UTKALMANI GOPABANDHU INSTITUTE OF ENGINEERING, ROURKELA



LECTURE NOTES

PREPARED BY- SATARUPA SAHU

SUBJECT- CHEMICAL PROCESS INDUSTRY-II

DEPARTMENT OF CHEMICAL ENGINEERING

SESSION- 2022-23

UTKALMANI INSTITUTE OF TECHNOLOGY, ROURKELA-4

DEPARTMENT
OF
CHEMICAL ENGINEERING

SUBJECT: CHEMICAL PROCESS INDUSTRY-II
COURSE CODE: TH-3

PRESENTED BY: SATARUPA SAHU

Chapter 1-Pesticides

LESSON OBJECTIVE

The topics help the students

- To understand the definitions & types of pesticides, Chemical reaction and process involved in DDT manufacturing

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 1	Definition of Pesticides
Lecture 2	General classification of Pesticides
Lecture 3	Classification based on Composition of Pesticides
Lecture 4	Manufacturers of India and Chemical Reactions involved in DDT manufacturing
Lecture 5	Flow diagram description of DDT
Lecture 6	Process description of manufacturing of DDT

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Define pesticides.
2. Classify various types of pesticides
3. Describe the manufacturing process of DDT with flow sheet
4. Differentiate between organophosphorus and organochloride pesticides.
5. Give examples of Fungicides, Bactericides
6. Write two pesticides manufacturer of India
7. Write down the reactions involved in manufacturing of pesticides

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

Pesticides:

- A **pesticide** is a substance used to kill feral animals, insects, fungi or plants. There are thousands of different pesticides in use today.
- Most of the pesticides used today are chemicals which have been developed in a laboratory by scientists and produced in factories.
- Some pesticides are quite hazardous, as they can be harmful to humans and other living things.
- They can contaminate land, the air, food crops, and water ways and seriously harm or kill native animals, pets and domestic animals.

Pesticides come in three different forms:

- solids, which come in powder form (like flour), or in crystal or granular form (like sugar)
- liquids, which look like milky water
- Aerosols, which are sprayed out in a fine mist.

Classification of Pesticides:

- Pesticides can be grouped according to the types of pests which they kill:
- Insecticides - insects
- Herbicides - plants
- Rodenticides - rodents (rats and mice)
- Bactericides - bacteria
- Fungicides - fungi
- Larvicides - larvae

Insecticides:

- It is important to know the target insect's habits when choosing the insecticide and which form (solid, liquid, granule or aerosol) to use.
- For example, flying pests such as adult mosquitoes are best attacked by aerosol sprays or fogs (droplets in the air), while crawling insects are best treated with surface powders, sprays or granules for dermal and/or oral entry.
- Insecticides kill insects by getting inside their bodies where they then act as poison.

Herbicides and Rodenticides:

Herbicides

- Herbicides are used to kill plants. This may be by:killing that part of the plant which they touchkilling the plant when they are absorbed into it through the leaves, stems or roots.

Rodenticides

- Rodenticides are used to kill rodents. These poisons are usually put into food to make poisonous baits which rodents eat.

Fungicides, Bactericides and Larvicides

Fungicides

- Fungicides are pesticides that kill or prevent the growth of fungi and their spores.
- They can be used to control fungi that damage plants, including rusts, mildews and blights.
- They might also be used to control mold and mildew in other settings.
- Fungicides work in a variety of ways, but most of them damage fungal cell membranes or interfere with energy production within fungal cells.

Bactericides

- A bactericide is a substance which kills bacteria. Bactericides are chemical substances like disinfectants, antiseptics, or antibiotics.

Larvicides

- A larvicide is a type of insecticide used to control mosquitoes indoors and outdoors around your home.
- They work by killing mosquito larvae before they can grow into adults.
- Some formulations are activated when ingested by the mosquitoes, and some formulations work when they come into contact with the larvae.

Organochlorine insecticides:

- These are synthetic organic compounds which contain chlorine. They include substances such as DDT, dieldrin, chlordane, heptachlor and endosulphan.

- Organochlorines are mainly used as contact and oral poisons which act on the nervous system.
- Because of their persistence in and impact on the environment, organochlorines are no longer used to treat pests in or around buildings.
- Only one organochlorine is currently registered and it is used only in agriculture under permit.
- All other organchlorines were deregistered for use in Australia in 1996.

Organophosphorus insecticides:

- These are synthetic organic pesticides which are manufactured from carbon chemicals and also contain phosphorus.
- They include chlorpyrifos, dichlorvos, malathion, diazinon and temephos.
- Some pesticides in this group are very toxic to mammals, such as people, kangaroos and dogs, and other animals such as bees and fish.
- Their use is restricted to prevent exposure to non-target species.
- Organophosphates tend to break down in the environment more rapidly than organochlorines but some of them do remain active for months or years.
- A number of organophosphate insecticides have been developed for the control of common household pests, for example: termites, flies, cockroaches, mosquitoes, and spiders.
- Some organophosphates contain solvents and can have a strong chemical odour.
- Some people object to this odour and as a consequence prefer only odourless pesticides be used around or in their homes.

Manufacturers of India:

- DhanukaAgritech Ltd.
- Bharat Rasayan Ltd.
- Insecticides India Ltd.
- Rallis India Ltd.
- Meghmani Organics Ltd.
- Sumitomo Chemical India Ltd.
- Bayer CropScience Ltd.
- P I Industries Ltd.

DDT Manufacturing:

- DDT refers to Dichlorodiphenyltrichloroethane.
- DDT is produced by a reaction between monochlorobenzene and chloral in the presence of Oleum as catalyst.

Monochlorobenzene + Chloral → DDT + H2O

- Therefore, to prepare DDT, first we need to prepare Chloral and purify it to the highest standard.
- Chloral is prepared by first forming chloral hydrate using chlorination of benzene route.
- The reaction for chloral is presented as

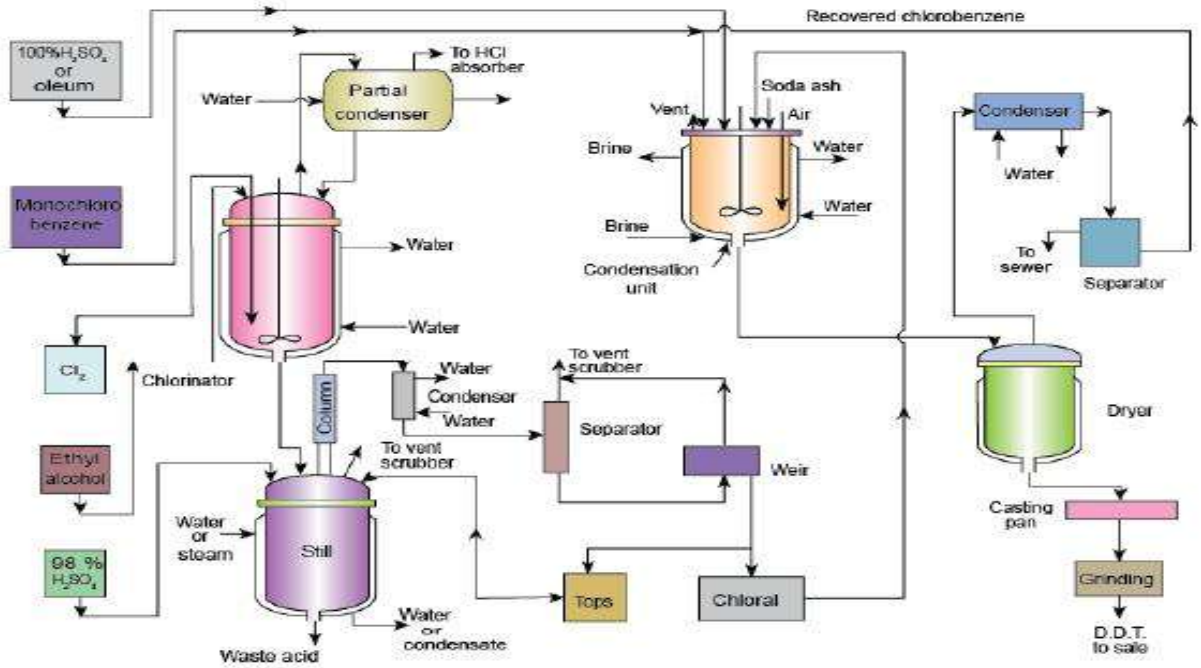
$$4\ Cl_2 + C_2H_5OH + H_2O \rightarrow Cl_3CCH(OH)_2 + 5\ HCl$$

- Then chloral hydrate is allowed to distill in the presence of sulphuric acid which dessicatesthe chloral hydrate to chloral.

Process Description:

- In the process technology, we first discuss the process technology of chloral which is an important ingredient.
- Dry chlorine is first absorbed into ethanol at room temperature conditions.
- In this process, the alcohol turns to a syrupy fluid.
- The operation occurs in a chlorination tank which produces chloral hydrate and HCl.
- From the chlorination tank, HCl is separated by using partial condenser.
- The uncondensibleHCl is sent for gas recovery using scrubbing.
- The liquid stream from the partial condenser is sent back to the chlorinator.
- The condensate from the chlorination tank is sent to a still, where distillation is facilitated in the presence of sulphuric acid which acts as a dessicant.
- Eventually, the still is operated at high temperature and for this purpose, steam is used for heating purposes.

- To control the operation, cooling water is also circulated in the jacket, as chloral hydrate conversion to chloral is a sensitive reaction.
- After the reaction, the batch still produces the waste acid as a product at the bottom and the clear chloral liquid at the top along with the vent gases.
- Eventually chloral is treated with lime to remove dissolved acidic impurities.
- The purified crude chloral is further sent to distillation in another still to remove chloral hydrates present in the stream. Therefore the second distillation unit is also operated in the presence of H_2SO_4.
- Vapors released during this step (from the partial condenser) are sent to the vent scrubber.
- Eventually, chloral is produced from the distillation unit and chloral hydrate is recycled back to the chloral hydrate converter to chloral.
- To manufacture DDT, purified chloral, mono-chlorobenzene, oleum are allowed to enter the DDT condensation unit.
- After condensation, the organic layer and spent acid are withdrawn.
- The organic layer consists of DDT and mono-chlorobenzene. This is first neutralized with soda ash.
- After reaction, the organic layer is sent to a dryer where the vapors generated from dryer enter a total condenser followed with gravity settling separator.
- The gravity settling unit separates mono-chlorobenzene from other organic impurities.
- The mono-chlorobenzene is recycled back to the condensation unit that is meant for preparing the DDT.
- The Dryer produces DDT powder which is sent for casting/pelletization process to obtain the DDT in either flakes or in pellets for sale.



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Chapter 2- PAINTS AND VARNISHES

LESSON OBJECTIVE

The topics help the students

- To understand definition and difference between paints, varnishes, lacquers, enamels. To understand the constituents of paint, manufacturing of paint and varnishes

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 7	Define paints, varnishes, lacquers, enamels
Lecture 8	Difference between paints and varnishes, Difference between lacquers, enamels
Lecture 9	Constituents of paints and their characteristics
Lecture 10	Manufacturing process of paints
Lecture 11	Manufacturing process of varnishes
Lecture 12	Latest advances in paint technology

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Define paint.
2. Define varnishes.
3. Define lacquer and enamel.
4. Write down the difference between paint and varnishes.
5. Write down the difference between lacquers and enamels.
6. Write down various constituents of paint.
7. Write down the manufacturing of paint with flow sheet.
8. Write any two famous Indian paints brand

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

PAINT

- Paint is any pigmented liquid, liquefiable, or solid matric composition that, after application to a substance in a thin layer, converts to a solid film.
- It is most commonly used to protect, color, or provide texture to objects.
- Paint can be made or purchased in many colors—and in many different types, such as watercolour or synthetic.
- Paint is typically stored, sold, and applied as a liquid, but most types dry into a solid.

Most paints are either oil-based or water-based

Varnish:

- Varnish is a clear transparent hard protective finish or film. Varnish has little or no colour and has no added pigment as opposed to paint or wood strain which contains pigment.
- Varnish finishes are usually glossy but may be designed to produce satin or semi-gloss sheens by the addition of "flatting" agents.
- Varnish is traditionally a combination of a drying oil, a resin, and a thinner or solvent.
- However, different types of varnish have different components.
- After being applied, the film-forming substances in varnishes either harden directly, as soon as the solvent has fully evaporated, or harden after evaporation of the solvent.

Differences between Varnish and Paint:

Paint:

1. Paint has added pigments.
2. It has long range of colour range from opaque to translucent.
3. It is applied to provide colour, texture and protection to the substrate.

Varnish:

1. Varnish has little or no colour, is transparent.
2. It has no added pigment.
3. Varnishes are also applied over wood stains as a final step to achieve a film for gloss and protection.

Lacquer:

- Unlike varnish, lacquer is a type of solvent based product. It's this makeup that allows to provide a particularly intense gloss finish.
- Lacquer is thinner than varnish and other finishes, so it's applied via a sprayer and is quicker drying as a result.
- This finish is even tougher than the one that varnish produces, being resistant to acid, alkali, water and casual bumps and knocks.
- Lacquer provides the extremely intense gloss finish because it contains a solution of shellac in alcohol that creates a synthetic coating.
- It is also durable and resistant to damage; however, it can begin to discolor and become scratched as time goes by.

Enamel:

- Enamel is one type of finish that is durable, attractive, and low maintenance.
- It can be used over old finishes and can cover small damages.
- Most furniture is covered with satin enamel finishes that come in high-gloss, semi-gloss, and matte forms.
- Enamel, especially shiny enamel, should only be applied on smooth surfaces with undercoats.
- Otherwise, it may emphasize the flaws in the furniture. It is also not advisable to use enamel over wax surfaces.

Constituents of Paints:

- Pigments
- Extenders or fillers
- Film forming materials
- Driers

- Thinners or Diluents
- Antiskinning Agent
- Plasticizers
- Resins
- Binders

Pigments

- Pigments are the organic or inorganic insoluble substances which are widely used in surface coatings.
- They protect the film by reflecting the destructive ultra violet light, to strengthen the film.

1. The important pigments used for making paints are:
   (i) White: White lead, titanium dioxide, zinc oxide.
   (ii) Red: Red lead, Iron oxides, cadmium reds
   (iii) Blue: Cobalt blue, Iron blues, etc.
   (iv) Green: Chromium oxide, chrome green
   (v) Black: Carbon black, lamp black, furnace black, etc.
   (vi) Metallics : Copper powder, zinc dust, aluminium, etc.
   (vii) Metal Protective pigments: Red lead, blue lead, zinc and basic lead, etc.

Extenders or fillers:

- The extenders or fillers are the low cost materials. These are added to the paint in order to decrease the cost of the paint. These supplement the pigment in increasing the covering and weathering power of the film. Talc, china clay, gypsum, silica, barite, glass flakes, asbestos and anhydrite, etc. are used as fillers in paints.

Film forming materials

- The vehicle or film forming materials serve dual purpose in the surface coating formulations.
- These are usually called drying and semi–drying oils, depending on the degree of unsaturation.
- Linseed oil, soyabean oil, tung oil, castor oil, varnishes, casein, fish oil, etc.are used as vehicles or drying oils.

Thinners or Diluents:

- Another ingredient, of paint is thinner. It is added to the paints to dissolve film forming materials and to dilute concentrated paints for better handling.
- After adding thinner, the paints may be applied more easily on the surface by brushing, spraying or dipping.
- Mineral spirits and solvents namely turpentine, maintains the fluidity of the freshly applied film for reasonable period of time.

Anti-skinning Agent

- Certain anti-skinning agents are also added to the paints in order to prevent gelling and skinning of the finished product before application of the paints by brushing, spraying or dipping.
- Polyhydroxy phenols are usually employed as antiskinning agents.

Driers:

- Certain driers (which are oxygen carriers) have also been used in the paints, in order to accelerate the drying of the film used as a drier.
- Modern driers are Co, Mn, Pb, Zn, resinoleate, linoleate and naphthenates, etc. oxidation and polymerization. Earlier, PbO was used.

Binders

- Binders act to fix the paint on the coated surface and provide tough, tenacious and glossy film on the painted surface.

Plasticizers

- Plasticizers are added to the paints to provide elasticity to the film and thus prevent cracking of the paint.
- Chemically, plasticizers are mostly esters.
- Triphenyl Phosphate, dibutyl phthalate and castor oil etc. are used as Plasticizers.

Resins:

- Varnishes are used as natural or synthetic resins.
- Examples of natural resins are copal or resin, while that of synthetic resins are Urea formaldehyde, acrylate, vinyl or silicone resins.

Paint (TiO_2):

- Titanium oxide is low cost per unit of hiding power.
- White paint contains 15 % TiO_2, 25% zinc oxide, 50% white lead, and 10% pigment extender.

Two ores of titanium

1. Rutile(TiO_2)
2. Ilmenite($FeO\text{-}TiO_2$)

Two process are there.

1. Wet chemical : Low quality, high cost
2. Flame process: Superior quality, low cost

Manufacturing of Paint:

- The various operation needed to mix paints are wholly physical.
- Chemical conversions are involved in manufacturing of constituents of paints and drying of paints.
- The weighting, assembling, and mixing of pigments takes place on the top floor.
- The mixer may be similar to a large dough kneader with sigma blades.
- The batch masses are conveyed to the floor below, where grinding and mixing take place.
- A variety of grinding mill may be used. Most commonly ball and pebble mills and steel roller mills are used.
- Recently sand mill, high speed agitator, high speed stone mills are used to grind paint and enamels.
- The mixing and grinding of pigments in oil requires much skill and experience to produce a smooth product without too high a cost.
- After mixing, the paint is transferred to the next floor, where it is thinned and tinted in agitated tanks, which may holds batches of several thousand litres.
- The liquid paint is strained into a transfer tank or directly into the hopper of the filling machine on the floor below.
- Centrifuges, screen, and pressure filters are used to remove non-dispersed pigments.
- The paint is poured into cans or drums, labeled, packed and moved to storage, each step being completely automatic.

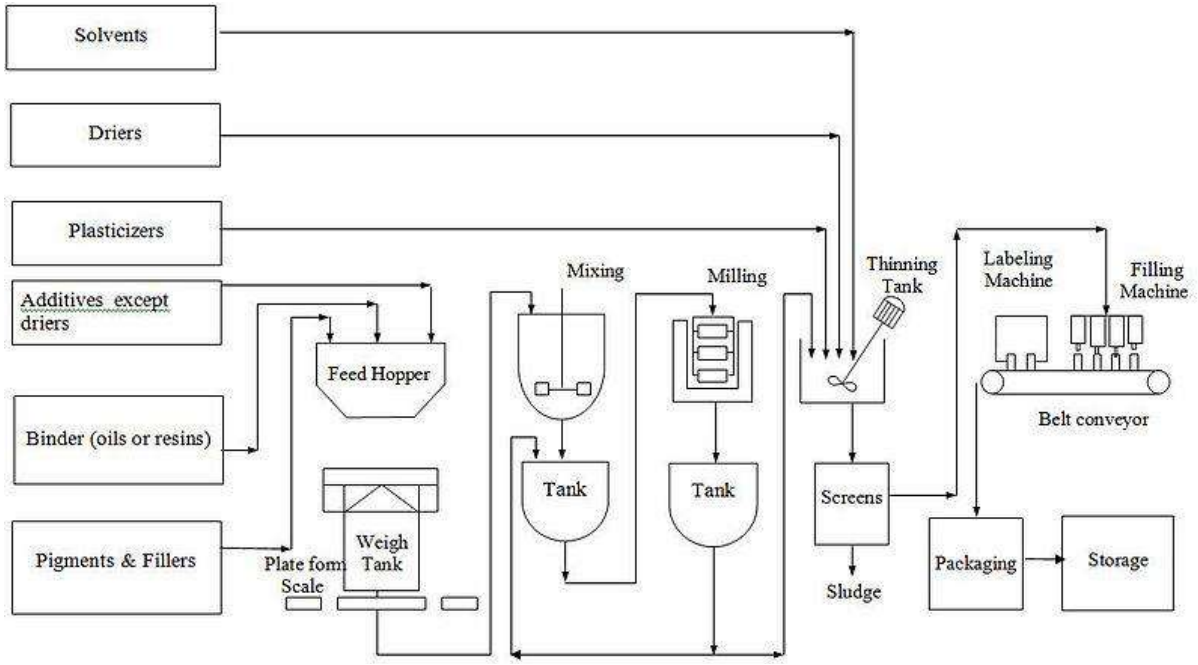


Table IIIC-2 Summary of Manufacture, Application and Use of Various Types of Surface Coatings

	Oil-based Paints	*Water-based Paints*	*Varnishes*	*Lacquers*	*Enamels*
Major unit operation in manufacture	Grinding or milling	Grinding or milling	Cooking	Mixing	See varnishes
Method of application	Brushing, dipping, spraying, or roller coating	Brushing, dipping, spraying, or roller coating	Brushing and spraying	Brushing, dipping and spraying	Brushing, spraying or baking
Mode of drying	Oxidation and/or polymerization	Evaporation and agglomeration	Oxidation and/or polymerization	Evaporation	See varnishes
Major product uses	General household and industrial applications	General household and industrial applications particularly for do-it-yourself application	Used in finishing furniture, exterior woodwork, marine application; also in electrical impregnation	Used in finishing metals and furniture, in food container linings and in coating fabrics	Used in finishing automobiles and other vehicles; used for small household appliances, lamps, etc.

Table IIIC-1 Components of Various Types of Surface Coatings

Component	*Oil-based Paints*	*Water-based Paints*	*Varnishes*	*Lacquers*	*Enamels*
Pigment	Titanium, lead, zinc oxides and colorants	Titanium, lead, zinc oxides and colorants	-	Optional	Titanium, lead, zinc oxides and colorants
Solvent (vehicle)	Oil	Water	Oil	Ethers, alcohols, esters, ketones	See varnishes
Film-former (resin)	Oil	Butadiene-styrene copolymer resin emulsion	Natural or synthetic resins	Nitrocellulose usually (or phenolic or alkyd resin)	See varnishes
Drier	Heavy metal carboxylates	-	Heavy metal carboxylates	-	Heavy metal carboxylates
Diluent (thinner)	Naphthas, turpentine	None used	Naphthas, turpentine	Naphthas, turpentine	Naphthas, turpentine
Plasticizer	Some oils	-	-	Dibutyl phthalate, tricresyl phosphate, etc.	-
Pigment extender	Clay, talc, etc.	Clay, talc, etc.	-	-	Clay, talc, etc.
Oil	Linseed, soya, tung, castor	-	Linseed, soya, tung, castor	-	Linseed, soya, tung, castor
Antiskinning agent	Polyhydroxy phenols	-	Polyhydroxy phenols	-	Polyhydroxy phenols
Dispersing agent	-	Casein	-	-	-
Antifoam agent	-	Pine oil	-	-	-
Preservative	-	Chlorinated phenols	-	-	-

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Chapter 3- EXPLOSIVE

LESSON OBJECTIVE
The topics help the students

- To understand different terms of explosives and difference between various explosives. To understand manufacturing of cellulose nitrate, nitro-glycerine and dynamite.

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 13	Definition of explosives and classification
Lecture 14	Difference between high and low explosives and their characteristics
Lecture 15	Blasting agent and slurry explosive
Lecture 16	Manufacturing of cellulose nitrate
Lecture 17	Manufacturing of nitro-glycerine
Lecture 18	Manufacturing of dynamite

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Define Explosive.
2. Classify various type of Explosive
3. Write down the difference between high Explosive and low Explosive
4. Write down two examples of booster.
5. Write down two examples of primary Explosive.
6. Describe the manufacturing of nitro-glycerine with flow sheet.
7. Describe the manufacturing of dynamite with flow sheet.
8. Describe the manufacturing of cellulose nitrate with flow sheet.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

EXPLOSIVE

- An explosive is a material that under the influence of thermal or mechanical shock, decomposes rapidly and spontaneously with the evolution of a great deal of heat and gas.
- The hot has causes extremely great pressure if the explosive is set off in a confined space.
- There are three types of explosives as per nature.

1. Mechanical
2. Chemical
3. Atomic

CLASSIFICATION OF EXPLOSIVE:

- According to behaviour, explosives are classified into two categories.
- Detonating, high explosive
    - Primary Detonator, initiating
    - Secondary, Booster
- Deflagrating, low explosive

HIGH EXPLOSIVE AND LOW EXPLOSIVE:

High Explosive:

- High rate, (2000-9000) m/s
- Reaction front is shock phenomenon
- Moving actively though out the material

Low explosive:

- Low rate, 10^{-2} m/s
- Reaction front is flame
- Burn in layers parallel to surface.

INITIATING OR PRIMARY EXPLOSIVE:

- Initiating or primary explosives are material that is quite shock and heat sensitive that can be made to explode by application of spark, flame, friction etc.
- Small quantities are required to start the explosion of large quantities.
- Used in primer, detonators, percussion caps.
- Mainly inorganic salts
- Ex: mercury fulminate, lead azide, tetrazine
- Glue acts as binder
- Ground glass increases internal friction.

BOOSTER/ HIGH EXPLOSIVE:

- These are insensitive to both mechanical shock and flame.
- These are energy amplifier
- Decomposition proceeds by means of detonations which is rapid chemical rupturing of bonds progressing directly through the mass of the explosive.
- Detonation is throught to be a chain reaction and proceeds at a rate of 6000 m/s.
- Ex: RDX, PETN, HMX

BLASTING AGENT AND SLURRY EXPLOSIVE:

Blasting agent:

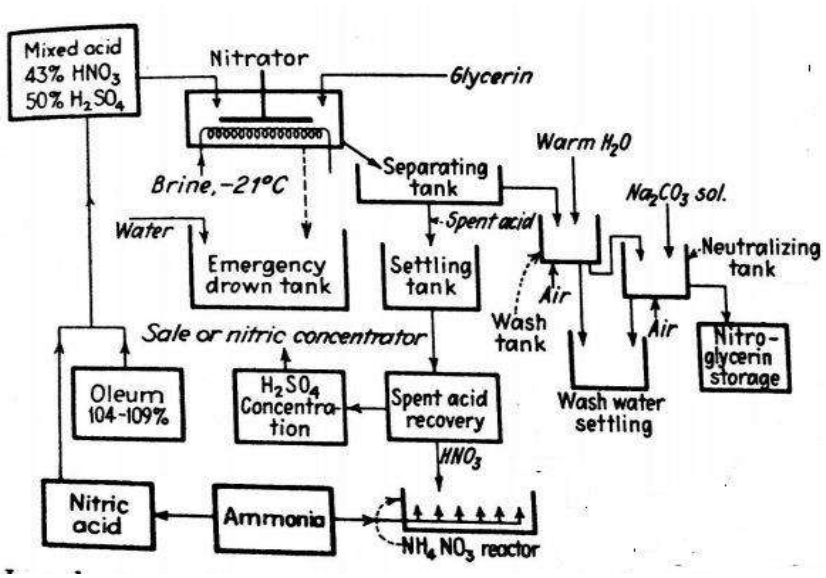
- Blasting agents are powerful explosive agents that meet the criteria that they cannot be detonated by means of blasting cap when unconfined.
- Very safe to handle.

Slurry Explosive:

- Slurry Explosive are ammonium nitrate mixture which frequently contain an oxidizer and fuel dispersed in fluid medium to control the rheology of gel slurry.
- KNO_3+ sulphur+ charcoal= initially used as explosive (75:15:10)

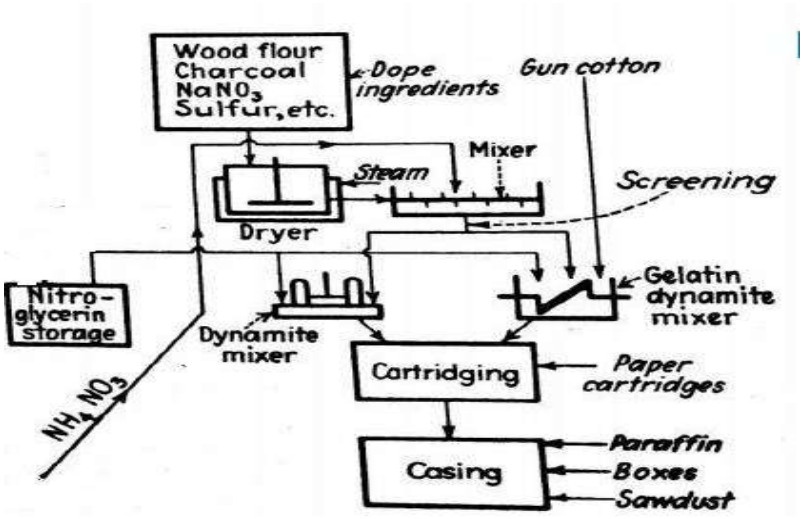
MANUFACTURING OF NITRO- GLYCERINE:

- Nitro-glycerine is made in nitrator with nitration reaction.
- Glycerol of high purity (99.9) % is added slowly to a mixture having composition of sulphuric acid (59.5) %, nitric acid (59) %, water (0.5) %.
- Nitration is accomplished in nitrator for (60-90) min with brine at 5C to control the temperature below 19C.
- After nitration the mixture of nitro-glycerin and spent acid is passed through a trough into separating tank and settling tank.
- In separation tank, nitro-glycerin and spent acid are separated. Nitro-glycerin proceeds towards wash tank whereas spent acid proceeds towards settling tank.
- From settling tank, the nitric acid, and sulphuric acid are sent to spent acid recovery section where sulphuric acid and nitric acid are separately sent to recovery section.
- Sulphuric Acid is concentrated and formed oleum with concentration (104-109)% and nitric acid. oleum and nitric acid are recycled back to nitrator.
- In wash tank, nitro-glycerin is washed with warm water twice and with a 2% sodium carbonate solution it is again neutralised.
- Wash water is collected in wash water settling tank.
- Nitro-glycerin is stored in its storage tank.
- Nitro-glycerin are made in continuous nitrator and nitrator is made of stainless steel.



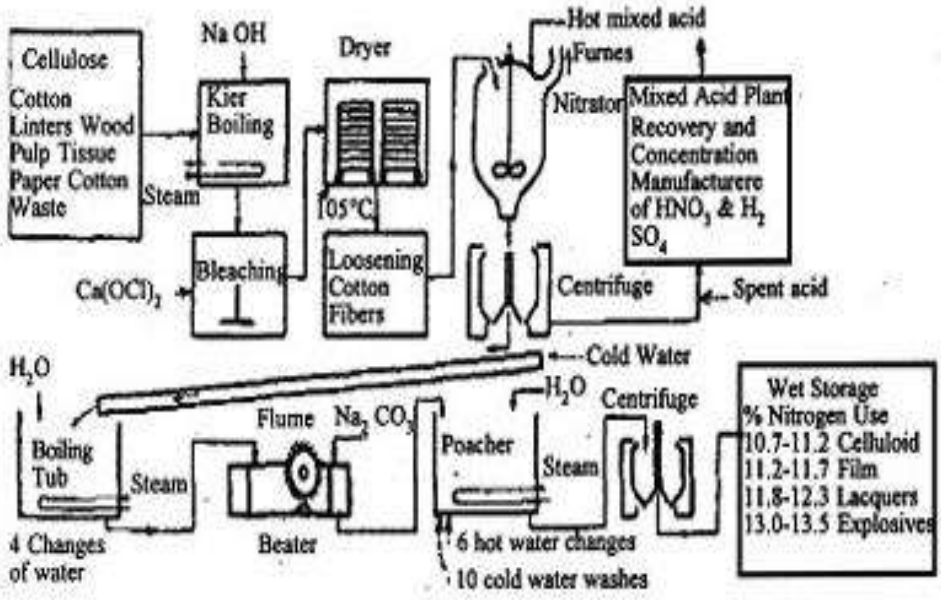
MANUFACTURING OF DYNAMITE:

- Nitro-glycerin is liquid and very sensitive to blows and freezes at 13 C.
- So nitro-glycerin is made into dynamite as in solid form, it is safer and easy to handle.
- Kieselguhr clay was earlier used as absorbing clay. In modern days, mixture of wood flour, ammonium nitrate or sodium nitrate acts as an absorber.
- This absorber can contains 75% nitro-glycerin.
- Non-freezing material such as glycol dinitrate is used.
- Gelatination of nitro+cellulose is done with nitro-glycerin.
- The product obtained as gelatin dynamite.
- Cartridging with paper cartilage is done and for casing, paraffin, sawdust are used.



MANUFACTURING OF NITRO- CELLULOSE:

- Cellulose molecule is a complicated one, with a molecular weight as high as 3, 00,000.
- Empirical formula $[C_6H_7O_2(OH)_3]_n$.
- Three hydroxy groups per fundamental (glucose) unit that may be esterified with nitric acid to yield a nitrogen content of 14%.



- Cotton linters or wood pulp high on alpha-cellouse are purified by boiling in kiers (bats) with dilute caustic soda solution.
- Bleaching is effected with $CaOCl_2$.
- The cotton is dried, fluffed and weighed.
- Mixed acid is made up from fortifying acid and spent acid brought to proper temperature and run into the nitrator.
- One nitrator charge contains 14.5 kg of purified cellulose and 682 kg of mixed acid at 30C for 25 min.
- Composition of acid: HNO_3 (21%), H_2SO_4(63%), N_2O_4 (0.5%), H_2O ((15.5%).
- Entire nitrator charge is dropped into centrifuge whereas the spent acid is centrifuged.
- The spent acid is partly fortified for reuse and rest is denitration and concentration of sulphuric acid.

- The nitrated cellulose is drowned with water, washed by boiling and washed in a beater.
- Forty hours of boiling with at least four changed of water is followed by pulping of fiber by means of beater.
- Poaching of washed nitrated cotton by boiling with a dilute Na_2CO_3solution (2.5 kg of soda ash/ton of cellulose nitrate) and then washes of boiling water.
- Poached nitrocellulose is free of most of water by centrifugation. The water content is now approximately 28%.

UTKALMANI INSTITUTE OF TECHNOLOGY, ROURKELA-4

DEPARTMENT
OF
CHEMICAL ENGINEERING

SUBJECT: CHEMICAL PROCESS INDUSTRY-II
COURSE CODE: TH-3

PRESENTED BY: SATARUPA SAHU

Chapter 4- PLASTICS

LESSON OBJECTIVE

The topics help the students

- To understand classification of polymer and definition of various polymers. To understand manufacturing of phenol formaldehyde, urea formaldehyde, polyethylene and P.V.C with their properties and uses.

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 19	Definition of Plastic/Polymer, Classification of Polymer
Lecture 20	Manufacturing of phenol formaldehyde one step resin method with their properties and uses.
Lecture 21	Manufacturing of phenol formaldehyde two step resin method
Lecture 22	Manufacturing of urea formaldehyde with their properties and uses
Lecture 23	Manufacturing of polyethylene with their properties and uses
Lecture 24	Manufacturing of P.V.C with their properties and uses.

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Define polymer.
2. Differentiate between thermosetting polymer and thermoplastic polymer.
3. Describe the manufacturing of phenol formaldehyde with a neat diagram and also write the properties and uses.
4. Describe the manufacturing of urea formaldehyde with a neat diagram and also write the properties and uses.
5. Describe the manufacturing of polyethylene with a neat diagram and also write the properties
6. Describe the manufacturing of P.V.C with a neat diagram and also write the properties and uses.

ASSESSNT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

Polymer:

- Polymers are large chain molecules having a high molecular weight in the range of 103 to 107.
- These are made up of a single unit or a molecule, which is repeated several times within the chained structure.

Monomer:

- A monomer is the single unit or the molecule which is repeated in the polymer chain. It is the basic unit which makes up the polymer.

THERMOSETTING POLYMER:

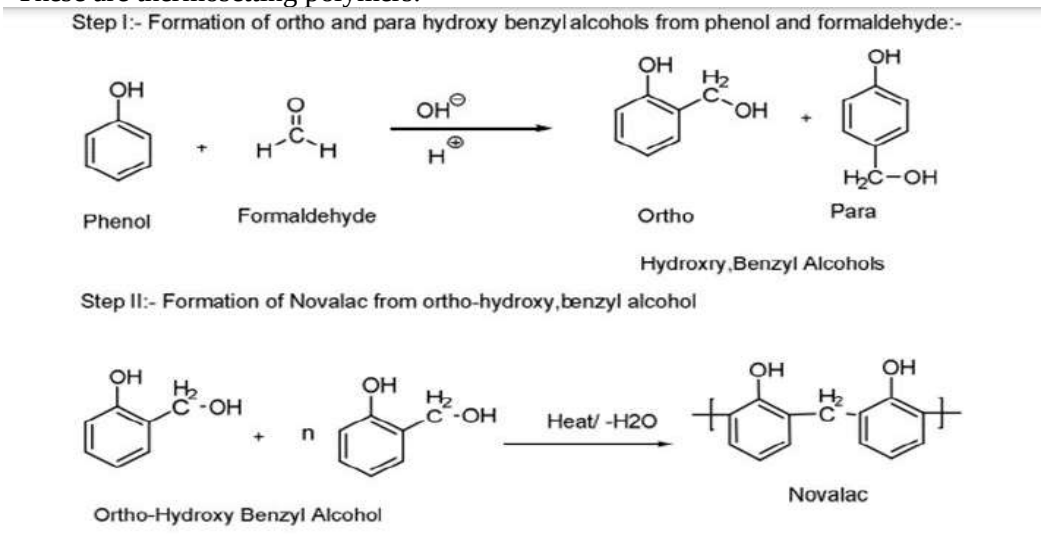
- The polymers which on heating change irreversibly into hard rigid and infusible materials are called thermosetting polymers.
- These polymers are usually prepared by heating relatively low molecular mass, semi fluid polymers, which becomes infusible and form an insoluble hard mass on heating.
- The hardening on heating is due to the formation of extensive cross-linking between different polymeric chains.
- This lead to the formation of a 3-Dimnesional network of bonds connecting the polymer chains.
- Since the 3D network structure is rigid and does not soften on heating, the thermosetting polymers cannot be reprocessed.
- Some important examples of thermosetting polymers are Urea-Formaldehyde resin and Melamine-Formaldehyde resins.

THERMOPLASTIC POLYMER:

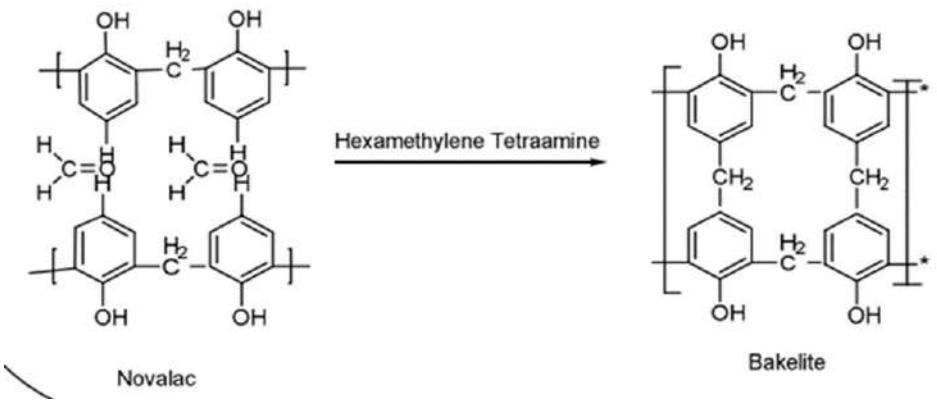
- The polymers in this category are composed of monomers which are linear or have moderate branching.
- They can be melted repeatedly and casted into various shapes and structures.
- They are soluble in solvents, but do not have appreciable thermal resistance properties.
- Example: Vinyls, cellulose derivatives, polythene and polypropylene fall into the category of thermoplastic polymers.

MANUFACTURING OF PHENOL FORMALDEHYDE:

- Phenol formaldehyde resins (PFs) are condensation polymers and are obtained by condensing phenol with formaldehyde in the presence of an acidic or alkaline catalyst.
- They were first prepared by Backeland, an American Chemist who gave them the name as Bakelite.
- These are thermosetting polymers.



Step III:- Formation of Bakelite from Novalac:-



PROPERTIES

- Phenol- formaldehyde resins having low degree of polymerization are soft.
- They possess excellent adhesive properties and are usually used as bonding glue for laminated wooden planks and in varnishes and lackuers.
- Phenol- formaldehyde resins having high degree of polymerization are hard, rigid, scratch resistant and infusible.
- They are resistant to non-oxidising acids, salts and many organic solvents.
- They can withstand very high temperatures.
- They act as excellent electrical insulators also.

USES:

- They are used for making moulded articles such as radio and TV parts, combs, fountain pen barrels, phonograph records etc.
- They are used for making decorative laminates, wall coverings etc.
- They are used for making electrical goods such as switches, plugs etc.
- They are used for impregnating fabrics wood and paper.
- They are used as bonding glue for laminated wooden planks and in varnishes and lackuers.
- Sulphonated phenol-formaldehyde resins are use as ion-exchange resins.

ONE-STEP RESIN:

- A mixture of phenol and formaldehyde are allowed to react in the presence of alkaline catalyst in resin kettle in definite proportion.
- The process involves formation of methylene bridges in ortho, para or both ortho and para positions.
- The resin discharged from the kettle is thermosetting or heat reactive so it requires further heating to complete the reaction to an infusible, insoluble state.
- This results first in the formation of linear polymer (Called NOVALAC) and then in to cross-linked polymer called phenol-formaldehyde resin or bakelite.

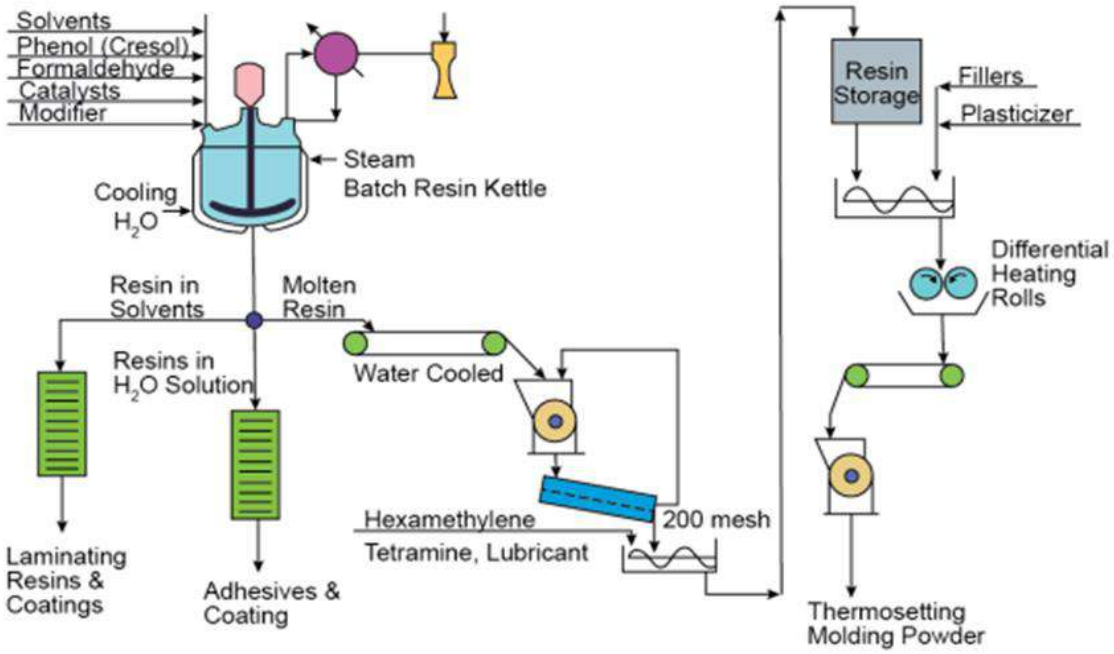
TWO-STEP RESIN:

- Only a part of formaldehyde is added in the kettle in making the resin and acid catalyst is used.
- The thermoplastic resin discharged from kettle is again reacted with thermosetting resin.
- The additional formaldehyde is furnished by hexa (hexa methylene tetra amine)

Process Description:

- The raw materials for the process – phenol, formaldehyde and the catalyst are mixed in a jacketed autoclave, which is also termed as a resin kettle and heated for 3-4 h at a temperature of (140-163) C.
- Inside the autoclave, the mixture is heated with steam.
- Water cooling and refluxing remove the excess heat of reaction.
- During the initial stages of the reaction, the heavy viscous resins settle as the bottom layer, with an aqueous layer on top.
- The warm viscous resin is send to shallow tray and allowed to cool and harden.

- The cooled brittle resin is crushed in crusher and finely ground in hammer mill and becomes the resin binder for molding.
- Activator (Hexa) is added to it in ribbon blender.
- Phenolic molding is done by compression and transfer molding.
- A combination of heat and vacuum in the resin kettle (autoclave) enables the dehydration of the reaction mixture.
- At around 130-150^{o}C, the resin fuses and is removed from the kettle.
- Then product is then cooled and is ground to form fine powders.
- This molding powder which forms can be mixed with fillers, colouring agents, lubricants and catalysts in a ball mill.
- In compression moulding, the powder is placed in hardened steel molds at a temperature of 132-182 C and pressure of 13.8-35 MPa.
- In transfer moulding, the thermosetting material is subjected to heat and pressure in an outside chamber and then these are sent to closed mold where curing occurred.
- In order to prepare the commercial phenolic molding powder, the final product may be further heated on a pair of differential heating rolls.



Manufacture of Phenol Formaldehyde.

MANUFACTURING OF POLYTHENE *(PE):*

Chemistry:

- The manufacture of polyethylene follows addition polymerization kinetics involving catalysis of purified ethylene.
- Its molecular formula is -$(CH_2$-$CH_2)_n$- with a molecular weight of 1,500 to 100,000.
- Its melting point is 85 – 110^{o}C.
- Its density is (0.91 -0.93) kg/m^3, when produced by high pressure process and 0.96 kg/m^3, when produced by low pressure process.

Technology: There are three processes by which polyethylene is manufactured

High Pressure Process:

- This process was developed in the UK by ICI.
- It uses peroxide catalyst at 100-300^{o}C and produces low density randomly oriented polymer which have a low melting point.
- The process is run at pressure of 1000 – 2500 atms. This process yields Low Density Polyethylene (LDPE).

Intermediate Pressure Process:

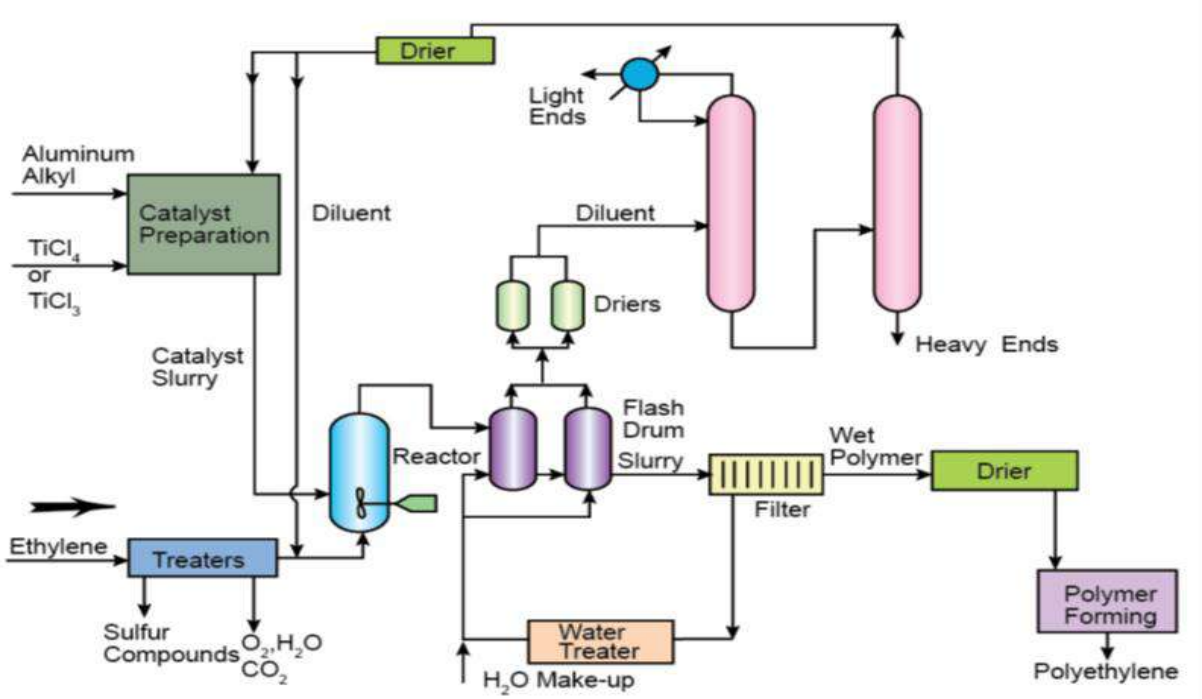
- This process was developed in the USA by Phillips Petroleum Co. for preparing high density polymer with increased rigidity, crystallinity, tensile strength and softening point.
- The process uses MoO_3 and Cr_2O_3 on alumina as catalyst and is operated at 30 – 100 atms.

Low Pressure Process:

- This process was originally developed in Germany for preparing high density polyethylene (HDPE).
- The catalyst used in this process consists of aluminium triethyl activated with heavy metal derivatives such as $TiCl_4$.
- In the process flow sheet (Figure 39.1), is the description of Low Pressure Ziegler Process to produce polyethylene.

PROCESS DESCRIPTION:

- At the very onset, through the process of desulphurization and removal of light ends, high purity ethylene is prepared.
- The ethylene is further treated to remove traces of oxygen and its compounds which can possibly deactivate the catalyst.
- The ethylene is first pumped into a reactor where it is mixed with catalyst diluents stream.
- The optimum temperature and pressure maintained should be 70°C and 7 atms gage.
- The effluent stream then follows across a series of flash drums in order to remove the solvent from the catalyst.
- The residual catalyst at this point is removed by adding water.
- The flashed solvent is thereafter recycled to the catalyst make –up unit after appropriate drying and redistillation.
- The slurry which results is then centrifuged to remove the water, and the water is treated to remove the catalyst before recycle.
- The final products of polyethylene solids are then dried, extruded and given the required final forms.



PROPERTIES:

- Excellent resistance to most solvents
- Very good resistance to alcohols, dilute acids and alkalis
- Moderate resistance to oils and greases
- Poor resistance to hydrocarbons (aliphatic, aromatic, halogenated).
- Higher tensile strength compared to other forms of polyethylene
- Low cost polymer with good processability.

- Good low temperature resistance
- Excellent electrical insulating properties
- Very low water absorption

APPLICATIONS

- **Packaging Applications** –Polyethylene is used in several packaging applications including crates, trays, bottles for milk and fruit juices, caps for food packaging, jerry cans, drums, industrial bulk containers etc.
- **Consumer Goods** – Low cost and easy processability make HDPE a material of choice in several household/ consumer goods like garbage containers, housewares, ice boxes, toys etc.
- **Fibers and Textiles** – Thanks to its high tensile strength, HDPE is widely used in ropes, fishing and sport nets, nets for agricultural use, Industrial and decorative fabrics, etc.
- Other applications of PE include **pipes and fittings** (pipes for gas, water, sewage, drainage, sea outfalls, industrial application, cable protection, steel pipe coating, large inspection chambers and manholes for pipe sewage etc.

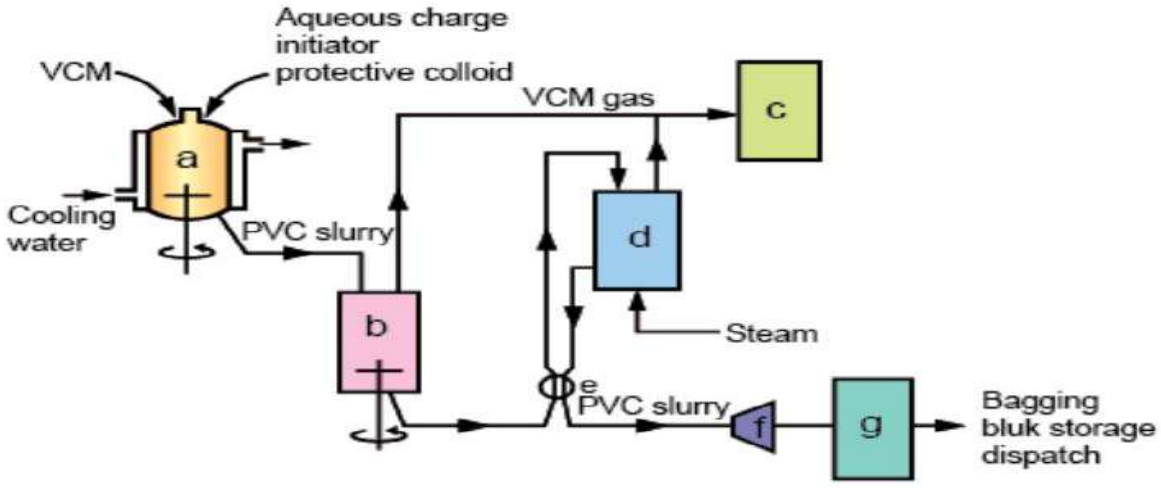
MANUFACTURING OF POLYVINYL CHLORIDE (PVC):

Chemistry:

- The manufacture of Polyvinyl Chloride (PVC) follows addition type kinetics and produces linear polymers. Its molecular formula is given as –
- The vinyl chloride monomer (VCM) has a boiling point of 13.4^{o}C and is a gas at room temperature and pressure.
- The vapor pressure of VCM over the typical polymerization temperature range of 50^{o}C to 70^{o}C is (800 – 1250) KPa.

PROCESS DESCRIPTION:

- The two most commercially use methods for the manufacture of PVC are Emulsion Polymerization and Suspension Polymerization.
- The Suspension Polymerization process provides 80 % of the world production.
- The Suspension Polymerization process is actually a bulk polymerization process which is carried out in millions of droplets.
- Each of these droplets act as small reactors. The liquid vinyl chloride is dispersed in water by vigorous stirring in a reactor.



a)Reactor; b)Blow down Vessel; c)VCM Recovery Plant; d)Stripping Column; e)Heat Exchanger; f)Centrifuge; g)Driers

- Even in the gel phase, the polymerization continues.
- The polymerization is rapid at first, but slowly, as the conversion reaches (80–85) %, the rate is reduced due to monomer starvation.

- At a predetermined pressure, the reaction is ended by adding a chain terminator or by venting the unreacted monomer to a recovery plant.
- Even after venting, the aqueous slurry contains (2–3) % unreacted monomer, which is then removed by stripping in a Stripping Column.
- The unreacted monomer is recovered and stored for later polymerization stages.
- The slurry is then passed through a heat exchanger and is passed through a continuous centrifuge to give a wet cake with (20–30) % moisture.

PROPERTIES:

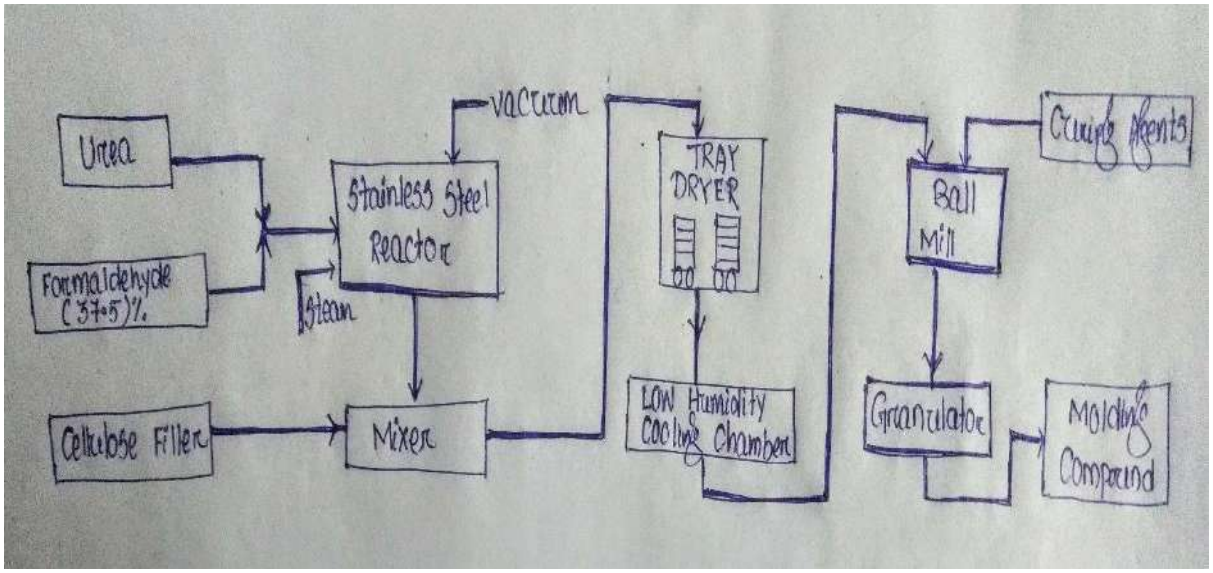
- **Electrical Properties**: PVC is a good insulation material, thanks to its good dielectric strength.
- **Durability**: PVC is resistant to weathering, chemical rotting, corrosion, shock and abrasion. It is therefore the preferred choice for many long-life and outdoor products.
- **Flame Retardancy**: Because of its high chlorine content, PVC products are self-extinguishing. Its oxidation index is ≥45.
- **Cost/Performance Ratio**: PVC has good physical as well as mechanical properties and provides excellent cost-performance advantages. It has long life span and need low maintenance.
- **Mechanical Properties**: PVC is abrasion-resistant, lightweight and tough.
- **Chemical Resistance**: PVC is resistant to all inorganic chemicals. It has very good resistance against diluted acids, diluted alkalis and aliphatic hydrocarbons.

APPLICATIONS:

Construction	Waterproof Membranes, Cable Insulations, Roof Lining, Greenhouses
Domestic	Flooring, Wall Coverings, Shower Curtains, Leather Cloth, Hosepipes
Packaging	Cling Film
Transport	Under Seal, Roof Linings, Leather Cloth Upholstery, Wiring Insulation, Window Seals, Decorative Trim
Medical	Oxygen Tents, Bags And Tubing For Blood Transfusions, Drips and Dialysis Liquids
Clothing	Waterproofs for Fishermen and Emergency Services, Life-Jackets, Shoes, Wellington Boots, Aprons and Baby Pants
Electrical	Cable & Wire insulation, plugs, cable jackets, sockets, Sable Heads and Distributors

UREA FORMALDEHYDE:

- Urea-formaldehyde (U) resin adhesive is a polymeric condensation product obtained by the chemical reaction off or maldehyde with urea, and it is considered as one of the most important wood adhesives.
- The UF resin adhesive is, an amino resin, and is most widely used for the manufacture of wood-based composite panels such as plywood, particleboard or medium density fibreboard.
- Therefore, the wood panel industry is a major consumer of UF resin adhesive.
- Urea, formaldehyde of 37.5% concentration are added to stainless steel reactor.
- Steam is provided to heat for the reaction and vacuum is maintained throughout the reaction to avoid production of extra by-product.
- Then the product is send to mixer where cellulose filler is added to enhance the stability and quality.
- Then the product from mixer is sent to tray dryer where removal of moisture takes place.
- In order to remove extra water, the product is fed to low humidity cooling chamber and a desired product is obtained.
- The product is sent to ball mill for making grounded powder where curing agents like lubricant, pigments and dyes are added.
- Then the product is sent to granulator for making the granules where desired sizes of products are obtained.



PROPERTIES:

- High tensile strength
- High flexural modulus
- High heat-distortion temperature
- Low water absorption
- Low mould shrinkage
- High surface hardness
- High elongation at break
- High volume resistance.

APPLICATIONS:

- Urea-formaldehyde is pervasive. Examples include decorative laminates, textiles, paper, foundry sand molds, wrinkle-resistant fabrics, cotton blends, rayon, corduroy, etc.
- It is also used as wood glue.
- UF was commonly used when producing electrical appliances casing (e.g. desk lamps).
- Foams have been used as artificial snow in movies.
- Urea-formaldehyde foam insulation (UFFI) dates to the 1930s.

UTKALMANI INSTITUTE OF TECHNOLOGY, ROURKELA-4

DEPARTMENT
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CHEMICAL ENGINEERING

SUBJECT: CHEMICAL PROCESS INDUSTRY-II
COURSE CODE: TH-3

PRESENTED BY: SATARUPA SAHU

Chapter 5-FIBER

LESSON OBJECTIVE

The topics help the students

- To understand classification of fiber and definition of fiber. To understand manufacturing of Nylon, Viscose rayon, Cupro ammonium rayon, Acetate rayon, Polyester with properties

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 25	Definition of Fiber and Classification fiber
Lecture 26	Manufacturing of Nylon with properties
Lecture 27	Manufacturing of Viscose rayon with properties
Lecture 28	Manufacturing of Cupro ammonium rayon with properties
Lecture 29	Manufacturing of Acetate rayon with properties
Lecture 30	Manufacturing of Polyester with properties

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Classify fiber.
2. Describe the manufacturing of Nylon with a neat diagram and also write the properties and uses.
3. Describe the manufacturing of Viscose rayon with a neat diagram and also write the properties and uses.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

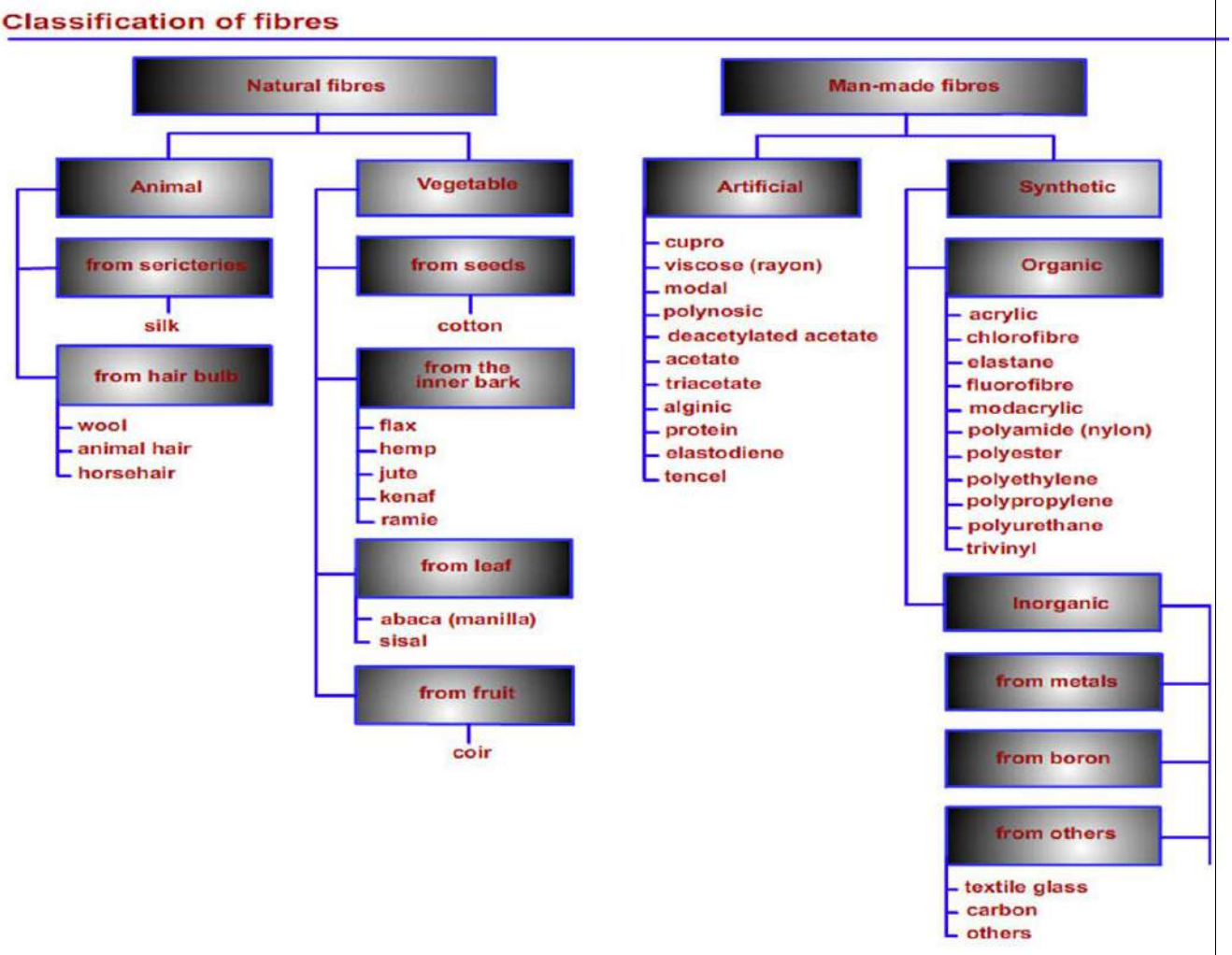
- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

INTRODUCTION:

- Textile fibers have been used to make cloth for several thousand years.
- First manufactured fiber was produced commercially on 1885 and was produced from fibers of plants and animals.
- Wool, flax, cotton and silk were commonly used textile fibers.
- Textile fibers are characterized by the flexibility, fineness and large length in relation to the maximum transverse dimension.

CLASSIFICATION:

I.	Natural fibers: Fibers which grow or develop and come from natural resources like plant and animals.
II.	Manufactured (or man-made) fibers: Fibers produced by industrial processes, whether from natural polymers transformed upon the action of chemical reagents or through polymers obtained by chemical synthesis (synthetic fIbers).
III.	Mineral Fibers: Asbestos is the only naturally occurring mineral fiber that was used extensively for making industrial products but is now restricted due to its suspected carcinogenic effect.



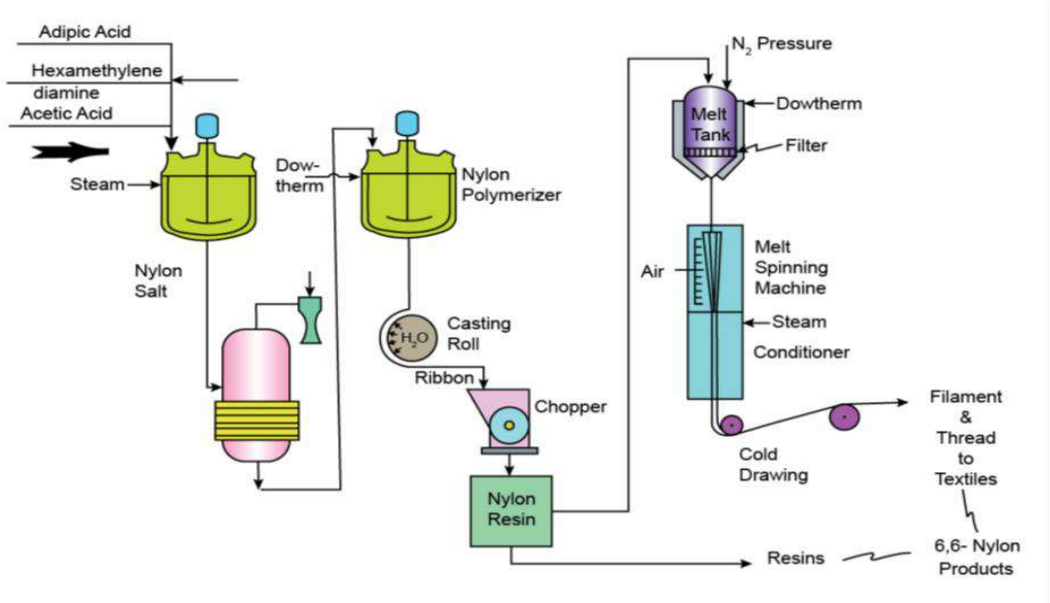
NYLON

POLYMER CHEMISTRY:

- Nylon 66 (or 6, 6- Nylon) is a condensation polymer formed by the condensation polymerization of Adipic acid (a dibasic acid) and hexamethylenediamine (a diamine).
- In the nomenclature, the first number refers to the number of carbon atoms in the diamine and the second number designates the number of carbon atoms in the dibasic acid.
- Nylon – 6 is a polymer of caprolactum.
- The number refers to the total carbon atoms in the ring, which can vary from 5 to 12.
- Both Nylon – 6 and Nylon – 66 have similar properties and can be used as thin films and fibres; and for extrusion and injection molding in plastics.
- The major difference in the physical properties of these two nylons is that the melting point of Nylon – 66 is 40 – 45^{o}C higher than Nylon – 6.
- Moreover, Nylon – 66 is harder, rigid and its abrasive – resistance is lower than that of Nylon – 6.

PROCESS DESCRIPTION:

- In the production of Nylon – 66, first, the amine and acid is mixed in an aqueous solution, with the pH adjusted at 7.8 to form Nylon salt.
- The salt is then concentrated under vacuum. It is thereafter charged to an autoclave where the rest of the water is removed.
- The temperature is gradually increased to 280^{o}C in the autoclave to complete the polymerization and the water of condensation is removed.
- The final product has a molecular weight of 12000 – 16000. It is extruded as ribbons onto chilling rolls.
- Then, it is sent to a chipper which produces small chips, which possesses the convenience of storage and rehandling.
- These chips are melted, metered through high pressure pumps. After filtration, these are passed via a melt spinnerette to produce nylon fibers.
- Upon cooling, these filaments harden and are wound on bobbins at a rate of 750 metres per minute or even higher.
- In order to give the fibre desirable textile properties, the threads are stretched to about 4 times its original length.
- The production of Nylon – 6 is similar to that of Nylon – 66 , the only difference being the nature of polymerization.
- Nylon – 6 is manufactured by the step – wise condensation of caprolactum with no net water removal.
- However, to maintain the thermal equilibrium between monomer and polymer at the melting and spinning temperatures is the only difficult task.
- Monomer retained on the fibres accounts upto 10%, so the fibres are water – washed to remove the soluble caprolactum retained.



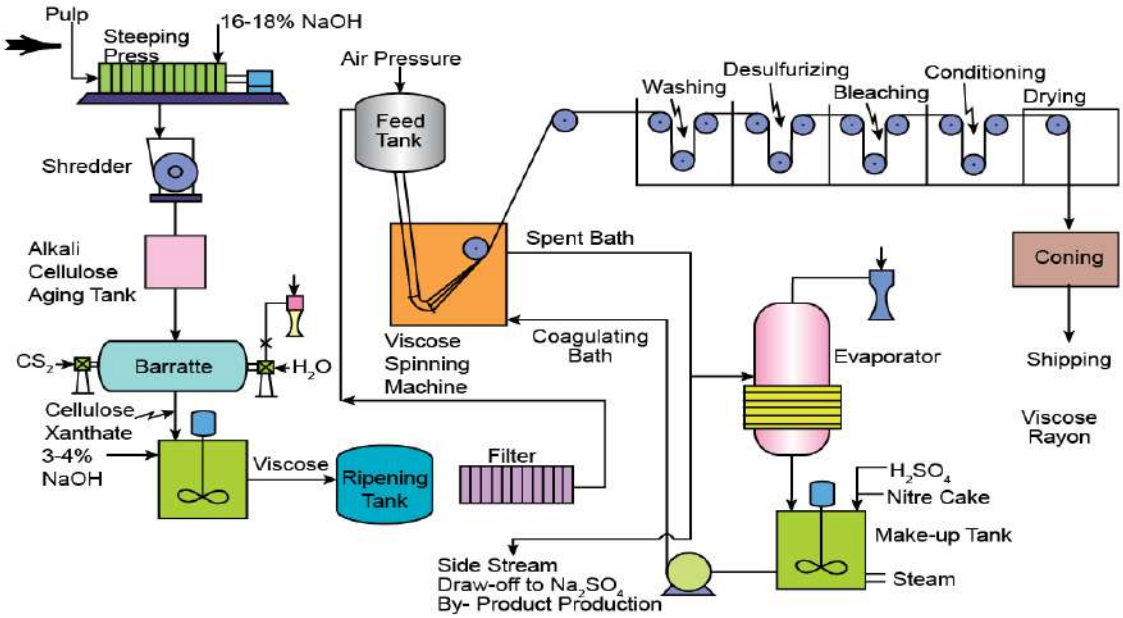
VISCOSE RAYON

POLYMER CHEMISTRY:

- The raw material for the production of Viscose rayon is wood pulp.
- However, the manufacturing process emits toxic effluents which have adverse environmental effects.
- Because of its cellulosic base, it has some properties which are similar to those of cotton and any other natural cellulosic fibres.
- It has moderate resistance to acids and alkalis.
- However, it may be damaged by relatively weak acids. Moreover, due to the inelasticity of fibers, it has poor abrasion resistance.

PROCESS DESCRIPTION:

- The raw materials used in this process are cellulose wood pulp sheets or cotton linters.
- These are placed in a steeping press with contact in aqueous NaOH Solution for a period of 2 – 4 hours at normal room temperature.
- A hydraulic ram presses out the excess alkali and the sheets are shredded to crumbs and aged for 2 – 3 days.
- The aging process has its direct consequence on the viscosity of the solution.
- Later CS_2 is added in a rotating drum mixer over a period of 3 hours.
- The orange cellulose xanthate which forms is transferred to a solubilizer , wherein it is mixed into dilute caustic .
- The mixing of cellulose xanthate and dilute caustic yields an orange colored viscous solution which contains 7 – 8 % cellulose and 6.5 – 7 % NaOH.
- It is digested at room temperature for 4-5 days.
- Thereafter, the solution is filtered and fed to spinning machines.
- The spinning is carried out in extrusion spinnerettes, which are made up of platinum or gold alloys.
- The orifices of these spinnerets have a diameter of 0.1 – 0.2 mm. for continuous filament yarns and of diameter 0.05 – 0.1 mm for short fibre shapes.
- The solution extruded from the spinnerette is contacted with an acid bath which precipitates the filaments without causing them to break or stick together.
- The processing treatments of washing, desulphurizing, bleaching and conditioning takes place continuously and in order after the filaments are wound on a series of plastic rolls.



CUPRO-AMMONIUM RAYON:

- Like Viscose Rayon, cuprammonium rayon is also a regenerated cellulose fibre.
- Cotton linters are used as the source of cellulose for this rayon.
- Ammonical copper oxide solution is also known as cuprammonium hydroxide solution.
- Cuprammonium hydroxide solution is a solvent for cellulose.
- When a solution of cellulose in cuprammonium hydroxide is diluted with water or treated with dilute sulphuric acid, the cellulose is regenerated or reprecipitated.
- By using a spinnerette, filaments of this regenerated cellulose can be produced.

Manufacturing of Cuprammonium Rayon:

- The source of cellulose for this rayon is cotton linters, the purification of cotton linters is carried out in two stages:
- Mechanical Treatment
- Chemical Treatment

Mechanical Treatment

- The cotton linters are transported in bales in highly compressed state and the object of the mechanical treatment is to loosen them and to remove mechanically admixed and loosely bound impurities such as dust sand, seed residues etc.

Chemical Treatment

- The mechanically opened and purified cotton linters are boiled under pressure for several hours with dilute soda-ash (Na_2CO_3) solution (2%) to which a little amount of caustic soda may be added.
- The natural fatty matter present in the cotton is converted into soluble substance by the action of soda ash and thus removed from cotton linters.

Dissolution of Cellulose:

- In this, a solution of hydrated copper sulphate in 300-400 liters of water is introduced in a vessel at ordinary temperature with stirring. Some sugar is also added followed by caustic soda solution to form copper hydroxide.
- Ground linters suspended in water are added to the above mixture to form copper cellulose.
- The copper cellulose is filtered to remove the liquid, well ground and dissolved in a solution of ammonia in water.

Spinning:

Spinning Solution

- By adding certain compounds to the cuprammonium cellulose solution, the solution is made more suitable for spinning.
- These compounds include glycerine, glucose, tartaric acid, citric acid, oxalic acid, can sugar etc.

Stretch Spinning

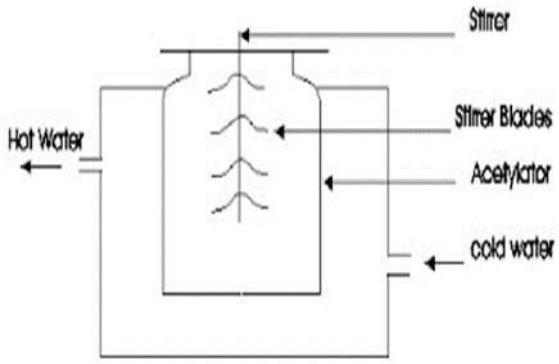
- In the spinning process, the cuprammonium cellulose solution is discharged through nozzles (spinnerette) into a solution of sulphuric acid in the form of relatively thick threads which are subsequently pulled (stretched) to very fine filaments.

Manufacturing Process of Acetate Rayon:

- Alcohol + Acid → Ester
- If the cellulose is treated with acetic acid under certain conditions the free hydroxyl groups of cellulose are converted into ester groups.
- Unlike in the case of viscose rayon and cuprammonium rayon, where cellulose is dissolved and regenerated.
- Cellulose acetate is manufactured by converting cellulose into a chemical compound of cellulose (or chemically modified cellulose) which is then dissolved in a suitable solvent (chloroform or acetone) and spun by evaporating the solvent.
- Thus while viscose and cuprammoniumrayons are regenerated fibres, acetate rayon is regenerated modified fibre.
- Raw Material
- Cotton linters and wood pulp are the most common employed raw materials for the manufacture of acetate rayon

Acetylation Process:

- The pre-treated purified cotton linters are fed into an acetylator (closed vessel) containing a mixture of acetic anhydride, glacial acetic acid and a small amount of concentrated sulphuric acid.
- For every 100 kg of cotton linters, 300 kg of glacial acetic acid, 500 kg of acetic anhydride and 8-10 kg of concentrated sulphuric acid may be used.
- The acetylator consists of a metal tank having a circular door at the top.
- The door is sealed after adding the mixture of chemicals and cotton linters.
- A stirrer having many blades rotates in the acetylator to mix the ingredients thoroughly.
- The acetylation reaction is an exothermic reaction.
- Heat is removed by circulating cold water through a jacket fitted to the acetylator.
- The acetylation reation is completed in 7-8 hours at 25-30 deg c.
- Triacetate is formed at this stage and it is in the form of a suspension in the acetylation mixture called the acid dope.



Hydrolysis (Partial Deacetylation)

- The acid dope from the above process is stored in jars for ageing. Acetic acid, water and sulphuric acid are added and allowed to stand for 10-20 hours.
- During this period, called ripening period, partial conversion of acetate groups to hydroxy groups takes place.

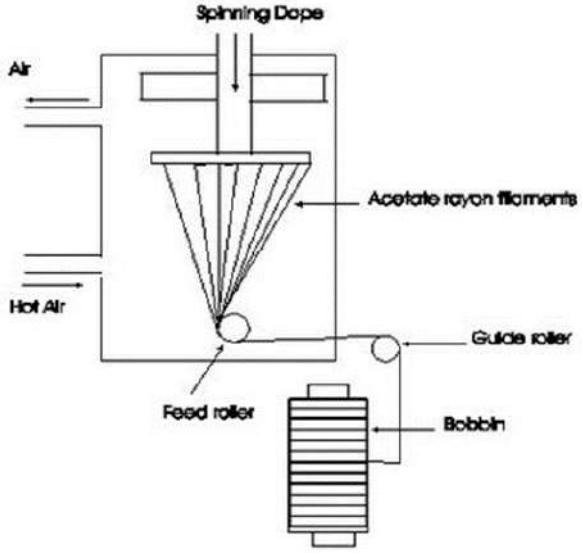
- The mixture is then diluted with water and stirred continuously when white flakes of acetate rayon get precipitated.
- The flakes are placed in a centrifuge and the excess water is forced out of the cage through perforations. The flakes are then dried.

Spinning Solution or Dope:

- Acetate rayon is manufactured by dry spinning.
- It is dissolved in a volatile solvent (Acetone) to form the spinning solution or dope.
- This solution is forced through a spinnerette into a chamber in which hot air is circulated.
- The solvent evaporates leaving filaments of acetate rayon.
- Dried acetate flakes are mixed with three times the weight of acetone in enclosed tanks which are provided with powerful stirrers.
- The acetate dissolves slowly in the solvent.
- It takes about 24 hours for the complete dissolution to give a thick clear liquid called dope.
- The solution is filtered and deaerated.

Spinning Process:

- The dope is spun into acetate rayon filaments on the dry spinning process.
- The dope is fed from a spinning tank into spinning cabinets.
- The dope coming out of the spinnerette travels a distance of 2-5 meters vertically downwards to a feed roller, from where it is guided on to a bobbin at a much greater speed than the speed of spinning.
- This imparts twist to the filaments.



UTKALMANI INSTITUTE OF TECHNOLOGY, ROURKELA-4

DEPARTMENT
OF
CHEMICAL ENGINEERING

SUBJECT: CHEMICAL PROCESS INDUSTRY-II
COURSE CODE: TH-3

PRESENTED BY: SATARUPA SAHU

Chapter 6-RUBBER

LESSON OBJECTIVE

The topics help the students

- To understand classification of rubber and definition of rubber. To understand manufacturing of NBR and SBR with properties

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 31	Natural and synthetic rubber and their properties
Lecture 32	Flow-sheet description for manufacturing of SBR
Lecture 33	Process description of SBR and their properties
Lecture 34	Flow-sheet description for manufacturing of NBR
Lecture 35	Process description of NBR and their properties
Lecture 36	Revision and Quiz Test

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Differentiate between natural rubber and synthetic rubber.
2. Describe the manufacturing of NBR and also write the properties and uses.
3. Describe the manufacturing of SBR with a neat diagram.
4. Write down the properties and application of SBR.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

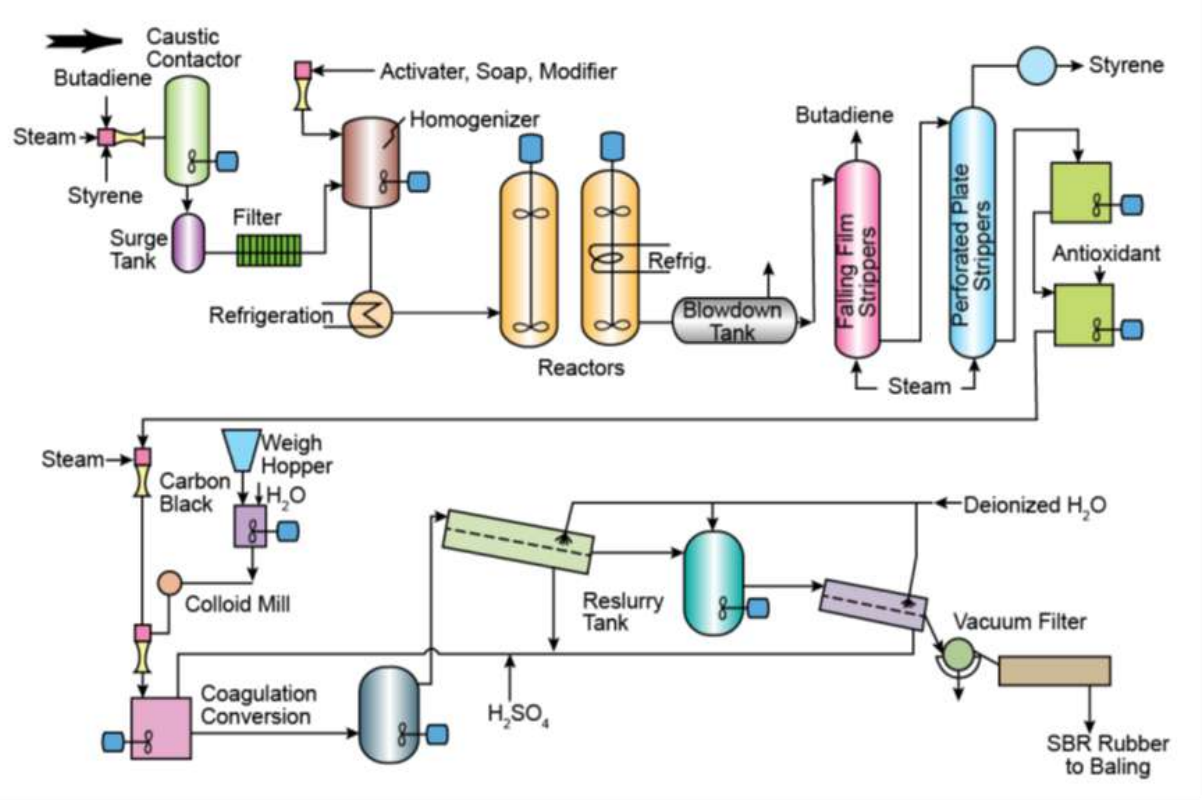
STYRENE BUTADIENE RUBBER

INTRODUCTION:

- The production of Styrene Butadiene Rubber (SBR) follows addition polymerization.
- Its glass transition temperature is approximately -55^{o}C, but may vary with the Styrene content.
- It can be used extensively within the temperature range of -40 to 100^{o}C.
- It may be blended with natural rubber or can be used by itself.
- It has good abrasion resistance properties and the addition of additives may endow it with aging stability.

PROCESS DESCRIPTION:

- SBR is produced by the copolymerization of Butadiene and Styrene by emulsion polymerization in 3:1 weight ratio.
- The fresh and recycle monomers are purified by 20 % aqueous caustic purification.
- Then the stream is continuously passed through 6 to 12 glass – lined or stainless steel reactors.
- The residence time in these reactors ranges from 5 to 15 hours.
- Steam heating, water cooling and refrigeration are carried out in these reactors.
- These reactors are equipped for producing both cold and hot SBR.
- Cold SBR is produced at 5^{o}C and 1 atm gage by refrigeration techniques; whereas hot SBR is manufactured at 50^{o}C, and 3-4 atm gage.
- The polymerization product is then stripped with chemical inhibitors and the latex resulting from the reactors are collected in blow down tanks.
- The latex is then sent to a falling film stripper to remove the butadiene; and the bottoms are fed to a perforated plate column where styrene is stripped out.
- The monomer – free emulsion is then added with certain compounding ingredients in blend tanks.
- The latex is coagulated to rubber. The crumbs of rubber float onto shaker screens where the catalyst, emulsifiers and other solubles are removed by the action with wash water.
- The crumbs are dried in continuous belt dryers with hot air and are subsequently pressed into bales.



PROPERTIES:

- SBR rubber is so widely used because of its cheapness and availability.
- SBR has high tensile and impact strength, resilience, and abrasion resistance.
- It is flexible in low temperatures (though not as flexible as natural rubber) and has decent heat resistance as well.
- SBR is also water, organic acid, ketone, chemical, alcohol, and aldehyde resistant.
- This type of rubber also ages better than natural rubber and is crack resistant while able to accommodate large amounts of filler, which is used to enhance its properties.

APPLICATIONS:

- SBR aids the bond strength, reduces the potential for shrinkage and adds an element of flexibility.
- It is also used by speaker driver manufacturers as the material for Low Damping Rubber Surrounds.
- Additionally, it is used in some rubber cutting boards.
- SBR is also used as a binder in lithium-ion battery electrodes, in combination with carboxymethyl cellulose as a water-based alternative for, e.g. polyvinylidene fluoride.
- Styrene-butane rubber is also used in gasketed-plate heat exchangers
- The elastomer is used widely in pneumatic tires. This application mainly calls for E-SBR, although S-SBR is growing in popularity.
- Other uses include shoe heels and soles, gaskets, and even chewing gum.
- Latex (emulsion) SBR is extensively used in coated papers, being one of the cheapest resins to bind pigmented coatings.
- It is also used in building applications, as a sealing and binding agent behind renders as an alternative to PVA, but is more expensive.
- It offers better durability, reduced shrinkage and increased flexibility, as well as being resistant to emulsification in damp conditions.

NITRILE BUTADIENE RUBBER

INTRODUCTION:

- Nitrile rubber, also known as NBR, Buna-N, and acrylonitrile butadiene rubber, is a synthetic rubber derived from acrylonitrile (ACN) and butadiene.
- Trade names include Perbunan, Nipol, Krynac and Europrene.
- This rubber is unusual in being resistant to oil, fuel, and other c
- Nitrile rubber, like styrene-butadiene rubber and other synthetic elastomers (elastic polymers), was a product of research that took place during and between the two world wars.
- A group of acrylonitrile-butadiene copolymers, given the name Buna N, was patented in 1934 by German chemists Erich Konrad and Eduard Tschunkur.

PROCESS DESCRIPTION:

- Emulsifier (soap), acrylonitrile, various butadiene monomers (including 1,3-butadiene, 1,2-butadiene), radical generating activators, and a catalyst are added to polymerization vessels in the production of hot NBR.
- Water serves as the reaction medium within the vessel.
- The tanks are heated to 30–40 °C to facilitate the polymerization reaction and to promote branch formation in the polymer.
- Because several monomers capable of propagating the reaction are involved in the production of nitrile rubber the composition of each polymer can vary (depending on the concentrations of each monomer added to the polymerization tank and the conditions within the tank).
- One repeating unit found throughout the entire polymer may not exist. For this reason there is also no IUPAC name for the general polymer.
- Monomers are usually permitted to react for 5 to 12 hours.
- Polymerization is allowed to proceed to ~70% conversion before a “shortstop” agent (such as dimethyldithiocarbamate and diethyl hydroxylamine) is added to react with the remaining free radicals.

- Once the resultant latex has “shortstopped”, the unreacted monomers are removed through a steam in a slurry stripper.
- Recovery of unreacted monomers is close to 100%. After monomer recovery, latex is sent through a series of filters to remove unwanted solids and then sent to the blending tanks where it is stabilized with an antioxidant.
- The yielded polymer latex is coagulated using calcium nitrate, aluminium sulfate, and other coagulating agents in an aluminium tank.
- The coagulated substance is then washed and dried into crumb rubber.
- The process for the production of cold NBR is very similar to that of hot NBR.
- Polymerization tanks are heated to 5–15 °C instead of 30–40 °C.
- Under lower temperature conditions, less branching will form on polymers (the amount of branching distinguishes cold NBR from hot NBR).

PROPERTIES:

- Good stability at high temperatures.
- Nitrile rubber is more resistant than natural rubber to oils and acids, and has superior strength.
- Nitrile gloves are puncture-resistant.
- Nitrile rubber has high resistant towards chemicals or ozone.

APPLICATIONS

- NBR is used in the automotive and aeronautical industry to make fuel and oil handling hoses, seals, grommets, and self-sealing fuel tanks.
- It is used in the nuclear industry to make protective gloves.
- NBR's stability at high temperatures from −40 to 108 °C (−40 to 226 °F) makes it an ideal material for aeronautical applications.
- Nitrile butadiene is also used to produce moulded goods, footwear, adhesives, sealants, sponges, expanded foams, and floor mats.
- Its resilience makes NBR a useful material for disposable lab, cleaning, and examination gloves.

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PRESENTED BY: SATARUPA SAHU

Chapter 7- SUGAR

LESSON OBJECTIVE
The topics help the students

- To understand manufacturing of cane sugar, industrial alcohol alcoholic beverages, Beer.

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 37	Flow-sheet description for manufacturing of cane sugar
Lecture 38	Process description of cane sugar and their properties
Lecture 39	Flow-sheet description for manufacturing of industrial alcohol
Lecture 40	Process description of industrial alcohol and their properties
Lecture 41	Classification of alcoholic beverages
Lecture 42	Manufacture of Beer

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Describe the manufacturing of sugar with a neat diagram
2. Describe the manufacturing of industrial alcohol with a neat diagram.
3. Describe the manufacturing of beer with a neat diagram.
4. Write down two non-food use of sugar**.**
5. Write down the classification of alcoholic beverage.
6. Write the by-products of obtained from sugar manufacturing.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

SUGAR MANUFACTURING

- Sucrose is a disaccharide that occurs naturally in most fruits and vegetables.
- Sugar occurs in greatest quantities in sugarcane and sugar beets from which sugar is separated economically and commercially.

Properties:

1. Chemical formula – $C_{12}H_{22}O_{11}$
2. Molecular weight – 342
3. Density = 1.58 kg/m^3
4. Sucrose is soluble in water but slightly soluble in methyl alcohol and ethyl alcohol.

Sucrose production: From beet root, sugar cane

Quantitative requirements:

- Basis: 1 ton of raw sugar (97% sucrose) yield from cane
- 95% on sucrose basis and (9.5-15) % cane basis.
- Sugar cane 6-10.5 tons, water 3-4 tons,
- Lime-12-15 kg, SO2 6-10 kg, plant capacity: 100-400 tons/day

Classification of processes:

1. Extraction of sugar to produce crystalline sugar
2. Extraction of sugar to produce gur, dark brown sugar concentrate

Process Description:

Cutter

- The cutter consists of knives on a cylindrical shaft which rotate at a velocity of 400 to 500 rpm.
- The knives cut the canes in diagonally into small pieces called chips.

Crusher

- Canes are shredded here.
- It consists of two rollers rotating in opposite direction.
- Crushed canes are passed through four pressure mills to extract juice.
- Each pressure mill is made up of cast iron rolls.

Series of Pressure mills

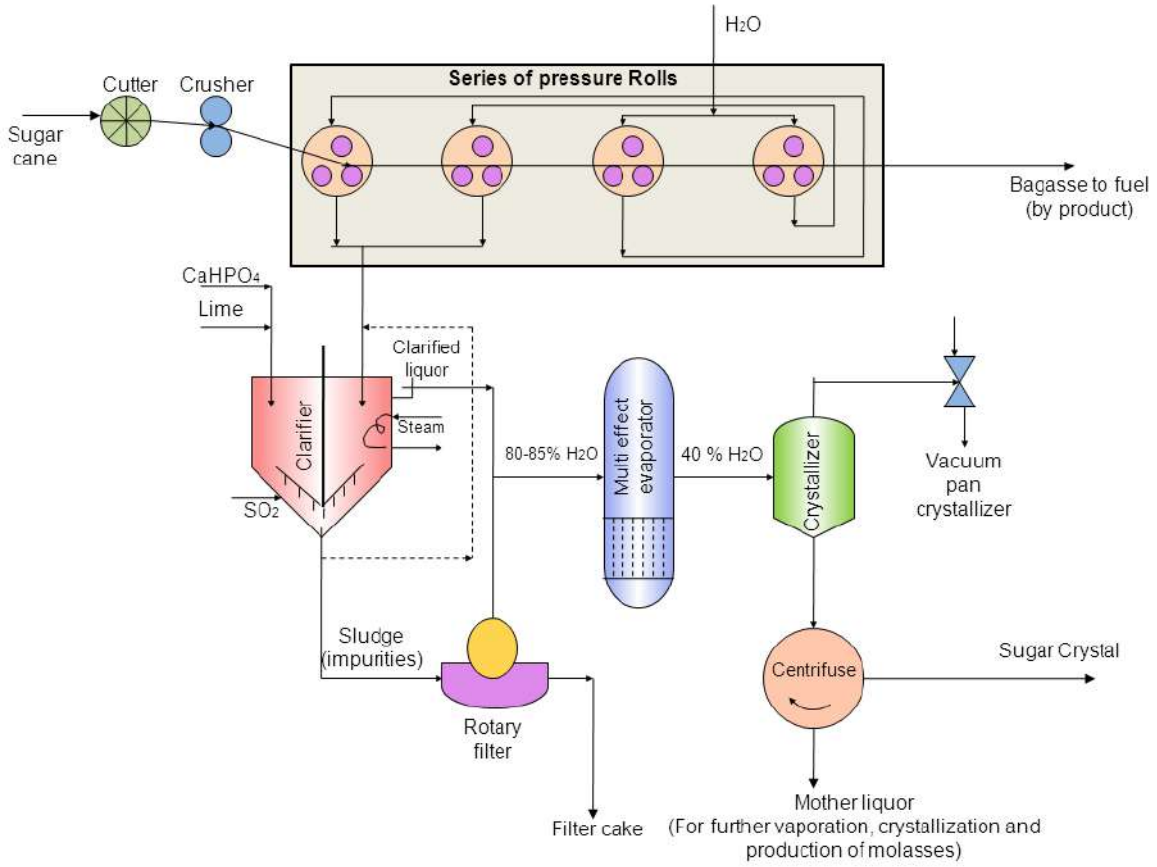
- Rolls are grooved and the width decreases from first roll to the last.
- Bagasses are produced as by-product.
- In roller, the juice content is reduced to 50% which is then sent to series of four mills.
- Juice extracted from first mill is collected in raw juice tank.
- The bagasses containing the remaining juice is sent to 2nd, 3rd and 4th mill.
- The juice obtained from 3rd mill is sprayed in the bagasses of 2nd mill for proper crushing and so on.
- Make up water is added into 3rd and 4th mill.
- About 90-96 % juice is extracted from cane.

Clarifier

- Divided into 3 parts.
- 1. Defection
- 2. Carbonation
- 3.Sulphitation
- The juice now comes to thickener.
- To precipitate the colloids, calcium phosphate (CaHPO4) is added followed by milk of lime.
- The milk of lime used has 9 to 10% strength and about 400mg CaO/litre alkalinity.
- Double Carbonation-Sulphitation are done for pure sugar crystals.

Purification of juice (Defection)

- Juice obtained is of green opaque liquid containing (10-20) % sugar, reducing sugar, gum, mineral salt vegetable proteins, pectin substances etc.
- All this impurities hampers the crystallization of sugar.
- The cane juice obtained is of pH-(5.1-5.7).
- Defection : Removing acidity
- The juice should be made alkaline otherwise pectic substances becomes pectic acid which converts cane sugar to non-crystallisable sugar.



Process:

- Adding the adequate amount of lime till the pH becomes 7-7.3.
  1. Precipitates the pectic substances as calcium pectates
  2. Sucrose as the calcium sucroses
  3. Phosphoric acid or soluble phosphate as into insoluble tricalcium phosphate.
  4. Vegetable protein, gums etc are also precipitated.
- Sent to tubular heater to reduce the density of the precipitate.
- Sent to settler tank where three layers of solutions formed.
  1. Thick scum at the surface
  2. Clear liquid (calcium sucrose and calcium hydroxide)
  3. Mud
- Mud is sent to rotary drum where it is washed with water and the wash water sent back to defection process.

Carbonation method (more efficient):

- Much amount of lime is added which increases the pH to 10.5-11(1^{st} column)
- Heated to (50-55)C
- Result: Removal of non-sugar and colouring matter by formation of large amount of precipitate.
- CO2 is added in order to remove the lime as CaCO3 which also reduced the pH to 8.5(2^{nd} column)

- The heating is done at (75-80) C and solution is filtered by rotary filters.

Sulphitation:

- 1st column temp is increased to 75 C and SO2 is supplied so as to obtain the pH as 6.9-7.1.
- 2nd column the heated solution is again heated to 103C where the pH is reduced to 5.5.
- Solution is filtered via rotary filters.
- It is called double sulphitation process.

Rotary filter

- The underflow mud from the bottom of thickener is passed to a continuous rotary filter press to recover sugar solution.
- This sugar solution if it is clear, is passed to multieffect evaporator or otherwise recycled back to clarifier.
- The filter cake produced is used for fertilizer.

Multieffect evaporator

- The clarified liquor overflows to the 3-4 forward feed multieffect evaporator.
- Here juice is concentrated from 80-85% H2O to 40% H2O to make juice ready for crystallization.
- A vacuum of 63cm is maintained in the last effect.
- Syrup tank ---- Sulphitation tank for reducing calcium sucrose by application of SO_2
- SO_2 also acts as bleaching agent.

Crystallizer

- The clarified concentrated sugar solution comes to crystallizer.
- The sugar solution is further boiled in vacuum pans at vapor temperature of 57˚C until fine cloud of crystals is seen.
- Crystallization is completed in vacuum pan unit.
- To reduce fuel externally sugar crystals are added to masscuite.
- 1 ton sugar crystal to produce (25-30) ton masscuite.

Centrifuge

- The mixture of crystals and syrup is called masscuite.
- The masscuite from crystallizer is centrifuged in basket type centrifuged to basket type to centrifuge remove mother liquor (molasses) which is a byproduct.
- The high grade sugar crystals are obtained here.
- The centrifuge speed is maintained at 800 to 1000 rpm.

Grades:

Large 30, large 29, medium 30, medium 29, small 30, small 29

- 30, 29 for measurement of visual whitening.
- Large medium and small for grain size.

Questions:

1. **Why last effect evaporator is maintained at vacuum?**
   To allow the flow of juice from first effect to other due to pressure drop and to increase temperature gradient for better heat transfer.
2. **What are the by-products of sugar industries?**
   Bagasse, filter cake and molasses.
   Bagasse: Fuel in boiler for regeneration of steam, raw material for paper industry, celotax.
   Press mud (filter cake): farm manure
   Molasses: 70% in industrial alcohol and 30% in potable alcohol
3. **What is the problem in storage of sugarcane?**
   There should be no delay in transporting freshly cut sugarcane to sugar mill because after 24 hours of cutting causes loss of sucrose by inversion to glucose and fructose
   $C_{12}H_{22}O_{11} + H_2O$ -----$C_6H_{12}O_6 + C_6H_{12}O_6$
   The extent of inversion is measured by polarimeter. The non-inverted sugar has +97° polarization and completely inverted sugar has -20° polarization.

4. **Why vacuum pan crystallizer is used?**
   With the use of vacuum pan crystallizer, the pressure is reduced so as to super saturate the sugar solution. After super saturation the formation of crystals starts. When the volume of massecuite (sugar solution 16 crystals) exceeds certain limit, then it is transferred to centrifuge for separation
5. **What are the environmental problems faced by sugar industries?**
   - Flue gas(fly ash) produced by combustion of bagasse.
   - The untreated effluent from sugar mills have BOD of 1.7 to 6.6 g/lit, COD of 2.3 to 8g/lit, TSS up to 5g/lit and high ammonium content.
   - Mill generates lot of dust and odour.
   - Sometimes pesticides are also present in sugar cane juice.

CLASSIFICATION OF ALCOHOLIC BEVERAGES

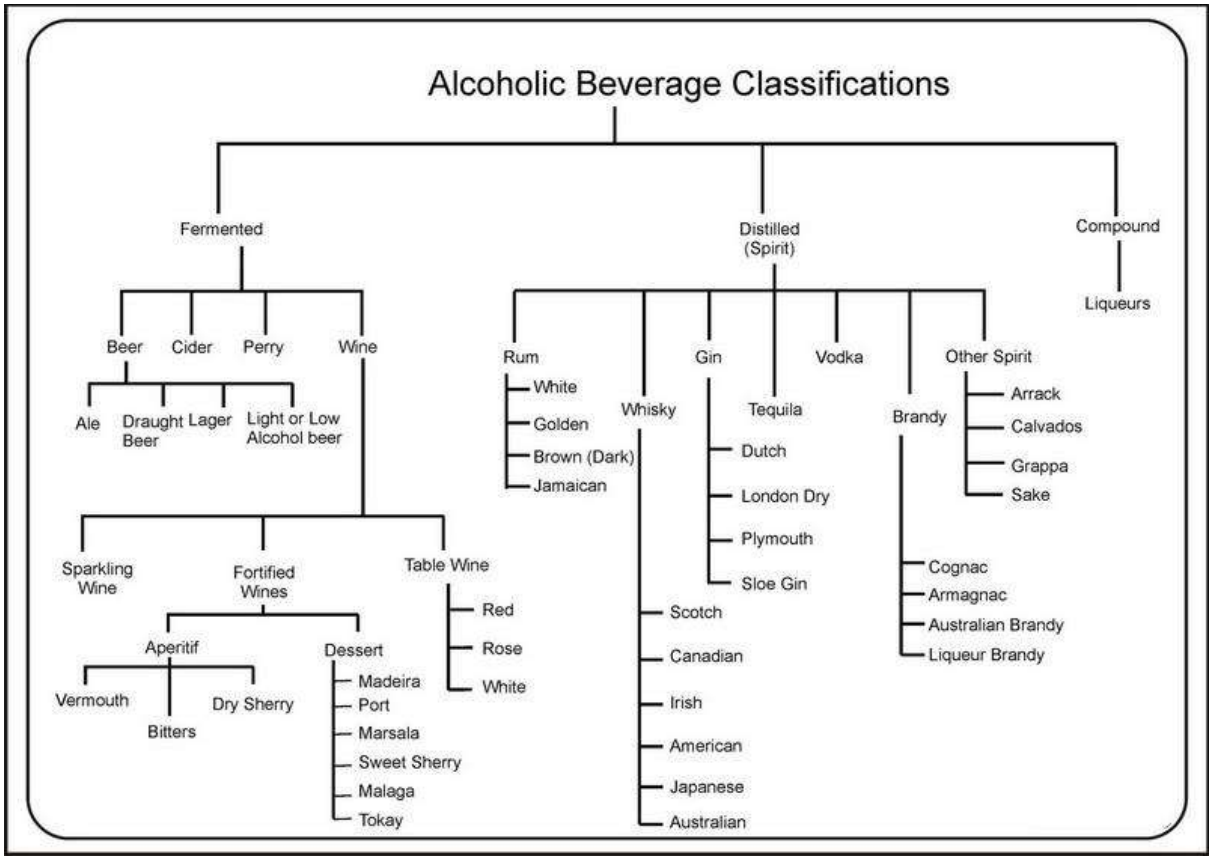
Definition — A potable (meaning drinkable) liquid containing ethyl alcohol or ethanol of 0.5 percent or more by volume is termed as 'alcoholic beverage'. Alcohol is mobile, volatile fluid obtained by fermenting a liquid containing sugar.

Process of extracting Potable Alcohol (Alcoholic Beverage)

All alcohol or alcoholic beverages are obtained by a process called fermentation. It is concentrated or increased in strength by distillation. The percentage of alcohol in a drink varies from 0.5 – 9.5%, depending on the method by which the alcohol is obtained.

1. **Fermentation** is the process in which the yeast acts on sugar and converts it to ethanol and gives off carbon dioxide. The fermented liquid has 3-14% alcohol and it can be concentrated up to 95% by a series of distillations.
2. **Distillation** is the process of separating elements in a liquid by vaporization and condensation. In the distillation process, the alcohol which is present in the fermented liquid (alcoholic wash) is separated from water.

Alcoholic beverages are classified as Fermented beverages, Distilled beverages and Compound beverages.



Fermented beverages

- Fermented beverages can be divided into two groups, wines and beers, broadly defined. Wines are fermented from various fruit juices containing fermentable sugars.
- Beers come from starch-containing products, which undergo enzymatic splitting by diastase, malting, and mashing, before the fermentable sugars become available for the yeasts and bacteria.
- In short, wines are fermented and beers are brewed and fermented.
- Examples – Wine, Cider and Perry
- Wines can be defined as alcoholic beverage made from fermented grape juice. Wines can be classified on the basis of following aspects

1. Nature / Characteristics – Still, Sparkling, Fortified, Aromatised, Tonic,
2. Organic Colour – Red, White, Rose
3. Taste / Degree of sweetness – Dry, Medium, Sweet

Cider – An alcoholic beverage made from fermented juice of cider apples. 25% of pear juice can be used while manufacturing cider. Cider is popular in countries like United Kingdom, New Zealand, and Australia. In USA, non – alcoholic cider is termed as 'sweet cider' and alcoholic cider is termed as 'hard cider'.

Perry – An alcoholic beverage made from fermented juice of pears similar to the way cider is made from apples. It has been common for centuries in England, particularly in the Three Counties (Gloucestershire, Herefordshire and Worcestershire. It is also made in parts of South Wales and France. It is also manufactured in Commonwealth countries like Canada, Australia and New Zealand.

Brewed and Fermented Drinks

- It is similar to fermented drinks but the only difference is that the base ingredient, which is usually malted and crushed cereal, is brewed in hot water to extract maximum soluble sugar from the malt.

- It is then cooled, and allowed to ferment with the addition of yeast. Example – Beer and Sake
- Beer is classified on the basis of type of fermentation – Top or Bottom.
- Top fermented beers are known as Ales while bottom fermented beers are known as Lagers.
- Sake – Sake, is an alcoholic beverage made from fermented rice and originates in Japan.
- Sake is light in colour, is noncarbonated, has a sweet flavour, and contains about 14 to 16 percent alcohol. (Britannica, 2020)

Distilled Beverages

- To obtain any alcoholic beverage fermentation is required and the strength of alcohol is increased by application of distillation.
- These drinks are distilled from a base of a fermented liquid and have a high percentage of alcohol compared to fermented drinks.
- Newly distilled spirit (young spirit) is raw, sharp and harsh in taste.
- These drinks are aged in wooden barrels to mellow and to make them flavourful. Examples are as follows – Spirits – Whisky, rum, gin, vodka, tequila, and brandy
- Other spirits – Arrack, Toddy, Feni, Slivovitz.

Compound Beverages

- Compound alcoholic beverages are defined as a mixed beverage, which is blended or composed carefully by extracting flavour, colour and sweetness from various fruits, herbs, plants, and nuts.
- Such beverages include: Liqueurs, Cocktails.

Liqueur

- A liqueur is alcoholic beverage, which has a base of spirit (grain spirit, neutral spirit) which is flavoured with fruits, herbs, spices, flowers, seeds, plants and are sweetened and can be coloured or colourless.
- They are also termed as Digestif / Digestive.
- Liqueurs are not usually aged for long periods, but may have resting periods during their production to allow flavours to blend.
- Liqueurs can be further categorised as – fruit liqueur, cream liqueur, coffee liqueur, chocolate liqueur, schnapps, herbal liqueur, depending upon the flavouring agents used.

Cocktails

- A cocktail is an alcoholic mixed drink, which is either a combination of spirits, or one or more spirits mixed with other ingredients such as fruit juice, flavoured syrup, or cream.
- There are various types of cocktails, based on the number and kind of ingredients added. Examples of Classic Cocktails – Martini, Margarita, Mojito, Whiskey Sour

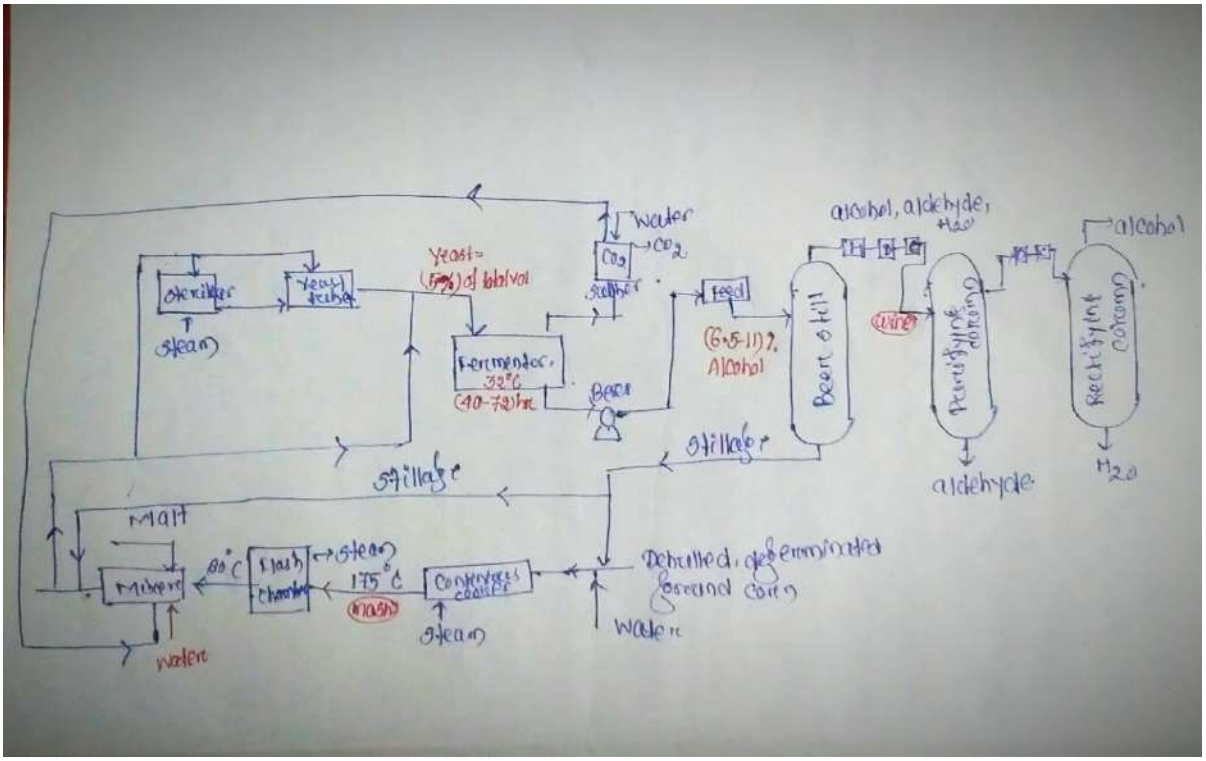
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MANUFACTURING OF INDUSTRIAL ALCOHOL

- The degerminated, dehulled,milled, grounded corn is fed to continuous cooker along with water and stillage(dealcoholized fermented beer from beer still)
- Precooking is done for 1 to 5 min to convert starch to fermentable sugar.
- The mash is then heated to 175 C with help of steam heater and then fed to flash chamber where cooking is done for 1.5 min, at a pressure of (60-100) Kpa gauge and the temperature is reduced to 60 C.

- The cooked mash is mixed with malt, water and stillage and at temperature of 60 C sent to fermenter. Stillage is added to reduce pH, furnish nutrients for yeast and add buffering action.
- The starch is hydrolysed to 70% maltose and 30% dextrin.
- A charge of selected yeast (5% of the total volume) growing in yeast tube on a corn- barley malt mash is pumped to fermenter.
- The pH is adjusted to 4.8-5 with H2SO4 and as the reaction is exothermic, cooling is done to control the temperature to 32C. The time of fermentation is (40-72) Hr.
- The effluent form the fermenter is called beer where alcohol is separated by distillation.
- This the beer contains (6.5-11) % alcohol, water, aldehyde is separated as top product and stillage as bottom product.
- The overhead product is sent to heat exchanger, partial condenser, dephelegmator to condense sufficient vapour for reflux.
- Then it is sent to condenser where high wine is obtained.
- The high wine is sent to purifying section to remove aldehyde and then rectifying section to separate water from alcohol.
- Industrial alcohol of strength 95.6% is obtained.



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COURSE CODE: TH-3

PRESENTED BY: SATARUPA SAHU

Chapter 8-OILS AND FATS

LESSON OBJECTIVE

The topics help the students

- To understand the classification of oil.
- To understand extraction and hydrogenation of oil.

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 43	Classify different types of oil
Lecture 44	Flow-sheet description for extraction of oil
Lecture 45	Process description for manufacturing of extraction of oil
Lecture 46	Flow-sheet description for hydrogenation of oil
Lecture 47	Process description for hydrogenation of oil
Lecture 48	Latest developments in edible oil production

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Define oil.
2. Write down the uses of oil
3. Write down the types of oil.
4. Briefly describe the extraction of oil with flow-sheet.
5. Write down the purpose of hydrogenation of oil.
6. Write down the chemical reactions involved in hydrogenation of oil.
7. Briefly describe the hydrogenation of oil with flow-sheet.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

EXTRACTION OF OIL

- Oils are organic molecule of carbon, hydrogen, oxygen and sometimes nitrogen and sulfur.
- It is composed of long chain fatty acids and esters (glyceride ester) as well as derivative of glycerine, long chain fatty alcohol, sulfate and sulfonates.
- Oils like caster oil, linseed oil are non-edible and medicines, polymers, paints and varnishes and in many other applications oils like ground nut oil, coconut oil are edible.

Uses:

1. Liquid oil -57%
2. Vanaspati ghee-19%
3. Soaps and detergents-10%
4. Cosmetics-9%
5. Paints and varnishes-2%

TYPES OF OIL

• Edible oil

1. Groundnut oil
2. Rapeseed
3. Mustard oil
4. Soya-bean oil
5. Sunflower oil
6. Sesame oil
7. Niger seed oil

Non-edible oil

1. Linseed oil
2. Castor oil

Other sources of oil

1. Animal sources:
   - (i) Lard from hog fat
   - (ii) Tallow from beef and mutton fat
2. Ocean sources:
   - (i) Menhaden fish
   - (ii) Sperm whale
   - (iii) Codfish

Functional role of various processes

(a) Cleaner and dehulling:

- Mechanical cleaning is done to remove stones and other undesirable material.
- Dehulling remove hulls, dry outer covering of seed.

(b) Cracking rolls:

- Crushing rolls crush the oil seeds and gets flacked seeds.

(c) Digester:

- 100 parts of flaked seeds are thoroughly mixed with 5-10 parts of water by rotating blades.
- Softening by means of heat and moisture is done here.
- Steam is added for heating purpose.
- Acid is formed by hydrolysis of ester.
- The seeds get swollen up.

(d) Expeller:

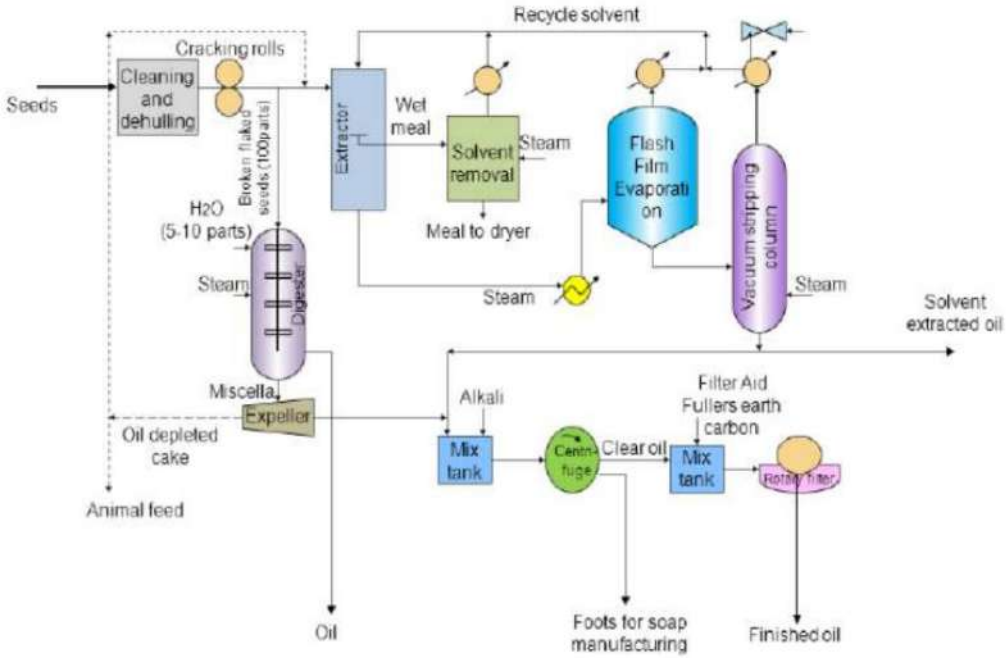
- The swollen seeds are crushed under great pressure.
- Cells of seeds get ruptured and oil is released.
- The tapering shape ensures more application of pressure on the seeds.
- The oil depleted cake is either sent for solvent extraction or used as animal feed. • Oil is sent for purification.

(e) Mix tank:

- The extracted oil is treated with alkali like NaOH or Na_2CO_3 to remove fatty acids.
- It also removes heavy metals, which can start oxidation of oil.

(f) Centrifuge:

- Acids are separated in centrifuge separator.
- These separated acids are used as foots for soap manufacturing.



HYDROGENATION OF OIL

- Hydrogenation process is used to remove double bonds and to make fats and oil saturated.
- Hydrogenation also raises its melting point and improves its resistance to rancid oxidation.
- The most common end product of hydrogenation is Vanaspati ghee.
- Other products include vegetable ghee, hardened industrial oils and partially hydrogenated liquid oil.

CHEMICAL REACTIONS:

Chemical Reactions: (* indicates activated catalytic state)

Ni* catalyst

(a) $R_1(C=C)_xR_2 + (x-y)H_2 \rightarrow R_1(C=C)_yR_2$

(b) Nickel catalyst preparation:

190°C

$Ni(HCOO)_2.2H_2O \rightarrow Ni^* + 2CO_2 + H_2 + 2H_2O$

This produces a finely divided catalyst which is preferred for well-stirred hydrogenation reactors.

(c) Nickel catalyst preparation (reduced Ni on inert catalyst support)

$Ni(OH_2) + H_2 \rightarrow Ni^* + H_2O$

$NiCO_3 + H_2 \rightarrow Ni^* + H_2O + CO_2$

Nickel salts are precipitated on inert porous carrier such as kieselguhr or diatomaceous earth and reduced at high temperature in a hydrogen atmosphere.

(d) Nickel catalyst preparation

$2Al.Ni + 6NaOH \rightarrow Ni^* + 2NaAlO_3 + 3H_2$

Alloy — Raney nickel

Produces spongy, high-surface area catalyst when the sodium aluminate is washed with water.

Raw material

1. Electrolytic H_2O
2. Steam-iron: Reaction of stream on Fe followed by regeneration with water gas.
3. Sulphur containing compounds (SO_2,H_2 S) are extreme poisons for the hydrogenation catalyst. This can be removed by hydrogen process.

Basic Operation:

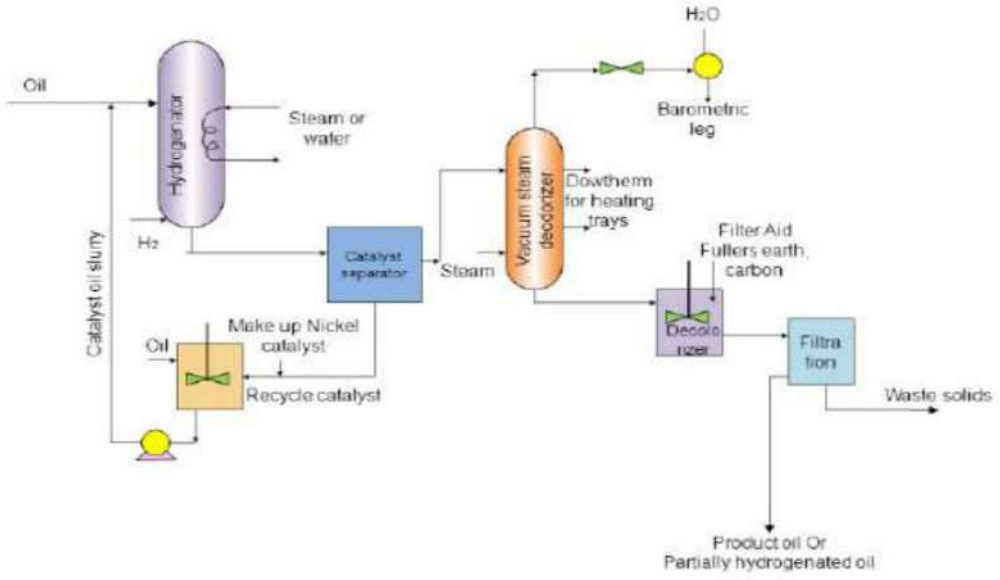
1. Residence time: (1-3)hr
2. Capacity-(5-30) ton
3. Ghee based oil- (low pressure :(1-2)atm gauge, high temp (135-180)C
4. Vanaspati-(high pressure (2-3.5) atm gauge, low temp(120-160)C

Functional role of main units:

(a) Hydrogenator:
- Oil is fed to the hydrogenator.
- Hydrogen, and steam is introduced in it.
- The catalyst oil slurry of concentration 5 to 15 kg per ton of oil is also put.
- The reaction is slightly exothermic so steam is sometimes turned off.
- After the desired level of hydrogenation achieved, which is checked by iodine number, the batch is cooled and filtered to recover the catalyst for reuse.

(b) Deodorizer:
- The hydrogenated oil is now fed to vacuum steam deodorizer.
- It operates in continuous basis.

(c) Finishing
- Oil colour is removed by treating with fuller's earth or carbon.
- It is then filtered, mixed with some vitamins.
- Now the finished oil is sent for packaging and storage



UTKALMANI INSTITUTE OF TECHNOLOGY, ROURKELA-4

DEPARTMENT
OF
CHEMICAL ENGINEERING

SUBJECT: CHEMICAL PROCESS INDUSTRY-II
COURSE CODE: TH-3

PRESENTED BY: SATARUPA SAHU

Chapter 9-SOAP & DETERGENT

LESSON OBJECTIVE

The topics help the students

- To understand classification of soap and detergent, detergent builders and constituents of detergent.
- To understand manufacturing of soap and detergent with properties

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 49	Definition soaps and detergent, principle of cleaning
Lecture 50	Detergent builders and constituents of detergent
Lecture 51	Flow-sheet description for manufacturing of soap
Lecture 52	Process description for manufacturing of soap
Lecture 53	Flow-sheet description for manufacturing of detergent
Lecture 54	Process description for manufacturing of detergent

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Differentiate between soap and detergent.
2. Differentiate between soft soap and hard soap.
3. Describe the manufacturing of detergent with a neat diagram.
4. Write down the components of detergent.
5. Write down five name of detergent builders and their uses.
6. Describe the manufacturing of Soap with a neat diagram.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

Introduction

SOAP

- Soaps are sodium or potassium salts of fatty acid.
- Common fatty acids used are oleic acid, stearic acid, palmitic acid, lauric acid and myristic acid.
- Soaps are used for human comfort, cleanliness and for industrial use.
- Most marketed bar soaps contains TiO_2 as an opacifier or as a whitener. A variety of dyes are also used to produce colour soaps.

DETERGENTS:

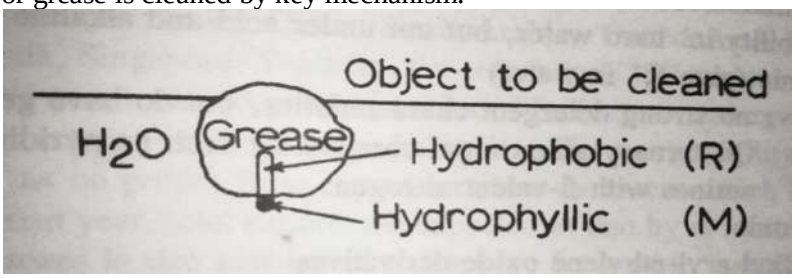
- It is an synthetic organic chemicals which promotes better surface tension lowering than soaps.

PROBLEMS WITH DETERGENT USE:

1. Excessive foaming,
2. Inability to reduce the organic content of sewage sludge,
3. Reduced ability of biodegradation of detergent.

Principle of cleaning:

- Soap is a surface active agent or surfactant. The soap molecules contain both hydrophilic part and hydrophobic part.
- The hydrophilic part of soap is carboxylate head group and hydrophobic part is aliphatic chain.
- The success of any cleaning agent is to supply compounds with hydrophobic and hydrophilic groups which will decrease the surface tension and increase wetability.
- The dirt or grease is cleaned by key mechanism.



DETERGENT MAKING COMPONENTS:

1. ANIONIC:

1. Sulfated fatty alcohols: these are quite stable in alkaline, acid and hard water.
2. Sulfonates: not as much stable as sulfates and requires additives for performance improvement. Ex: Aryl benzene sulfonates

2. CATIONIC:

No strong detergent characteristics but have germicidal properties.
Ex: pyridinium derivates and amines

3. NON-IONIC:

1. Alkyl-aryl-ethylene oxide derivates
2. Aliphatic polyhydric alcohol esters
3. Fatty acid amides

These have little foam producing properties but excellent soil and grease removal characteristics.
Detergent Builders

1. Phosphate: Sodium tripolyphosphate and tetrasodium pyrophosphate used as much as (30-50) % to extend foam.
2. Sodium carboxycellulose (1-3)% to improve soil and dirt suspension.
3. Fluorescent dye as brighteners.
4. Sodium silicates to avoids aluminum corrosion in washing machines
5. Zeolites as alternative phosphorus-free builders.

Chemical Reactions:

Fat splitting reaction:

$(RCOO)_3C_3H_5 + 3H_20 \rightarrow 3RCOOH + C_3H_5(OH)_3$

triglycerides water fatty acid glycerin

Saponification Reaction:

$RCOOH + {}^{*}1OH \rightarrow RCOOM + H_2O$

fatty acid base soap water

Functional role of various processes

(a) Hydrolyser

- The fat and catalyst are mixed together and enter the hydrolyser.
- Hot water is added here
- Intimate mixing is required for the water oil immiscible phase.
- Water has 10 – 15% solubility in oil and fats.
- Temperature is maintained at 230°C - 250°C and pressure at 40 – 45 atm for reaction between water and organic compound.
- The fatty acids stream is produced as top product while glycerin stream is produced as bottom product.

(b) Flash tank:

- Fatty acids from the hydrolyser enters the steam flash tank to remove water & concentrate the fatty acids.

(c) Vacuum still:

- The concentrated fatty acids enter a high vacuum still.
- Jet ejecter is used to generate vacuum in the still.
- Wastes are separated from the bottom.
- Fatty acid is also taken out as a marketable product.

(d) Mixer:

- Fatty acid produced from vacuum still is now pumped to mixer.
- Base such as NaOH or KOH is mixed in appropriate proportions and mixed thoroughly.
- After mixing a viscous mass is produced.

(e) Blender:

- The viscous mass from the mixer is sent to the blender.
- Ingredients like scents, anti-fungal & anti-bacterial chemicals etc. is mixed in the blender.
- The blender removes the solid mass which is then sent to:

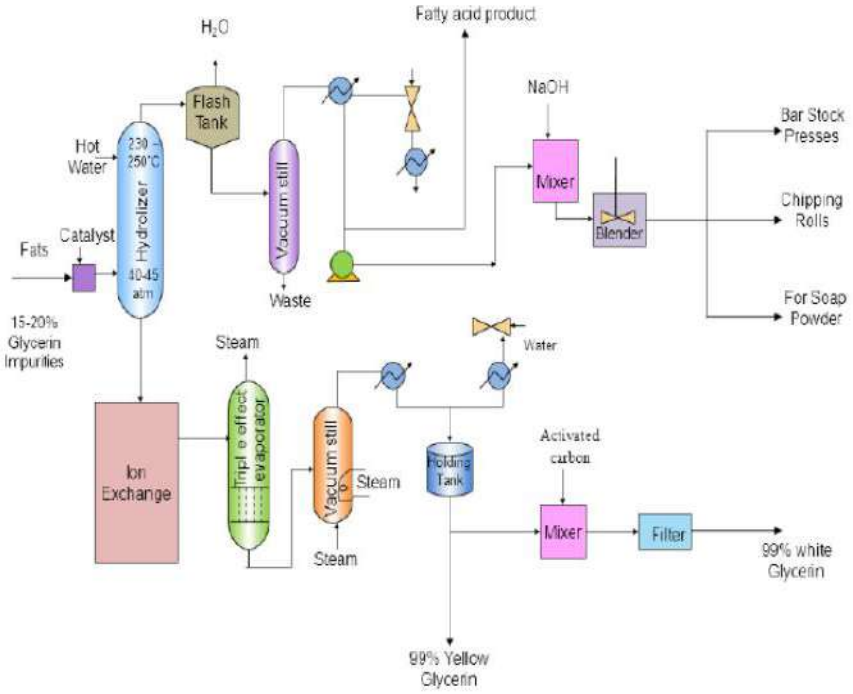
1. Chipping rolls: to manufacture soap strips.
2. Spray dryer: To get soap powder (used in manufacture of liquid soaps).
3. Bar Press Stock: To press and cut the viscous mass into bars of soap.

Detergents

1. Detergents have better surface tension lowering action than soaps. Due to excessive foaming, it is unable to reduce organic content of sewage effluent.

2. Biodegradation of detergent is an important environmental factor. Detergents react with hard water ions.

3. Detergents are of four types - anionic, cationic, non- ionic and amphoteric. Most common type is anionic which is generally made up of sodium salts of an organic sulfate or sulfonate.



General method to make synthetic detergents:

Alkylbenzene + oleum → alkylbenzene sulfonate

Tallow fatty alcohol + oleum → fatty alcohol sulfate

Sulfonate + sulfate + NaOH → sodium salts

Sodium salts + builders → Detergents

Technical Questions

1. Discuss about raw material of soap?

Fatty constituents from refined tallow, coconut and palm oil, refined grease, byproducts of vegetable oil refining etc.

In India, for the source of fatty acids mostly depends on imported tallow and palm oil.

Coconut oil is the primary vegetable oil used for the manufacture of soaps.

2. Discuss economy in soap manufacturing process?

The vacuum still uses the steam from triple effect evaporator thus reducing the make up steam in the still.

Good amount of glycerin is produced as a byproduct which is sold in market.

Fatty acid is also taken out as a marketable product. These fatty acids find use in manufacturing cosmetics, beauty products etc.

3. What is the difference between soft soaps and hard soaps?

1. Sodium salts are called hard soap whereas potassium salts are soft soaps.
2. A hard soap is moderately soluble in water and does not lather easily whereas soft soap dissolve faster and lather readily.
3. Soft soap performs better than hard soaps in cleansing action.
4. Tallow, animal fats and coconut oils are the main sources of hard soaps, while linseed oil, castor oil etc produces soft soaps.
5. Mahua and ground nut oil produce intermediate consistency soaps.

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Chapter 10- PHARMACEUTICAL INDUSTRY

LESSON OBJECTIVE
The topics help the students

- To understand the definition and classification of pharmaceutical products.
- To understand manufacturing of penicillin by fermentation

COURSE OUTCOMES:

1. Describe various manufacturing processes used for various inorganic and organic chemicals synthesis.
2. Understand major engineering problems encountered in chemical process industries.
3. Determine process aspects like yield, by products formed.
4. Draw and explain process flow diagrams for a given synthesis process.

TOPIC TO BE COVERED:

Lecture No	Topics to be covered
Lecture 55	Definition pharmaceutical products
Lecture 56	Classification of pharmaceutical products-I
Lecture 57	Classification of pharmaceutical products-II
Lecture 58	Major pharmaceutical industry in India and their products
Lecture 59	Flow-sheet description for manufacturing of penicillin by fermentation
Lecture 60	Process description for manufacturing of penicillin by fermentation

TOOLS USED:

- Chalk and duster
- K-Yan

MODEL QUESTIONS:

1. Classify the types of Pharmaceutical Products.
2. Write down the types of penicillin products.
3. Describe the manufacturing of pencilling with a neat diagram.
4. Write down names of few Indian Pharmaceutical Companies**.**
5. Write down the basic structure of penicillin.
6. Give two examples of antibiotics.

ASSESSMENT METHODS APPLIED:

- Class quiz
- Assignment

REFERENCES:

- Outline of Chemical Technology by Dryden, East West Press Publication.
- Chemical Technology by N Shreeve, Tata Mc Grawhill Publication

Introduction to Pharmaceutical Industry

- The pharmaceutical industry discovers, develops, produces, and markets drugs or pharmaceutical drugs for use as medications to be administered (or self-administered) to patients, with the aim to cure them, vaccinate them, or alleviate the symptoms.
- Pharmaceutical companies may deal in generic or brand medications and medical devices. They are subject to a variety of laws and regulations that govern the patenting, testing, safety, efficacy and marketing of drug.

Indian Pharmaceutical Companies:

- Sun Pharmaceuticals is the largest pharmaceutical company from India and the fifth largest specialty generic company in the world.
- Cipla is a leading pharmaceutical from India with presence across the world. It was established in 1935 as Chemical Industrial & Pharmaceutical Laboratories Ltd and changed to its current name in 1984.
- Lupin Ltd. is a leading pharmaceutical company from India and is amongst the top 10 generic companies in the world. It started its business in 1968 and over the years has become one of the largest pharmaceutical companies in India and the world.
- Dr.Reddy's Laboratories is an Indian multinational pharmaceutical company located in Hyderabad, Telangana, India.
- Divi's Laboratories Limited is an Indian producer of active pharmaceutical ingredients (APIs) and intermediates headquartered in Hyderabad, Telangana, India.
- The company manufactures and custom synthesizes generic APIs, intermediates and nutraceutical ingredients.
- Divi's Laboratories is India's second most valuable pharmaceutical company by market capitalization.

Types of Pharmaceutical Products:

- Antibiotics
- Synthetic Drugs
- Vitamins
- Synthetic Hormones
- Drugs of vegetable Origin

Antibiotics:

- Antibiotics are medicines that help stop infections caused by bacteria. They do this by killing the bacteria or by keeping them from copying themselves or reproducing.

Types of Antibiotics

Penicillin

- Penicillins were the first antibiotic that doctors used. There are several antibiotics in the penicillin class. Experts credit Alexander Fleming with discovering penicillins. Penicillin works by interfering with bacteria cell walls. Less than 1 percent of people are dangerously allergic to penicillin.

Streptomycin

- This medication is used with other medications to treat active tuberculosis (TB) infection which is a type of TB that cannot be treated with other drugs (drug-resistant TB). Streptomycin belongs to a class of drugs known as aminoglycoside antibiotics. It works by killing the organisms that cause the infection.

Tetracyclines

- Tetracyclines are a group of broad-spectrum antibiotic compounds that have a common basic structure and are either isolated directly from several species of *Streptomyces* bacteria or produced semi-synthetically from those isolated compounds. Tetracyclines are growth inhibitors (bacteriostatic) rather than killers of the infectious agent (bacteriocidal) and are only effective against multiplying microorganisms.

Chloramphenicol

- Chloramphenicol is an antibiotic useful for the treatment of a number of bacterial infections. This includes use as an eye ointment to treat conjunctivitis. By mouth or by injection into a vein, it is used to treat meningitis, plague, cholera, and typhoid fever. Its use by mouth or by injection is only recommended when safer antibiotics cannot be used.

Other Synthetic Drugs

- Important among these are sulfa drugs, anti TB drugs, antileprotic drugs, analgesics, anesthetics, antimalarial.
- Sulfa Drugs: Sulfa drugs are bacteriostatic; i.e., they inhibit the growth and multiplication of bacteria but do not kill them.
- Example: Sulfamethoxazole, sulfathiazole, sulfapyridine.
- Anti TB Drugs: The drugs have the aim of killing all the TB bacteria in the person's body. However TB bacteria die very slowly, and so the drugs have to be taken for quite a few months.
- Example: Isonicotinic acid Hydrazide., p- amino salicylic acid
- Antileprotic Drugs: A leprostatic agent is a drug that interferes with proliferation of the bacterium that causes leprosy.
- Examples: DDS and its derivatives, Dapsone,.

Synthetic Hormones:

- Natural hormones include 17α-estradiol, 17β-estradiol, estrone, estriol, 17α-dihydroequilin, testosterone, and progesterone.
- Synthetic hormones do not have a chemical structure that is identical to a human being's natural hormones.
- Synthetic hormones are also used in medicine and include gestodene, norgestrel, levonorgestrel, medrogestone, 17α-ethynylestradiol, and trimegestone.
- Synthetic Human Growth Hormone (HGH) was developed over 30 years ago and approved by the FDA for specific uses in children and adults.
- HGH is used in children as treatment for short physique of unidentified reason, or poor growth due to a number of medical causes, including Turner's syndrome and Prader-Willi syndrome.

Drugs of vegetable origin:

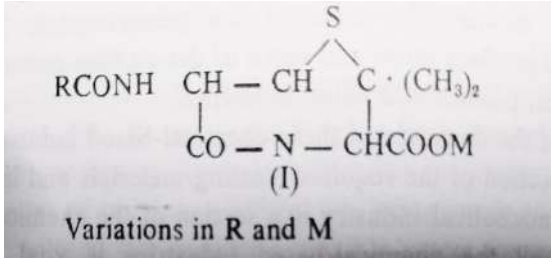
- Natural drugs obtained from plants and animals are called drugs of biological origin and are produced in the living cells of plants or animals.
- Crude drugs are plants or animals or their parts which after collection are subjected only to drying or making them into transverse or longitudinal slices or peeling them in some cases.
- Most of the crude drugs used in medicine are obtained from plants and only a small number comes from animal and mineral kingdom.
- Quinine:Cinchona trees remain the only economically practical source of quinine. Quinine is a medication used to treat malaria and babesiosis.
- Strychnine and brucine: Brucine, an alkaloid closely related to strychnine, is most commonly found in the *Strychnos nux-vomica* tree. While brucine has been shown to have good anti-tumor effects, on both hepatocellular carcinoma and breast cancer.
- Emetine:Emetine is a drug used as both an anti-protozoal and to induce vomiting. It is produced from the ipecac root.
- Digitalis Glycosides: Glycosides are a class of organic compounds that increase the output force of the heart and decrease its rate of contractions. It is produced from *Antiaris toxicaria* (upas tree).

Penicillin Manufacturing:

Basic Structure

Name of derivative	*Designation*		*R in side chain*
	UK	*USA*	
2-Pentenyl-	I	F	$CH_3CH_2CH{=}CHCH_2-$
n-Amyl	Dihydro I	Dihydro F	$n\text{-}C_5H_{11}-$
Benzyl-	II	G	$C_6H_5CH_2-$
p-Hydroxy-benzyl	III	X	$HOC_6H_4CH_2-$
n-Heptyl	IV	K	$n\text{-}C_7H_{15}$
Phenoxy-methyl	V	Vee	$C_6H_5{-}OCH_2-$

Types of Penicillin



Variations in R and M

Changes of M in main ring will impart solubility and ingestion rate control:

- Direct rapid action injection: M = Na or K
- Oral tablets: M = K, Ca, Al
- Delayed action oil-base injection: M = procaine or other derivative to impart limited water solubility

Penicillin II and IV are considered clinically most desirable.

Process Description:

1. An aerobic batch fermentation is carried out.
2. Maize steep liquor is diluted with water to a (4-5)% solid, fortified with (4-5)% lactose solids and nutrients such as Mg, Zn, Sodium sulfate, ammonium acetate in amount of less than 0.2%.
3. $CaCO_3$ is added to adjust pH (5-6).
4. Organic Precursor chemicals are added to control type and yield of penicillin. Phenyl acetic acid Precursor → Type II Penicillin

↑ fermentation Medium

5. Specific mold culture → Penicillium chrysogenum for Type II Penicillin.
6. Batch fermentation medium is sterilized with steam at 115°C for ½ hr. and cooled with water to 25°C.
7. Sterile air is blown through the tank for (4-5) days under temp control of ± ½°C.
8. Fermented broth is then mixed with refrigerant and then passed through rotary drum filter. Suspended solids (in form of Mycelia for food supplement) is separated by continious feltration at (1-2)°C.
9. The clear liquid is then mixed with 10% H_3PO_4 to maintain a pH of 2.5.
10. Penicillin salt is then extracted in extraction section using amyl acetate as solvent.
11. The raffinate is sent to a solvent recovery still.

3 Stages
1. Fermentation
2. Extraction
3. Purification

2 types of Product
1. Penicillin Powder
2. Penicillin Crystals

(12) The extract is buffered with Sodium Phosphate salt solution to maintain a PH of 7.5 in a Continious mixer.
(13) Crude Penicillin is centrifuged and solvent is recirculated to extractor.
(14) Purification of Penicillin is done in a second aeidic extraction unit, followed by addition of pyrogen free distilled water.
(15) Pyrogen free distilled water contains Na, K, Ca or Al.
(16) Purified concentrate is separated from solvent using scraper-centrifuge.
(17) Biological filter separates final traces of bacteria and pyrogens.
(18) Penicillin solution is then concentrated by Freeze drying or vacuum spray drying.
(19) For vacuum production, high vacuum ejector is used.
(20) After drying, Penicillin powder is processed and sterile packaging is done.
(21) Crude Penicillin from centrifuge of extraction section is divided into two Parts. One for production of Penicillin powder and second for Penicillin crystal.
(22) For production of Penicillin crystal, the crude Penicillin is passed through two crystallizer and drying results in Penicillin crystals.

