Quick Revision

Water

Impurities
- Dissolved
- Suspended
- Biological

Disadvantage
- Domestic use
- Industrial use
- Steam generation

- ~~Soft water~~
- Hard water
- Temp : $Ca(HCO_3)_2 + \cancel{H_2O}\ \Delta \rightarrow CaCO_3\downarrow + H_2O + CO_2\uparrow$

  $Mg(HCO_3)_2 + \Delta \rightarrow Mg(OH)_2\downarrow + 2CO_2$

  Perm : chemical method

- 1ppm = 1mg/L = 0.07°Cl = 0.1°Fr

- EDTA method

$M_1 = \frac{a}{100}$ M → ('a' weight of $CaCO_3$) → SHW 'm'

$M_2 = \frac{M_1 V_1}{V_2}$ → V_1 Volume of sample, V_2 → Volume of EDTA

↓

EDTA 'm'

$M_3 = \frac{M_2 V_2}{V_3}$ → V_3 Volume of ~~water~~ sample

↓

To find Total Hardness

Total Hardness = $M_3 \times 10^5$ (ppm or mg/L)

After boiling

$M_4 = \frac{M_2 V_2}{V_4}$ → V_4 volume of sample

↓

Permanent

Perm = $M_4 \times 10^5$ ppm (or mg/L)

Temp = $(M_3 - M_4) \times 10^5$ ppm (or mg/L)

→ Boiler Trobbles

1) Priming & foaming → ~~Can~~ ~~increases~~ decreases efficiency, ht of H₂O cant be ~~dif~~ determind.

2) Caustic embrittlement → $Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2 \uparrow$

$NaOH + Fe \rightarrow Na_2FeO_2 + H_2 \uparrow$ → Concentration cell → rivet

→ High stress ~~to~~

3) Boiler corrosion → dissolved O_2 → Removed by Na_2S, Na_2SO_3

→ Dissolve CO_2 → due to H_2CO_3 → Removed by NH_4OH

→ Dissolved salts → Forms acid → Chain rxn → ~~Rem~~ Prevented by

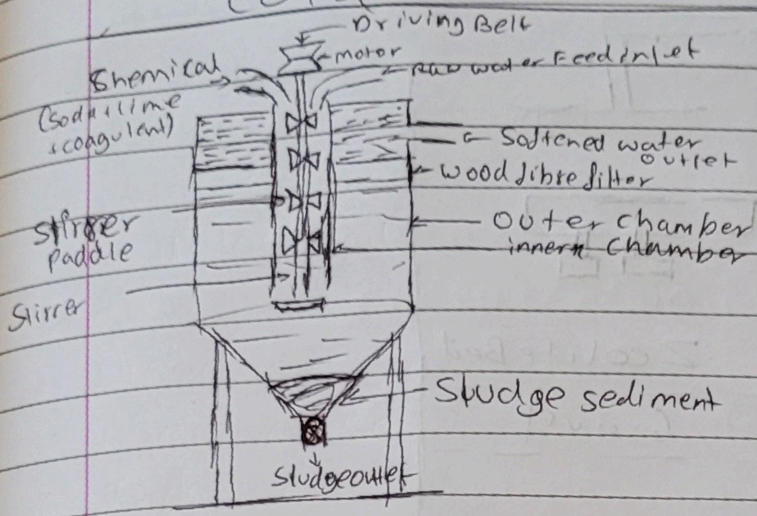
Additional ← Mg salt ← Removal

corrosion inhibiter

4) Sludge & scale → Formed by substance which is soluble in hot & the cold water, $CaCO_3$ deposition → Disadvantage → Bad heat conductor, reduces the efficiency

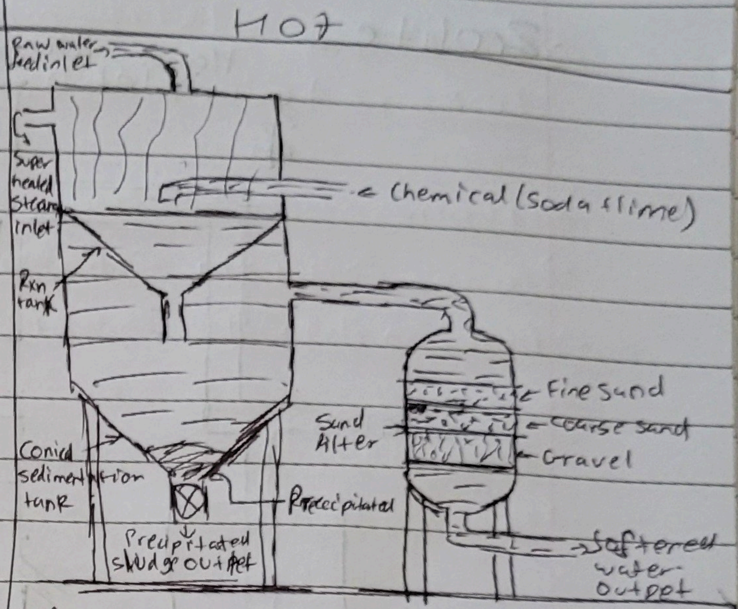
Softening water

Cold



- → Coagulent needed.
- → Slow Process
- → Softened water is passed through wood fibre filter
- → Hardness ~~remain~~ 50 - 60 ppm

Hot



- → No coagulent needed
- → Fast process
- → Sodtem water is passed through sand filter
- → Hardness 15 - 30

~~Advantan~~

Advantages

- → economical
- → Mineral content ↓
- → PH value of water ↑
- → Improves corrosion resistance

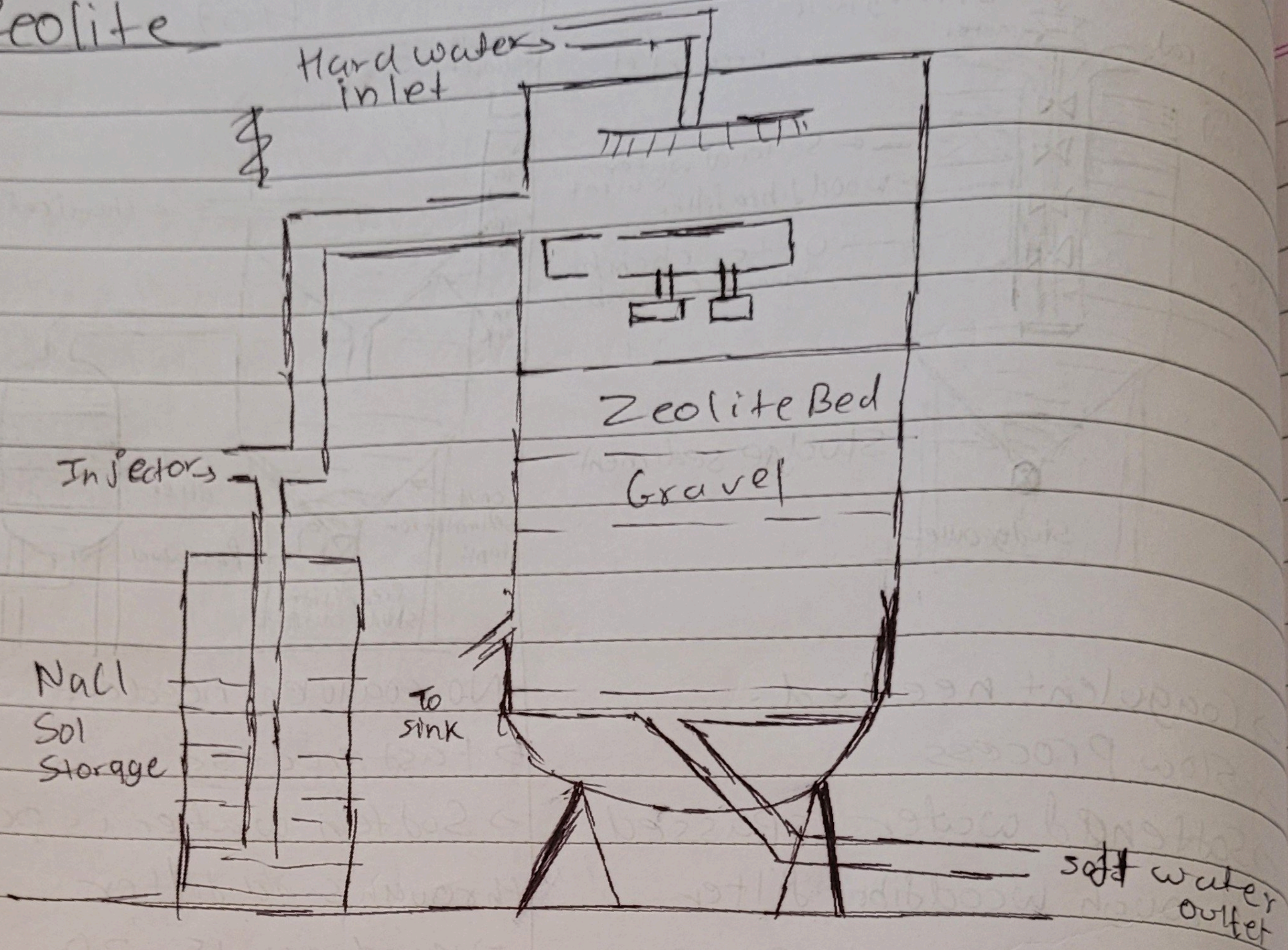
Disadvantage

- → High pressure boiler (X)
- → large amount of sludge

$$\text{Lime} = \frac{74}{100}\left(\text{Temp } Ca^{2+} + 2 \times \text{Temp } Mg^{2+} \text{ Perm}(Mg^{2+} + Fe^{2+} + Al^{3+}) + CO_2 + H^+ + HCO_3^-\right) \times \left[(\text{Vol of water})/1000\right] \times (100/\%P)$$

$$\text{Soda} = \frac{106}{100} \times \left(\frac{\text{Vol water}}{1000}\right) \times \left(\frac{100}{\%P}\right)\left(\text{Perm}(Ca^{2+} + Mg^{2+} + Fe^{2+} + Al^{3+}) + H^+ - HCO_3^-\right)$$

Zeolite



→ Passed throught zeolite bed

→ Ca^{2+}, Mg^{2+} salts present in Hard water gets exchange with Na

$CaCl_2 + Na_2Ze \rightarrow CaZe + 2NaCl$

$MgCl_2 + Na_2Ze \rightarrow MgZe + 2NaCl$

→ Regneration of zeolite bed is done by washing the zeolite bed with 10% NaCl solution.

$CaZe + 2NaCl \rightarrow Na_2Ze + CaCl_2$

$MgZe + 2NaCl \rightarrow Na_2Ze + MgCl_2$

Advantage

→ ~~Sa~~ Small & easy to handle

→ Less time

→ upto 10 ppm of residual

→ No sludge

Disadvantage

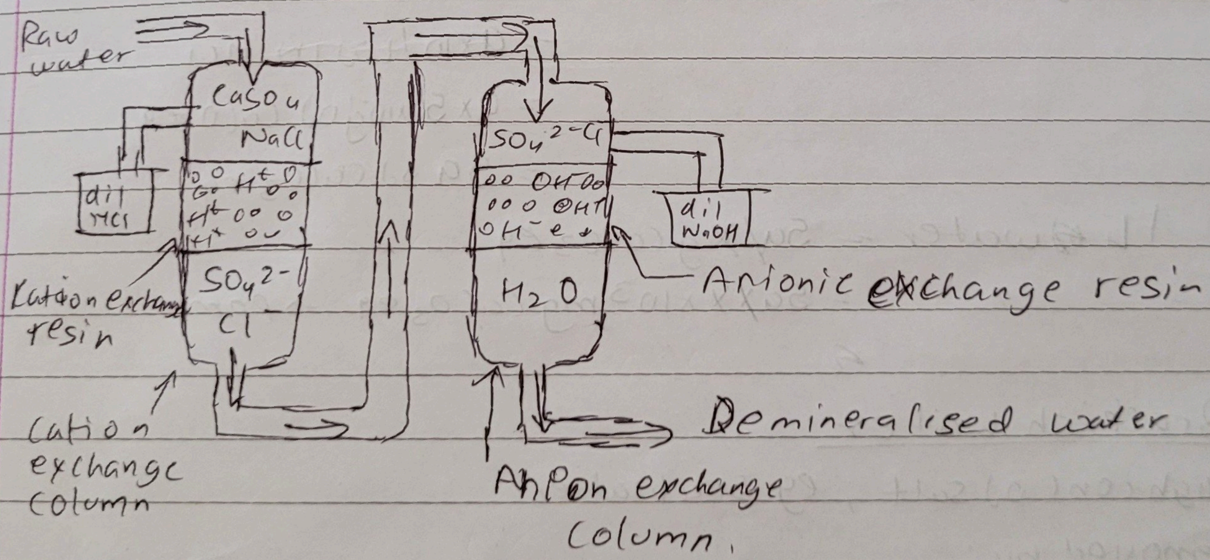
-> Highly turbid water (X)
-> Contains more Na^+ salts
-> Acidic ions (X)

'X'L of NaCl = a × b mg/Lit
= ab mg
= $ab \times \frac{50}{58.5}$ mg $CaCO_3$ eq

'y' litre water = $\frac{ab \times 50}{58.5}$ mg

1 litre = $\frac{ab}{y} \times \frac{50}{58.5}$ mg of $CaCO_3$ eq -> ppm

Ion exchang / Demineralization



-> 1st chamber

When passed H^+ exchanges Ca^{2+}, Mg^{+2} etc

$2RH^+ + Mg^{2+}Cl_2 \rightarrow R_2Mg^{2+} + 2H^+Cl$

$2RH^+ + Ca^{2+}Cl_2 \rightarrow R_2Ca^{2+} + 2H^+Cl$

-> 2nd chamber

When passed OH^- exchanges Cl^{-}, SO_4^{2-} etc

$R\text{-}OH + Cl^- \rightarrow RCl + OH^-$

$2R\text{-}OH + SO_4^{2+} \rightarrow R_2SO_4 + 2OH^-$

→ The H^+ from 1st chamber, OH^- from second cham combine to form H_2O.

Regeneration of Resin

→ Cation → dil HCl → $R_2Mg^{2+} + 2H^+ \rightarrow 2RH^+ + Mg^{2+}$

→ anion → dil NaOH → $RCl + OH^- \rightarrow ROH + Cl^-$

Advantage

→ Free of salts & and fit for use of boiler

→ Low Hardness nearly 2ppm

Disadvantage

→ Costly

→ Turbid water (x)

Hardness of 'X' litre of water = 'a' L of 0.1N HCl

$= a \times 10^{-1}$ L of 1N HCl

$= a \times 50 \times 10^{-1}$ g of $CaCO_3$ eq

$= 5a$ of $CaCO_3$ eq

1L water = $5a/X$ g $CaCO_3$ eq

$= 5a/X \times 10^3$ mg $CaCO_3$ eq → ppm

Brackish water

→ High conc of salt, eg seawater

→ Removed by:

- Electrodialysis

→ Based on principle that the ions present in saline water migrate towards respective electrode

→ Consist of a chamber with two electrode, the cathode & anode

→ anode place near anion selective membrane

→ Cathode place near cation selective mebrame

→ Under influence of applied emf across the electrodes the cation move towards cathode through membrane, and anion move towards

M T W T F S S
Page No.:
Date:
YOUVA

~~Advantage~~

anode through membrane.

→ Net result is depletion of ions in central compartment

Advantage

→ compact

→ economical

Reverse osmosis

→ ~~too~~ Higher → Lower conc

→ Hydrostatic pressure (15 – 40 kg/cm^2)

→ Polymethacrylate, Polyamide

Advantage

→ Low cost

→ Can be used for high pressure boilers.

BOD	COD
→ It measures oxygen demand of biodegradable organic pollutants only	→ It measures oxygen demand of bio & non bio degradable organic pollutants
→ It is a measure of oxygen ~~for the~~ required for the biological oxidation of organic matter under aerobic condition at 20°C for a period of 5 days	→ It is a measure of oxygen required for the chemical oxidation of organic matter when refluxed in acidified $K_2Cr_2O_7$ in the presence of Ag_2SO_4 or $HgSO_4$ catalyst for 3 hr.
→ Less stable measurement technique	→ More stable measurement technique
→ Slow process	→ Fast process
→ BOD < COD	→ COD > BOD.

Significance

BOD

- Helps in pollution control of water
- Express self purification ~~or~~ capacity of any waterbody

COD

- It helps in rapid determination of pollutants
- taken as basis for calculation of efficiency & designing of water treatment plants

$$BOD = [(DO)_{Blank} - (DO)_{incubated}) \times D.F$$

$$D.F = \frac{\text{Volume after dil}}{\text{Volume before dil.}}$$

$$COD = \frac{(V_b - V_t) \times N_{FAS} \times 8 \times 1000}{Y} \rightarrow mg/L / ppm$$

Y → volume of water

Polymers

Classification

→ **Structure**
- Linear
- Cyclic
- Branched
- Network

→ **Molecular Force**
- Thermoplastic
- Thermosetting
- Elastomers
- Fibers

→ **Source**
- Natural
- Synthetic
- Addition
- condensation
- Semisynthetic.

→ **Tacticity**
- Isotatic
- Syndiotatic
- Atatactic

Ideal Polymer

→ Inert
→ Non-toxic
→ Producible
→ Good mechanical strength

Why polymer

- → Strong, ligh weight
- → Optical & superior
- → ~~Size~~ Mouldable
- → Mechanical strength
- → Long lide
- → Cheap
- → reusable

Compounding Polymer

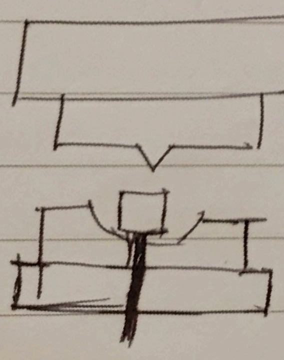
- → Resin → main constituent
- → Filler → strength or reduce cost eg carbon black, $CaCO_3$
- → Plasticizers → sodten & improve flow eg triphenyl phosphate
- → Colorants → pigments ~~or~~ or dyes eg Titanium oxide
- → Lubricant → Reduce friction eg vegetable oil
- → Flame retardents → flammability ↓
- → Cross-linking agents → thermosets
- → Stabilizer → UV light absorbers, Antioxidants
- → Cataylst → H_2O_2, etc

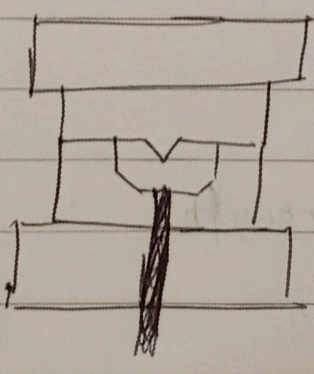
Moulding

Compression

→ In which a moulding polymer is squeezed into a preheated mold taking a shape od the mold cavity & performing curing due to heat & pressure applied.

→ Thermo setting resin





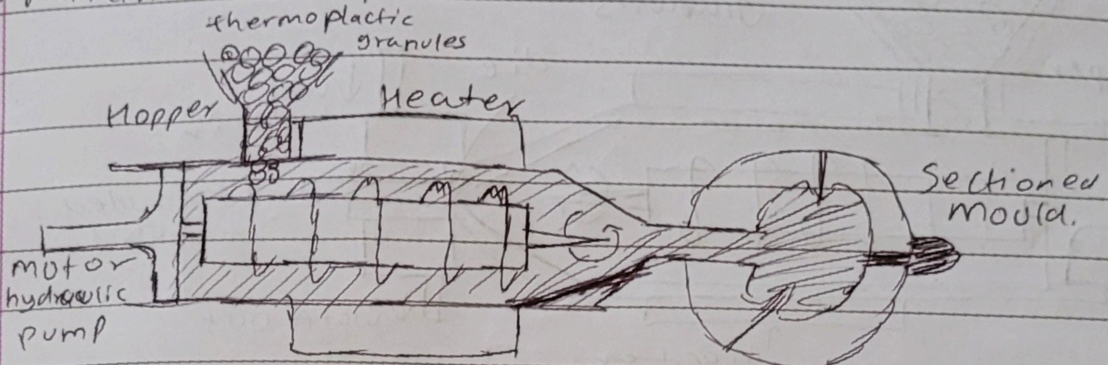
Injection

-> Obtained molded products by injecting plastic materials molten by heat into a mold & then cooling & solidifying them.

-> High production rate

-> low laboor costs

-> minimal scrap losses

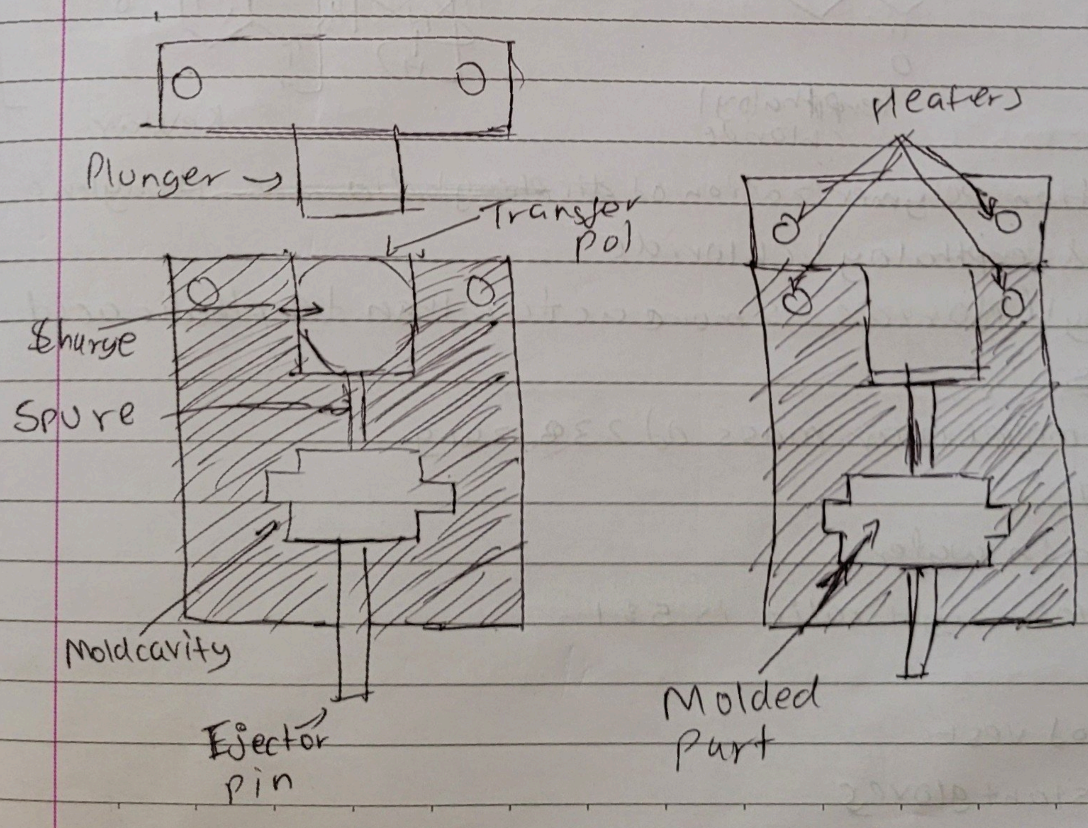


Transfer

-> Combines Compression & injection

-> Pot transfer

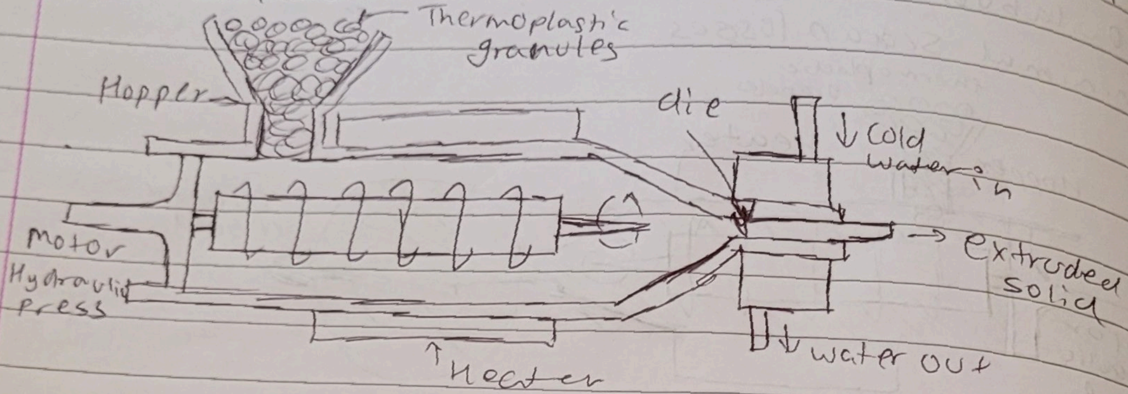
-> Plunger transfer



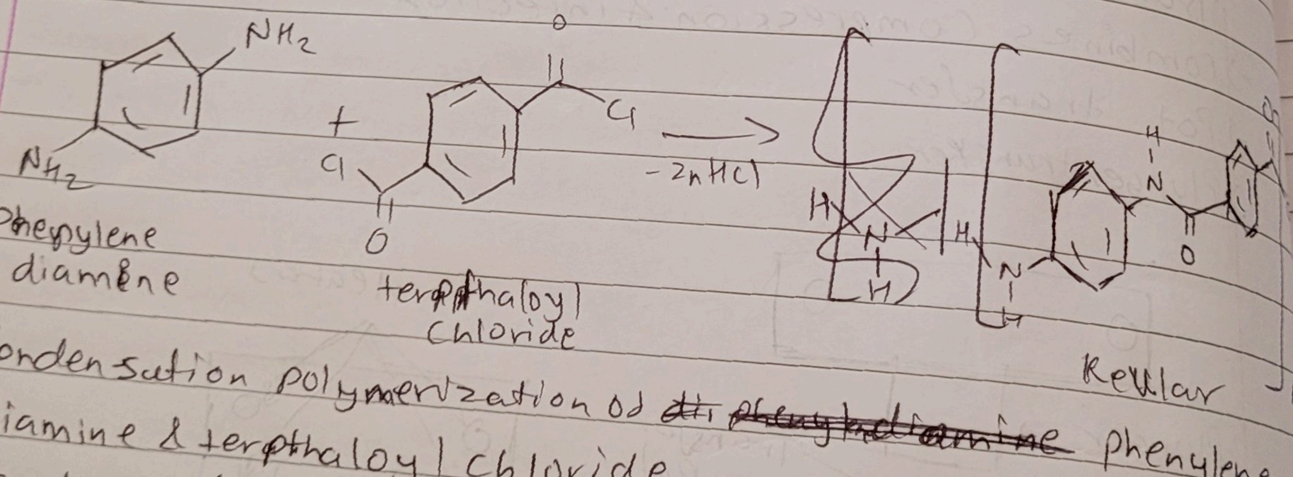
Extrusion molding

→ Same as injection molding

→ Only difference being ~~that~~ the softened material is allowed to flow out through a die in a continuous stream rather than be pumped intermittently in measured amounts into a mould.



Kevlar



→ Condensation polymerization of ~~phenyl diamine~~ phenylene diamine & terpthaloyl chloride

→ Terpthaloyl Chloride is more active than terpthalic acid.

Properties

→ Relative molecular mass of 238.241g

→ g_t of 170°c

→ Insoluble in water

→ Tensile to weight ratio is 5:1

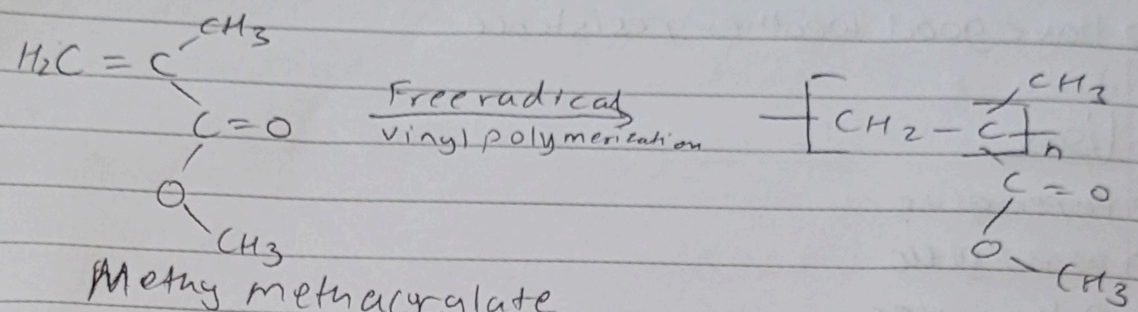
Uses

→ Bullet proof vest

→ Heat resistant gloves

M T W T F S S
Page No.:
Date:
YOUVA

PMMA



Methy methacrylate

- Addition polymerization od Methyl methacrylate
- Catailysts used - Butyl lithium

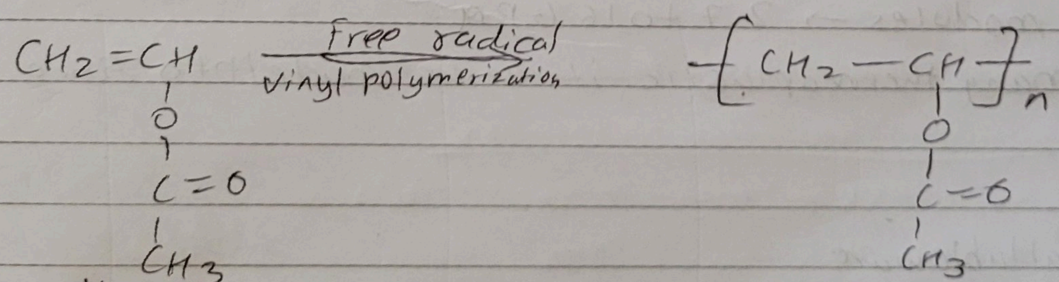
Properties

- Lighter theanglass
- shatter prooof
- transmits more lightthanglass
- Sofster & easier to scratch thenglass

Uses

- Pelxiglass inaqurimdiums
- In bome cement
- In Pacemaker

PVA



Vinylacetate

- Addition polymerization od vinyl acetate
- ~~Roofer~~

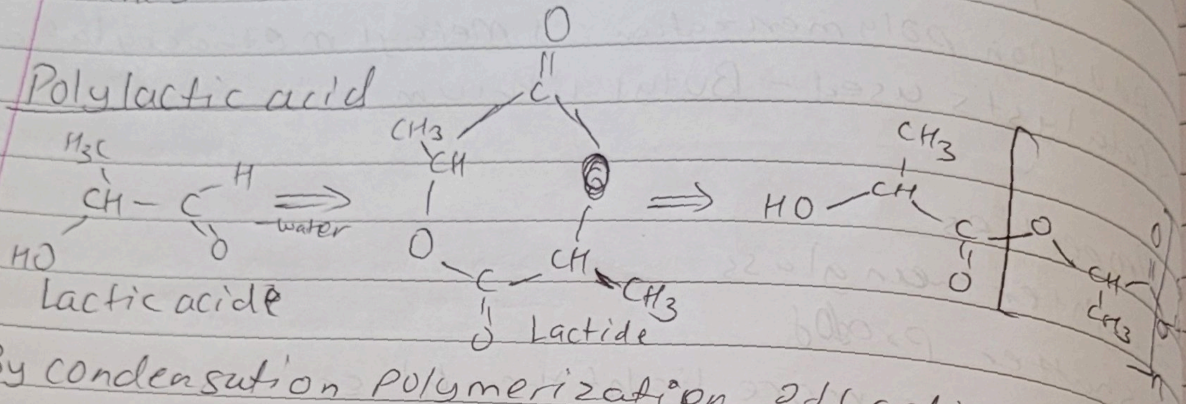
Properties

- Mp 30-45°c
- Can absorb 3-5% od water at 60°c for 10hr

→ Combustible
→ Have good weather resistance

Uses
→ Paper glue
→ wood glue
→ Adhesives

Polylactic acid



→ By condensation polymerization of lactic acid by removal of water
→ By open ring polymerization of Lactide
→ ~~One of the~~ second largest used biodegradable ~~poly~~ plastic
→ Made from corn, cassava, etc
→ Made by injection moulding, extrusion.

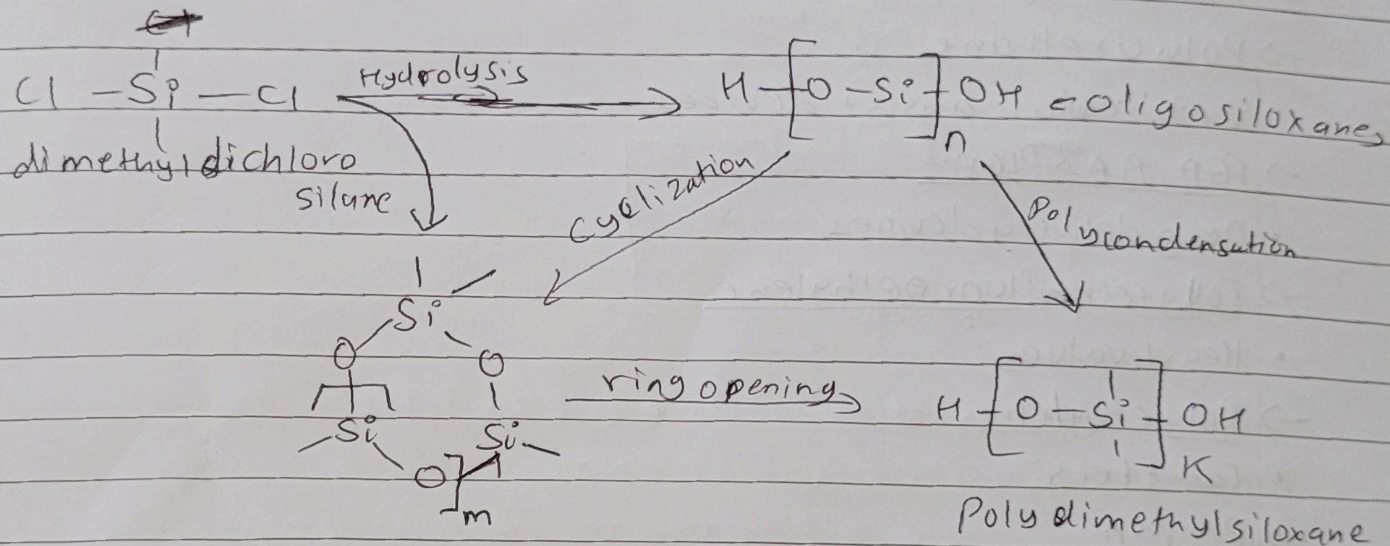
Properties
→ g_t → 60–65°C
→ Mp → 130–180°c
→ Youngs modules → 2.7 to 16 GPa
→ Like many thermoplastic it can be made into fibre

Uses
→ Disposal tableware
→ Diapers
Used is sculptra used to treat lipoatrophy.
Made into screws, mesh, etc to be implanted

Degradation

→ Hydrolysis
→ Thermal degradation
→ Photodegradation
→ Recyclable
→ Composting
→ Incineration
→ landfill.

PolyDimethylsiloxane



Cyclic Oligosiloxane

→ It is a inorganic polymer
→ Prepared by poly condensation
→ Known for ~~unsual~~ unusual rheological properties

Properties

→ viscoelastic
→ Inert
→ non toxic
→ nonflammable
→ Hydrophobic
→ soluble in acetone, Pyridine

Uses

- Surfanct
- Rain-X
- Synthesis of geko adhesion dry adhesive materials
- antifoaming
- implants

Applications of biomaterial

- PDMS
  - Heart valve
- Polyurethane
  - Ventricular assist devices
- PGA, PLA & PLGA
  - Drug delivery devices
- Polytetrafluoroethylene
  - Heart valves
- Polyethylene
  - Catheters
- PMMA
  - Fracture fixation
- Cellophane
  - Dialysis membrane

Conducting polymers

Intrinsically conducting polymers

- Belongs to class of organic materials
- Unique electronic properties
- Conjugated electrons is responsible for these properties
- Investigated in opto electronics, etc.
- Eg → Polythiophene

M T W T F S S
Page No.:
Date:
YOUVA

Doped conducting polymer

- Redox rxn
- Formation of soliton
- It exhibit's very low conductivities
- Until an electron is removed from the valance bond (p-doping)
  or
- Added to conduction band (n-doping)
- Doping generates charge carriers which move in the electric field
- This movement is responsible for electrical conductivity

Oxidation

$(C_2H_2)_n + FeCl_3 \rightarrow (C_2H_2^+)_n FeCl_4 + FeCl_2$

Reduction

$(C_2H_2)_n + C_{10}H_7NH_2 \rightarrow [(C_2H_2^-)_n NH^+] + C_{10}H_8$

ECP

- Consists of polyethene with % of conducting Carbon black
- The degree of electric conduction depends on temperatures.
- At Higher temp conductivity decreases as the material expanded, seperating the Carbon black
- Visa-versa
- Used as ~~self~~ self regulating heater cable & poly switch.

Equations

$$\overline{M_n} = \frac{\sum_{i=1}^{N} N_i M_i}{\sum_{i=1}^{N} N_i}$$

$$\overline{M_w} = \frac{\sum_{i=1}^{N} N_i M_i^2}{\sum_{i=1}^{N} N_i M_i}$$

$$[\eta] = K M^{a}$$

$$PDI = \frac{M_w}{M_n}$$

$$DP_w = \frac{M_w}{M_0}$$

$$DP_m = \frac{M_n}{M_0}$$

Nanoparticle

Properties
1) Large fraction of surface atoms
2) High surface energy
3) Spatial confinement
4) reduced imperfection

Principle factor
i) Relative surface area
ii) Quantum effects:
→ Quantum confinement effect can be observed on the diameter of particle is of the same magnitude as the wave length of electron
→ Responsible for increase of energy gap between energy state and bandgap
→ When particles are small there electric, optical & magnetic properties differ significantly from bulk material.

Classification
→ zero (dots)
→ one (wires, rod)
→ two (plates, network)
→ three (fullerenes – C60, haeckelites)

Synthesis & processing
→ Deals with very fine structures
→ $1m = 10^9 nm$
→ This indeed allows us to think in both the 'bottom up' or the 'top down' approaches.
→ Bottom up (assemble atoms) eg synthesizing nanometallic inorganic material like glasses, glass ceramics or ceramics at very low temp)

-> Topdown (Dis-assemble) eg the synthesis od porous silicon by electrochemical etching.

Shortnote on fullerenes

-> They are spherical carbon-cage molecules with sixty (C60) or more carbon atom.

-> Named after R. Buckminster fuller.

-> It is a hollow pure carbon molecules in which atom lies at the vertices od polyhedron with 12 pentagonal faces and any number od hexagonal faces.

-> Each carbon is bound to other three carbon in pseudo spherical arrangement od alternating pentagonal and hexagonal rings like a football.

-> They measure about 0.7 - 1.5 nm in diameter.

-> studied for potential medical use: they are strong antioxidants, when binded to specific antibiotics we get a target resistant baterica and also target cancer cell.

-> ~~Studied~~ heat resistance and superconducttivity.

Quantum ~~bots~~ dots

-> Semiconductor nanocrystal.

-> Easily tunable by changing the size and composition od the nanocrystal.

-> Changing size and shape and composition: can change dramatically their absorptive and emissive properties

Application

Medicine

-> Useful tool monitoring cancerous cells.

-> Qdots in future could be armed with tumor-fighting toxic therapies to provide the diagnosis and treatment od cancer

→ They are more resistant to degradation than other optical imaging probes, allowing them to track cell processes for longer periods of time.

LED-

→ To produce inexpensive, industrial quality white light.

→ Marked improvement over traditional LED.- phosphor integration by dot's ability to absorb and emit at any desired wavelength.

Solar cells and photo voltaics

→ Traditionally made of semiconductor and expensive to produce.

→ Upperlimit (Theoretical) is 33% efficiency for conversion of sunlight to electricity for these cells.

→ Use of Qdots allows realization of 3rd-gen solar cells at ~60% efficiency while being $100 or less per m^2 of paneling necessary.

→ Effective due to Qdots ability to preferentially absorbs and emit radiation that results in optimal generation of electric current and voltage.

Other (Future)

→ Anti-counterfeiting capabilites: Ability to specifically control absorption and emission spectra to produce unique validation signatures. Almost impossible to mimic with traditional semi-conductor.

→ Counter-espionage/Defense application: Integrate quantum dots into dust that track enemies. Protection against friendly-fire events.

Page No.:
Date:

Haeckelite

-> It has been proposed to designate a three fold coordinated network generated by a periodic arrangement of pentagons, hexagons and heptagons.

-> Starting from a planar Haeckelite array, tubular structures are obtained by applying the same wrapping procedure as for the usual nanotubes, which are rolled up sheets of graphene.

-> The Haeckelite nanotubes may a adopt various shapes, among which coiled structures, double screw molecules, corrugated cylinders, and pearl-necklace-like nanotubes are the most spectacular.

-> A planar structure containing square and octagonal rings which is called Haeckelite 8-4

Properties

-> Regular coiled nanotubes exhibit exceptional mechanical, electrical, and magnetic properties due to the combination of their peculiar helical morphology and the fascinating properties of nanotubes.

-> For straight nanotubes with small diameter, it has been demon-strated that they exhibit either metallic or semi conducting electrical ~~conducting~~ conduction depending on their chiral vectors and independent of the presence of dopant or defects.

-> Coiled nanotubes can show even semimetallic characteristics, in addition to the metallic and semiconducting behaviors, which could not be manifested in straight nanotubes.

-> straight carbon nanotubes as discontinuous reinforcement for polymer matrices is regarded as the ultimate carbon fiber with break strengths as high as 200 GPa and elastic moduli in the 1 TPa range.

-> Carbon nanotubes also have aspect ratios of around 10^3, w 500 times more surface area per ~~gram~~ gram, and possess extraordinary capability of returning to their original, straight structure following deformation.

Application

-> Use in resonating elements or nano-springs and in reinforcement composites.
-> Carbon-based material that can be used as carbon filler
-> Use as tactile sensors
-> Ability to inhibit the breeding of keloid fibroblast.
-> Detect smallest mass changes.

SN on CNT (Carbon nanotube)

-> Derived from long hollow structure with wall formed by one atom thick sheets of carbon called graphene.
-> The sheets are rolled at specific and discrete (chiral) angle.
-> Properties differ by rolling angle and radius.
-> They have outstanding mechanical & electrical properties and are good thermal conductors.
-> The tensile strength is 6-7 times stronger to steel.
-> It can be metallic or semiconducting depending on their structure.

Nano

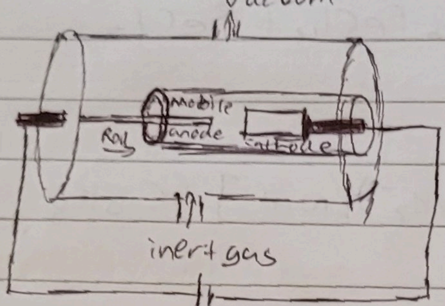
CNTs

Properties

→ Electrical conductivity → Good
→ Strength & Elasticity → Good
→ Thermal conductivity → high
→ High aspect ratio → High
→ Field emission

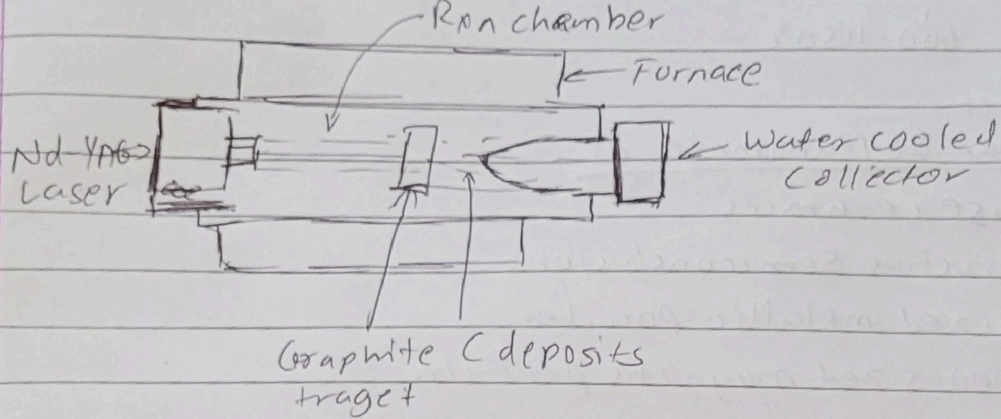
Method of preparation

→ ~~Las~~ Arc Method



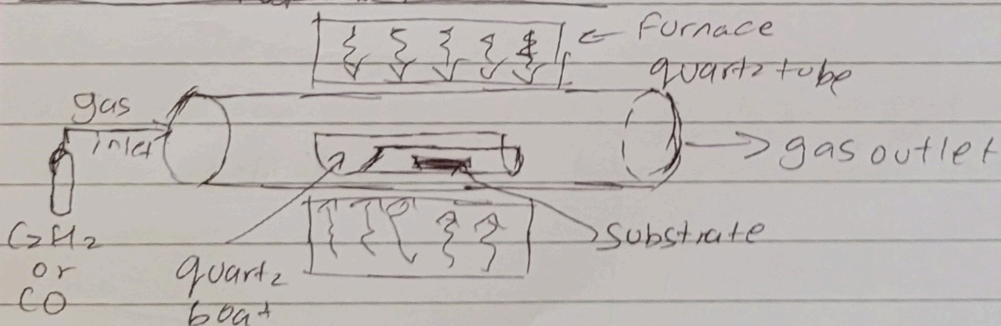
→ Initially used to produce C60 fullerenes
→ Easyiest way to produce CNTs
→ It produces a complex mixture of components and will need further purification.
→ CNTs is produced by arc-vaporization of two carbon rods placed end to end, seperated by 1mm
→ It is filled with inert gas at low pressure
→ A ~~dire~~ dc of 50A to 100A ~~driven~~ with voltage of 20V,
→ Creating a high temp discharge.
→ It forms a rod shaped deposit
→ Producing CNTs in high yield depends on uniformity of the plasma arc & temp of the deposite forming on the carbon electro

Laser Method



- Dual-pulsed laser is used
- Graphite rods with a 50:50 catalyst mixture of cobalt & Nickel at 1200°C in flowing argon
- Followed by heat treatment in a vacuum at 1000°C to remove fullerences
- The two successive laser pulses minimizes the amount of carbon deposited as soot
- Material produced appear as a mat of 'rope', 10-20 nm in diameter & upto 100 μm or more in length
- Diameter & sizes ~~by~~ changes by changing temp, catalyst & other parameters

Chemical Vapor Deposition



- Large Amount of CNTs can be produced.
- Catalytic CVD of acetylene over cobalt and iron catalysts supported of silica or zeolite
- In this CH_4 and C_2H_6 are cracked under pressure of 10^4 Pa in presence of catalyst like Fe, Co, Ni, Pt

→ MWNT & SWNT are formed
→ 300-800°C   600-1150°C

~~Importance~~
~~Application~~ Od Nanomaterial

→ Nano phase ceramics
→ Nano structure semiconductors
→ Nano-sized metallic powder
→ single nano-sized magnetic particles
→ Sunscreen
→ Microbial fuel cell

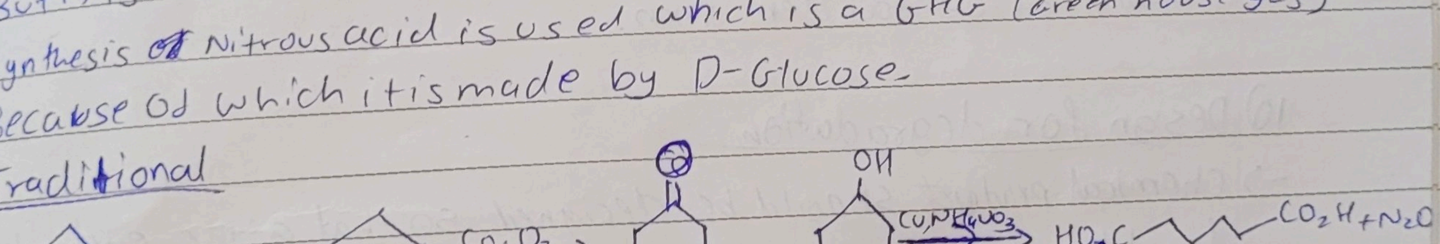
Disadvantage

→ Instability od the particles
→ Impurity
→ Biologically harmful
→ Difficult in synthesis, isolation, application.

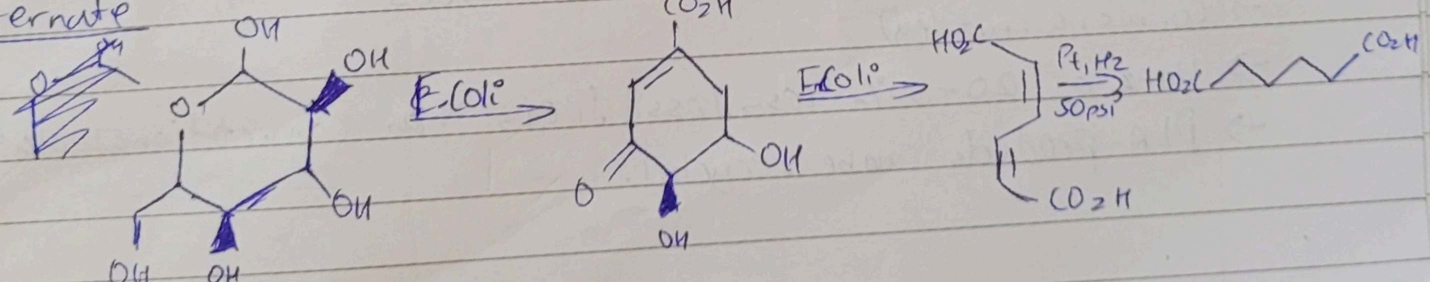
5) Use od safer solvent.
-> The solvents & seperating agents should not be used unnecessarily
-> Chlorinated solvents are toxic & carcinogenic
-> If solvent is necessary water is good medium or some ecofriendly solvents like supercritical CO_2 can be used

6) Energy Efficiency
-> The aim od green chemistry is to increase energy efficiency
-> This is achieved by using catalyst instead od fossils fuels.
-> Energy efficiency can be increased by:-
i) Proper heat transfer
ii) minimal wastage od energy during the process

7) Renewable Feedstock
-> Adipic acid is require in large amount as raw material to synthesis it into nylon & Lubricants.
-> But it is made by benzene which is toxis & carcinogenic. Also during synthesis Nitrous acid is used which is a GHG (Green house gas)
-> Because od which it is made by D-Glucose.
-> Traditional



-> Alternate



Green chemistry

Goals & Objective

- To reduce adverse enviromental impact, try innovate & appropriate choice od chemicals
- To develop process ~~es that produce~~ renewable instead od non-renewable raw material
- To develop processes that are less prone to obnoxious chemical realise, fire & explosion
- To develop less toxic ~~prosses~~ processes.
- To improve energy ~~effiency~~ efficiency od processes
- To ~~delo~~ develop efficient & reliable method to monitor the process.

Principles

1) Prevention od waste

- It is better to prevent waste than to treat or clean up the waste
- $A + B \rightarrow C + W$ → original
- $1 + 2 \rightarrow C$ → zero waste
- Enviromental factor (E-factor) concept that has play a major role in focusing the attention on the problem od waste generation in electronic manufacture

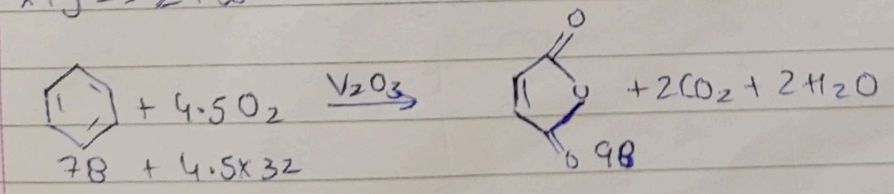
2) Atom economy

- It is the method od expressing how eddiciently a particular reaction makes use od the reactant atom.
- $$\%\text{ Atom economy} = \frac{\text{mass od desired product}}{\text{Sum od mass od reactants used}} \times 100 = \frac{\text{Mass od } Z \times 100}{\text{Mass od } X + \text{Mass od } Y}$$

reactant desired

$$X + Y \Rightarrow Z + W$$

eg)



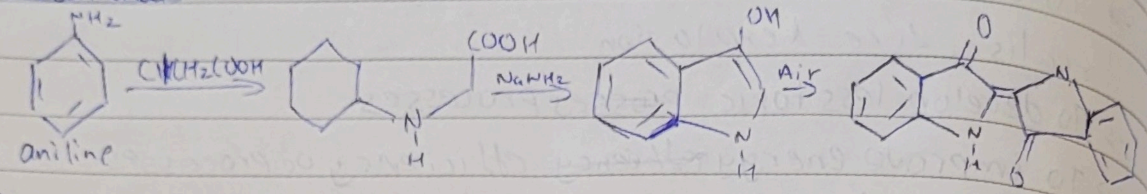
$$\%\text{ Atom economy} = \frac{98}{78+144} \times 100 = 44.156\%$$

3) Non Hazardous synthesis

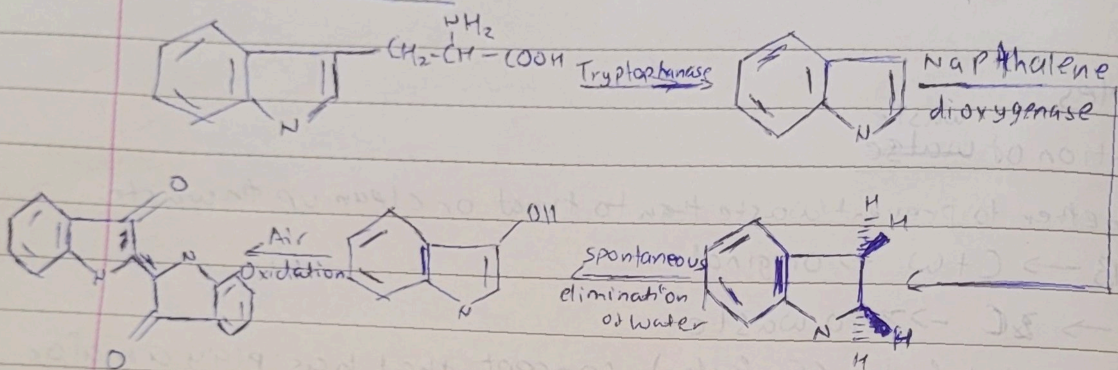
→ Wherever practicable, synthetic methods should be designed to use and generate substances that ~~proce~~ possess little or no toxicity to human health or enviroment.

eg Indigo dye

Traditional



Green synthesis



4) Sader chemicals and product

→ For reducing toxicity, the eddiciency od desired product should be preserved

→ Chemicals products should be designed to carry out their desired function while minimizing their toxicity.

→ There are two crucial ~~points~~ elements in approaching the goal od sustainability in chemical products and process: alternative ~~assessment~~ assessment & molecular design.

8) Avoid chemical derivatives

-> Unnecessary derivatization or temporary ~~modification~~ modifying should be avoided.

-> Derivatives increases the steps and reduces the atom economy

-> Additional reagents are required & generates more step

9) Catalysis

-> Catalytic reagents are superior to stoichiometric reagents

-> Catalyst facilitates transformation without being consumed or without being incoporated into the final product.

-> It helps in energy efficiency

-> It is recyclable & reusable

-> Bio-catalysis

i) Enzymes or whole cell micro-organisms

ii) Benifits

- Fast rxn due to correct orientation.
- Water soluble
- Moderate conditions
- Possibility of tandem rxn.

10) Design for degradation

-> Chemical product should be designed so that at the end of their function they do not persist in the enviroment and instead should break down into innocuous degradation products

-> Manufactured from renewable resources

-> Corn or wheat (eg)

-> Uses of 20-50% less fossil fuels than conventional plastic

-> PLA products can be recycled.

11) Real time analysis

→ Analytical methodologies need to be futher developed to allow for real-time in-process monitoring and control prior to the formation of Hazardous substances.

→ Methods & tech should be developed so that the prevention or minimization of generation of hazardous waste.

→ This can prevent any accidents which may occur in chemical plants

12) Inherently safe chemistry

→ substances and the form of substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires