrow OH + e^-$

$4OH \rightarrow 2H_2O + O_2$

Imp.- SO_4^{-2} ions are not discharged on anode as their discharge potential is higher than that of OH^- ions.

(D) Hydrogen from acids -

(i) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

(ii) $Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$

(E) Hydrogen from alkalies -

(Zn, Al, Sn, Pb, Si)

$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$

Sodium zincate.

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

Sodium meta aluminate.

(F) From natural gas -

$CH_4 + H_2O \xrightarrow{\text{Ni or Cr}} CO + 3H_2$.

(G) Lane's Process -

$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$.

(H) Bosch process -

Reacting CO with steam in presence of iron chromate as catalyst

$CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$

Physical properties

(i) It's critical temperature is very low (–236.9°C) so it is difficult to liquify.

(ii) It is adsorbed by certain metals like Fe, Au, Pt & Pd. Palladium in the powdered state can occlude nearly 1000 times its own volume of hydrogen. This property is used for the purification of hydrogen because only pure hydrogen is adsorbed by these metals and is given out when they are heated in vacuum.

Adsorption - It is a process of soaking up only on the surface while absorption is a process of soaking up through the entire mass.

Chemical reactions

(i) Reaction with metals -

(a) $2Na + H_2 \rightarrow 2NaH$

(b) $Ca + H_2 \rightarrow CaH_2$

(c) $Be + H_2 \rightarrow$ No reaction

(ii) Reaction with non metals - F combine with H_2 readily even in low temperature & in dark. While the combustion with chlorine takes place in presence of sunlight. Similarly with bromine combines on heating while iodine combines when heated in presence of a catalyst.

$H_2 + X_2 \rightarrow 2HX$

(iii) Reducing nature -

(a) $CuO + H_2 \rightarrow Cu + H_2O$

(b) $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

(c) Unsaturated fat + $H_2 \xrightarrow{\text{Ni}}$ Saturated fat

(Oil) (Vanaspati Ghee)

(iv) Synthetic petrol - Petrol substitute are obtained by subjecting a paste of powdered coal in crude oil to the action of hydrogen under pressure and in presence of catalyst.

(v) Oxyhydrogen flame - It produces a temperature of 2800°C while oxy - atomic hydrogen flame produced a temperature of 4000°C. The heat generated is used for melting substances having very high melting points such as Quartz, Pt etc. & also for welding.

(vi) Syn gas : $C(s) + H_2O(g) \xrightarrow{1270K} CO(g) + H_2(g)$

(vii) Water gas shiftreaction : $CO(g) + H_2O(g) \xrightarrow[\text{Catalyst}]{673K} CO_2(g) + H_2(g)$

(viii) Producer gas : $2C(s) + O_2(g) + 4N_2(g) \xrightarrow{1273K} 2CO(g) + 4N_2(g)$

Uses of hydrogen :

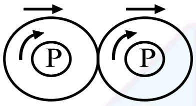
1. Hydrogenation of vegetable oil to form solid fats i.e. vanaspati ghee.
2. In liquid form as a rocket fuel. (Liquid H_2 + Liquid O_2)
3. In a air ship of balloons as a mixture of Hydrogen & Helium. (15 H_2 + 85% He)
4. Formation of different compounds.

Like → NH_3, (Haber process) alkane, alcohol and other hydrocarbon.

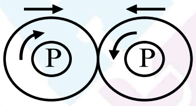
Ortho-hydrogen and para hydrogen

Ortho-hydrogen	Para hydrogen
Spin of proton in same direction	Spin of proton in opposite direction
More stable	Less stable
Less conducting	More conducting
Magnetic movement twice that of proton	Magnetic moment is zero

At room temperature about 75% of ortho & 25% of para means 3 : 1 forms of hydrogen exist. At low temperature para form increases.



spin of proton in
same direction



spin of protons in
opposite direction

Hydrides

Compound of hydrogen with less electronegative elements.

⇒ (i) Ionic hydride : Hydrogen + IA
Hydrogen + IIB

eg. LiH, NaH, KH, MgH_2, CaH_2 etc.
CaH_2 → Hydrolith → Rich source of hydrogen

⇒ (ii) Covalent hdyrides : Hydrogen + Non-metals

eg. SiH_4, B_2H_6

⇒ (iii) Interstitial hydrides : Hydrogen + Transition metal

Hydrogen is held by vander Waal's force. These hydrides are non stoichiometric

Ti : H
1 : 1.67

(i) Electron deficient compounds of hydrogen do not have sufficient number of electrons to form normal covalent bonds.

Example : Hydrides of group 13 such as BH_3, AlH_3 etc. They exist in polymeric forms such as B_2H_6, Al_2H_6. Thus, they make up their deficiency.

(ii) Electron precise compounds of hydrogen contain sufficient valence electrons to form covalent bonds.

Example : Group 14 hydrides CH_4, SiH_4, GeH_4, SnH_4, PbH_4 etc. These compounds have tetrahedral shape.

(iii) Electron-rich compounds of hydrogen contain excess valence electrons to form covalent bonds.

Example : Group 15 and group 17 hydrides such as NH_3, PH_3, HCl, HBr etc. These compounds contains lone pairs of electrons.

Water H_2O

Properties of pure water:

(a) Physical properties:

(i) Pure water is colourless, tasteless and odourless. It gives bluish tinge in thick layers.

(ii) It freezes at 0°C and boils at 100°C.

(iii) Its maximum density is 1.00 at 4°C.

(iv) It is a polar molecule and has V-shaped structure. The bond angle is 104.5°.

(v) It has a high dielectric constant. The polar character of water makes it an excellent solvent for polar and ionic substances.

(vi) It is a poor conductor of electricity.

(vii) It has the tendency to associate. It exists in the liquid state not as a single H_2O molecule but as associated molecules through hydrogen bonding. The existence of hydrogen bonding is responsible for high values of specific heat, the latent heat of fusion and latent heat of vaporisation.

(b) Chemical properties:

(i) Water is neutral in nature. pH of the pure water is 7 . It is a weak electrolyte and feebly ionises into $H^+$and OH^- ions.

$$H_2O \rightleftharpoons H^+ + OH^-$$

In pure water $[H^+] = [OH^-] = 10^{-7}$ at 25°C.

(ii) With metals : It reacts with active metals and evolves hydrogen. The reaction is exothermic in the case of alkali and alkaline earth metals.

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

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

(iii) Reaction with non metals :

Chlorine decomposes cold water forming HCl and HClO.

$$Cl_2 + H_2O \rightarrow HCl + \underset{\text{(Hypochlorous acid)}}{HClO}$$

When steam is passed over red hot coke (1000°C), water gas is formed.

$$C + H_2O \rightarrow \underbrace{CO + H_2}_{\text{Water gas}}$$

(iv) Action on nonmetalic oxides : Acidic oxides combine with water to form acids.

$CO_2 + H_2O \rightleftharpoons H_2CO_3$	(Carbonic acid)
$SO_2 + H_2O \rightarrow H_2SO_3$	(Sulphurous acid)
$SO_3 + H_2O \rightarrow H_2SO_4$	(Sulphuric acid)
$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$	(Orthophosphoric acid)
$N_2O_5 + H_2O \rightarrow 2HNO_3$	(Nitric acid)
$Cl_2O_7 + H_2O \rightarrow 2HClO_4$	(Perchloric acid)

(v) Action on metallic oxides: basic oxides combine with water to form alkalies.

$Na_2O + H_2O \rightarrow 2NaOH$

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

(vi) Action on hydrides, carbides, nitrides, phosphides : Water decomposes these compounds with liberation of hydrogen, acetylene (or methane), ammonia, phosphine respectively.

$CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$

$CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$

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

$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$

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

(vii) Hydrolysis : Many salts specially the salts of strong bases with weak acids, weak bases with strong acids and weak bases with weak acids undergo hydrolysis with water.

$CH_3COONa + H_2O \rightleftharpoons CH_3COOH + NaOH$

$CH_3COONH_4 + H_2O \rightleftharpoons CH_3COOH + NH_4OH$

Halides of nonmetals are decomposed by water.

$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$

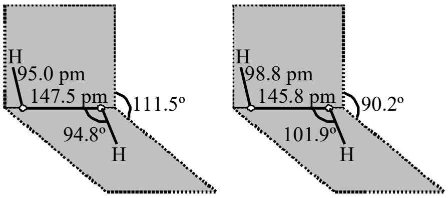
Uses of water :

1. There are countless uses for water. Not only does water substain life through several uses, but it is a critical component in manufacturing transport and energy.
2. The most common use of water is through drinking.
3. Agriculature use of water is one of the most common uses of water.
4. Water plays a critical role in numerous industries.

Hydrogen peroxide (H_2O_2)

Structure of H_2O_2

H_2O_2 has open book like structures.



(a) Gas phase (b) Solid phase

Methods of perparation of Hydrogen peroxide (H_2O_2)

Discovered by **L.J.Thenard**

(a) Lab method of preparation of H_2O_2 - H_2O_2 obtained by passing a current of CO_2 through a cold pasty solution of BaO_2 in water.

$BaO_2 + CO_2 + H_2O \rightarrow H_2O_2 + BaCO_3$

(b) Treating Na_2O_2 with H_2SO_4 -

(A) $Na_2O_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O_2$

(B) Also by small amount of Na_2O_2 added to ice cold water.

$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$

(c) Industrial process - By electrolysis of 50% H_2SO_4 at 0°C using Pt electrode.

$2H_2SO_4 \rightarrow 2H^+ + 2HSO_4^-$

At cathode (Pt) - $2H^+ + 2e^- \rightarrow H_2$

At anode (Pt) - $2HSO_4^- \rightarrow H_2S_2O_8 + 2e^-$

$H_2S_2O_8 + 2H_2O \rightarrow H_2O_2 + 2H_2SO_4$

(d) Electrolysis of ammonium hydrogen sulphate : In the electrolysis of ammonium hydrogen sulphate, ammonium per sulphate is formed. It is separated and distilled with dil. H_2SO_4 to give 30 - 40% H_2O_2 (aqueous solution).

$NH_4HSO_4 \Leftrightarrow NH_4SO_4^- + H^+$

At cathode :

$2H^+ + 2e^- \rightarrow H_2$(reduction)

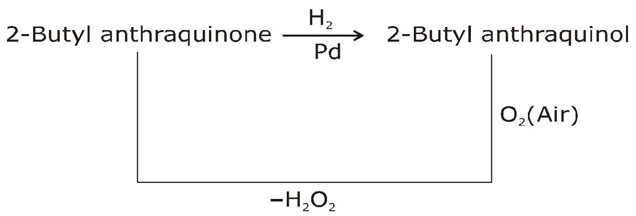
At anode :

$2NH_4SO_4^- \rightarrow (NH_4)_2S_2O_8 + 2e^-$ (oxidation)

Distillation :

$(NH_4)S_2O_8 + 2H_2O \xrightarrow{H_2SO_4} 2NH_4HSO_4 + H_2O_2$

(e) Auto - oxidation of 2-butyl anthraquinol : This is the most modern method and needs H_2, atmospheric oxygen and water as the major raw material.



Physical properties of H_2O_2

(a) Pure H_2O_2 is weak acidic in nature and exist as associated liquid due to hydrogen bonding.

(b) Smell of H_2O_2 resembles like nitric acid.

(c) It causes blisters on skin.

(d) Stored in plastic containers after addition of stabilizers.

(e) A dilute solution of H_2O_2 is concentrated by vacuum distillation or by distillation under pressure.

Chemical reaction

(a) Decomposition : $2H_2O_2 \rightarrow 2H_2O + O_2$

Pt, Au, Ag accelerates its decomposition while acetanilide, alcohol acts as negative catalyst to retard the decomposition of H_2O_2.

(b) H_2O_2 acts as oxidising and reducing agent in acidic as well as alkaline medium :

(i) Oxidising action

(1) Black lead sulphide to white lead sulphate

$$\underset{\text{(Black)}}{PbS} + 4H_2O_2 \rightarrow \underset{\text{(White)}}{PbSO_4} + 4H_2O$$

(2) Acidified potassium dichromate is oxidised to blue peroxide of chromium, confirmatory test of H_2O_2.

$$K_2Cr_2O_7 + H_2SO_4 + 4H_2O_2 \rightarrow \underset{\text{(Blue colour)}}{2CrO_5} + K_2SO_4 + 5H_2O$$

(3) Bleaching action -

Coloured material + (O) → Colourless

It bleaches materials like silk, hair, cotton, wool etc.

(ii) Reducing Action -

(1) It reduces Ag_2O to silver -

$Ag_2O + H_2O_2 \rightarrow 2Ag + H_2O + O_2$

(2) Acidified $KMnO_4$ is decolourised by H_2O_2

$2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$

(3) It reduces potassium ferricyanide to potassium ferrocyanide

$2K_3[Fe(CN)_6] + 2KOH + H_2O_2 \rightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$

Uses of hydrogen peroxide

(1) As germicide and antiseptic due to its oxidising property.

(2) As fuel for rocket.

(3) In refreshing old oil paintings due to formation of black PbS. H_2O_2 converts it into white $PbSO_4$.

$PbO + H_2S \rightarrow PbS + H_2O$
(White) (Black)

$PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$
(White)

Soft and Hard water

Soft water give lather easily while hard water give with difficulty

Temporary Hardness

Because of bicarbonates of Ca and Mg (removed by boiling or by adding slaked).

$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + H_2O + CO_2$

Clark's method -

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

Permanent hardness

Because of sulphates, chlorides of Ca & Mg
(removed by Permutit process, by washing soda, by calgon's process & by synthetic resin method).

(a) By Permutit Process -

Permutit is sodium alumino silicate ($Na_2Al_2SiO_3 . x H_2O$) or sodium zeolite (Na_2Z) where Z is $Al_2SiO_3 . xH_2O$. It is insoluble in water & has the property to exchange basic radical which helps in softening water.

$Na_2Z + CaSO_4 \rightarrow CaZ + Na_2SO_4$

(b) By washing soda (Na_2CO_3) -

$MgCl_2 + Na_2CO_3 \rightarrow MgCO_3 + 2NaCl$

$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

In place of sodium carbonate, caustic soda or sodium phosphate can also be used.

$MgCl_2 + 2NaOH \rightarrow \underset{\text{Insoluble}}{Mg(OH)_2} + 2NaCl$

$3MgSO_4 + 2Na_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3Na_2SO_4$

(c) Calgon's method : Sodium hexametaphosphate ($Na_6P_6O_{18}$), commercially called 'calgon', when added to hard water, the following reactions take place.

$N_6P_6O_{18} \rightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$ (M = Mg, Ca)

$M^{2+} + Na_4P_6O_{18}{}^{2-} \rightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$

The complex anion keeps the Mg^{2+} and Ca^{2+} ions in solution.

(d) Synthetic resins method : Nowadays hard water is softened by using synthetic cation exchangers. This method is more efficient than zeolite process. Cation exchange resins contain large organic molecule with - SO_3H group and are water insoluble, Ion exchange resin (RSO_3H) is changed to RNa by treating it with NaCl. The resin exchanges Na^+ ions with Ca^{2+} and Mg^{2+} ions present in hard water to make

$2RNa(s) + M^{2+}(aq) \rightarrow R_2M(s) + 2Na^+(aq)$

The resin can be regenerated by adding aqueous NaCl solution. Pure de-mineralised (de-ionized) water free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the H^+ form) and an anion exchange (in the OH^-) resins :

$2RH(s) + M^{2+}(aq) \rightleftharpoons MR_2(s) + 2H^+(aq).$

In this cation exchange process, H^+ exchange for Na^+, Ca^{2+}, Mg^{2+} and other cations present in water. This process results in proton release and thus makes the water acidic. In the anion exchange process

$RNH_2(s) + H_2O(\ell) \rightleftharpoons RNH_3^+.OH^-(s)$

$RNH_3^+.OH^-(s) + X^-(aq) \rightleftharpoons RNH_3^+.X^-(s) + OH^-(aq)$

OH^- exchange for anions like Cl^-, HCO_3^-, SO_4^{2-} etc. present in water. OH^- ions, thus, liberated neutralize the H^+ ions set free in the cation exchange.

$H^+(aq) + OH^-(aq) \longrightarrow H_2O(\ell)$

The exhausted cation and anion exchange resin beds are regenerated by treatment with dilute acid and alkali solution respectively.

Heavy water (D_2O)

Method of Preparation:

Repeated electrolysis of H_2O : On electrolysis of water (impure) H_2O dissociate into H^+ & OH^- while a fractional part of D_2O will dissociate into D^+ & OD^-

$H_2O \rightleftharpoons H^+ + OH^-$

$D_2O \rightleftharpoons D^+ + OD^-$

D^+ & OD^- due to more mass have less mobility i.e. why H^+ & OH^- will move towards cathode & anode respectively while D^+ & OD^- will be in solution.
This process will repeated for six time.

Properties of Heavy water:

Physical properties: (a) Heavy water is a colourless, odourless and tasteless mobile liquid; (b) Nearly all the physical constants are higher than the corresponding values of ordinary water.

Chemical properties:

Heavy water is chemically similar to ordinary water. However, D_2O reacts more slowly than H_2O in chemical reactions.

(a) Action of metals: D_2O reacts with alkali and alkaline earth metals liberates heavy hydrogen.

$$2D_2O + 2Na \rightarrow \underset{\text{Sodium deuteroxide}}{2NaOD} + D_2$$

$$2D_2O + Ca \rightarrow \underset{\text{Calcium deuteroxide}}{Ca(OD)_2} + D_2$$

(b) Action with metallic oxides: D_2O reacts slowly with basic oxides to form heavy alkalies.

$Na_2O + D_2O \rightarrow 2NaOD$

$CaO + D_2O \rightarrow Ca(OD)_2$

(c) Action with nonmetallic oxides: D_2O reacts slowly with acidic oxides to form deutero acids.

$$N_2O_5 + D_2O \rightarrow \underset{\text{Deutero nitric acid}}{2DNO_3}$$

$$P_2O_5 + 3D_2O \rightarrow \underset{\text{Deutero phosphoric acid}}{2D_3PO_4}$$

$$SO_3 + D_2O \rightarrow \underset{\text{Deutero sulphuric acid}}{D_2SO_4}$$

(d) Action with metallic carbides, phosphides, nitrides, arsenides, etc.: Like H_2O heavy water reacts with carbides, phosphide nitrides, arsenides, etc. to form corresponding deutero compounds.

$$CaC_2 + 2D_2O \rightarrow Ca(OD)_2 + \underset{\text{Deutero acetylene}}{C_2D_2}$$

$$Al_4C_3 + 12D_2O \rightarrow 4Al(OD)_3 + \underset{\text{Deutero methane}}{3CD_4}$$

$$Mg_3N_2 + 6D_2O \rightarrow 3Mg(OD)_2 + \underset{\text{Deutero ammonia}}{2ND_3}$$

$$AlN + 3D_2O \rightarrow Al(OD)_3 + \underset{\text{Deutero ammonia}}{ND_3}$$

$$Ca_3P_2 + 6D_2O \rightarrow 3Ca(OD)_2 + \underset{\text{Deutero phosphine}}{2PD_3}$$

$$Na_3As + 3D_2O \rightarrow 3NaOD + \underset{\text{Deutero arsine}}{AsD_3}$$

(e) Electrolysis: A solution of heavy water containing Na_2CO_3 when electrolysed evolve heavy hydrogen at cathode.

$$2D_2O \xrightarrow{\text{Electrolysis}} \underset{\text{(cathode)}}{2D_2} + \underset{\text{(Anode)}}{O_2}$$

Uses : As a neutron moderator : Fission in uranium-235 is brought by slow speed neutrons. The substances, which are used for slowing down the speed of neutrons, are called moderators. Heavy water is used for this purpose in nuclear reactors.

ENVIRONMENTAL CHEMISTRY

Indroduction

(i) Pollution may be defined as any undesirable change in the physical, chemical or biological characteristics of air, water and soil which may cause any harm to man and other living organisms of the environment.

Types of pollutants

The agents causing pollution are termed as **pollutants**.

A. On the basis of form of their occurrence, pollutants are divided into two categories.

(i) **Primary pollutants** – These are present in the same form in which they are produced. eg. carbon monoxide, DDT

(ii) **Secondary pollutants** – These are formed by reaction between the primary pollutants in the presence of sunlight eg. PAN, Ozone, HNO_3 H_2SO_4 etc. Nitrogen oxides and hydrocarbons react photochemically to produce peroxyacetyl nitrates (PAN) and ozone.

The secondary pollutants may be more toxic than the primary once. The phenomenon is called **synergism**.

B. On the basis of their degradation, pollutants are divided into two categories.

(i) **Biodegradable Pollutants** – Pollutants which are decomposed or degraded by biological or microbial action are called biodegradable pollutants eg. domestic sewage.

(ii) **Non-biodegradable Pollutants** – Pollutants which are not decomposed or degraded by living organisms or micro-organisms are called non-biodegradable pollutants eg. DDT, glass, plastics, aluminium cans, phenolic compounds, pesticides, radioactive substances, heavy metals like mercury, lead, cadmium etc.

C. On the basis of their existance in nature, pollutants are divided into two categories.

(i) **Quantitative pollutants** – These are naturally present in nature and are also added by man. These become pollutants only when their concentration reaches beyond a threshold value in the environment. eg. CO_2.

(ii) **Qualitative pollutants** – These are not present in the nature but are added in nature only due to human activities eg.

insecticides, fungicides, herbicides etc.

Kinds of pollution

On the basis of environmental study pollution is of following types.

(1) Air pollution
(2) Water pollution
(3) Soil pollution
(4) Noise pollution
(5) Radioactive pollution

(1) Air pollution

(i) It is mainly caused by industries and automobiles. Automobiles are the greatest pollutior of the atmosphere and are responsible for 75% of noise pollution and about 60-80% of air pollution of big cities.

(ii) The combustion of fossil fuels (coal, oil, gas etc.) releases CO, CO_2, nitrogen oxides, fluorides, hydrocarbons etc. into atmosphere usually in the form of smoke causing air pollution.

(iii) Particulate matters released by mills, factories and mines also cause air pollution.

(iv) Some of the natural air pollutants are pollen grains, spores, volcanoes etc.

Major air pollutants

(I) Carbon monoxide –

(i) It is formed by incomplete combustion of fuels in various industries, automobiles etc.

(ii) CO accounts for about 50% of total air pollution. It is largest pollutant in Delhi's air.

(iii) CO combines with haemoglobin, produces **carboxyhaemoglobin** and therefore decreases oxygen carrying capacity leading to hypoxia, headache, decreased vision, muscular weakness, nausea, exhaustion etc.

(iv) When 50% of haemoglobin has been transformed into carboxyhaemoglobin, then death occurs due to CO-poisoning leading to anoxia (oxygen starvation)

(II) Carbon dioxide –

(i) It is a **green house gas**. It is produced due to combustion of fuels, volcanic eruptions and during the process of respiration.

(ii) Its average concentration in the atmosphere is 300 ppm (0.03%) .

(iii) It is normally not an atmospheric pollutants, but under very high concentration it may act as a pollutant.

(iv) It causes **Global warming** .

(III) Sulphur dioxide (SO_2) –

(i) It is produced during combustion of fossil fuels (mainly coal) and smelting of sulphur containing ores.

(ii) It causes acid rain (gaseous SO_2 oxidises to SO_3, which on combination with water forms H_2SO_4).

(iii) Acid rain is 60-70% due to SO_2 and SO_3, and 30-40% due to NO_2 and NO_3.

(iv) Due to acid rain the leaves develop chlorotic and necrotic spots.

(v) SO_2 corrodes stones, metals, leather, paper and fabrics. There is deterioration of colour and lusture of fabries, stones and painted surfaces.

(vi) **Tajmahal of Agra** is affected by gases (SO_2, H_2S etc.) discharged from oil refinery of Mathura.

(vii) **Lichens** (*e.g.* ***Usnea***) are extremly sensitive to SO_2 and could be regarded as indicators of SO_2 pollution. (indicators of air pollution)

(viii) Garden pea is another SO_2 pollution indicator.

(ix) Lichen vegetation (*parmelia, usnea, cladonia,*) Garden pea and mosses are completely destroyed due to SO_2.

(x) SO_2 causes chlorosis (destruction of chlorophyll) and necrosis of vegetation, membrane damage and yeild reduction.

(xi) In plants and animals, SO_2 destroys all membrane systems.

(xii) In human beings SO_2 increases the chances of occurence of asthma, bronchitis and emphysema.

(xv) It produces eye irritation, damage respiratory tract.

(IV) Hydrocarbons –

(i) They are produced naturally (e.g. marsh gas CH_4) and by burning of petroleum.

(ii) Benzene (C_6H_6) is a major constituent of petrol and automobile exhaust.

(iii) Hydrocarbons are carcinogenic, cause irritation of eyes and mucous membrane.

(iv) Benzene is a known carcinogen causing **leukemia**.

(v) Ethylene (C_2H_4) causes premature senescence and abscission in many plants especially in orchids and cotton,

(vi) Methane (marsh gas) has the potential of destroy ozone.

(V) Nitrogen oxides –

(i) There are three oxides of nitrogen which act as air pollutants : Nitric oxide (NO), nitrogen dioxide(NO_2) and nitrogen trioxide(N_2O_3).

(ii) Nitrogen and oxygen combine together at high temperature in any combustion process to produce nitrogen oxides.

(iii) These are also released by furnaces, forest fires, industries and denitrifying bacteria.

(iv) NO is less toxic but NO_2 is a poisonous gas.

(v) Nitrogen oxides are responsible for forming photochemical smog.

(vi) They also cause acid rain due to formation of HNO_3.

(vii) They produce lesions, necrosis, defoliation, dieback and death of many plants.

(viii) Like SO_2, they corrode metals and deteriorate paints, textiles as well as various articles.

(ix) They cause eye irritation, dilation of arteries, injury of lungs, liver and kidneys.

(VI) Fluorides –

(i) Fluorides are emitted during refinement of aluminium and rock phosphates .

(ii) Fluorides cause necrosis and chlorosis of leaf tips and leaf margins.

(iii) In human fluorides cause mottling of teeth, weak bones, boat-shaped posture, knocking knees etc.

(iv) Disease caused by fluoride is known as **fluoosis**.

(VII) Particulate matter –

(i) It is the non-gaseous matter in the atmosphere.

(ii) It consists of soot, dust, mist, fibres, fly ash, fur, spores, pollen grains etc.

(iii) It is of two types settleable (larger than 10 μm) and suspended (less than 10μm)

(iv) SPM (suspended particulate matter) is classified into 3 categories –

- (a) Aerosols (less than 1 μm)
- (b) Dust (solid particles with more than 1 μm diameter)
- (c) Mist (liquid particles with more than 1 μm diameter)

(v) It is added in the atmosphere by burning of fuels.

(vi) Particulate matter causes about 10-15% of air pollution.

(vii) Under condition of high humidity, the particulate matter causes corrosion and erosion of surfaces.

(viii) In human beings, it may cause respiratory problems.

(ix) Particulate matter from processing industries (eg. cotton dust, iron mill dust, flour mill dust, mine dust) causes **pneumoconiosis**, byssinosis, siderosis, emphysema and other pulmonary problems.

(x) The asbestos fibers cause asbestosis which is a type of cancer.

(xi) Dust and smoke produce smog.

(xii) The ill effects of different kinds of dusts are listed below –

(a) Coal dust – **Anthracosis**
(b) Silica – **Silicosis**
(c) Asbestos – **Asbestosis**, Lung cancer
(d) Iron – **Siderosis**
(e) Cotton dust – **Byssinosis**
(f) Hay or grain dust – **Farmer's lung**

(VIII) Aerosols –

(i) These are chemicals released in the air with force in the form of mist or vapour by jet planes.

(ii) Aerosols contain **CFC (chlorofluor-ocarbons)** which destroy ozone layer in the stratosphere. This permitting some more harmful

(iii) U.V. radiations to reach the earth surface, U.V. radiations cause skin cancer and increases mutation rates.

(iv) Ozone acts as preventive shield against the U.V. rays.

(v) Freons are several CFMS (chlorofluoromethanes) released into troposphere where they dissociates and release free chlorine that causes depletion of ozone.

(vi) Freon or CFC also used in refrigerator, air conditioners and in making plastic foams.

Effect of air pollutants

Air pollutants are involved in causing four major environmental effects :

(1) smog (2) acid rain

(3) global warming and (4) ozone layer depletion.

(1) Smog –

(i) The term smog was coined by Des Voeux.

(ii) It is produced by the combination of smoke and fog.

(iii) It causes silvering/glazing and necrosis in plants, allergies and asthma/bronchitis in human.

(iv) Smog is of two types :

(a) **Classical or London smog or sulphurous smog** – It occurs at low temperature andcontainsH_2S, SO_2, smoke and dust particles. It was first observed in winter months at London in 1905. It is formed due to domestic and industrialcombustion of coal.

(b) **Photochemical smog or Los Angeles smog** – It was first observed in the mid day at Los Angeles in 1943. The cause of this smog was thought to be due to combustion of petroleum in automobiles. Photo chemical smog occurs at high temperature over cities and towns. It is formed by the reaction of two air pollutants nitrogen oxides (mainly NO_2) and hydrocarbons (HC) that react with one another in the presence of UV radiations of sunlight to produce ozone (O_3) and PAN (peroxyacetyl nitrate) which constitute the photochemical smog.

$$\text{Nitrogen oxides} + \text{Hydrocarbons} \xrightarrow[\text{of sunlight}]{\text{U.V.radiation}} \text{PAN} + \text{Ozone}$$

Ozone and PAN are commonly referred to as oxidants. Breathing ozone affects the respiratory and nervous system, resulting in headache, respiratory distress and exhaustion. It also causes irritation in eyes and asthma. The ozone is known to destroy crops of potato, alfalfa and spinach to the extent of 50%. It also damages leaves of tobacco, tomato and pine as also the grap fruits. Besides, the PAN also blocks Hill reaction of photosynthesis.

(2) Acid rain –

(i) The coal and oil burned by power plants release SO_2 into the air.

(ii) Automobile exhaust puts NO_2 in the air.

(iii) Both SO_2 and NO_2 are converted to acids (H_2SO_4 and HNO_3 respectively) when they combine with water vapour in the presence of O_2 in the atmosphere. These acids return to the earth as acid rain.

(I) $NO + O_3 \longrightarrow NO_2 + O_2$ $\quad NO_2 + O_3 \longrightarrow NO_3 + O_2$

$NO_2 + NO_3 \longrightarrow N_2O_5$ $\quad N_2O_5 + H_2O \longrightarrow 2HNO_3$

(II) $2SO_2 + O_2 \xrightarrow{\text{No.soot or metalions}} 2SO_3$

(iv) The pure rain has a pH of about 5.6 while the acid rain has pH below 5.6.

(v) Acid rain is actually a mixture of H_2SO_4 and HNO_3 (usually 60-70% H_2SO_4 and 30-40% HNO_3)

(vi) Acid rain affects the ability of the trees to tolerate cold temperatures and the weakened trees are killed by cold conditions or become more susceptible to diseases.

(vii) Acid rain leaches lead, mercury and calcium, from the soils and rocks and discharges them into rivers and lakes. The metals may become concentrated in fish and then passed on to people through food chain.

(viii) Acid rain also damages building materials, including steel, paint, plastics, cement and marble.

(3) **Green house effect and Global warming** –

(i) The sunlight that reaches to the earth, warms both atmosphere and the earth surface. The earth's atmospheric system then reradiates the heat as infra-red radiations.

(ii) Gases like CO_2 , CH_4, CFCs, NO_2 are strong absorbers of long-wave or infra-red radiations emitted by the surface of the earth, and warm the earth's atmosphere. This is called the **green house effect** because it is like the glass panel of a green house that allows sunlight to pass through and then traps the resulting heat inside the structure.

(iii) CO_2 in the principal green house gas responsible for warming of the earth.

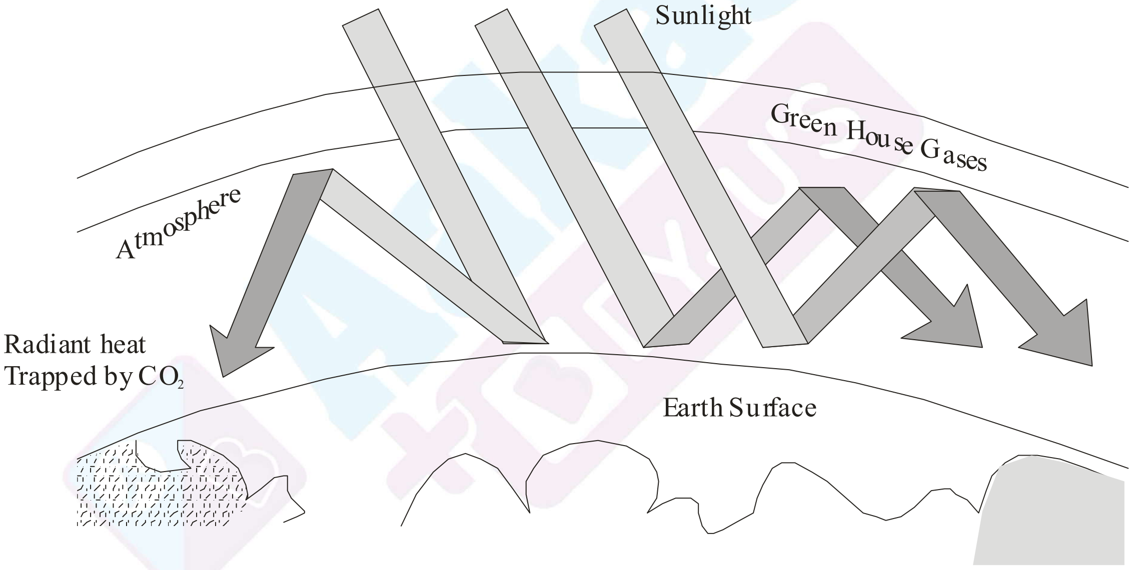


Fig. The green house effect of CO_2

(iv) CO_2 is rising into the atmosphere slowly as a result of large scale burning of fossil fuels (coal, oil etc), volcanic activities and respiration

(v) 50% of the increase in earth's temperature in due to CO_2, 20% is due to CFCs and remaining 30% is due to other gases.

(vi) Some ecologists visualise that the green house effect shall lead to global warming. In the next fifty years time the temperature of earth shall rise by 2° – 5°C.

(vii) A rise of global temperature by 2 to 5°C may lead to

(a) Melting of glacies and polar ice caps.

(b) Flooding of low lying coastal plains.

(c) Increase in the flow of rivers and change in rainfall pattern.

(d) Possible submersion of islands.

(viii) The UNEP (United Nations Environment Programme) has appropriately choosen the slogan "Global Warming : Global Warning" and since 1989, 5th june is celebrated as World Environment Day.

(4) Ozone layer depletion –

(i) The ozone layer present in the stratosphere acts as an ultraviolet absorbant thus protecting the earth from its harmful effect.

(ii) Depletion/destruction of ozone layer is primarily caused by CFCs (Chlorofluoro carbons) and halons (halocarbons $C_xF_x Br_x$)

(iii) CFCs are heat transfer agents used in refrigerators, air conditioners, fire extinguishers.

(iv) Halons are antifire agents used in fire extinguishes.

(v) The CFCs react with ozone and thus cause thining of ozone layer which permits more UV radiations to reach the surface of earth.

(vi) UV radiations cause mutations that can develop skin cancer and cause eye cataracts. UV rays also affect our immune system.

(vii) Severe depletions of ozone layer are commonly called ozone holes.

(viii) A hole in the ozone layer has been discovered in the Antarctica region. There was a severe depletion of some 40–50% above the Antarctica region.

(ix) The ozone layer depletion is caused by chlorine atoms. These chlorine atoms comes from the break down of CFCs. These atoms combine with ozone and remove the oxygen atoms one by one.

$Cl + O_3 \rightarrow ClO + O_2$

$ClO + O \rightarrow Cl + O_2$

(x) One atom of chlorine can destroy upto 100,000 molecules of ozone.

(xi) Most countries of the world have agreed to stop using CFCs by the year 2000.

Bhopal gas tragedy

Occured on 2nd December 1984, when a poisonous gas **MIC** (**methyl isocynate**) was leaked in the atmosphere from a fertilizer plant of union carbide company. MIC was used to manufacture an insecticide marked in the name of SAVIN. The gas caused death of about 2500 persons. December 2 is recalled as National Pollution Prevention Day.

Important days

- Hiroshima day – 6th August –
- World earth day – 22nd April
- World environment day – 5th june

- International day for preservation of ozone layer
  [OR] Ozone day – 16th September
- Bhopal gas tragedy – 2nd December,1984

Important abbreviations

- N.E.E.R.I. – National Environmental Engineering Research Institute, Nagpur.
- I.U.C.N. – International Union for Conservation of Nature and Natural Resources, Switzerland.
- C.P.C.B. – Central Pollution Control Board.
- U.N.E.P. – United Nations Environment Programme.
- O.D.P. – Ozone Deplecting Potential. (It is maximum in CFCs)
- I.A.P. – Indices of Atmospheric Pollution. [prepared with the help of lichens (sensitive to SO_2)]
- C.N.G. – Compressed Natural Gas
- C.T.B.T – Comprehensive Test Ban Treaty
- C.S.E. – Centre for Science and Environment.

Important acts to control air pollution

- National Environment Policy Act, 1969
- Air (Prevention and Control of Pollution)Act, 1981 (water act, 1974)
- Environment Protection Act, 1986
- Motor Vehicle Act, 1988

Important points

(i) Benzpyrene/polycyclic hydrocarbon is a powerful carcinogen (cancer causing agent). It is emitted by cigarette smoking, combustion of petrol, diesel etc.

(ii) Carbon monoxide (CO) accounts for about 50% of total air pollution .

(iii) Sulphur dioxide (SO_2) accounts for 6% of total air pollution.

(iv) Particulate matter accounts for 10 -15% of total air pollution.

(v) First Earth Summit of United Nations Conference on Environment and Development (UNCED) was held at Rio-de-Janerio (Brazil) in 1992.

(vi) First International Conference on “Environment and Development” was held at Stockholm in 1972.

(vii) Second International Conference on “ Environment and Development “ was held at New Delhi in 1985.

(viii) Cyclon collector is used for minimising air pollution.

(ix) Most polluted city of the world – Tokyo (Japan)

(x) Most polluted city of India – Kolkata.

(xi) In Delhi and Kolkata pollution is mainly due to automobiles and fire.

(xii) In Mumbai pollution is mainly due to industries.

(xiii) Cotton dust is main source of air pollution in Surat and Ahmedabad.

(xiv) Level of suspended particulate matter (SPM) concentration is highest in the atmosphere of Kolkata.

(xv) In Bihar and Andhra Pradesh major source of air pollution is thermal power plants.

(xvi) Pittsburg city (USA) was once named as “Smoke city “.

(xvii) The automobile emission can be reduced by adding barium salts in the petrol.

(xviii) CFCs have maximum Ozone Depleting Potential (ODP)

(xix) Ozone, PAN, HNO_3 and H_2SO_4 are secondary pollutants.

(xx) Green Charter– Drawn by the World Wildlife Fund for Nature for India in December, 1997. It states that “ Protection of environment is crucial for human survival and well being now and in future”.

(xxi) Excessive inhalation of manganese causes pneumonia.

(xxii) Methane is released by cud–chewing domestic animals.

(xxiii) Excess of pollen causes allergic reactions in several human beings. The common reactions are collectively called hay fever.

(xxiv) The smoke reduces visibility. To visualise the extent of darkness caused due to smoke Ringelmann charts are used.

(xxv) Tocofarol produces resistance against carcinogen.

(xxvi) Formation of ozone hole is maximum over Antarctica.

(2) Water Pollution

Water pollution is defined as the addition of some substances (organic, inorganic , biological, radio logical) or factor (eg. heat) which degrades the quality of water so that, it either becomes health hazard or unfit for use.

Kinds of water pollution

The water pollution may be physical, chemical or biological.

(a) **Physical pollution** – It involves the changes in the physical properties of water eg. colour, taste, adour, temperature, turbidity etc.

(b) **Chemical pollution** – It is caused due to change in the chemical properties of water. They mainly include the pH, dissolved O_2, inorganic or organic chemicals, heavy metals etc.

Inorganic chemicals include fluorides, chlorides, phosphates and nitrates. Organic chemicals include phenols, dyes, pesticides and chlorocompounds.

(c) **Biological pollution** – It is caused due to the presence of living organisms in water such as algae, fungi, bacteria, viruses, protozoans, insects etc.

Sources of water pollution and effects of water pollutants

Water pollution is a serious health hazards in India, especially in villages. It is estimated that 50-60% of Indian population suffers from diseases caused by it. 30-40% of all deaths are believed to be due to it. The principal sources of water pollution and effects of water pollutants are as follows.

Domestic wastes and sewage

(i) Sewage containing human faeces, urine, kitchen and cloth washings, organic waste, industrialwaste etc. is usually poured into water bodies which cause water pollution.

(ii) The villagers often wash their animals, cloths and take bath in the same pond. Such water get contaminated with infectious agents for cholera, typhoid, dysentery, Jaundice and skin diseases.

(iii) Sewage provide food for decomposers, so the population of decomposers increases.

(iv) Decomposers/micro-organisms causing decomposition of sewage take up most of the oxygen present dissolved in water. So in this water BOD (Biological oxygen demand or Biochemical oxygen demand) increased very much.

(v) BOD is the amount of oxygen in milligrams required by micro-organisms for five days to metabolise waste present in one litre of water at 20°C .

(vi) A weak organic waste will have BOD below 1500 mg/litre, medium organic waste between 1500 – 4000 mg/litre while in strong waste above 4000 mg/litre.

(vii) The degree of pollution is directly proportional to BOD.

(viii) In sewage phosphorous and nitrogen compounds are present which are necessary for the growth of algae. In polluted water these are accumulated which result into excessive growth of algae on water surface. Excessive growth of algae is called **water bloom** .

(ix) The phosphates present in detergents stimulate algal growth in the water bodies and cause eutrophication.

(x) Presence of extra nutrients brings about dense growth of plants and animals life. The phenomenon is called **eutrophica-tion**.

(xi) Eutrophication leads to organic loading, depletion of oxygen,death of animals and fouling of water.

(xii) Sewage produces foul odour and makes the water brownish and oily.

Pollutant	Source
Micro-organisms	Domestic sewage
Organic wastes	Domestic sewage, animal excreta and waste, decaying
Plant nutrients	Chemcial fertilizers
Toxic heavy metals	Industries and chemical factories
Sediments	Erosion of soil by agriculture and strip mining
Pesticides	Chemicals used for killing insects, fungi and weeds
Radioactive substances	Mining of uranium containing minerals
Heat	Water used for cooling in industries

Industrial effluents (or industrial discharges)

Industries usually discharge waste water into ponds, lakes and rivers. Industrial waste water contains heavy metals (mercury, lead, copper, arsenic and cadmium), inorganic pollutants (acids, alkalies and bleaching liquors), organic pollutants (phenol, naphtha, proteins, aromatic compounds, cellulose fibres etc.) Industrial effluents are the most hazardous pollutants on land and water.

(a) **Mercury (Hg)** –

(i) It is released during combustion of coal, smelting of metallic ores, paper and paint industries.

(ii) Mercury is highly persistent . In water it gets changed into water soluble dimethyl form $[(CH_3)_2Hg$ and enters the food chain (undergoes biomagnification).

(iii) It kills fish and poisons the remaining fauna. Human beings feeding on such poisoned animals develop a crippling deformity called **minamata disease** which is characterised by impairment of various senses, diarrhoea, haemolysis, meningitis and death.

(iv) The minimata disease was first detected in Japan.

(v) Mercury inhibits chromosomal disjunction during gamete formation. So it brings about genetic changes also.

(b) Lead (Pb) –

(i) The sources of lead pollution are smelters, battery industry, paint, chemical and pesticide industry, automobiles exhausts etc.

(ii) Lead is pollutant of air, soil and water.

(iii) It is used as anti-knock reagent in petrol and released by automobile exhausts.

(iv) Lead is a persistant pollutant and may show biological amplification or biomagnification.

(v) It is a mutagenic and causes anemia, headache, vomitting, colic, loss of muscle power, bluish lines around the gums, loss of appetite and damage of liver, kidney and brain.

(c) Cadmium (Cd) –

(i) It is added to the environment by metal industries, welding and electroplating, pesticides and phosphate industries.

(ii) Cd shows biological amplification and accumulates inside kidneys, liver, pancreas and spleen.

(iii) It causes hypertension, anemia, diarrhoea and damages liver and kidneys.

Metal	**Maximum concentration (ppm or mg dm^{-3})**
Fe	0.2
Mn	0.05
Al	0.2
Cu	3.0
Zn	5.0
Cd	0.005

Oil

(i) During extraction and transportation of oil from the sea to different parts, some of the oil spreads over the surface of water. Refineries also discharge a lot of oil present in their effluents into rivers.

(ii) Oil spreading on the surface of water prevents its oxygenation and inhibits photosynthetic activity of aquatic plants. Animal life is destroyed due to reduced availability of oxygen , food and toxic effects of oil.

(iii) Oil spilled over the surface of water may catch fire and hence kill all organic life.

Thermal pollution

(i) Hot water is produced by many industries , power generation plants and thermal power plants-.

(ii) Thermal pollution is caused by addition of hot water effluents in water bodies, it bring about rise in water temperature.

(iii) Warmer water contains less oxygen. Therefore, there is decrease in the rate of decomposition of organic matter.

(iv) In hot water green algae are replaced by less desirable blue green algae.

(v) Many organisms fail to reproduce in hot water e.g. Salmon, Trout.

Radioactive wastes

(i) The nuclear tests performed into sea pollute the water.

(ii) The animals and plants are affected by the remaining radioactivity of the wastes. Radioactive elements (eg. cesium –137, strontium –90, Iodine – 131) enter the human system.

(iii) Cesium–137 accumulates inside body muscles, strontium-–90 in bones while Iodine–131 in thyroid

(iv) Cesium – 137 brings about functional and genetic changes.

(v) Strontium – 90 causes blood and bone cancer.

(vi) Iodine – 131 affects normal functioning of thyroid.

Important points related to water pollution

(i) Some organism like Daphnia, Trout and fishes are sensitive to water pollution, they are indicator of water pollution.

(ii) I.W.P.– Indices of Water Pollution.

(iii) Drinking water rich in nitrates cause methemoglobinemia.

(iv) Faecal pollution is indicated by Escherichia coli. **MPN** is Most Probable Number of E-coli. It is indicator of water pollution.

(v) Algal Genus Index – High organic pollution is indicated by presence of 20 or more genera of algae in a water body. Growth of less than 5 genera of algae is indication of clear water. It is called as **Algal Genus Index** (AGI)

(vi) Water (Prevention and control of pollution) Act, 1974. It has been amended in 1988.

(vii) Putrescibility- – Decay and decomposition of organic matter present in water by bacteria and micro-organisms.

(viii) Silent spring– Novel written by Rachel Carson (1962) mentioning the effect of DDT on birds. DDT use has been banned in USA since then.

(ix) In India, DDT banned for agricultural use in 1985. It is a chlorinated hydrocarbon and show biomagnification.

(x) **Fluorosis** –13 states of India possess high fluoride content in drinking water (more than 1.5 mg/L) which causes fluorosis in human.

(xi) ABS (Alkyl Benzene Sulphonate)- – It is most harmful component of detergents causing water pollution.

(xii) Maize (Zea mays) is sensitive indicator of fluoride pollution.

(xiii) Ganga Action Plan started in 1985 for controlling pollution in Gangas.

(xiv) Reed plants yellow iris are used to purify water. This method of purifying water is called "Green method of water cleaning". Yellow iris plant is less affected by herbicides, so reed beds are highlyeffective in those areas where pesticides are in use and provides microbiological methods of pesticie detoxification. These plants filter out the particulate matter, while the microbes living in association with the plants, decompose the organic wastes.

(xv) **Endrin** is most toxic amongst chlorinated hydrocarbons.

(xvi) **Aldrin** in most persistent insecticide in the water and soil.

(xvii) Water hyacinth (Eichhornia) popularly known as Jalkumbhi or Kaloi, can purify water polluted by biological or chemical wastes. It can also filter out heavy metals like cadmium, mercury, lead and nickel as well as other toxic substances found in industrial waste waters.

(xviii) **Biotic index** :- It gives an idea of pollution of a particular water body. Any water body with a biotic index of more than 15 is clean, while index lower than 10 is polluted.

(xix) C.O.D. (Chemical Oxygen Demand) – It is amount of oxygen required to oxidise all pollutant materials is one litre of water at 20°C in five days. The value of COD is much higher than BOD.

(xx) B.O.D. of pure drinking water - Less than 1 ppm or mg/L

(xxi) Soil salinity can be measured by conductivity meter.

(3) Soil Pollution

(i) Unfavourable alteration of soil by addition or removal of substances and factors which decrease soil productivity, quality of plant products and ground water is called soil pollution.

(ii) The soil pollutants include pesticides, fertilizers, industrial wastes, salts, radionuclides , tin, iron, lead, copper, mercury, aluminium, plastics, paper, glass, broken bottles, discarded food etc.

Types of Soil pollution

Soil pollution is of two main types

(A) Negative soil pollution

(B) Positive soil pollution

(A) Negative soil pollution

(i) It includes over use of soil and erosion .

(ii) Soil erosion is caused by water and wind.

(iii) Water erosion of soil is found near the hills where high speed flooding removes top soil.

(iv) Soil erosion also occurs by high speed winds which bring sand particles from dry desert.

(B) Positive soil pollution

It is caused by addition of undesirable substances (eg. pesticides, fertilizers, industrial waste, air pollutant washed down from atmosphere through rain)

(a) Pesticides –

(i) These include insecticides (kill insects), fungicides (kill fungi), algicides (kill algal blooms), weedicides or herbicides (kill weeds), rodenticides (kill rodents).

(ii) Pesticides are generally broad-spectrum and affect other animals, man and even plants. They are hence, also called **biocides**.

(iii) DDT (dichloro diphenyl trichloroethane), BHC (benzene hexachloride or gamaxine), aldrin, dieldrin, endrin, heptachlor etc. are chlorinated hydrocarbons used as pesticides.

(iv) Dieldrin is five times more toxic than DDT when ingested and 40 times more poisonous when absorbed.

(v) Endrin in the most toxic amongst chlorinated hydrocarbons.

(vi) Chlorinated hydrocarbons are persistent, fat soluble and show **biomagnification**.

(vii) DDT and other chlorinated hydrocarbons affect CNS, cause softning of brain, cirrhosis of liver (liver cancer), cerebral haemorrhage, cancer, hypertension, thinning of egg shells in birds, malformation of sex hormones, failure of gonad development.

(viii) The population of certain birds (e.g. Bald **e**agle) has declined due to these biocides.

(ix) DDT also affects the photosynthetic activity of plants, especially phytoplankton.

(x) DDT was banned in 1985 for agricultural purpose in India.

(xi) In India concentration of DDT in fat tissue of people is 18-31 ppm.

(xii) The weedicides (or herbicides) are usually metabolic inhibitors which stop photosynthesis and other metabolic activities and hence kill the plants.

(xiii) 2,4-D, 2,4,5-T, DCMU and CMU are weedicides.

(b) Fertilizers –

(i) The fertilizers contain plant nutrients particularly N,P and K , but the soil also gets polluted mainly due to organic pollutants present as impurities.

(ii) Excessive use of fertilizers cause soil deterioration through decrease of natural microflora (nitrogen fixing, nitrifying bacteria)

(iii) Fertilizers added to soil enter the crop plants. Nitrogen fertilizers produce toxic concentration of nitrate in the leaves and fruits. When these leaves and fruits are eaten, nitrates changed into nitrites by the activity of bacteria in the alimentary canal. The nitrites enter the blood and combine with haemoglobin to form methemoglobin. As a result oxygen transport is reduced. It gives rise to disease known as **methemoglobinemia**. In infants it produces **cyanosis (blue baby syndrome)**

(c) Industrial wastes –

(i) Wastes of the industries are dumped over the soil. They contain a number of toxic substances including cyanides, acids, chromates, alkalies and metals like mercury, copper, zinc, lead, cadmium etc.

(ii) The industrial pollutants increase the toxicity level of the soil.

(iii) Heavy metals destroy useful micro-organisms of the soil.

(iv) In 1970 some 200 people died in Japan by Cd pollution of soil due to itai–itai disease.

(4) Noise Pollution –

(i) Various kinds of undesirable loud sounds, which disturb our environment are called noise pollutants.

(ii) Noise pollution is produced by loud sounds of various machines, loudly played radio, automobiles, thundering of jet planes, loud speakers etc.

(iii) The intensity of noise is measured in decibels (or dB).

(iv) The sound above 80 dB causes noise pollution.

(v) Moderate conversation produces 60 dB sound, loud conversation 70dB.

(vi) Scooter, buses, trucks etc. create noise of about 90 dB, Jet aeroplanes 150 dB, rocket 180 dB.

(vii) Noise pollution may cause hypertension (high B.P), respiratory and cardiac problems.

(viii) Noise stimulates the secretion of adrenaline which increases irritability, nervousness, neuromuscular tension and feeling of fatigue, so decreasing the working efficiency.

(ix) Noise has an adverse effect on mind health and behaviour of man.

(x) Noise may damage ear drum and eye sight.

(xi) Noise brings about interference in conversation and hearing.

(xii) The first effects of noise are anxiety and stress.

(xiii) Noise can impair the development of nervous system of unborn babies which leads to abnormalbehaviour in later life.

(xiv) Plantation of trees is very essential for reducing the noise pollution.

(xv) Green plants are being planted along the road sides to check the noise pollution. This is called as **Green muffler**.

(5) Radioactive pollution

(i) It is a special type of physical pollution of air, water and soil with radioactive materials.

(ii) Nuclear explosion results into production of radioactive substances as Sr^{90}, U^{235}. I^{131} and cause pollution of air, water and soil.

Sources of Radioactive pollution

(A) Natural (Background) radiations –

(i) These include cosmic rays that reach the earth surface from outer space and terristrial radiations from radioactive elements(radium–224, thorium -–232, uranium–235, uranium – 238, radon –222, carbon–14, potassium – 40 etc.) present in the earth's crust. These radioactive elementsare present in rocks, soil and water.

(ii) Maximum back ground radiation is found in Kerala beach where 75% of thorium deposits of the world are found

(iii) Monazite is the source of thorium.

(B) Man-made radiations –

Man made sources of radiations include mining and refining of plutonium, uranium and thorium, production and explosion of nuclear weapons, nuclear power plants, nuclear fuels and preparation of radioactive isotopes.

Green chemistry in day to day life

(i) Dry Cleaning of Clothes

Tetra chlroroethene ($Cl_2C{=}CCl_2$) was earlier used as solvent for dry cleaning. The compound contaminates the ground water and is also a suspected carcinogen. The process using this compound is now being replaced by a process, where liquefied carbondioxide, with a suitable detergent is used. Replacement of halogenated solvent by liquid CO_2 will result in less harm to ground water.

These days hydrogen peroxide (H_2O_2) is used for the purpose of bleaching clothes in the process of laundary, which gives better results and makes use of lesser amount of water.

(ii) Bleaching of paper

Chloring gas was used earlier for bleaching paper. These days, hydrogen peroxide (H_2O_2) with suitable catalyst, which promotes the bleaching action of hydrogen peroxide, is used.

(iii) Synthesis of Chemicals

Ethanal (CH_3CHO) is now commercially prepared by one step oxidation of ethene in the presence of ionic catalyst in aqueous medium with an yield of 90%.

$$2CH_2 = CH_2 + O_2 \xrightarrow[\text{Pd(III)/Cu(II)(in water)}]{\text{Catalyst}} 2CH_3CHO(90\%)$$

Green chemistry, in a nutshell, is a cost effective approach which involves reduction in material, energy consumption and waste generation.