CHAPTER-4 (C3, C4 Chemicals)

Manufacturing of Butadiene

Butadiene is used primarily as a chemical intermediate and as a monomer in the manufacture of polymers such as synthetic rubbers or elastomers, including styrene-butadiene **rubber** (SBR), polybutadiene **rubber** (PBR), polychloroprene (Neoprene) and nitrile **rubber** (NR)

- CHEMICAL FORMULAE : $(CH_2{=}CH)_2$
- Its molecular weight is 54.092 g/mol
- It has a specific gravity of 0.62 at 68 degrees Fahrenheit.
- It has a vapor pressure of 1,840 mm Hg (millimeter of mercury) at 69.8 degrees Fahrenheit

Reactions::

- Main reaction: n-Butane → Butadiene + Hydrogen.
- Side reaction: n-Butane→ n-Butylene + Hydrogen.
- Catalyst: Chromium oxide on alumina.
- Coke deposition is a very important issue. Therefore, catalyst regeneration needs to be carried out very frequently.
- Reaction is exothermic .
- Operating conditions: $650^{o}C$ and 120-150 mm Hg (low pressure).
- Feed stock: n-Butane with some isopentane from refinery processes.

Process Technology

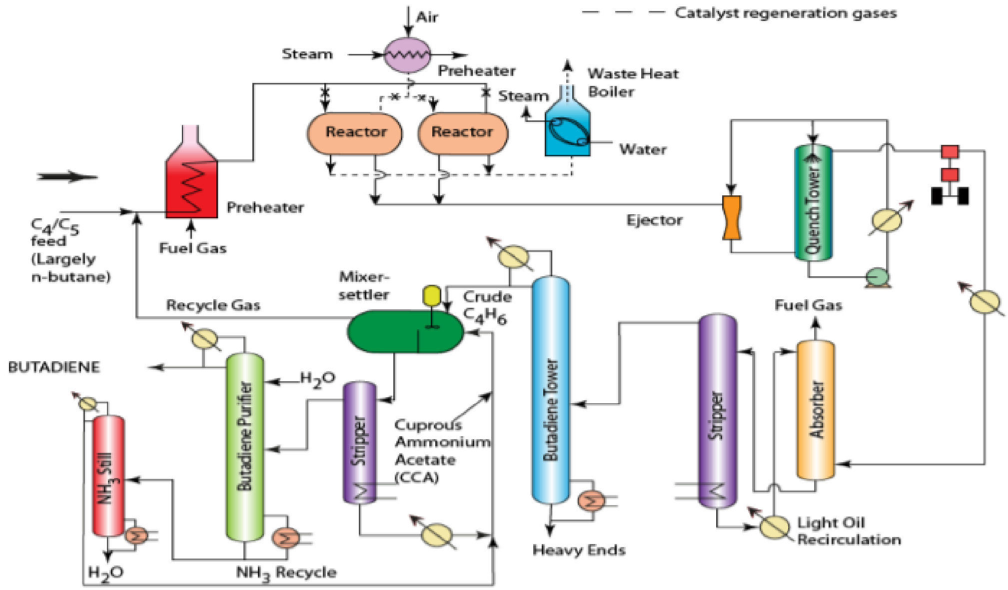


Figure 21.1 Flow sheet of Butadiene manufacture

- The process technology for Butadiene manufacture consists of a reactorseparator-recycle system.

- The separation network is extremely complex and involves quenching, absorption, distillation and extractive distillation process.
- First, the feed stock is pre-heated in a furnace along with unreacted gases that have been recovered in the process using the separator network.
- After pre-heating in a furnace to desired temperature, the gases enter the catalytic packed bed reactors loaded with the catalyst.
- After the specified residence time, the product is withdrawn and the feed to the unit is stopped. The product withdraw and stoppage of the feed flow to the reactor unit is carried out using valves.
- The coked catalyst is subjected to combustion using pre-heated air. Air pre-heating is done using steam in an extended area heat exchanger equipment. Therefore during regeneration, another set of valves operate to allow the pre-heated air in and enable the product withdrawal after the combustion.
- The pre-heated air not only removes the coke as CO_2 but increases the reactor temperature to 650 ^{o}C.
- The flue gases are sent to a waste heat recovery boiler so as to generate steam from water.
- The entire operation of a feed entry, product withdrawal, pre-heated air entry and combustion gases withdrawal from the packed bed reactor corresponds to one single cycle.
- Since the above operation is a batch operation, to make the operation continuous in accordance to the separation network, two reactors are used and these reactors are operated in cyclic fashion i.e., when the first reactor is subjected to reaction, the second reactor is subjected to catalyst regeneration and vice-versa.
- The hot reactor outlet gases are sent to a quenching operation where light gas oil is used to quench the gases using a recirculating quenching tower.
- After product gases from the quenching tower are compressed and cooled to enter an absorber

- In this absorber, naphtha is used as an absorbent to absorb all hydrocarbons except fuel gas.
- The absorbent + hydrocarbons enter a stripper that produces fresh naphtha and hydrocarbon mixture. The hydrocarbon mixture consists of unreacted feed stock and butadiene and some heavy ends.
- This mixture now enters a fractionator to separate the crude butadiene and heavy ends.
- The crude butadiene consists of butadiene and unreacted feed stock i.e., n-butane and isopentane. The separation of n-butane, other hydrocarbons with butadiene is one of the difficult separations and they cannot be separated using ordinary distillation. Therefore, a complicated route of separation is followed next that involves azeotropic distillation using ammonia.

- The crude butadiene is mixed with ammoniated cuprous ammonium acetate solution in a mixer settler. This solution is generated by absorbing ammonia into fresh cuprous ammonium acetate solution.
- The ammoniated cuprous ammonium acetate is sent to a mixer settler unit where the butadiene dissolves in the ammoniated solution. The gas from the mixer settler unit is recycled to mix with the feed stock and enter the pre-heater.
- The ammoniated cuprous ammonium acetate solution is thereby stripped to separate butadiene + ammonia from the ammonium acetate solution. The regenerated fresh solvent is allowed to absorb NH_3 and thereby enter the mixer-settler unit.
- The ammonia + butadiene mixture enters a fractionator fed with water. Here, water interacts with ammonia and generates the ammonium hydroxide product as the bottom product and butadiene is obtained as the top product.
- The ammonia solution is subjected to stripping to separate water and ammonia. The water is recycled back to the butadiene purifier and ammonia is allowed to get absorbed into the fresh cuprous ammonium acetate solution.
  This process is not followed in India . In India, it is manufactured from ethanol by catalytic cracking at 400-450 ^{o}C over metal oxide catalyst.

Production of Methanol

From synthesis gas[edit]

Carbon monoxide and hydrogen react over a catalyst to produce methanol. Today, the most widely used catalyst is a **mixture of copper and zinc oxides**, supported on alumina, as first used by ICI in 1966. At 5–10 MPa (50–100 atm) and 250 °C (482 °F), the reaction is characterized by high selectivity (>99.8%):

$$CO + 2\ H_2 \rightarrow CH_3OH$$

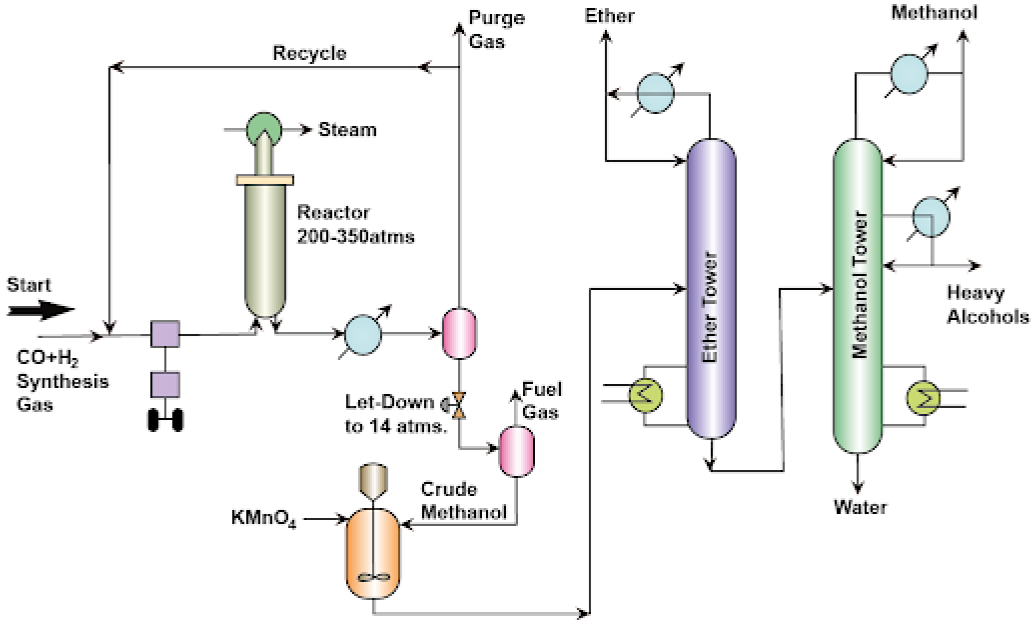
The production of synthesis gas from methane produces three moles of hydrogen for every mole of carbon monoxide, whereas the synthesis consumes only two moles of hydrogen gas per mole of carbon monoxide. One way of dealing with the excess hydrogen is to inject carbon dioxide into the methanol synthesis reactor, where it, too, reacts to form methanol according to the equation:

$$CO_2 + 3\ H_2 \rightarrow CH_3OH + H_2O$$

In terms of mechanism, the process occurs via initial conversion of CO into CO_2, which is then hydrogenated:[51]

Note: KMnO4 is used as an oxidizing agent here.

Production ::



Usage ::

Methanol is primarily converted to formaldehyde, which is widely used in many areas, especially polymers

<u>Production of Ethyl Alcohol or Ethanol(C2H5OH)</u>

Introduction

Ethanol is a volatile, flammable, clear, colourless liquid. Ethanol is a good solvent. It is also used as a germicide, beverage, antifreeze, fuel, depressant and chemical intermediate. It can be made by the fermentation process of material that contains sugar or from the compound which can be converted to sugar. Yeast enzyme readily ferment sucrose to ethanol.

Molecular formula- C_2H_5OH

Molecular weight- 46.07

Density- 0.791 at 20˚C

Boiling Point- 78.3˚C

<u>Chemical Reactions:</u>

(a) Main Reaction

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{invertase}} 2C_6H_{12}O_6$$

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2C_2H_5OH + 2CO_2 \qquad \Delta H = -31.2 \text{ kcal}$$

Glucose Ethanol

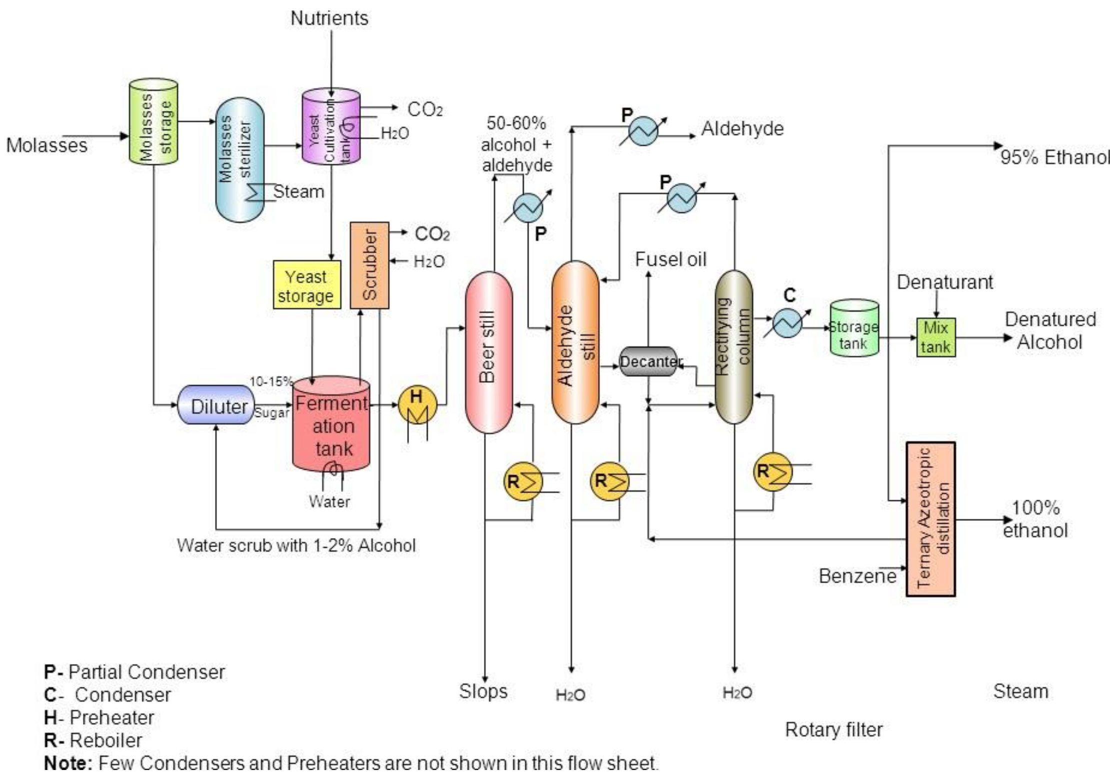
(b) Side reaction

$$2\ C_6H_{12}O_6 + H_2O \rightarrow ROH + R'CHO$$

Fusel oil

Ethanol is raw material for many downstream organic chemical industries in India.

Raw Material: Molasses



Functional role of various units

(a) Molasses storage tank:

Molasses is liquor obtained as by product of sugar industries.

Molasses is a heavy viscous material ,which contains sucrose, fructose and glucose (invert sugar) at a concentration of 50-60(wt/vol).

(b) Sterlization tank:

Yeast is sterilized under pressure and then cooled.

(c) Yeast cultivation tank:

Yeast grows in the presence of oxygen by budding.

Yeast is cultivated in advance.

(d) Yeast storage tank:

Yeast are unicellular, oval and 0.004 to 0.010mm in diameter.

PH is adjusted to 4.8 to 5 and temperature up to 32˚C

(e) Fermentation tank:

Chemical changes are brought by the action of enzymes invertase and zymase secreted by yeast in molasses.
Fermentation is anaerobic,
Heat is evolved which is removed by cooling coils.
Residence time is 30-70 hours and temperature is maintained at 20-30˚C
8-10%alcohol by volume(beer) is produced by fermentation process.
HCl or sulfuric acid is added to obtain 4.5 P^H.

(f) Diluter:

Here molasses is diluted to 10 to 15% sugar solution.

(g) Scrubber:

Carbondioxide is released and utilized as by product.
By-product CO_2 contains some ethanol due to Vapor liquid evaporation and can be recovered by water scrubbing.
Water is sent back to continuous diluter stream.

(h) Beer still:

50-60% concentration alcohol and aldehyde is produced.
Slops are removed as bottom product.
Slop is concentrated by evaporation for cattle feed or discharged as waste.
Slop contains proteins, sugar and vitamins.

(i) Aldehyde still:

Undesirable volatile liquid; aldehyde is taken off from the top of the still.
From the side stream alcohol is feed to the decanter.
It is extractive distillation column, and operates at a pressure of around 0.6-0.7 MPa.

(j) Decanter :

Fusel oil which is high molecular weight alcohol is recovered by decantation.
Fusel oil is fractionated to produce amyl alcohol or are sold directly.
The principle behind extraction of fusel oil from ethanol is that higher alcohols are more volatile than ethanol in solution containing a high concentration of water.

(k) Rectifying column:

In the column, azeotropic alcohol- water mixture of 95% ethanol is withdrawn as side product.
This 95% ethanol is condensed in condenser and stored in storage tank.
Side stream is withdrawn and sent to decanter.
At the bottom, water is discharged.

Here, alcohol – water mixtures are rectified to increase the strength of alcohol.

(l) Storage tank:

From storage tank, three streams are evolved: Direct
sale as portable.
For industrial use.
To anhydrous still to produce 100% ethanol.

(m) Mix tank:

For producing denatured alcohol, denaturant is mixed with the 95% ethanol produced from rectifying column.
Denaturant is normally methanol (10vol%)

(n) Ternary Azeotropic distillation:

The product from rectifying column is a ternary minimum boiling azeotrope of ethanol, water and benzene.
Benzene is an azeotropic agent.
Here mainly two units are present; anhydrous still, decanter, stripper and few heat exchangers.
Anhydrous motor fuel grade ethanol (100% ethanol) is produced as product.
Heat integration and energy recovery plays a vital role in reducing energy requirements.

Technical Questions

1. Explain Azeotropic distillation process for manufacturing 100% ethanol?

Ans1: The separation process of ethanol and water is energy intensive. Complete separation of ethanol and water is not possible by simple distillation. This is due to the fact that ethanol forms a minimum boiling azeotrope with water at 89 mole % (96.4 vol%) ethanol concentration at atmospheric pressure and 351 K. Therefore, a third component benzene is added as azeotropic agent. With addition of benzene, unfortunately, a ternary azeotrope containing benzene (53.9 mol%), water (23.3mol%) and ethanol (22.8mol%) is formed with a boiling point of 338K which is lower than the boiling point of ethanol. Eventually, the anhydrous still produces 100% pure ethanol as bottom product and ternary azeotrope at the top. The ternary azeotrope on cooling separates into two phases in the decantation unit in which two phases are formed:

(a) Benzene rich organic phase. (b)Aqueous phase of benzene and ethanol.

While the benzene rich organic phase is recycled as reflux to the anhydrous still, the aqueous phase of benzene and ethanol is sent to a second column (stripper) which separates the ethanol/water from benzene. It is interesting to

note here that cooling enabled the phase separation of the azeotrope which eventually was further separated using stripping.

2. Why yeast storage is required?

Ans2: In due course of the fermentation process, it is possible that due to variations in the addition of nutrients, flow rates and conditions of the fermenter, there could be a possibility in the variation of solution concentration of microorganisms. In addition, prolonged biological activity could also encourage genetic modification. Therefore, yeast is always stored after the yeast culture tank so that always a reference stock is available and can be used for further growth of the microorganisms as a base cell culture.

3. What is the function of scrubber?

Ans3: In natural mass transfer processes, it is inevitable that 100 % separative distribution of compounds such as ethanol is not possible. Ethanol having a boiling point of 78.3 ^{o}C at atmospheric pressure due to existing vapor pressure circumstances enters the air leaving the fermentation tank. Therefore, the ethanol produced could get lost if left to the atmosphere as a vent stream.
Henceforth,

4. Why molasses is sterilized?

Ans4: The molasses consist of other types of microorganisms which contribute to the production of other types of alcohols other than ethanol. Therefore, to allow the larger production of ethanol in comparison to other alcohols and ketones, the molasses is sterilized for the removal of other types of microorganisms.

5. What is denatured alcohol?

Ans5: Denatured Alcohol is ethanol which has been rendered toxic or otherwise undrinkable, and in some cases dyed. It is used for purposes such as fuel for spirit burners and camping stoves, and as a solvent. Some agents such as denatonium benzoate, methanol, naphtha, pridine are added to the ethanol.

6. Why alcohol obtained from rectifying column can't be more than 95% strength?

Ans6: Water form a binary constant boiling mixture which has higher boiling point than alcohol, anhydrous and absolute alcohol.

7. Why are partial condensers used in the process

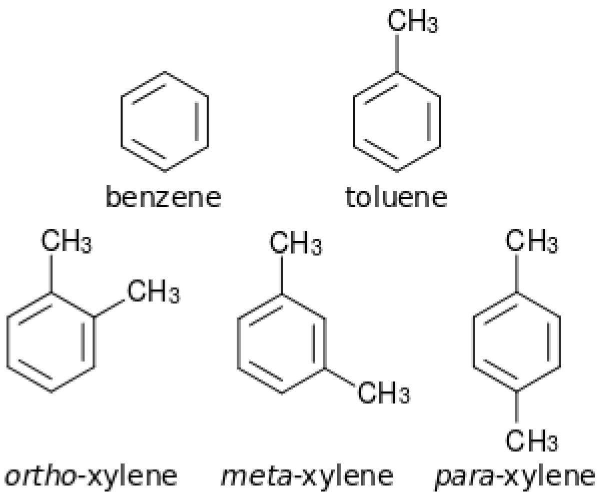
Ans.7: A partial condenser is typically used in a distillation column when the product desired is send for further processing and the vapors are only cooled to obtain the desired reflux stream flow rates. In this way, in a sequence of distillation columns, it will lead to energy savings. The ethanol process flow

CHAPTER-5 (AROMATIC CHEMICALS)

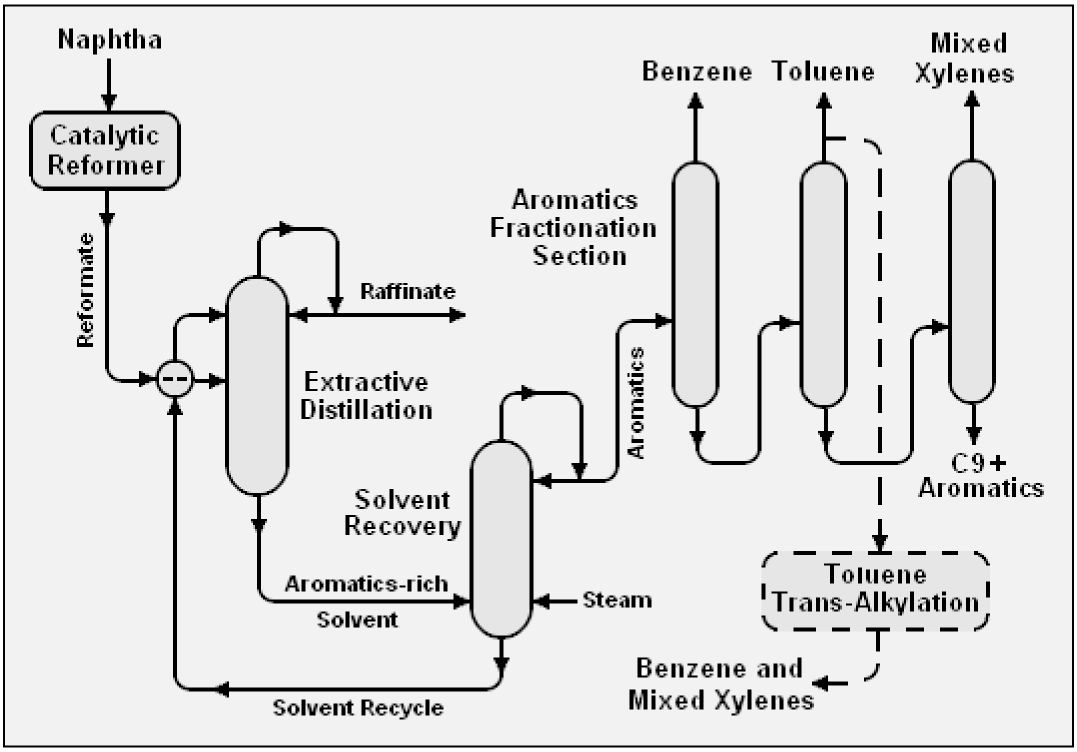
Production of BTX

BTX refers to mixtures of benzene, toluene, and the three xylene isomers, all of which are aromatic hydrocarbons

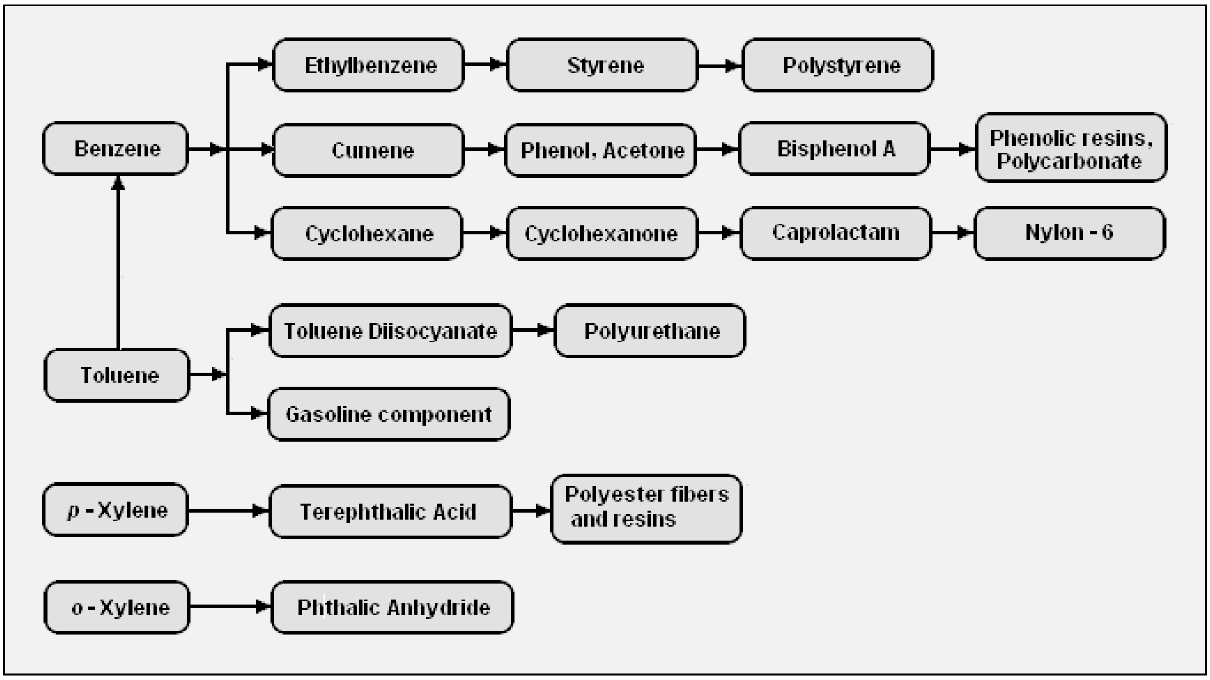
Toluene is also a valuable petrochemical for use as a solvent and intermediate in chemical manufacturing processes and as a high octane gasoline component.



- Benzene, toluene, and xylenes can be made by various processes. However, most BTX production is based on the recovery of aromatics derived from the catalytic reforming of naphtha in a petroleum refinery.
- Catalytic reforming usually utilizes a feedstock naphtha that contains non-aromatic hydrocarbons with 6 to 12 carbon atoms and typically produces a ***reformate*** product containing C_6 to C_8 aromatics (benzene, toluene, xylenes) as well as paraffins and heavier aromatics containing 9 to 12 carbon atoms.
- The BTX aromatics can be extracted from catalytic reformate or from pyrolysis gasoline by many different methods. Most of those methods, but not all, involve the use of a solvent either for liquid-liquid extraction or extractive distillation


Naphtha
Catalytic Reformer
Reformate
Raffinate
Extractive Distillation
Aromatics Fractionation Section
Benzene
Toluene
Mixed Xylenes
Aromatics
Solvent Recovery
Aromatics-rich Solvent
Steam
C9+ Aromatics
Toluene Trans-Alkylation
Benzene and Mixed Xylenes
Solvent Recycle

Usases


Benzene
Ethylbenzene
Styrene
Polystyrene
Cumene
Phenol, Acetone
Bisphenol A
Phenolic resins, Polycarbonate
Cyclohexane
Cyclohexanone
Caprolactam
Nylon - 6
Toluene
Toluene Diisocyanate
Polyurethane
Gasoline component
p - Xylene
Terephthalic Acid
Polyester fibers and resins
o - Xylene
Phthalic Anhydride

Usage of Benzene:

It's used to make plastics, resins, synthetic fibers, **rubber** lubricants, dyes, detergents, drugs and pesticides. Benzene is produced naturally by volcanoes and forest fires. In homes, benzene may be found in glues, adhesives, cleaning products, paint strippers, tobacco smoke and gasoline.

Usage of Tolune .

TOLUENE is generally used for making of xylene

it also used for production of

1. toluene diisocyanate used in the manufacture of polyurethane foam

2. trinitrotoluene (the explosive, TNT)

3. fuels Toluene can be used as an octane booster in gasoline for internal combustion engines.

4. solvents for various compound .and a number of synthetic drugs.

XYLENE ::

- P-Xylene is the principal precursor to terephthalic acid and dimethyl terephthalate, both monomers used in the production of polyethylene terephthalate (PET) plastic bottles and polyester clothing.
- O-Xylene is an important precursor to phthalic anhydride.
- Xylene is substituted for toluene where slower drying is desired and thus is used by conservators of art objects in solubility testing.
- It is used in the laboratory to make baths with dry ice to cool reaction vessels, and as a solvent to remove synthetic immersion oil from the microscope objective in light microscopy.
- In histology, xylene is the most widely used clearing agent.
- Xylene is used to remove paraffin from dried microscope slides prior to staining.
- Xylene applications in concrete sealer

- Acrylic concrete sealer is a decorative concrete material widely used for concrete surfaces. In this type of sealers, xylene is used as a sealer/carrier solvent.
- Xylene is used in the production of terephthalic acid monomer. It is a good cleaning agent for silicon wafers, steel and to sterilize many substances. Xylene is used as a feedstock in the production of petrol. It is also found in small proportions in gasoline and jet fuel.

Manufacturing of Aniline

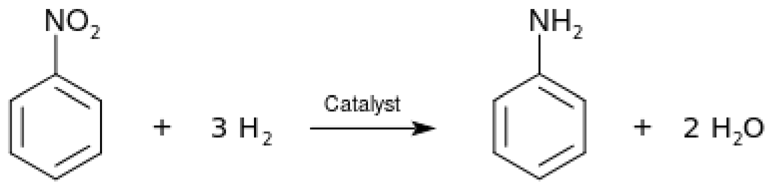
Aniline is an organic compound with the formula $C_6H_5NH_2$. Consisting of a phenyl group attached to an amino group, aniline is the simplest aromatic amine. Its main use is in the manufacture of precursors to polyurethane and other industrial chemicals. Like most volatile amines, it has the odor of rotten fish. It ignites readily, burning with a smoky flame characteristic of aromatic compounds.[6]

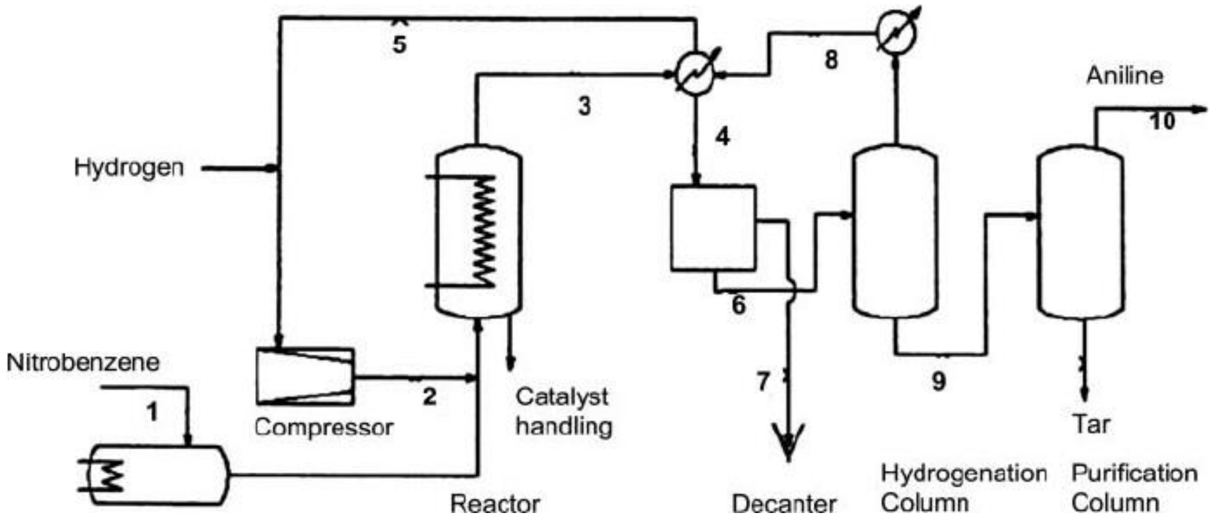
Anilines – Physical Properties

The physical properties of Anilines are given below-

- Aniline has a boiling of about 184 ^{o}C and melting of about -6 ^{o}
- The compound is slightly soluble in water and sometimes freely soluble in the chemicals such as alcohol and ether.
- This organic compound tends to darken when exposed to air and light.
- It is said to be weak base and on its reaction with strong acids, it forms anilinium ion -C_6H_5-NH_3+.
- The compound is said to be toxic when it gets inhaled through the air or gets absorbed into the skin as it produces nitrogen oxides which are harmful to the environment.

Industrial aniline production involves two steps. First, benzene is nitrated with a concentrated mixture of nitric acid and sulfuric acid at 50 to 60 °C to yield nitrobenzene. The nitrobenzene is then hydrogenated (typically at 200–300 °C) in the presence of metal catalysts:[10]





Aniline production process: hydrogenation of nitrobenzene. Stream (1) nitrobenzene, (2) hydrogen feed, (3) reactor product gases, (4) condensed materials, (5) non- condensed materials, (6) crude aniline, (7) aqueous phase, (8) overheads, (9) bottom streams, (10) overheads containing aniline product and (11) bottoms containing tars.

- **Anilines** are used in the rubber industry for the processing of rubber chemicals and products such as car tyres, balloons, gloves, etc.
- It is used as a dyeing agent in the manufacture of clothes such as jeans, etc.
- It is employed in the production of drugs such as paracetamol, Tylenol, acetaminophen.

Manufacturing of Styrene

Styrene, also known as **ethenylbenzene**, **vinylbenzene**, and **phenylethene**, is an organic compound with the chemical formula $C_6H_5CH=CH_2$. This derivative of benzene is a colorless oily liquid although aged samples can appear yellowish. The compound evaporates easily and has a sweet smell, although high concentrations have a less pleasant odor. Styrene is the precursor to polystyrene and several copolymers.

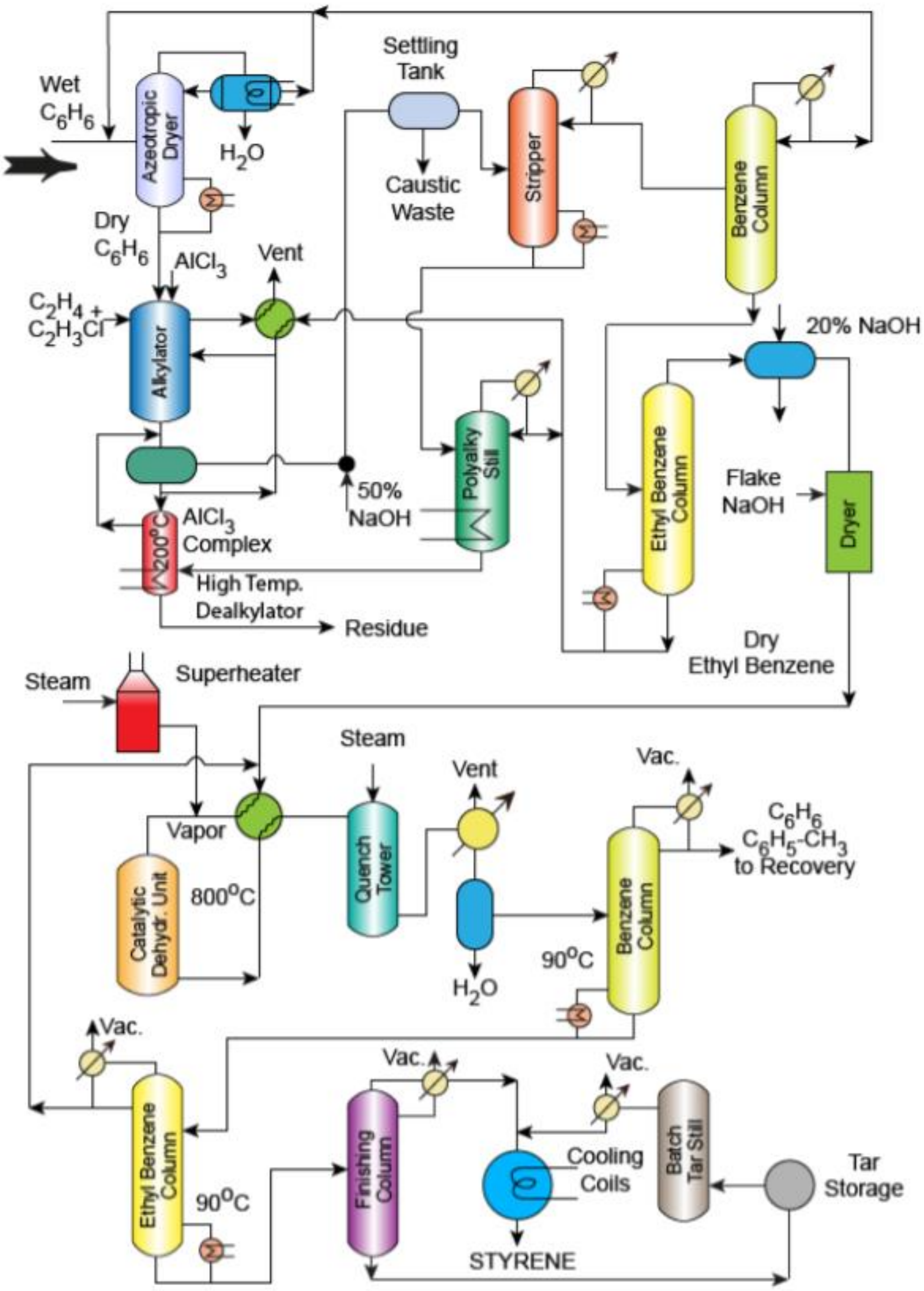
The vast majority of styrene is produced from ethylbenzene,[19] and almost all ethylbenzene produced worldwide is intended for styrene production. As such the two processes are often highly integrated. Ethylbenzene is produced via a Friedel–Crafts reaction between benzene and ethylene, originally this used aluminum chloride as a catalyst but in modern production this has been replaced by zeolites.

Alkylation of Benzene

- Benzene + ethylene → Ethyl benzene
- Catalyst: $AlCl_3$ granules
- C_2H_5Cl provides hydrogen and chlorine free radicals
- Operating conditions: 95°C and 1 atm pressure
- Reaction is exothermic

Dehydrogenation of ethylbenzene

- Ethylbenzene → Styrene + Hydrogen
- Reaction is endothermic
- Catalyst: SnO or FeO
- Operating conditions: 800°C



- The process consists of two separate reactor-separator-recycle networks in which one corresponds to the ethylbenzene flow sheet and the other corresponds to styrene flowsheet.
- We first present the flowsheet for ethylbenzene production
- Benzene (wet) is sent first to an azeotropic distillation unit that separates water and produces dry Benzene. Dry Benzene is required so as to avoid

unnecessary reactions in the alkylation reactor as well as damage to the catalyst as alumina can get formed.

- Dry Benzene + Ethylene + Ethyl chloride + $AlCl_3$ enter the alkylator catalyst
- The reactor could be a jacketed tower where water is used as a cooling fluid in the jacket to control the reactor temperature.
- The reactor produces two products namely uncondensible gases and the liquid product in which $AlCl_3$ complex is available. This complex needs to be regenerated and sent back to the alkylator.
- The alkylator product is sent to a cooler which upon cooling to 40°C separates the aluminium chloride complex stream from the product stream. The other stream from the cooler is the ethylbenzene rich product stream.
- The aluminium chloride stream is partially recycled to the alkylator so as to maintain the required catalyst requirements. The other portion of the $AlCl_3$ complex is sent to a dealkylator unit in which the feed is heated to 200 °C. By doing so, the polyethylbenzenes formed in the alkylator are converted to benzene and ethylbenzene (cracking reaction).
- The benzene and ethylbenzene are returned to the cooler.
- The delkylator produces a residue product consisting of tar + $AlCl_3$ mixture.
- From this mixture, $AlCl_3$ is recovered using water extraction as $AlCl_3$ is soluble in water. From there $AlCl_3$ is recovered from the water and returned back to the alkylation reactor.
- The product stream from the cooler consisting of ethylbenzene is mixed with 50 % NaOH to remove acidic impurities. Eventually, after settling waste is eliminated.

- The purified ethylbenzene then enters a stripper that separates ethylbenzene + benzene from the polyalkylbenzenes. The polyalkylbenzenes are sent to a polyalkyl still that separates the benzene + ethylbenzenes from the polyalkylbenzenes (bottom product). The polyalkyl still is operated under vacuum. The polyalkylbenzenes are fed to the dealkylator and the benzene + ethylbenzene rich stream is sent to a heat integrated exchanger that extracts heat from the vent gases and then eventually enters the alkylation reactor.
- The top product from the stripper is ethylbenzene + benzene and it enters a benzene column that separates wet benzene from crude ethylbenzene. The wet benzene is recycled to the azeotropic dryer where it is mixed with fresh wet benzene to enter the azeotropic dryer.
- The crude ethylbenzene is further purified in a fractionator where the bottom product (with benzene) is mixed with the top product of the polyalkyl still. Thereby, the stream enters the heat integrated exchanger.
- The ethylbenzene is further subjected to caustic wash and finally it is sent to a dryer to produce dry ethylbenzene.
- We now move to the dehydrogenation flow sheet.
- The ethylbenzene (dry) is heated with superheated steam to enter the catalytic dehydrogenator. Excess steam is used in this process. The feed pre-heating is

carried out using the product vapour stream. The reaction is gas phase catalytic reaction.

- The vapour stream after cooling with the feed stream in a heat integrated exchanger is fed to a quench tower using steam quenching.
- After quenching, partial condensation of the quenched vapors produces three streams one being the vapour vent, the other being water and the third being the organic phase rich with styrene.
- The styrene rich stream is sent first to a benzene column to recover the benzene + toluene and this is sent to a benzene-toluene distillation column to recover benzene. The benzene is sent to the azeotropic distillation unit as a raw-material.
- The bottom product from the benzene column enters an ethylbenzene column which separates ethylbenzene from the styrene stream. The ethylbenzene stream is mixed with the dry ethylbenzene to enter the catalytic dehydrogenator.
- The bottom product from the ethylbenzene column is the styrene enriched stream and this is sent to the finishing column where styrene is further purified from unwanted impurities such as tar. The tar is further batch distilled to recover styrene from the tar. The styrene finishing column also produces styrene product. Both styrene products from batch still and styrene finishing column are mixed and cooled to store as styrene product.
- All three columns namely benzene, ethylbenzene and finishing columns are operated under vacuum.

Uses : Styrene is mainly used for making plastic toys and model kits. Moreover, housing for machines as well as refrigerator doors and air conditioner cases are made of styrene.

1. **Explain how azeotropic distillation unit functions to convert wet benzene to dry benzene?**

Ans: Wet benzene upon heating produces a heterogenous azeotrope at the top and dry benzene at the bottom. Therefore, the unit upon condensation of the top vapors produces two streams namely water and benzene rich wet stream which is recycled back as the reflux stream.

2. **Why is the benzene + ethylbenzene stream returned back to the cooler but not the alkylation reactor?**

Ans: The alkylation reactor should be fed with very important chemicals only. It is possible that the temperatures prevailing in the dealkylator could enable the loss of polyalkylbenzenes to the vapour. Therefore, there is no point in feeding this stream to the alkylator. Instead the stream is sent to the cooler so that any polyalkylbenzenes could be condensed back and sent to the dealkylator again.

3. Why the $AlCl_3$ complex is partially returned to the reactor?

Ans: To maintain the required catalyst conditions. If not, then $AlCl_3$ fresh has to be provided to the reactor as $AlCl_3$ forms a complex with the hydrocarbons and would leave the alkylator along with the product streams.

4. Why do polyalkylbenzenes enter the ethylbenzene rich product?

Ans: This is the basic problem of the equilibrium separation factors of polyalkylbenzenes between the $AlCl_3$ complex rich product and the ethylbenzene rich product. Since sharp distribution of these compounds is not possible, polyalkylbenzenes get distributed between both these organic phases.

5. Why there are ethylbenzene + benzenes still available in the bottom product of the stripper?

Ans: The answer is same as that of question 3 i.e., the phase equilibrium limitations enable the availability of both benzene + ethylbenzene in the polyalkylbenzene stream.

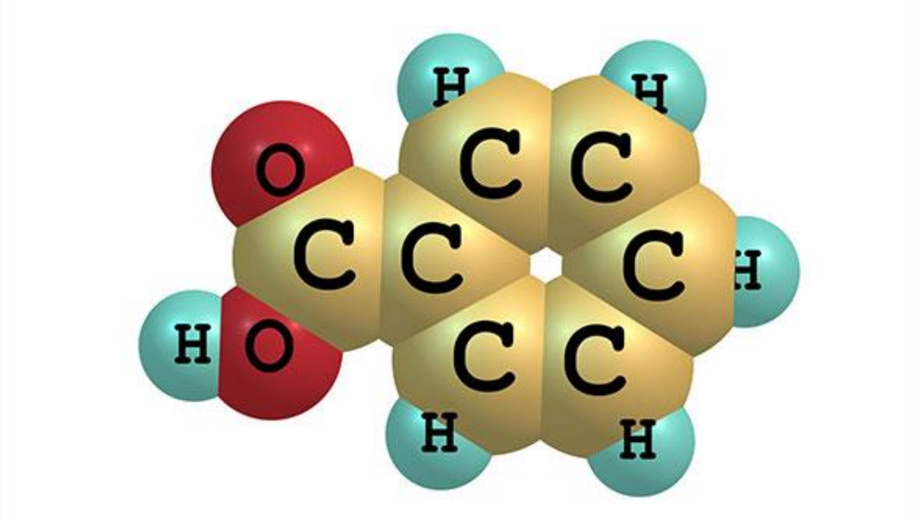
6. Why the benzene is wet from the benzene column?

Ans: This is because caustic wash operation enabled the contact with water and some water will enter the organic phase due to phase equilibrium of water with the organic phase. This water therefore enters the benzene stream from the benzene column.

7. Why caustic wash followed by drying is carried out is carried out for the ethylbenzene stream?

Ans: Caustic wash removes any undesired impurities where as dryer removes the water. Both water and acid are important compouds which if not eliminated contribute significantly to side reactions during the heating process with superheated steam. Therefore, totally dry and acid free conditions are targeted for ethylbenzene.

PRODUCTION OF BENZOIC ACID



Benzoic acid is a white (or colorless) solid with the formula $C_6H_5CO_2H$. It is the simplest aromatic carboxylic acid. The name is derived from gum benzoin, which was for a long time its only source. Benzoic acid occurs naturally in many plants[9] and serves as an intermediate in the biosynthesis of many secondary metabolites. Salts of benzoic acid are used as food preservatives. Benzoic acid is an important precursor for the industrial synthesis of many other organic substances. The salts and esters of benzoic acid are known as **benzoates**

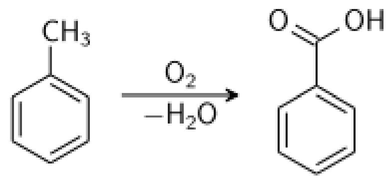
Benzoic acid has a colorless appearance in its solid state, which is of a crystalline nature. The crystal structure is monoclinic. The presence of the aromatic ring gives this compound a faintly pleasant odor

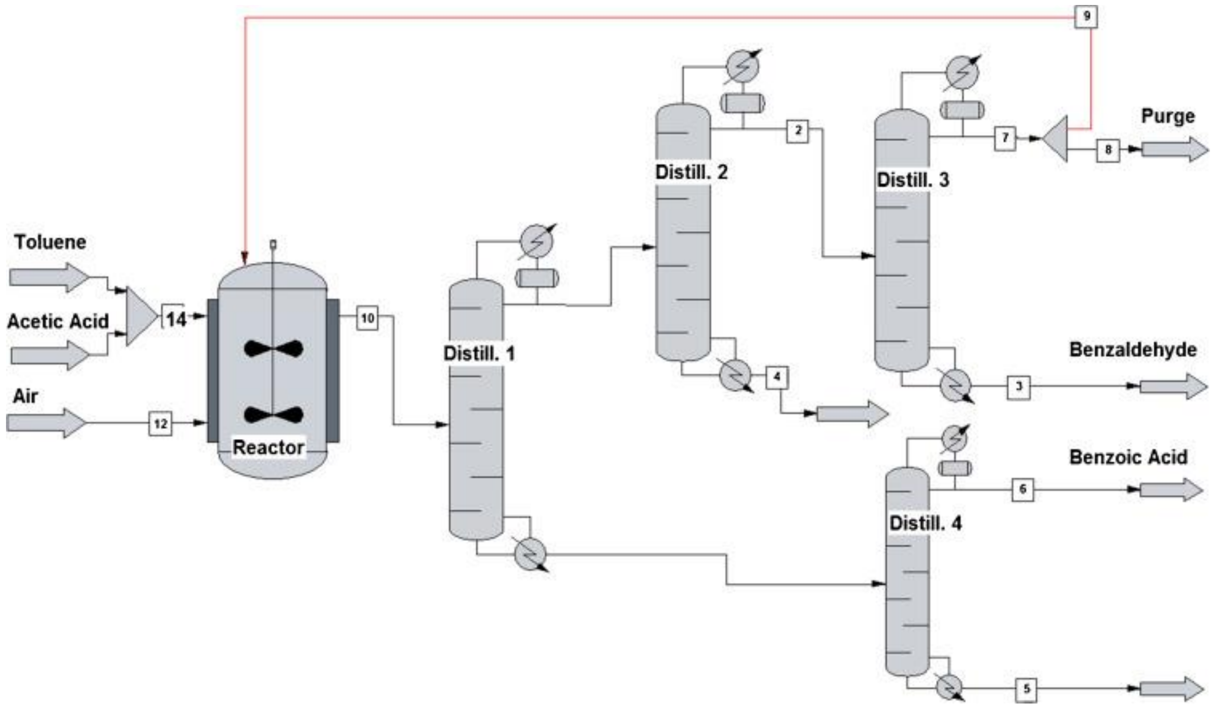
Benzoic Acid Formula: $C_7H_6O_2$ or C_6H_5COOH

Density: 1.27 g/cm^3 at 15^{o}C

Benzoic acid is produced commercially **by partial oxidation of toluene wit**h oxygen.The process is catalyzed by cobalt or manganese naphthenates. The process uses abundant materials, and proceeds in high yield.[

Reaction





Usage ::

Benzoic acid is most commonly found in industrial settings to manufacture a wide variety of products such as perfumes, dyes, topical medications and insect repellents. **Benzoic acid's** salt (sodium benzoate) is commonly used as a pH adjustor and preservative in food, preventing the growth of microbes to keep food safe.

CHAPTER-6 (LUBRICANTS)

LUBRICANTS AND THEIR TYPES

What are lubricants?

Lubricants are substances which reduce friction and wear between two surfaces. It is applied at the interface of the two surfaces. Lubricants also help reduce the heat that is generated at the interface of the two surfaces that are in contact with each other and moving.

Some of the main functions of lubricants are:

- Keep parts moving smoothly
- Transfer heat to prevent overheating
- Reduce friction and increase efficiency
- Anti-stick coating on surfaces that tend to stick to one another
- Carry away debris to prevent clogging
- Transporting foreign particles
- Transmit power from one equipment to another
- Protect against wear and lengthen the life of the equipment
- Prevent corrosion when a piece of equipment is being used in a corrosive or wet environment
- Seal for gas to prevent it from escaping or losing pressure

Besides industrial applications, lubricants have some interesting domestic applications as well. For example, lubricants are used as oils in cooking and baking. They are also used in medical applications like ultrasound therapy.

Properties of lubricants

Lubricants that are considered good or high-quality will normally possess the following properties:

- High boiling point
- Low freezing point
- High viscosity index
- Thermal stability
- Hydraulic stability
- Demulsibility
- Prevention of corrosion

- High resistance to oxidation

Types of Lubricants::

4 Types of lubricant

- ➢ **Liquid,**
- ➢ **Solid,**
- ➢ **Gas**
- ➢ **Semi-Solid**

.

Types of lubricants

Based on the molecular structure of the lubricant material as well as its shear strength, lubricants are classified as follows:

Solid Lubricants

A solid lubricant is a solid material which is applied or inserted between two moving surfaces or bearing surfaces. This material will shear a lot more easily than the bearing or moving surfaces. The three main requirements for a material to be a solid lubricant are the ability to support the applied load without major distortion, a low coefficient of friction, and a low rate of wear. Solid lubricants are generally used when the conditions are extreme. Solid lubricants are used in a powder form, as lubricating grease, in suspensions, in metallic films, or in bonded lubricants. Anti-friction linings use solid lubricants.

The durability of solid lubricants is increased by coating the binders along with lubricating pigments. These bonded coatings provide greater film thickness and increase the wear life of the lubricant and the surface on which the lubricant is applied. The popular applications of bonded coating of solid lubricants are cylindrical brushes, separator cage of rolling bearing, and electrical brushes.

Solid lubricants can be further classified into four sub-types, namely polymer, metal-solid, carbon and graphite, and ceramic and cermet.

Polymers

Polymers are one of the largest groups of solid lubricants. They are suitable for use with light loads. They have a lower thermal conductivity which the amount of heat that they are able to dissipate. There are three main polymer solid lubricants, polytetrafluoroethylene (PTFE), Nylon, and synthetic polymers.

Polytetrafluoroethylene is a polymer which is derived from ethylene. All the hydrogen atoms in an ethylene molecule are replaced by fluorine atoms to give polytetrafluoroethylene. It is more popularly known as Teflon, a trade name given to PTFE by the famous company Du Pont. It is commonly used as a solid lubricant because of its low friction, its chemical stability, its low surface energy, and its greater chemical inertness. PTFE also happens to be non-toxic and hence is suitable for use in industries such as food and pharmaceuticals.

For all the plus points of polytetrafluoroethylene, there are some downsides as well. Firstly, it has a relatively high rate of wear. Secondly, it has high thermal expansion and low thermal conductivity which makes it less desirable for use in high-temperature environments. Lastly, it has low load capacity.

However, many of these disadvantages can be addressed through the use of synthetic polymers. Synthetic polymer lubricant can be prepared by mixing glass and carbon-based fillers with PTFE. Impregnating PTFE with metal structures such as bronze or lead is also an option. This modification also allows the synthetic PTFE to withstand higher loads and improve the wear rate.

Metal-solid

These solid lubricants contain lamellar solids and achieve low friction through a process known as film transfer. Molybdenum disulfide is the most commonly used metal-solid lubricant. Some of the advantages of a metal-solid lubricant like molybdenum disulfide are a high load carrying capacity, good high-temperature performance, and low friction. It is also stable in vacuum up to 1000 degrees Celsius. Hence, molybdenum disulfide also finds use in space applications. Its disadvantages are sub-optimal performance in the presence of moisture and high film thickness. A thicker film does not last as long because it is more prone to wear and tear.

Carbon and graphite

Carbon graphite seals are used as solid lubricants. They have desirable properties such as high-temperature stability, high oxidation stability, and sustainable performance in high sliding speed applications. Graphite as a material has low friction and can withstand moderate loads. Graphite, however, is prone to corrosion and does not work very well in vacuum. The lubrication performance of graphite actually increases with an increase in temperature. However, beyond 500 degrees Celsius, the incidence of corrosion increases.

Ceramic and cermet

Ceramic and cermet coatings are used as lubricants in situations where a lower wear rate is more important than low friction. Ceramic/cermet coatings can be used at high-temperature ranges of around 1000 degrees Celsius. A 0.5mm thick coating of ceramic/cermet material offers a low-cost way of utilizing its wear resistance. The coating can be sprayed using a detonation gun, plasma spraying, or electrolytic deposition using an electrolyte that contains ceramic particles.

Semi-Solid Lubricants/Grease

Grease is considered to be one of the most versatile forms of lubricants. It can be used in a wide range of environments across various temperatures, load conditions, or speeds. Be it a dry or wet environment, dusty or clean environment, or even corrosive environment, grease finds use in all sorts of applications.

Grease is a type of pseudo-plastic fluid. One of the most significant properties of grease is consistency. Consistency is nothing but the relative hardness or softness of any material. Grease consists of lubricating oils which have low viscosity and are thickened by finely dispersed solids known as thickeners. Grease is made up of the following:

Base Oil

Petroleum and synthetic base oils are used in the manufacturing of grease. The properties of the base oil are very important, as they affect the properties of the grease that gets produced from the oil. A low viscosity and light base oil is used to produce grease that works at low temperatures. A heavier and high viscosity base oil is used to produce high-temperature grease.

Additives

Certain chemical additives are added to the grease in order to improve its properties. The choice of additives depends completely on the end use or application of the grease. Factors like performance parameters, environmental impact, sustainability parameters, compatibility, cost, and color all play a role in the choice of additives.

Thickeners

Thickeners are added to the base oil in order to thicken the material and produce grease. There are two types of thickeners, organic thickeners and inorganic thickeners. Inorganic thickeners are non-soap based while organic thickeners can be soap-based or non-soap based.

Some of the advantages of using grease as a lubricating material are its water resistance, its binding strength to the surface where applied, lower frequency of application, its ability to reduce noise and vibration, its ability to seal against contaminants, and its usability with vertical/inclined shafts.

Some of the disadvantages of using grease as a lubricant are its poor heat dissipation, its vulnerability to being contaminated by dust, and the inability to filter out contaminants from the grease.

Lubricants may also be used in a paste form in heavy load applications, in sliding applications, and with slow running bearings. The paste form of lubricant may also be used as assembly paste or as a high-temperature paste.

Liquid Lubricants

Liquid lubricants are used extensively in applications that are high in terms of speed and load size. Liquid lubricants are the most dominant type of lubricant in the market. Liquid lubricants are comprised of base oil and some additives. The various types of liquid lubricants are as follows:

Mineral Oil

Mineral-based lubricants are extracted from crude oil.

Mineral oil lubricants are of four types.

The first type is **paraffinic oil**. It has good resistance to oxidation. It exhibits good thermal stability, is less volatile, and has a high flash point.

The second type of mineral oil lubricant is **naphthenic oil**. This type of lubricant is good for low-temperature applications. It has a lower flash point than paraffinic oil lubricant. When naphthenic oil lubricant is burnt, soft deposits are formed which in turn lowers the abrasive wear.

The third type of mineral oil **lubricant is**

multigrade oil. It is made by adding polymers in mineral oils, thus enhancing the viscosity index of the lubricant. These lubricants have different grade levels whereby a specific grade of lubricant oil can offer optimal performance in low temperatures or in high temperatures.

Lastly, **synthetic oil** is another type of mineral oil lubricant. This type of lubricant was created to withstand harsh operating conditions. Jet engines use synthetic lubricants. These lubricants are expensive but they can withstand high levels of heat and stress. Some commonly used synthetic oils are esters, silicon, polyglycols, perfluoropolyalkylether, and perfluoropolyethers.

Vegetable Oil

Oil-based lubricant made from rapeseed and castor is known as vegetable oil lubricant. Vegetable oil contains more natural boundary lubricant than what is observed in mineral oil. However, vegetable oil lubricant is less stable than mineral oil lubricant at high-temperature ranges.

Animal Oil

Fats extracted from fish and animals are the sources of animal oil. Animal oil is sometimes also known as fixed oil. It is added to mineral oil in order to improve the film forming ability of the mineral oil. Animal oil does not volatilize. The main drawback with animal oil is its availability.

Gas Lubricants

Gases like nitrogen and helium are used as lubricants in applications where film thickness between tribo-pair is ultra small. The advantages of using gas lubricants are large temperature range, no sealing required for lubrication, very low friction due to low viscosity, no vaporization, no solidification, and no decomposition.

The downsides of using gas lubricants are low load capacity, lower tolerance for any errors in load estimation, and the need for a specialist designer in creating smooth surfaces with low clearance.

Selection of the right lubricant

You may know the different types of lubricants as well as the pros and cons of each type. However, you ultimately have to be able to pick the right kind of lubricant for the job at hand. The major factors that one needs to look at when selecting lubricants are load level, speed, sealing requirements, and environmental parameters.

One also needs to look at the coefficient of friction, the operating temperature, the area of contact, and the thermal conductivity. Once you have studied these metrics and have a good idea of the environment in which the lubricant is to be used, you will be able to select the right kind of lubricant.

Generally speaking, for lower loads and speeds, solid lubricants are a good bet. Then as you move towards higher loads and higher speeds, grease becomes a better bet. Grease is then followed by high viscosity oils, low viscosity oils, and finally gas lubricants. For the highest speed applications, gas lubricants are used.

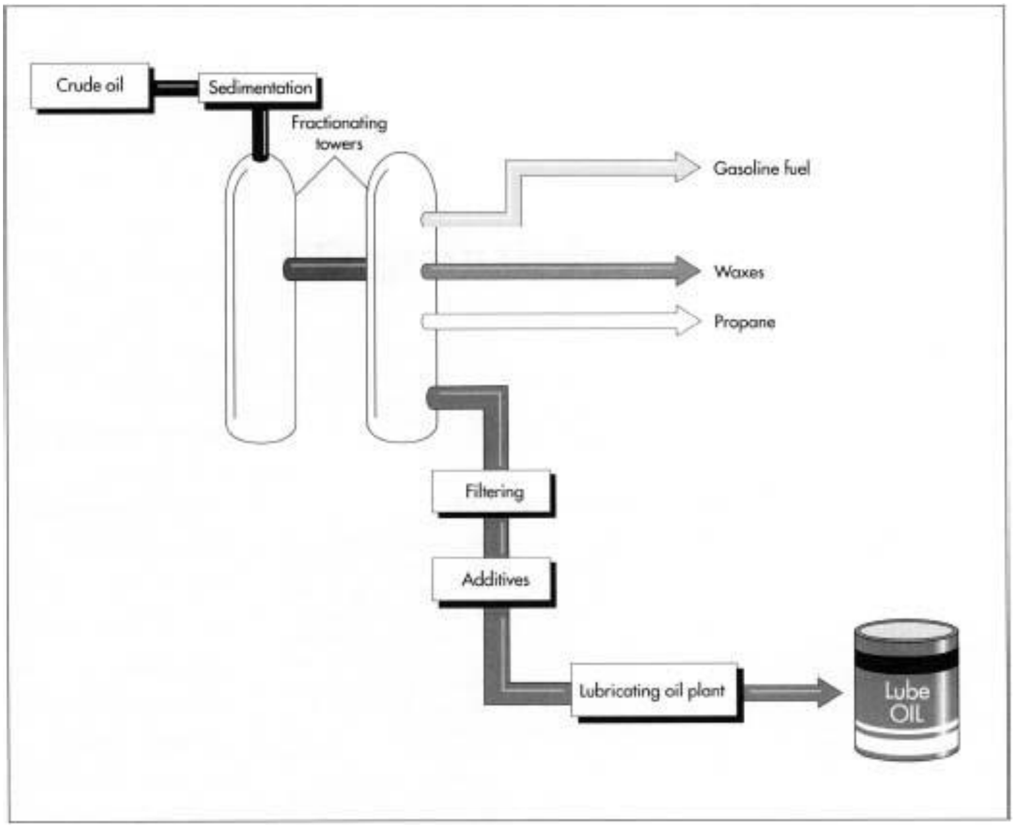
Manufacturing of lubricating Oil

Raw Materials

raw petroleum

The Manufacturing Process

Lube oil is extracted from crude oil, which undergoes a preliminary purification process (sedimentation) before it is pumped into fractionating towers. A typical high-efficiency fractionating tower, 25 to 35 feet (7.6 to 10.6 meters) in diameter and up to 400 feet (122 meters) tall, is constructed of high grade steels to resist the corrosive compounds present in crude oils; inside, it is fitted with an ascending series of condensate collecting trays. Within a tower, the thousands of hydrocarbons in crude oil are separated from each other by a process called fractional distillation. As the vapors rise up through the tower, the various fractions cool, condense, and return to liquid form at different rates determined by their respective boiling points (the lower the boiling point of the fraction, the higher it rises before condensing). Natural gas reaches its boiling point first, followed by gasoline, kerosene, fuel oil, **lubricants**, and tars.



Sedimentation

- 1 The crude oil is transported from the oil well to the refinery by pipeline or tanker ship. At the refinery, the oil undergoes sedimentation to remove any water and solid contaminants, such as sand and rock, that maybe suspended in it. During this process, the crude is pumped into large holding tanks, where the water and oil are allowed to separate and the contaminants settle out of the oil.

Fractionating

- 2 Next, the crude oil is heated to about 700 degrees Fahrenheit (371 degrees Celsius). At this temperature it breaks down into a mixture of hot vapor and liquid that is then pumped into the bottom of the first of two fractionating towers. Here, the hot hydrocarbon vapors float upward. As they cool, they condense and are collected in different trays installed at different levels in the tower. In this tower, normal atmospheric pressure is maintained continuously, and about 80 percent of the crude oil vaporizes.
- 3 The remaining 20 percent of the oil is then reheated and pumped into a second tower, wherein vacuum pressure lowers the residual oil's boiling point

so that it can be made to vaporize at a lower temperature. The heavier compounds with higher boiling points, such as tar and the inorganic compounds, remain behind for further processing.

Filtering and solvent extraction

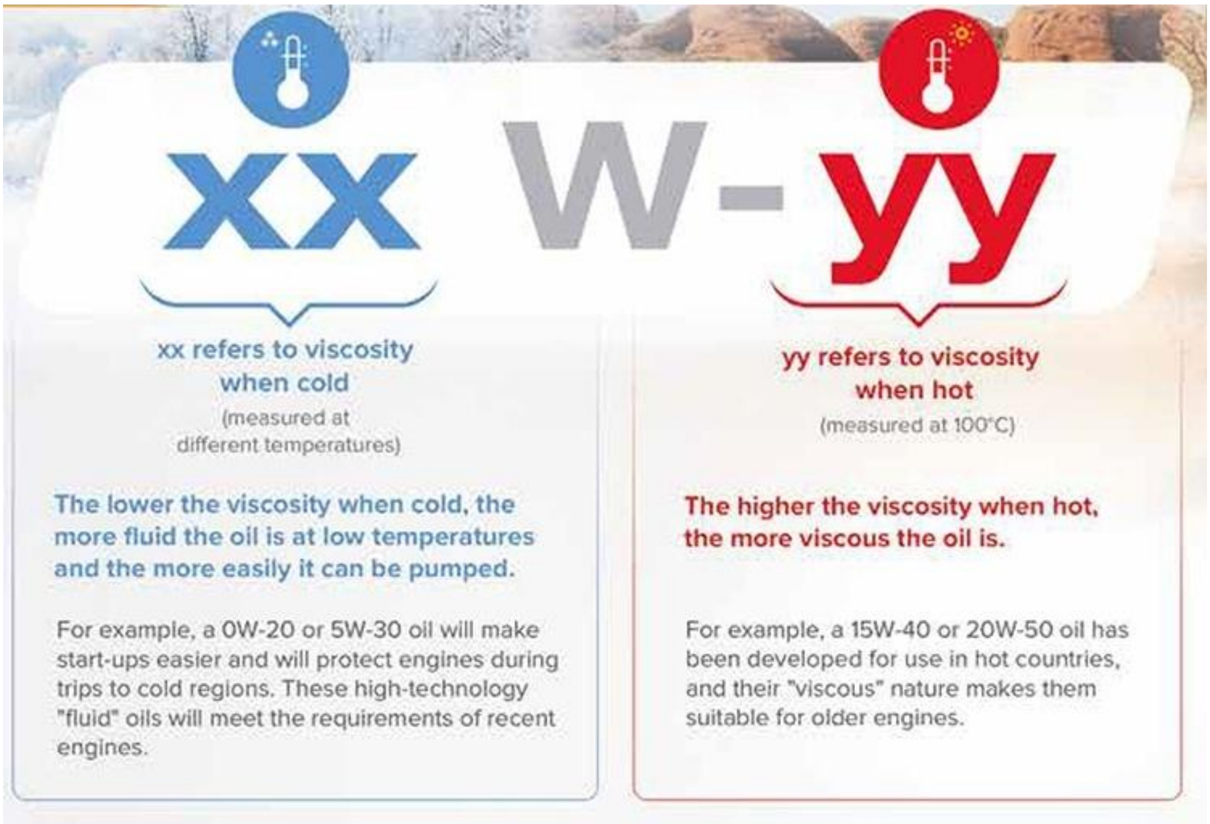
- 4 After further processing to remove unwanted compounds, the lube oil that has been collected in the two fractionating towers is passed through several ultrafine filters, which remove remaining impurities. Aromatics, one such contaminant, contain six-carbon rings that would affect the lube oil's viscosity if they weren't removed in a process called solvent extraction. Solvent extraction is possible because aromatics are more soluble in the solvent than the lube oil fraction is. When the lube oil is treated with the solvent, the aromatics dissolve; later, after the solvent has been removed, the aromatics can be recovered from it.

Additives, inspection, and packaging

- 5 Finally, the oil is mixed with additives to give it the desired physical properties (such as the ability to withstand low temperatures). At this point, the lube oil is subjected to a variety of quality control tests that assess its viscosity, specific gravity, color, flash, and fire points. Oil that meets quality standards is then packaged for sale and distribution.

Q: What is the meaning of the commercial grade of lubricants i.e 20W40 ?

A:



<u>CHAPTER -7 (Future of Petrochemical Industry)</u>

<u>Integrated Petroleum Complex</u>

It is a megaproject project which includes all component plants related to petroleum refinary.

Objective:

It will have

1. **<u>oil refineries</u>,**
2. **<u>naphtha</u> crackers,**
3. **<u>petrochemical</u> plants,**

4. **liquefied natural gas (LNG) terminals**
5. **regasification plant**

Operation::

Raw or unprocessed crude oil is not generally useful in industrial applications, although "light, sweet" (low viscosity, low sulfur) crude oil has been used directly as a burner fuel to produce steam for the propulsion of seagoing vessels. The lighter elements, however, form explosive vapors in the fuel tanks and are therefore hazardous, especially in warships. Instead, the hundreds of different hydrocarbon molecules in crude oil are separated in a refinery into components that can be used as fuels, lubricants, and feedstocks in petrochemical processes that manufacture such products as plastics, detergents, solvents, elastomers, and fibers such as nylon and polyesters.

Petroleum fossil fuels are burned in internal combustion engines to provide power for ships, automobiles, aircraft engines, lawn mowers, dirt bikes, and other machines. Different boiling points allow the hydrocarbons to be separated by distillation. Since the lighter liquid products are in great demand for use in internal combustion engines, a modern refinery will convert heavy hydrocarbons and lighter gaseous elements into these higher value products.

Products::

- Gaseous fuel such as Liquified petroleum gas and propane, stored and shipped in liquid form under pressure.
- Lubricants (produces light machine oils, motor oils, and greases, adding viscosity stabilizers as required), usually shipped in bulk to an offsite packaging plant.
- Paraffin wax, used in the packaging of frozen foods, among others. May be shipped in bulk to a site to prepare as packaged blocks. Used for wax emulsions, construction board, matches, candles, rust protection, and vapor barriers.
- Sulfur (or sulfuric acid), byproducts of sulfur removal from petroleum which may have up to a couple percent sulfur as organic sulfur-containing compounds. Sulfur and sulfuric acid are useful industrial materials. Sulfuric acid is usually prepared and shipped as the acid precursor oleum.
- Bulk tar shipping for offsite unit packaging for use in tar-and-gravel roofing.
- Asphalt used as a binder for gravel to form asphalt concrete, which is used for paving roads, lots, etc. An asphalt unit prepares bulk asphalt for shipment.
- Petroleum coke, used in specialty carbon products like electrodes or as solid fuel.
- Petrochemicals are organic compounds that are the ingredients for the chemical industry, ranging from polymers and pharmaceuticals, including ethylene and benzene-toluene-xylenes ("BTX") which are often sent

to petrochemical plants for further processing in a variety of ways. The petrochemicals may be olefins or their precursors, or various types of aromatic petrochemicals.

- Gasoline
- Naphtha
- Kerosene and related jet aircraft fuels
- Diesel fuel and Fuel oils
- Heat
- Electricity

Advantage ::

1. **Lower transportation cost**
2. **Lower operation cost**
3. **Better efficiency**
4. **More utilization of byproducts**
5. **Better management**

Questions::

1. **What is a Integrated petroleum comples?**
2. **What are the adventages of it?**

Development and Trends Of Petroleum Industry

MAJOR DEVALOPMENTS are ::

Focus On Infrastructure

Infrastructure, while being one of the larger parts of the petroleum industry, has been somewhat underserved for quite some time. This has been changing in the past few years as more businesses place more investment into their supply and logistics.

While this investment can be large, it can often be vital for a variety of processes outside of the extraction of oil and gas. Many of the investments that have been seen haven't solely been focused on expanded networks, although this does play a large role.

Instead, many companies have focused on improving and repairing their existing networks so that they're better able to meet needs. This has been beneficial in allowing firms to increase their capacity while delivering products at a faster timeframe.

Increased Sustainability

While many consumers believe that sustainability is solely the area of wind and solar energy. This isn't the case, as the oil and gas industry has been focusing more and more on sustainability in the past few years.

Much of this has been seen in reducing their environmental impact. The majority of this has been driven by consumer expectations, which has resulted in ecological causes becoming increasingly more commonplace across the industry.

There are a few ways that this has been done, such as focusing on renewable, non-carbon energy.

Growth In Natural Gas

Oil has gotten most of the attention in the energy industry, with much of the rest going to wind and solar power. This hasn't meant that natural gas had gone away, however. In contrast, there has been somewhat of a resurgence in natural gas in recent years.

This is driven by the fact that it's a low-carbon alternative to oil, which means that it's more sustainable and environmentally-friendly. Alongside this has been the United States having a greater access to natural gas fields.

Wearables

Employee health and safety is often one of the largest concerns for any company in the petroleum industry. While standards have remained high for decades, there have been several improvements in how to meet and exceed this, with wearables beginning to make an impact on this.

This has included the implementation of augmented reality and virtual reality devices, such as headsets, which allows for the inspection of dangerous areas without the need for a physical presence. As a result, workers will be able to inspect an area through these smart headsets and determine whether it's safe for work to begin.

There is also a range of devices that monitor air-quality, employee vitals, and much more to ensure that workers remain physically safe while on the job.

4D Seismic Technology

Deep sea exploration has often been one of the largest costs associated with the oil and gas industry, which has led to various ways to bring this cost down. As a result, there have been several technologies developed to help with this.

Alongside the above mentioned augmented and virtual reality software has been 4D seismic technology. This is predominantly used by petroleum geophysicists and geologists to map out potential reserves for exploration. There are a variety of benefits associated with this, with the most obvious being cost-savings.

Companies will also see less time investment for areas that may not be as fruitful as they may have believed. It also means that they'll be able to plan out subsequent moves more effectively from an earlier stage.

While this was already seen with 3D technology, 4D helps firms determine how a reservoir should change over time, providing them with much more data.

Increased Labor Costs

Though there's been an expansion in the number of positions available in the industry, this has been met with an aging workforce, which provides several challenges. Many of these are seen in the areas of retention and training, which are compounded by the wealth of opportunities available elsewhere.

This has subsequently meant that many companies have struggled to attract younger employees. One of the core ways that they've done so is through offering higher salaries, as well as more benefits. Because of this, labor costs have continued to stay high, despite technology reducing the overall total number of workers needed.

This has been driven further by the increasingly specialized needs and skills of certain roles, which is one of the few side effects of more technology being implemented.

Skills Shortages

Though technological needs in the petroleum industry have increased rapidly, the pace of employee upskilling hasn't kept the same pace. This has meant that many companies have found themselves in a position where they often have an underskilled workforce.

There have been a few ways that many companies have been tackling this skills shortage, however. The first, as we mentioned above, is attracting newer talent that's already skilled with a particular technology, although this provides many of the challenges that we've mentioned above.

Secondly, many firms have been upskilling their existing workforce. This avoids many of the costs associated with hiring new employees, although it does mean that there will be both a time and financial investment needed to do so.

Either of the above options should offer a large number of dividends over time, especially once the related technology is implemented and capitalized on.

Fracking Challenges

Fracking is one of the more traditional techniques used in the petroleum industry. Because of some unwanted side effects of the practice, however, it's started to become increasingly challenged across the world.

This has primarily been international, such as in the United Kingdom and several other countries, it has started to affect more American companies. The majority of this has been focused on chemicals being leaked into the surrounding water, as well as the potential for seismic activity.

Much of this has been seen through protests and legal challenges, which has made fracking-related activities increasingly more difficult. While the United States has only begun seeing opposition to this, it's expected that this is likely to grow in the coming years.

As a result, American companies may need to begin adjusting their strategies accordingly.

Robotics

There are several tasks in the petroleum industry that are repetitive and laborious, although they're often essential. This has led to companies increasingly focusing on automation and robotics. These have been primarily used in wastewater disposal, drill pipes, and repairing broken machinery.

While the majority of companies utilizing robotics in the industry have been on the larger side, including The Petroleum Institute and others, smaller companies have begun taking advantage of the tech. This is being driven by its increasing affordability, as well as several of the benefits it can offer.

Chief among these has been that automation and robotics can reduce labor costs, which is further enhanced by how quickly they can perform a task compared to a typical worker. This offsets much of the upfront investment a firm will need to make to purchase the technology needed for these tasks.

Increased Connectivity

Alongside the increased use of hardware in the petroleum industry has been the implementation of software. This has been used in several capacities, with one of the largest of these being what’s known as the Internet of Things (IoT).

Through this, robotics and other machinery are connected and can subsequently monitor each other. There are a variety of benefits that this provides, with performance being key. This results in companies having more data on where and when their machinery should be repaired to optimize results.

Alongside this is the reduced need to replace equipment, as preventative maintenance will avoid any breakages. As a result, the majority of companies will be able to see much less associated with downtime and machine replacement

Key Petroleum Trends based on stastistics You Need To Know

There are a variety of statistics that have become increasingly more obvious in the petroleum industry. With the number of shifts in the niche over the past few years, it can be quite easy for many of these to be overlooked. There are a few that companies should be aware of:

1. Upstream Capital expenditure for oil and gas worldwide is expected to grow by 4% during 2019.
2. LNG demand is set to grow by 60% by 2030.
3. Demand for natural gas grew 1% from 2018 to 2019.
4. The petroleum industry grew to employ approximately 8% by the end of 2018.
5. Petroleum inventories are up 4.1% compared to the five-year average.
6. An 9% growth in the market is expected by Data Business in Oil & Gas.
7. Oil remains the largest part of the petroleum industry, typically averaging between 35% and 40% of the market per year.
8. OPEC member countries saw an increase in exports by 0.1%.
9. The bulk of OPEC exports, 64.3% went to the Asia-Pacific region.
10. Refinery capacity worldwide grew by 6% through 2018.

Questions ::

1. Describe different trends of modern petroleum industry with some of the roughly statistic of growth.

ENERGY CRISIS

What is the Energy Crisis?

The energy crisis is the concern that the world's demands on the limited natural resources that are used to power industrial society are diminishing as the demand rises. These natural resources are in limited supply. While they do occur naturally, it can take hundreds of thousands of years to replenish the stores. Governments and concerned individuals are working to make the use of renewable resources a priority, and to lessen the irresponsible use of natural supplies through increased conservation.

The energy crisis is a broad and complex topic. Most people don't feel connected to its reality unless the price of gas at the pump goes up or there are lines at the gas station. The energy crisis is something that is ongoing and getting worse, despite many efforts. The reason for this is that there is not a broad understanding of the complex causes and solutions for the energy crisis that will allow for an effort to happen that will resolve it.

Causes of the Energy Crisis

It would be easy to point a finger at one practice or industry and lay the blame for the entire energy crisis at their door, but that would be a very naive and unrealistic interpretation of the cause of the crisis.

1. Overconsumption: The energy crisis is a result of many different strains on our natural resources, not just one. There is a strain on fossil fuels such as oil, gas and coal due to overconsumption – which then in turn can put a strain on our water and oxygen resources by causing pollution.

2. Overpopulation: Another cause of the crisis has been the steady increase in the world's population and its demands for fuel and products. No matter what type of food or products you choose to use – from fair trade and organic to those made from petroleum products in a sweatshop – not one of them is made or transported without a significant drain on our energy resources.

3. Unexplored Renewable Energy Options: Renewable energy still remains unused is most of the countries. Most of the energy comes from non-renewable sources like coal. It still remains the top choice to produce energy. Unless we give renewable energy a serious thought, the problem of energy crisis cannot be solved. Renewable energy sources can reduce our dependance on fossil fuels and also helps to reduce greenhouse gas emissions.

4. Wastage of Energy: In most parts of the world, people do not realize the importance of conserving energy. It is only limited to books, internet, newspaper ads, lip service and seminars. Unless we give it a serious thought, things are not going to change anytime sooner. Simple things like switching off fans and lights when not in use, using maximum daylight, walking instead of driving for short distances, using CFL instead of traditional bulbs, proper insulation for leakage of energy can go a long way in saving energy. Read here about 151 ways of saving energy..

5. Major Accidents and Natural Calamities: Major accidents like pipeline burst and natural calamities like eruption of volcanoes, floods, earthquakes can also cause interruptions to energy supplies. The huge gap between supply and demand of energy can raise the price of essential items which can give rise to inflation.

6. **Terrorist Attack :** Due to capturing of oil wells and other oil supplying sources by terrorists, the world faces a major energy crisis.

6. Wars and Attacks: Wars between countries can also hamper supply of energy specially if it happens in Middle East countries like Saudi Arabia, Iraq, Iran, Kuwait, UAE or Qatar. That's what happened during 1990 Gulf war when price of oil reached its peak causing global shortages and created major problem for energy consumers.

7. localized shortages: Artificially shortage of the supply.

8. Miscellaneous Factors: Tax hikes, strikes, military coup, political events, severe hot summers or cold winters can cause sudden increase in demand of energy and can choke supply. A strike by unions in an oil producing firm can definitely cause an energy crisis.

Environmental/Ecological impact of energy crisis

1. **Climate change**
2. **pollution control**
3. **More ecological balance**
4. **Biofuel usage**
5. **Energy conservation**
6. **Development of clean enery sources**

Possible Solutions of the Energy Crisis

Many of the possible solutions are already in place today, but they have not been widely adopted.

1. Move Towards Renewable Resources: The best possible solution is to reduce the world's dependence on non-renewable resources and to improve overall conservation efforts. Much of the industrial age was created using fossil fuels, but there is also known technology that uses other types of renewable energies – such as steam, solar and wind. The major concern isn't so much that we will run out of gas or oil, but that the use of coal is going to continue to pollute the atmosphere and destroy other natural resources in the process of mining the coal that it has to be replaced as an energy source. This isn't easy as many of the leading industries use coal, not gas or oil, as their primary source of power for manufacturing.

2. Buy Energy Efficient products: Replace traditional bulbs with CFL's and LED's. They use less watts of electricity and last longer. If millions of people across the globe use LED's and CFL's for residential and commercial purposes, the demand for energy can go down and an energy crisis can be averted.

3. Make fuel efficient engines: There are a number of new technologies which helps producing higher grade engines like BS4, BS6 etc. They have a better fuel efficiency.

4. Use of electric vehicle

5. **Blending of Ethanol:** By adding ethanol to petrol and gasoline the pressure on natural oil supply can be reduce. In the recent days usage of Bio diesel has been promoted so as less demand on petroleum products.

6. **Use of Natural gases.** Natural Gas(CH_4) is abundantly available in the river basins of India. If they can be used as an alternative of oil, demands on crude oil can be reduced.

Questions::

1. What were the causes and effects of the energy crisis?
2. What is energy crisis how can it be prevented?
3. What are the solutions of energy crisis ?
4. What are the ecological impact of energy crisis?