UNIT-02 - Environmental chemistry :

→ Elements are pure substances made up of a single kind of atom, which is a basic building block of all matter in the universe.

→ chemical formula & symbols are used to identify elements.

118 Elements

Artificial - 24 Natural - 94.

classification of elements :-

→ Mendeleev's Approach for periodic law:

chemical & physical properties of elements are the periodic functions of **atomic mass** of corresponding element.

no. of proton + no. of neutron

→ Modern approach for the periodic law: chemical & physical properties of elements are the periodic functions of **atomic no.** of corresponding element.

no. of proton

Based on properties :-

Types	characteristics	ex
• Metals	Good conductor of heat & electricity, shiny, malleable	→ Fe, Cu, Al, Zn
• Non Metals	poor conductor, dull appearance, brittle	→ O, N, S, C
• Metalloids	properties b/w metal & non metals	→ Si, Ge, As, B

Stoichiometry :-

is the calculation of reactants & products in chemical reactions.

→ It is founded on **law of conservation of mass**.

→ It depends upon no. of moles

→ 1 moles = 6.023×10^{23}

- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- $C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

Molarity :-

$$M = \frac{\text{no. of moles of solute } (n)}{\text{Vol. in Litre} \quad V(l)}$$

$$n = \frac{\text{Given wt } (m)}{\text{Molecular wt } (M)}$$

~~$M = n$~~

$$M = \frac{m}{M \cdot V(l)}$$

Normality :-

$$= \frac{\text{No. of gram equivalent}}{\text{Vol. of so}^n \text{ in litre}}$$

$$\text{No. of gm equi} = \frac{\text{given wt}}{\text{Eq weight}}$$

$$\text{Eq wt} = \frac{\text{molecular wt}}{\text{z factor}}$$

$$N = \frac{\text{Given wt}}{\text{Eq wt} \times V(l)}$$

$$= \boxed{\frac{GW \times Z.F.}{MW \times V}}$$

$$\boxed{N = M \times Z.F.}$$

$$\text{No. of gm eq} = \frac{GW \times Z.F.}{MW}$$

$$\boxed{\text{No. of gm equi.} = \text{no. of mole} \times Z.F.}$$

Z-factors :

$H = 1$, $H_2 = 2$
$HCl = 1$
$H_3PO_2 = 1$
$NaOH = 1$
$O = 2$, $O_2 = 4$
$H_2SO_4 = 2$
$Mg(OH) = 2$
$MgCl_2 = 2$
$Na_2CO_3 = 2$
$NH_4SO_4 = 2$
$H_3PO_3 = 2$
$Al(OH)_3 = 3$
$H_3PO_4 = 3$
$K_2Cr_2O_7 = 6$

Molality :-

$$m = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

- mass based
- Temp. independent

Chemical Potential :

is a thermodynamic property that measures the change in total free energy when one particle or mole of a substance is added to a mixture while maintaining constant pressure, temp & other factors.

$$(\mu) \text{ chemical potential} = \left(\frac{\Delta G}{\Delta n}\right)_{T,P}$$

→ High CP - substance tends to move out

→ Low CP - substance tends to move in

chemical potential of Ideal Gases :-

$$\boxed{\mu = \mu o + RT \underbrace{\ln P}_{\text{Natural log}}}$$

μo = standard chemical potential
R = gas constant
T = temp.
P = pressure

If pressure increases then chemical potential, μ increases.

Factors affecting μ !

- Temp.
- pressure.
- conc.
- phase of substance

Gibbs Free Energy :-

is a measurement of greatest amount of work that may be done in a thermodynamic system under constant pressure and temperature.

Josiah willard Gibbs discovered in 1876.

$$\boxed{\Delta G = \Delta H - T\Delta S}$$

ΔH = enthalpy
ΔS = Entropy

$\Delta G > 0 / +$ = non-spontaneous & Endergonic → Energy added
$\Delta G < 0 / -$ = Spontaneous & Exergonic → Energy released
$\Delta G = 0$ = Equilibrium

Solubility of Gases in water :-

Henry's law :-

$S_{gas} \propto P_{gas}$

$$\boxed{\underbrace{S_{gas}}_{\text{Solubility of Gas}} = \overset{\text{Henry's constant}}{K_H} \underbrace{P_g}_{\text{partial pressure of gas}}}$$

Factors affecting Henry's law constant :-

(i) Nature of Gas - If gas is acidic in nature, then it is soluble in basic component & vice versa.

(ii) $S_{gas} \propto P_{gas}$

(iii) $S_{gas} \propto \frac{1}{\text{temp}}$

(iv) $S_{gas} \propto \frac{1}{\text{salinity}}$

(v) $S_{gas} \propto \frac{1}{\text{Density}}$

Limitation :-

(i) This law is only applicable system is in equilibrium.

(ii) Does not hold true under extremely high pressure.

(iii) Not applicable when gas & solution participate in chemical reactions with each other.

$$\boxed{P = P_0 - 1.15 \times 10^{-4} H}$$

~~P = pressure at altitude H~~

P_0 = atmospheric pressure at sea level

H = altitude

P = atmospheric pressure at altitude H.

$$\boxed{P = P_0 e^{-Z/H}}$$

H = 7km (Scale height)

$P_0 = 10^5$ Pa

NOTE :- Henry's law provide equilibrium conc. called saturation values.

often actual values differ considerably from those at equilibrium.

Henry's law :

- Equilibrium = saturation values.
- Measured (Actual) values often differ.
- photosynthesis can raise O_2 above saturation
- Bacterial decomposion can lower O_2
- pressure changes push system back to saturation.
- pH control helps gas transfer (air - water).
- Used to remove nitrogen from wastewater.
- N_2 → causes algal growth (eutrophication)
- ↑ Nitrate in babies cause methemoglobinemia.
- Nitrogen removed by Ammonia stripping.
- Decomposition releases $\underset{\text{gas}}{NH_3}$ or $\underset{\text{Acid}}{NH_4^+}$.
- NH_3 dissolves in water Henry's law.
- $NH_4^+ \rightleftharpoons NH_3 + H^+$

→ NH_3 removed in gas stripping tower.

- Air enters bottom of tower for aeration.
- Polluted water flows downward and clean water flows upward
- Gas stripping removes NH_3, H_2S & VOCs.
- $NH_4^+ + OH^- \rightleftharpoons NH_3 + H_2O$

Henry's law coefficients :

T(°C)	CO_2	O_2
0	0.0764	0.0021
5	0.0635	0.0019
10	0.0532	0.0016
15	0.0454	0.0015
20	0.0391	0.0013
25	0.0333	0.0012

→ $S_{gas} \propto \frac{1}{temp.}$

→ CO_2 is 200 time more soluble than O_2.

Raoult's law :-

Partial Vapour pressure of solvent in solution = mole fraction of solute × VP of pure solvent.

$$\boxed{P = x \times p_0}$$

$$\boxed{X + X_2 = 1} \rightarrow \text{Total moles of sol}^n$$

solute solvent

The carbonate system :

primary acid-base system regulating the PH of natural H_2O

H_2CO_3 = Carbonic acid

HCO_3^- = Bicarbonate ion

CO_3^{2-} = Carbonate ion

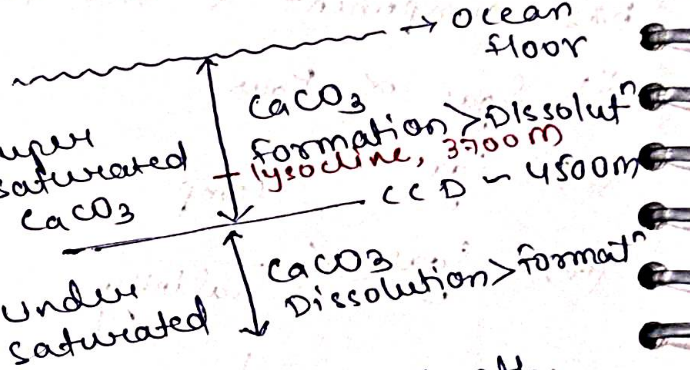
- Aq. CO_2 is formed when atmospheric CO_2 dissolved in H_2O.

$CO_2 + H_2O \rightarrow H_2CO_3$ acidification

$H_2CO_3 \rightleftharpoons HCO_3^- + \textcircled{H^+}$

$HCO_3^- \rightleftharpoons CO_3^{2-} + Ca^{2+}$

CCD - Carbonate compensation Depth :-



→ Lysocline - Ocean depth above CCD, where $CaCO_3$ dissolution starts increasing rapidly.

→ Lysocline & CCD are two phenomena that affect stability of calcite (marine life with hard skeleton) and aragonite (soft calcium carbonate skeleton) in ocean

Factors affecting CCD :-

① Temp - cold water ↑ dissolution

② pressure - High pressure ↑ dissolution

③ CO_2 conc. - more CO_2 ↑ ~~diss~~ Acidity

④ Calcium Carbonate supply - more shell ↓ CCD depth

⑤ Amount of terrigenous sediment - More salt ↑ dissolution.

Hence : ↑ dissolution ↓ CCD depth

Hydrocarbon

Saturated

- Alkane C_nH_{2n+2}
- single bond
- simplest - methane CH_4

Unsaturated

- Alkene & Alkyne C_nH_{2n} C_nH_{2n-2}
- double & triple
- Ethene C_2H_4 Acetylene C_2H_2

Radioactive Isotope :-

Isotopes with unstable nucleus that emit radiation.

Ex- Radium, thorium, uranium, Radon (indoor air pollutant)

Carbon 14 - Isotope use in carbon dating.

Isotopes	Use
Tritium	measure water content of body
Carbon 11	Brain scan
Carbon 14	Radio immunology
Iodine - 131	Hyperthyroidism
Mercury 197	Kidney scan
Phosphorus 32	Detection of eye tumors
Iron 59	Diagnosis of Anemia
Cobalt 60	Treatment of cancer
Sodium 24	Blood clots & circulatory disorders
Gold 198	Curing of Cancer
Strontium 90	Thickness of Coating

Composition of Air :-

↳ unit 1 (Refer)

One standard atmosphere is defined as the pressure equal to that exerted by 760 mm of mercury at 0°C sea level and at standard gravity (32.174 ft/sec²).

Dust particles :

- found in lower level of atm.
- i.e. sand, smoke, soot, sea salt, ash, pollen, etc.
- Dry wind cause a higher conc. of dust particles in subtropical & temperate regions than equitorial & polar regions.
- Dust particles contributes to condensation of WP, which is source of all types of precipitation.
- WP reduces with height (decreases from equator to pole).
- WP absorb incoming solar radiation & preserves earth's radiated heat
- Act like blanket allowing earth neither to become too cold nor too hot.

Properties of Air :-

→ colorless & odorless.
→ Occupies space ex. Baloon
→ Air pressure - cold air > warm air
→ Expansion

Atmospheric particles !

AKA aerosols or PM
↳ size - 0.002 um - 100 um

Aerosols
- primary
  emitted directly into atm
  ex - sea salt, dust, VOC, smoke, soot
- secondary
  after conversion process.
  ex - sulfates, nitrates, etc.

Natural Atmospheric particles

Types	Source	compositions
Mineral Dust	wind erosion of soil, sand	silicates, clay minerals
sea salt	ocean waves & sea spray	sodium chloride, other salts
Volcanic ash	volcanic eruptions	silicate & metal oxides
Biological particles	plant, fungi, microorganisms	pollen, spores, bacteria
smoke from natural fire	forest or Grassland fires	carbon particles & Organic compounds

Artificially Generated particles

soot Black carbon	Burning of coal, diesel	Elemental carbon
Industrial dust	Mining, cement factories, construct^n	Metal oxides, minerals
Fly Ash	coal based plants	Oxides of silica, Al, Fe
Secondary	chemical reaction	Sulfates, nitrates Ammonium salts

~~• primary aerosol → Inorganic → large in size~~
~~short life ← coarse &~~
~~ex- sea spray, mineral dust & volcanoes.~~

Primary Aerosol
- Inorganic
  e.g. Dust mineral volcanoes spray
  ↓
  Large/coarse
  ↓
  short life (few days)
- organic
  ↓
  Biomass Burning, Black carbon
  ↓
  smaller than 1um
  ↓
  long life

Aerosol size modes !-

Trick: NAAC

Nucleation	0.001 - 0.01 um
Aitken	0.01 - 0.1 um
Accumulation	0.1 - 1 um
coarse	> 1 um

properties of Aerosol !-

(i) can scatter, absorb & emit EMR
(ii) can serve as cloud nuclei.

NOTE: BCDE - Black carbon dual Effect
↳ temp of atm ↑ & earth ↓ as aerosol absorbs solar radiation.

• Aerosol Emission
Day → absorb
Night → Emits

Sink of Aerosols :-

① **Dry deposition** :- Direct settling of particles on land, water, plant or buildings by gravity.

(a) Gravitational settling :-

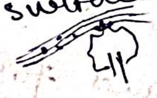
- Occur for large & heavy particles
- coarse particle $> 1\text{-}10\ \mu m$
- Ex- Dust, pollen & ash

(b) Brownian Diffusion :-

- Influence very small particles which move randomly, they collide & settled down.
- size $< 0.1\ \mu m$, nucleation mode aerosol
- Tiny combustion particles attaching building or leaves.

(c) Impaction :- When moving air carrying particles change direction but aerosol collide with surface.

(d) Interception :- Airflow touches very close to surfaces & particle stick.



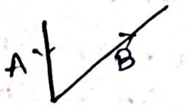
(e) Turbulent Transfer :- Transport particles from higher layer of atmosphere to lower, increasing chance of deposition on ground.

② **Wet Deposition** :- Aerosol particals are removed by rain, snow.

Rain Out → Aerosols become cloud droplets inside clouds

washout → falling raindrops collect particles present.

Radiation budget :-

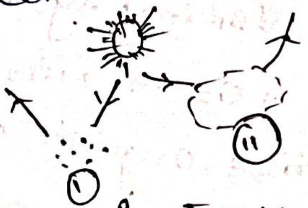


Radiative forcing = A-B

- Radiation absorbed → +ve Radiative forcing
  ↳ Warming of Earth
- Radiation Reflected → -ve Radiative forcing
  ↳ cooling/dimming of Earth.

① → Direct effect - Aerosol particle directly reflects radiation as it is in particle form.

⑪ → Indirect effect - Aerosol particle makes cloud then reflect back.



Atmospheric Ions :-

→ Electrically charged atoms or molecules present in the air.

Anion
- -ve ion
- Gain e-

Cation
- +ve ion
- loose e-

→ Formation of Ions :-

- Ionization of Air molecule
- Cosmic rays entering Atm
- solar UV radiation
- Radioactive element in Soil
- photochemical reaction
- Lightning & electrical discharge

Free radical:

Any atom or molecule with an unpaired e^- in its outer shell, is free radical.

↳ easily attack & form bonds with other molecules in an effort to obtain a paired e^-.

→ OH radical – most important atmospheric oxidising agent. AKA atmospheric scavengers * Not react – CFCs, N_2O & CO_2

→ short-lived

→ OH formation occurs only day time.

$O_3 + h\nu\ (320nm) \rightarrow O_2 + O^1D$

$O^1D + H_2O \rightarrow 2OH + O_2\ (<3\%)$

→ Nitrate Radical ($NO_3^{\cdot}$):-

- Night dominating Radical

$NO_2 + O_3 \rightarrow NO_3$

- Oxidizes organic compounds at night

→ Chlorine Radical ($Cl^{\cdot}$):-

$Cl_2 + \underset{(215nm)}{h\nu} \rightarrow 2Cl^{\cdot}$

→ Ozone layer depletion.

↳ Role Br > Cl > F

O_{3P}	O_{1D}
Ground state energy state	Excited state
Lower reactivity	Very high
Longer life	Short
Role – Ozone formation	OH radical formation

chemical speciation:

Distribution of an element into different chemical forms (species) in a system.

Forms depend on pH, temp., redox conditions, etc.

Types:-

(i) Redox Transformation – chemical reaction involving oxidation & reduction.

(ii) Complexation – Binding with organic or inorganic ligands.

(iii) Sorption – Attachment of substances on surface of soil/particles.

(iv) precipitation – Formation of solid phases.

Forms of chemical Speciation:-

(a) Free Ionic species – Element present as free ion.

Ex- Na^+, Ca^{2+}, Cu^{2+}, Fe^{2-}.

(b) complexed form – Ion bound with ligands (molecule or ions that donate e^- pairs).

Ex- CO_3^{2-}, OH^-, Cl^-.

↓ metal toxicity & changes its transport properties.

(c) colloidal species – are very small particles (typically b/w 1nm & 1μm) that remain suspended in water.

Ex- Iron hydroxide
Aluminium oxide

Help to transport metals over long distance in water.

(d) particulate species :

large solid particles or sediments.

- Less mobile than dissolved species but can become mobile when environmental cond. change.

(e) Oxidation state speciation :

Many elements exist in multiple oxidation states, & each oxidation state represents a different chemical species.

Ex : Cr (III) – less toxic & stable.
Cr (VI) – highly toxic & mobile.

NH_4^+ – Ammonium
NO^{2-} – nitrite
NO^{3-} – nitrate
N_2 – Nitrogen gas

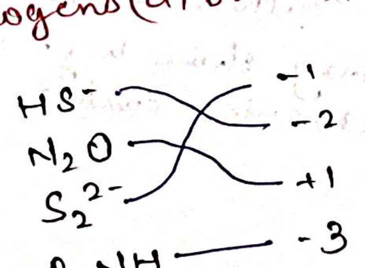
Trick :–

Free element = 0
Na, K, Fe = 0
$S_8, O_2, H_2, Cl_2 = 0$

H = +1
O = –2

- Group 1 = +1 (H, Li, Na, K, Rb, Cs, Fr)
- Group 2 = +2 (Be, Mg, Ca, Sr, Ba, Ra)
- monoatomic ion = charge on ion, $Cl^- = -1$, $O^{2-} = -2$
  $Na^+ = +1$, $Mg^{2+} = +2$
- Halogens (Cl, Br, I), = –1

Q.



① HS^-
$+1 + x = -1$
$x = -2$

② $N_2O = 0$
$2x - 2 = 0$
$x = \frac{2}{2}$ +1

③ S_2^{2-}
$S_2 = -2$
$2x = -2$
$x = -1$

④ $R_2NH = 0$
$2 + x + 1 = 0$
$x = -3$

Q. $Cr_2O_7^{2-}$?
$2x - 14 = -2$
$\cancel{2}x = \cancel{12} + 6$

Q. CH_2F_2 ?
$x + 2 - 2 = 0$
$\boxed{x = 0}$

Redox reaction :–

Oxidation & reduction

- H_2 – reducing agent
- O_2 – Oxidising agent
- positive redox potential indicates the ability to accept electron. (oxidant)
- Negative redox potential indicates ability to donate e^- (reductant)

$$\boxed{\Delta G = -nFE}$$

n = no. of e^-
F = faraday law (96500)
E = voltage

- Redox potential – (Rp) :

$Rp \propto O_2$
$Rp \propto \frac{1}{H_2}$
$Rp \propto H^+$
$Rp \propto \frac{1}{OH^-}$

Analytical Tech. for speciation :–

Separation Tech :–

- HPLC
- GC
- capillary electrophoresis

NOTE :- $As^{3+} > As^{5+} >$ MMA > DMA (Toxicity)

→ Detection Tech. :-

- AAS
- ICP-MS
- UV-VS
- Electrochemical methods

→ chemical processes in atmosphere convert large quantities of atmospheric gas to PM.
Responsible for conversion are organic pollutants & Nitrogen oxides that cause formation of O_3 & photochemical smog in tropo.

chemical processes in formation of Organic & Inorganic PM :-

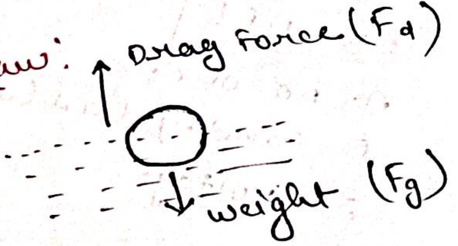
* size = 0.001 - 10 μm

\+ very small - Ex - carbon black, silver iodide, combustion nuclei and sea-salt nuclei.

\+ large - cement dust, soil dust, foundry dust, pulverized coal.

\+ Liquid PM - mist, raindrops, fog & sulfuric acid mist.

Stokes law:



$$F_d = F_g$$

$$6\cancel{\pi} r \eta V_g = \frac{\cancel{\pi} d^3 \rho g}{6}$$

$$6\frac{\cancel{d}}{\cancel{2}} \eta V_g = \frac{\cancel{d}^3 \rho g}{\cancel{6}\,3}$$

$$\boxed{V_g = \frac{d^2 \rho g}{18\eta}}$$

↓ Settling velocity - V_s or V_g

→ $\boxed{V_g / V_s \propto d^2}$

→ zig zag motion.

→ Inorganic PM formation :-

- pyrite containing coal → Iron oxide

$$3FeS_2 + 8O_2 \longrightarrow Fe_3O_4 + 6SO_2$$

- calcium carbonate → calcium oxide

$$CaCO_3 \longrightarrow CaO + CO_2$$

- $2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4$

NOTE : In Volcanic eruption - $H_2O > CO_2 > SO_2$

Secondary PM :-

$$NH_3 + HNO_3 \rightleftharpoons NH_4NO_3$$

$$NH_3 + HCl \rightleftharpoons NH_4Cl$$

- Ammonium nitrate, chloride & sulfate salts in atmosphere are corrosive.

- Proportion of element in atm PM → Abundance of element in parent material

Ex: PM largely from an ocean spray origin in coastal area receiving sulfur dioxide pollution may show high sulphate & low chlorine content.

Organic particles :

→ Organic PM produced by pyrolysis & pyro synthesis.

→ PAH - polycyclic Aromatic Hydrocarbon ex - Benzo(a)pyrene
↳ carcinogenic · Indenol, etc
· chrysene

↳ · formed during incomplete combustion
· forest & grass fire
· from saturated hydrocarbon under O_2 deficient condition.

The tendency of hydrocarbon to form PAH by pyrosynthesis is -
Aromatics > cycloolefins > olefins > paraffins

→ Cracking : Breaking down of Organic compounds to form smaller molecules.

→ composition of Organic PM - reflects its origin.

↳ Hydrocarbon in nature

Neutral Group
→ Mainly hydrocarbons (aliphatic, aromatic, oxygenated).
→ long chain (C16 - C28)
→ Ex Aldehyde, ketones, Esters, etc
→ May cause cancer or mutagenic

Acidic ~~Aromatic~~
→ long chain fatty acid.
→ non-volatile phenols.
→ Ex - lauric, palmitic, stearic acids, oleic.

Basic Group
consist of largely of alkaline N Hetero cyclic hydrocarbon
ex - Acridine

PAH :-
Natural - 20 $\mu g/m^3$
coal - 1000 $\mu g/m^3$
cigarette - 100 $\mu g/m^3$

Soot :- H - 1 to 3 %.
O_2 - 5 - 10 %.

Benzo(a) Pyrane
↓
Epoxides, quinones, phenols, aldehyde, Carbonylic acid.

Thermochemical Process.

is a chemical reaction in which heat energy causes the breaking & formation of chemical bonds.

Arrhenius equation :

$$\boxed{K = A e^{-Ea/RT}}$$

K = Rate constant
A = frequency factor
Ea = Activation energy
R = Gas constant
T = temp.

→ ↑ Temp then ↑ Rate of reation

Factors :
→ Temp ∝ Reaction Rate
→ conc. ∝ collision
→ Pressure ∝ reaction
→ catalyst ∝ Reaction

photochemical Reaction

is chemical reaction ~~that~~ occur when atmospheric molecules absorb solar radiation (UV) & undergo chemical transformation.

photodissociation of O_2

$$O_2 + h\nu \longrightarrow 2O$$

$$O + O_2 \longrightarrow O_3$$

∴ $h\nu$ = UVC < 242 nm

NO2 create Toposphric O_3 :-

$N_2 + O_2 \longrightarrow 2NO$

$2NO + O_2 \longrightarrow 2NO_2$

$NO_2 + h\nu\ (<390\,nm) \longrightarrow NO + O$
UV-A

$O + O_2 \longrightarrow O_3$

NO destroy Ozone :-

$NO + O_3 \longrightarrow NO_2 + O_2$

NOTE :- oxidatⁿ NO – ↑ in early morning
NO_2 – Afternoon

Ozone :-

Stratospheric O_3 :

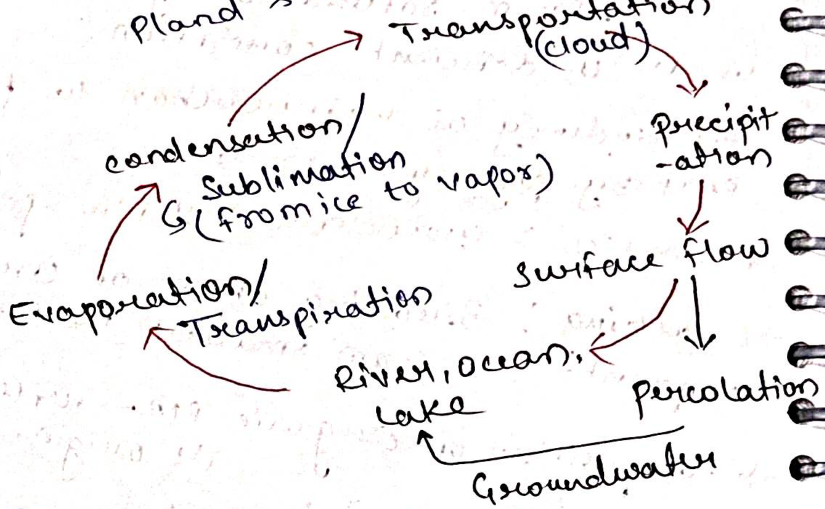
- 90% present (15 – 35 km)
- Unit = DOBSON
  1 Dobson = $\frac{1}{100}$ mm of O_3
- Avg global thickness of O_3 layer is 300 DU or 3 mm

PAN - Peroxyacetyl Nitrate
- See. air pollutant
- photochemical smog
- formula - $CH_3(CO_2)ONO_2$
- eye irritation, plant damage & respiratory problems.

Hydrological cycle :-

2/3 of Earth is water

Pland & animal made → 70% H_2O



properties :

(i) Density – maximum density at 4°C, temp move away, H_2O become lighter and more buoyant.

(ii) Specific heat – Absorb heat slowly Five times higher than rock, concrete.

(iii) High heat of vaporization need more energy to evaporate

(iv) Melting & Boiling point – high boiling & freezing temp.

- H-O-H → non linear bending

Smog – smoke + fog
↳ calm wind

Photochemical
- AKA Los Angeles
- Sun + NO_2 + VOC + O_3
- from Automobiles, Factories
- Oxidizing
- Dry, Sunny climate
- Mobile
- By product PAN
- Brown smog

Sulfurreous
- AKA classical, london smog
- smoke + Fog + SO_2 + PM
- from Industries, volcanoes
- Reducting
- cool, humid
- Stationary
- Gray smog

(v) water as solvent -
Universal solvent

(vi) Greenhouse effect -
105° bong angle,
balance overall temp
of earth.

(vii) Dipolar molecule -
uneven (+ & -) charge
distribution. $O-H^-$, H^+

(vii) cohesion & adhesion:
Stick to itself & other surface.
water - water   water - soil
soil - soil

DO :- Dissolved Oxygen -

→ Amount of O_2 dissolved in H_2O.
→ most imp measures of quality of water is DO present.
~~atm~~ amount of

→ Minimum 5 mg/L.
5 mg/L - coldwater fish
8 mg/L - embryonic & larval stage
5 mg/L - first 30 days after hatching
4 mg/L - warm water fish

Measure - winkler method.

→ Oxygen demanding wastes are usually biodegradable organic substance contained in wastewater.

BOD: Biological Oxygen Demand:

is the amount of oxygen that will be consumed by bacteria or other aerobic microorganisms while decomposing om under aerobic condition.

The amount of O_2 required by Organism to oxidize organic wastes aerobically

BOD

CBOD
Carbonaceous Oxygen demand
↳ Breaks carbon comp.

NBOD
Nitrogenous Oxygen Demand
↳ Breaks nitrous compound

$$\boxed{BOD \propto \frac{1}{DO}}$$

↳ Only for Biodegradable materi
↳ 5 day Test at 20° C

COD - Chemical Oxygen Demand

Amount of O_2 required to chemically oxidize OM in water.
↳ non-biodegradable
↳ 3 hour test
↳ potassium dichromate used as strong oxidizing agent ($K_2Cr_2O_7$)

TOD - Total Oxygen Demand

Total O_2 required to completely oxidize all organic substance in water.

$$\boxed{TOD > COD > BOD}$$

BOD
public sewage - 350 mg/L
Irrigation - 100 mg/L
other - 600 mg/L & 200 m/g irrigat

formula:

$$BOD_{ultimate} = BOD_5 + BOD_u 10^{-kt}$$

$$BOD_5 = BOD_u - BOD_u 10^{-kt}$$

$$\boxed{BOD_5 = BOD_u(1 - 10^{-kt})}$$

$$BOD_u = \frac{BOD_5}{1-10^{-kt}}$$

$$K_t = K_{20} \cdot \theta^{(T-20)}$$

Imp

$$\boxed{BOD_5 = \frac{DO_i - DO_f}{P}}$$ P → dilution factor

$$P = \frac{\text{Vol. of wastewater sample}}{\text{Vol. of wastewater same + dilution sample}}$$

BOD Rate constant at 20° C

Sample	BOD/COD	BOD/TOC
Untreated	0.3 – 0.8	1.2 – 2
After primary settling	0.4 – 0.6	0.8 – 1.2
Final effluent	0.1 – 0.3	0.2 – 0.5

Water Treatment plant :-

Screening
↓
primary sedimentation
↓
Mixing & coagulation
↓
flocculation
↓
Secondary settling
↓
filteration

Groundwater Treatment :-

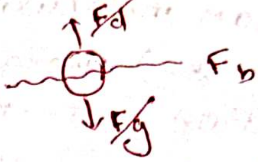
① Aeration
② Flocculation
③ Sedimentation
④ Recarbonation
⑤ filteriation

Sedimentation : Settling of suspended PM by gravity.

→ longer detention time, bigger & more expensive the tank ~~take~~ for better performance.

→ Bottom scraper removes collected sludge, suspended solids & pathogens.

Stokes law -



The drag force is a functional of particle's Reynolds no.

i.e. $$\boxed{Re = \frac{\rho V_s d_p}{\mu}}$$

ρ = density of water
V_s = particle settling velocity
d_p = particle hydrodynamic diameter
μ = absolute viscosity of water.

~~→ Although many clarifiers are circular~~

→ Circular clarifiers are prefered, as effluent enters at center & surface area is π times basin radius

→ flow rate - 1 to 2.5 $m^3/m^2 h$

→ hydraulic detention time in any tank is its Volume by influent flow i.e. Ranges from 1 to 4 hrs

* Factors affecting BOD –

① Nature of waste
② Ability of microorganisms to degrade waste
③ Temp.

Coagulation & Flocculation :

$\nearrow$ (-ve) colloids (0.001 - 1 μm) need
$\nearrow$ (+ve) coagulants to adhere then remove by sedimentation.

→ Neutralize charges.

→ Alum - $Al_2(SO_4)_3 \cdot 18H_2O$, $FeCl_3$, $FeSO_4$ are used.

* 100% collision, $\alpha = 1.0$, 25% = 0.25

Flocculation : Gentle agitation mixing for ½ hr, helps keep floc from settling in tank.

- monodisperse distribution - initially nearlly partical of same size
- Laminar mixing - mild mixing
- coalescing aggregation - aggregate vol.
  ↳ first order process.

$$r(N) = -KN$$

Filteration :-

The rapid depth filter consists of a layer or layers of carefully sieved filter media such as sand, anthracite coal or graded gravels.

Its clogged filter with particles, cleaned by forcing water backward.

$$\boxed{r_{ef} = \frac{V_f - V_b - V_r}{A_f(t_f + t_b + t_r)}}$$

V_f = Vol. of filtered water

V_b = — backwash

V_r = — rinse

t_b = time to filter backwash

t_r = rinsing, t_f = clean water prodn.

+ PH & POH :-

$$\boxed{\begin{aligned} PH + POH &= 14 \\ PH &= 14 - POH \\ POH &= 14 - PH \end{aligned}}$$

$$\boxed{\begin{aligned} PH &= -\log H^+ \\ POH &= -\log OH^- \end{aligned}}$$

$$\boxed{\begin{aligned} H^+ &= 10^{-PH} \\ OH^- &= 10^{-POH} \end{aligned}}$$

$$\boxed{\begin{aligned} H^+ \times OH^- &= 10^{-14} \\ H^+ &= \frac{10^{-14}}{OH^-} \\ OH^- &= \frac{10^{-14}}{H^+} \end{aligned}}$$

log 1 = 0
log 2 = 0.30
log 3 = 0.47
log 4 = 0.60
log 5 = 0.69
log 6 = 0.77
log 7 = 0.84
log 8 = 0.90
log 9 = 0.95
log 10 = 1
log 100 = 2

$\log m \times n = \log m + \log n$

$\log \frac{m}{n} = \log m - \log n$

$\log m^n = n \log m$

Q. when PH into H^+, PH = 6.7
H^+ = ?

PH = 6.7
$H^+ = 10^{-PH} = 10^{-6.7}$ ⌒ 0.3 = log 2
$= 2 \times 10^{-7}$
Ans

POH = 11.6, $OH^- = ?$

$OH^- = 10^{-POH}$

$= 10^{-11.6} = \frac{10^{12}}{0.4}$

$= 3 \times 10^{-12}$

pure rain pH = 5.6

Soil :-

5% - Organic matter &
95% - inorganic matter

For peat soil -
95% - organic & 5% is inorganic matter

→ Typical soil exhibit distinctive layers called horizons with increasing depth.

• Size :- Gravel > sand > silt > clay
2 - 75mm > 0.05 - 2 mm > 0.002 - 0.05 mm > less than 0.002 mm

• Soil composition - 25% water, 25% air, Organic matter 5% & Mineral -45%.

properties of soil colloids :

→ Always in motions → charged particle (-ve)
→ Transformed from liquid to semisolid or solid mass by adding opposite ion (+ve)
→ have ability to absorbed gases, liquid & solid.
→ cohesion & adhesion
→ colloidal particles never pass through a semipermeable membrane.

4 Types of soil colloids -

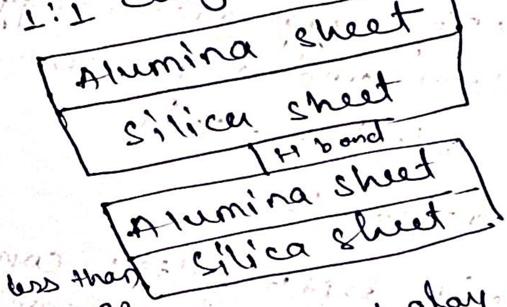
① crystalline silicate clays
② Non crystalline silicate clays
③ Iron & aluminium oxides
④ Organic (humus) colloids

→ particle less than 0.001 mm known as soil colloids

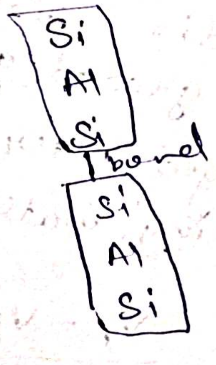
All clay particle are colloidal soil But not voice versa..

→ Crystalline silicate clays - They are composed of tetrahedral silica sheets (SiO_4) & octahedral sheets of aluminium or magnesium.

a) 1:1 clay structure



b) 2:1 clay structure



→ Non-crystalline silicate clays - This clays lack a well-ordered crystalline structure i.e. amorphous clays.

→ Iron & Aluminium Oxides :-

formed during intense weathering of silicate minerals.

→ Organic (humus) colloid :-

The organic colloids include highly decomposed organic matter called humus (C, H, O & N).

Soil in Temperal – ↑ organic colloids than in tropical & subtropical. (because of decomposition diff) due to temp.

Organic matter Humus :-

Thick dark brown / black substance that remain after most of organic litter has decomposed called humus.

↳ Earthwarm helps in mixing humus with minerals in soil.

↳ Rate of degradation –

Hemicellulose > Cellulose > Lignin > chitin

↳ The chief element – C > O > H > N > S

C : N = 10-12 : 1

HUMUS
- Humic
  - Fulvic. Soluble in both acid & base.
  - Humic soluble in Base & Insoluble in acid.
- Non-humic
  - Humin Insoluble in both.

→ colour intensity ↑

→ carbon content ↑

→ oxygen content ↓

→ solubility ↓

→ weight ↑

Inorganic colloids :

↳ colloids – < 0.001mm

↳ All clay are not colloidal

Nutrient :

Substance obtained from food, soil, water, or env that is required for the growth, maintenance & reproduction of living organisms.

- Micro (< 0.1 mg) ex- Fe, B, Cu, Mn, Mo, Zn, Co, Ni, etc
- Macro (1-10 mg)
  - → structural – C, H, O
  - → primary – N, P, K
  - → secondary – Ca, Mg, S

Cation Exchange capacity (CEC) :-

CEC is ability of soil to hold and exchange positively charged ions (cations).

↳ cmol(+) / kg soil

• centimoles of positive charge per kilogram of soil.

→ Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, H^{+} are exchanged with hydrogen ion released by roots.

→ CEC are imp for soil fertility & nutrient availability

→ Kaolinite -
- 1:1
- $Al_2Si_2O_5(OH)_4$
- Use - making paper, paint, pottery & pharmaceutical

→ Montmorillonite - (2:1)
- High water absorption & swelling capacity.
- AICA Mg-smectite clay

→ Illite (2:1) -
- Fine grained micas

→ Vermiculite (2:1) -
- Generally regarded as a weathering product of mica.
- very high CEC

→ Chlorite (2:1) -
- Fe or Mg

→ Smectite (2:1) -
- most expandable of all clays
- High CEC

Swelling capacity - Trick

AICA Interlayer expansion

My > V>C>In > kitchen

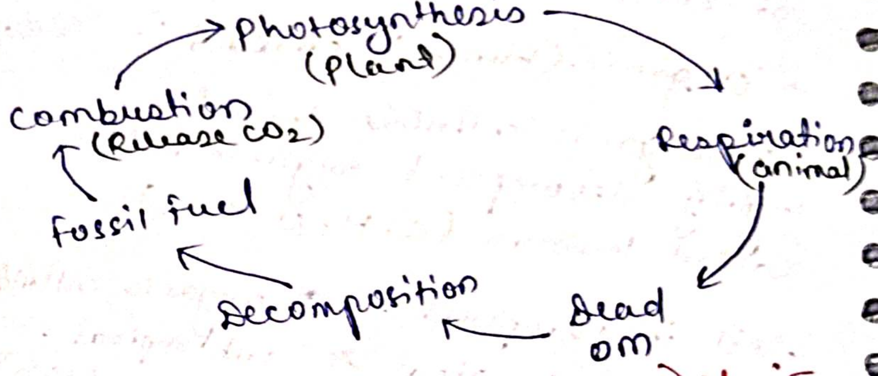
CEC :- V > M > C > I > K

Biogeo-chemical cycles :-

- Flow of energy - Unidirection
- & nutrient - cyclic
  - Bio - living
  - geo - rock
  - chemical - element

① CARBON CYCLE :-

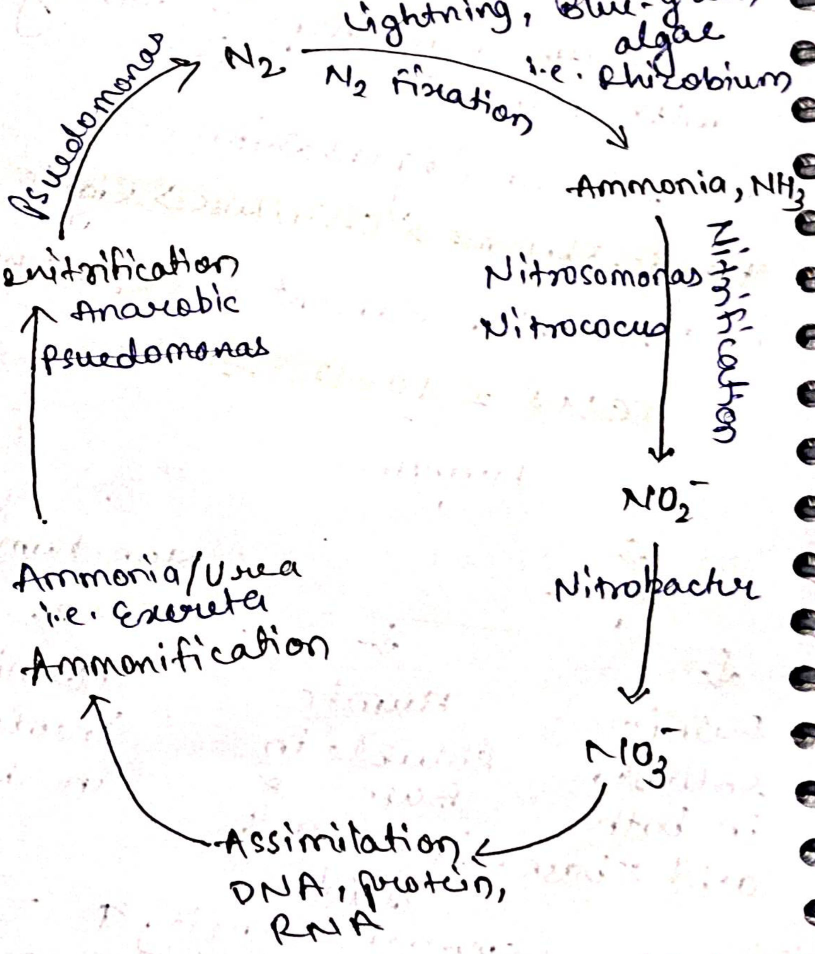
Carbon sink : Ocean > soil > forest



② NITROGEN CYCLE (N≡N) N_2 :-

→ N_2 is essential constituent of protein, 16% by weight of all protein.

→ Elemental N is useless for living Org.



$$N_2 + 8H^+ + 8e^- + 16\,ATP \rightarrow 2NH_3 + H_2 + 16\,ADP + 16\,P_i$$

Nitrogenase enzymes -

① Iron protein

② Molybdenum protein

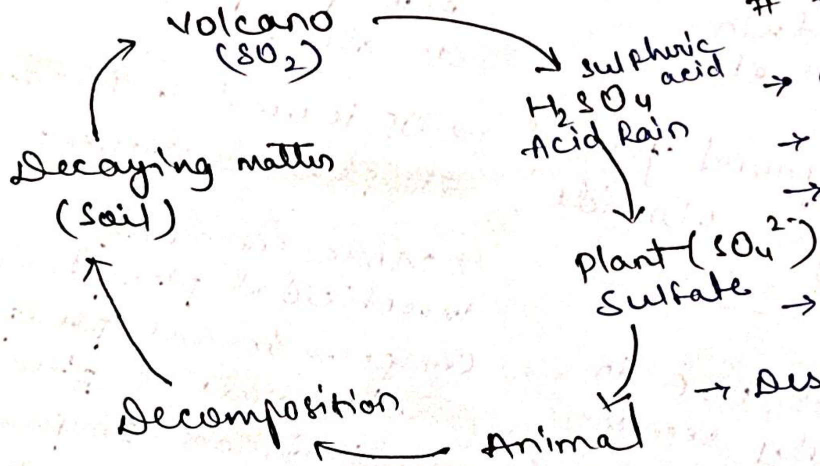
③ Vanadium protein

legume → gives nutrients & ATP to bacteroids

leghemoglobin (leg-hb) present in root nodules.

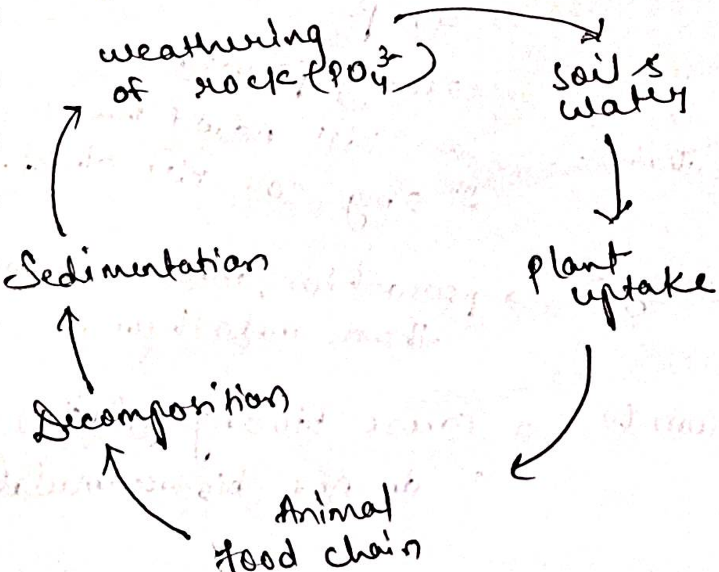
leg-Hb - red/pink pigment

SULFUR CYCLE :-



PHOSPHORUS CYCLE :-

→ pure sedimentary cycle.



→ Plant utilise inorganic Phosphorus.

- mineralization - Bacteria convert organic forms to inorganic form of phosphorus, which plant can use.
- Most phosphorus is locked in soil, can not use by plants.

Adsorption
↓
chemically P unavailable for plants

Desorption
↓
P Available for plants

- PH:- 4-8

Pesticide :-

→ cide - To kill

→ Algaecides - for algae control

→ Antimicrobials - Bacteria & viruses.

→ Biopesticides - for living things

→ Desiccants - for dry up living plant tissues

→ Defoliants - to drop leaves

→ Disinfectant - control germs

→ foggers - kill by touch

→ fungicides - fungal control

→ Herbicides - for unwanted plants (weeds)

→ Miticides - control mites (not exactly insects)

→ Mollucicides - control snails.

→ Ovicides - control eggs of insect & mites

→ Pheromones - disrupt insects mating

→ Repellents - repel unwanted pests by smell or taste.

System Insecticide	contact Insecticide
• Kills pests feeding on the plant	Kills pests when they touch or are sprayed
• Used to control aphids, caterpillars & nematodes	• for mites leafhoppers.

On the basis of chemical nature:

① Organo-chlorine pesticides:

Stable, long persistent & residence time in years.

Ex- DDT (Dichloro-Diphenyl-Trichloro-ethane), DDE (Dichloro-Diphenyl Dichloro ethylene), Aldrin, Endosulfan, chlordane, etc.

→ DDE :- chemical compound formed by the loss of hydrogen chloride from DDT $\boxed{DDT - HCl = DDE}$.

- Massive use of DDT & DDE in agriculture, still widely seen in tissues of animals.
- DDE > DDT – Dangerous, coz DDE is fat soluble, bioaccumulated & rarely excreted.
- DDT accumulates in fat cells & cause biomagnification (food chain).
- DDT shows mimic effect with Estrogen i.e. Endocrine Disruptor.
- Also shows Teratogenic (from mom to fetus) & Neurotoxic
- DDT cause egg shell thinning (lack calcium).

⑤ Organo phosphates :- (OP)

Biodegradable, water soluble, more toxic than Organo-chlorine, Neurotoxic and low residence time (some weeks).

ex- parathion, Malathion, methyl parathion.

→ OP produced by the process of esterification b/w phosphoric acid & alcohol.

→ OP is used in production of plastics, solvents.

→ More commonly, insecticidal phosphorus compounds are phosphorothionate & phosphorodithionate compounds, which have an =S group rather than =O group bound ~~with~~ to P.

→ 120 mg parathion can kill Adult human & 2mg can kill child.

→ parathion, more toxic than melathion.

→ cause biodegradation & do not bio-accumulate

(A) phosphotriesters :
ex- paraoxon, dichlorvos,
& tetrachlorvinphos

(B) Thiophosphotriesters :
ex- chloropyrifos, methyl-
parathion & diazinon

(C) phosphorothiolesters :
ex- Malathion, oxydemeton
methyl & phosmet.

A → most Volatile & break down faster.

B → more stable than type A
break into A.
some insect absorb type B & C better than type A

C → Generally but not always less toxic than type A.

③ Carbamates :

- most soluble but less toxic than organophosphate.
- Mechanically similar to OP.
- Toxic exposure - dermal, inhalation & gastrointestinal
- Residence time days to weeks
- ex - carbaryl, aldicarb, zectran & carbofuran.

carbaryl - for lawns / garden

carbofuran - ↑ water solubility, plant systematic insecticide.

④ Herbicides :-

→ AKA weed killers.

→ Ex Triazine → Atrazine, simazine.

Ureas → Monouron, Diuron

phenoxy acid → 2,4-D (dichloro phenoxy acetic acid) & 2,4,5 (trichloro phenoxy acetic acid)

→ Triazine - contains 3 heterocyclic nitrogen atom in ring structure.

It inhibit photosynthesis.

- Atrazine - for corn weeds
- Metribuzin - for soyabean, sugarcane & wheat.

NOTE - Imp :

- 2,4-D (Dichloro phenoxy acetic acid) & 2,4,5 (trichloro phenoxy acetic acid) combinedly called AGENT ORANGE (Defoliants)

→ Residence time :-
OC > Herbicides > OP > Carbamates

→ Toxicity :-
OP > carbamates > Herbicides > OC.

POPs - persistent Organic pollutants :

→ Negative effects on env through -
(i) long range transport
(ii) Bioaccumulation.

→ Stockholm convention 2001, to protect human & env from POPs.

→ POPs can cause cancers, birth defects, dysfunctional immune & reproductive sys, and damage nervous system

→ Stockholm adopted in 2001 & enforced in 2004.

→ Initially convention recognized only 12 POP called dirty dozens.

common ex - Dioxins, Furans.

Heavy Metals :-

① **Nitrate** - NO_3^- :-
- Cause blue baby or methemoglobinemia.
- Affect infants upto 6 month
- Source - contaminated groundwater.

② **Fluoride** :-
- Have both +ve & -ve impact on tooth enamal.
- cause - knock knee syndrom.
- Adults - 1-1.5 ppm
children - ~~0.025~~ 0.25 - 0.5 ppm
- Affect Bones & tooth.

③ Mercury (Hg) :
- Cause minamata (Japan)
- Affect central nervous sys
- Methyl mercury is organic form which is more toxic than inorganic form.
- Undergo biomagnification.
- Minamata in Human, cat dancing & Dropsy in fish.

④ cadmium (Cd) :- (Japan)
- cause Itai-Itai
- weaken bones | Brittle Bones
- Source - Minning waste & industrial discharge
- Cd^{2+} can replace Zn^{2+} and Ca^{2+}.
- Main source : (Ni-Cd) Batteries.

⑤ **chromium** :- Cr^{3+} & Cr^{6+}
$\underset{\text{chromite}}{Cr^{3+}}$ & $\underset{\text{chromate}}{Cr^{6+}}$
- carcinogen.
- Toxicity - $Cr^{6+} > Cr^{3+}$
- Easily enter cells,
- more mobile in water & soil.
- Source - Leather | tanning industries.
- $Cr^{6+} \longrightarrow Cr^{3+}$
transformation in nature by microorganism & om.

⑥ Lead (Pb) :-

→ Affect central nervous sys. & other dysfunctioning.

→ less Pb use in plumbing & other products that come in contact with food & water.

⑦ Arsenic (As) :-

→ cause Black foot

→ Toxicity : $As^{3+} > As^{5+}$

→ conc. - 0.05 mg/L

→ Nervous system, Endocrine Diabetes, Dermal system etc.

VOCs :- Volatile Organic Comp chemicals -

Are toxic & their presence in drinking water cause for special concern :

- Vinyl chloride - most toxic
- Tetrachloroethylene - commonly found in groundwater.
- ~~Tet~~ Trichloroethylene - cleaning electronic parts.
- 1,2-dichloroethane - metal degreaser manufacturing varnish remover, soap compounds, fumigants.
- carbon tetrachloride - household cleaning agent, fire extinguisher.

Cause - carcinogenic, death causing, acute toxicity & groundwater contamination.

Carcinogens in Air :-

→ Benzene, Arsenic, chromium Radon, Asbestos, Vinyl chloride, Trichloroethylene, Tobacco smoke & UV rays.

→ Carbon monoxide (CO) :-

- highly toxic, colourless, odourless, flammable gas
- produced by incomplete combustion
- CO replace O_2 in human body & bind with Haemoglobin & produce carboxy hemoglobin
- short lived & variable.

→ PAN - peroxy Acetyl Nitrate

- secondary air pollutant
- Byproduct of photochemical smog.
- $CH_3COOONO_2$ - formula
- Oxidizing agent
- can travel long dist.
- Eye irritation, lung function, Respiratory tract irritation.
- In plant - damages chloroplasts & inhibits photosynthesis cause - leaf bronzing & Necrosis.

Analytical chemistry :–

it involves separation, identification & quantification of matter.

① Titrimetric method :

Determining conc. using volume of standard solution.

- Volumetric – involves measuring the volume of sol^n.
- Gravimetric – differs only in mass of reagent is measured
- Coulometric – reagent is constant direct electrical current that consumed by analyte.

Types :

① Acid Base – HCl vs NaOH
② Redox – $KMnO_4$, $K_2Cr_2O_7$
③ complexometric – EDTA
④ precipitation – $AgNO_3$ – Mohr method

Titration is tech. where sol^n of known conc. is used to determine the conc. of unknown sol^n.

② Gravimetric Analysis :–

Analysis based on mass of precipitation. of known unknown conc.

NOTE : Analyte – The substance being measured or analyzed in a sample.

① Analyte
↓
② precipitate form
↓
③ Filteration
↓
④ Drying
↓
⑤ Igniting
↓
⑥ Weighing
↓
⑦ calculations

Types :– (flowchart)

(i) precipitation – insoluble
(ii) Volatilization – vapour
(iii) Electrogravimetry – e^-
(iv) Thermogravimetry – heat

③ Bomb Calorimetry :–

- Measure heat of combustion in chemical / physical reaction.
- Energy of fuels such as coal, oil, gasoline & kerosene are tested by Bomb calorimetry.

→ Energy content of food on human & animals etc.

Principle :–
→ On first laws of therodyn. when substan burns it releases heat.

④ CHROMATOGRAPHY :–

→ Technique for separation, purification & testing of compounds.

→ separation technique based on distribution b/w stationary (solid & liquid) & mobile phase (liquid or gas).

- Eluent – fluid that enters & process.
- Eluate – fluid coming out of column.
- Elution – process of removal of solid by washing out it with suitable solvent.

Types :-

① column chromatography :-

Use - extract a single chemical compound from a mixture (fluid).

→ principle of adsorption.

- Adsorb strongly on stationary phase → move slowly
- Adsorb weakly → move faster
- stationary phase - polar (SP)
- mobile phase - non polar (mp)

② paper chromatography :-

- cheap
- how quickly they migrate across paper sheets.
- layer of cellulose used.
- ~~stationary - liquid phase~~
- stationary - cellulose fibres of papers.

Mobile - Solvent (alcohol).

③ Thin layer chromatography :-

TLC separate mixture of chemicals by coating very thin layer of an adsorbent i.e. silica gel or alumina.

- Stationary - Thin layer of silica gel on glass / plastic plate
- Mobile phase - Liquid
- Adsorption affinities -
  - ↳ strong - move slow
  - ↳ weak - move faster
- polarity :-
  - ↳ polar - travel less
  - ↳ non polar - travel more

④ Gass chromatography :-

- Its carrier phase consists of gases (He & N_2)
- Mobile phase - Inert gas
  ex - He, N_2, H_2
- stationary - Liquid / solid
- separation -
  - ↳ low boiling point & weak interaction
    ↓
    Elute faster
  - ↳ High boiling point & strong interaction
    ↓
    Elute slower

⑤ Ion-Exchange chromatography

- Separated based on charge
- principle - Electrostatic attraction

Anionic exchangers
- +ve
- attract -ve
- Basic

Cationic exchangers
- -ve &
- attract +ve
- Acidic

⑥ Gel permeation chromatography (GPC) :

- separate molecules based on their size or sieving.
- stationary - porous gel
  ex - Agarose, polyacrylamide
- Mobile - liquid solvent.
- principle - Sieve permeation

7) Affinity chromatography :-

- Separation tech. based on Specific biological interaction b/w target molecule & ligand.
- principle - specific binding (affinity)
- stationary - solid matrix (agarose beads, silica)
- mobile - Buffer sol^n

8) HPLC - High pressure liquid chromatography :-

→ very accurate
→ widely used
→ short time
→ mobile phase in high pressure under 10-400 atm pressure

Types :- Elution in HPLC -

(i) Isocratic elution - mobile phase composition remains constant throughout the run.

(ii) Gradient elution - changes with time.

- HPLC works on principle of partition/ adsorption chromatography.
- stationary - solid (silica based, packed in column).
- mobile - Liquid solvent (pumped in high pressure)

Type :- HPLC

(i) Normal HPLC -	(ii) Reverse HPLC
↳ stationary - polar	↳ Non polar
↳ Mobile - non-polar	↳ polar

(iii) Ionic exchange HPLC -
↳ used for ionic compounds.

5) Flame photometry :-

- Measure conc. of metal ion using flame emission.

Priciple -
atom absorb heat
↓
Excited state
↓
Return Ground state
↓
Emit light

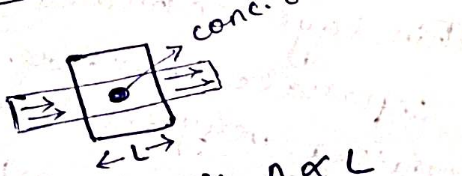
- The intensity of emitted light is proportion to conc. of element.

6) Spectrophotometry :-

- Measures absorbance of light by a substance over certain range of wavelength.

Principle - Beer-lambert law.

$$\boxed{A = KCl}$$



$A \propto C$ & $A \propto L$

$A \propto \frac{1}{T}$ → Transmitance

$$\boxed{A = -\log T}$$

$$\boxed{A = 2 - \log T\%}$$

- Shows linear relation.
- No unit of A.

Application -
↳ water quality analysis
↳ pollutant detection.

factors :-

i) polychromatic light
↳ use monochromator
ii) stray light - unwanted light
iii) side reaction - react with other substance
iv) High conc. - should be limited in conc.

ICP-AES :- Inductively coupled plasma - Atomic Emission Spectroscopy

- determining very precisely elements present in sample by measuring the light emitted by excited atom & ions in high temp plasma.

principle :-

Sample introduced into very hot argon plasma
↓
convert sample into atom and ions
↓
Atom Excited to higher energy level
↓
Return to their lower energy state
↓
Emit light of certain wavelength
↓
light intensity ∝ proportion of element

ICP-MS :- Inductively coupled plasma Atomic Emission Spectroscopy.

- Detect ions based on mass

principle & process —
① Nebulizer converts liquid → aerosol
↓
Argon plasma ionizes sample
↓
③ Transfers ions into MS
↓
④ Separates ions
↓
⑤ Measures ion signal

Use - for ultra trace & isotones.

- Measure ions by mass to charge ratio.

AAS - Atomic Absorption Spectrometry -

- determining conc. of metal element by measuring the absorption of light by free atoms in gaseous state.

principle - Beer lambert law.

process - sample in instrument
↓
nebulizer convert into aerosol
↓
Sample enter flame/graphite furnance
↓
Sample atomized into free ground state atoms
↓
light from hollow cathode lamp passes through atoms
↓
Atom absorb light
↓
light intensity is measured by detector
↓
Absorbance is compared with standard sol^n to determine the conc.

properties :-
→ Highly sensitive & selective
→ Good accuracy
→ Trace element analysis
→ Usually single element analysis.
→ Requires atomization

→ can inject no. of atoms but single element/atom analysed.

Electrophoresis :-

- Separate charged particles in electric field.
- principle :- -ve towards +ve electrode & vice versa.
- Diff charge, size & shapes, their Speed is diff, helps in separation.

factors :-
- charge on molecules (∝)
- size of molecules $(\frac{1}{\alpha})$
- shape of molecules
- PH, temp.
- Strength of electric field (voltage) (∝)
- Nature of supporting medium.

Application :-
- To separate serum proteins
- To analyze DNA & RNA
- To detect purity of proteins
- To identify genetic disorders.

XRF – X-ray fluorescence :

Elemental analysis using X-ray emission.

principle – Atom emit secondary X-rays when excited.

- Non - destructive analytical tech.

XRD - X ray diffraction :

Determining crystal structure.

principle - Diffraction of X-rays by crystal lattice.

→ follow bragg's law

$$\boxed{\underset{\downarrow}{n\lambda} = 2d \sin\theta}$$

path difference.

NMR – Nuclear magnetic Resonance :

Study of molecular structure using magnetic field.

- Nuclei absorb radiofrequency in magnetic field.
- specially for C & H.

process :

Sample In strong Magnetic field.

↓

Excite the nuclei

↓

Higher energy state aka Resonance

↓

Back to original state, they emit relaxation signals

↓

Both signals are detected.

FTIR : Fourier Transform Infrared spectroscopy :

- Identifies functional groups using IR radiation.

principle - molecules absorb IR, (Infra red) → vibration changes.

- can analyze solid, liquid & Gases.
- Non destructive tech.

GC - MS : Gas chromatography : Mass spectrometry :

- combination of GC + MS for separation & identication of molecule of their mass to charge ratio.

SEM- scanning electron microscope

Principle - electron beam scans surface.

- Surface image - 2D
- Info about surface morphology

TEM- Transmission electron microscope

electron pass through thin sample

- Internal image - 3D
- Internal ultrastructure.

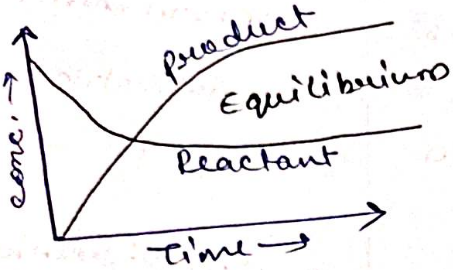
	Industrial...		Ecological sensitive		Methods of Measurement
Pollutant	Annual µg/m³	24 hrs —	Annual —	24 hrs —	
PM 2.5 (respirable)	40	60	40	60	◦ Gravimetric ◦ TOEM
PM 10	60	100	60	100	◦ Gravimetric • TOEM
SO_2	50	80	20	80	◦ west & Greek method ◦ UV fluroresenc
NO_2	40	80	30	80	◦ Jacob & Hochheiser • chemiluminescence
(Pb) Lead	0.5	1	0.5	1	◦ AAS ◦ XRF
O_3	8 hrs -100	1 hrs-180	100	180	◦ UV photometric • chemiluminescence
NH_3 Ammonia	100	400	100	400	Indophenol blue method.
Benzene	5		5		◦ GC
Benzo(a) pyrene	1 ng/m³		1ng/m³		◦ HPLC • GC
Arsenic	6ng/m³		6 ng/m³		• AAS ◦ ~~EP~~ICP
Nickel	20 ng/m³		20 ng/m³		• AAS • ICP

~~KEMI~~

Chemical Kinetics :-

is a branch of physical chemical reactions & reasons behind them.

Rate of Reaction :-



Factors :-

- (i) conc. of Reactants
- (ii) Nature of Reactants
- (iii) Temp & pressure
- (iv) catalysts < promotor, poision
- (v) physical state of Reactants
- (vi) surface area of Reactants

concentration Units :-

1 PPM = $1/10^6$ = 10^{-6}

1 PPB = $\frac{1}{10^9}$ = 10^{-9}

1 PPM = 1000 PPb

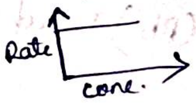
1 PPM = 0.0001 %

chemical Equilibria :-

$$K = \frac{(C)^c (D)^d}{(A)^a (B)^b}$$

- for solid reactant is denoted by equilibrium constants (K).
- for gas – Henry law.

→ Both, solubility in liquid.

Reaction	Units of Rate constant	Integrated Rate law	Graph
Zero order	mole L^{-1} sec^{-1}	$A^t = -K \cdot t + (A_0)$	 Rate, conc.
First Order	sec^{-1}	$\ln(A)^t = -Kt + \ln(A_0)$	
Second Order	L $mole^{-1}$ sec^{-1}	$\frac{1}{(A)^t} = Kt + \frac{1}{(A_0)}$	

concentration :-

→ molar volume of ideal gas :

At STP (0°C, 1 atm)

volume = 22.4 L

At ATP (25°C, 1 atm)

volume = 24.46 L

$$\boxed{\text{Conc.} = \frac{\text{PPM} \times \text{Molecular wt}}{24.46}}$$