

Section-A

Q1. Choose the correct answer:

- (i) (d) Carbon dioxide
- (ii) (c) Chlorination
- (iii) (b) Shift Conversion
- (iv) (b)  $-183^{\circ}\text{C}$
- (v) (b) Triple superphosphate
- (vi) (b) Urea
- (vii) (d) pollution of water stream by mercury
- (viii) (b) Reverse osmosis
- (ix) (a) Iron oxide
- (x) (a) Exothermic

Section-B

Unit-I

Q2.

Sedimentation is used in primary, secondary & advanced treatment processes to remove solids. Rectangular or circular tanks are used for sedimentation process. After wastewater enters a settling tank, velocity reduces & the heavier solids settled to the bottom, which is removed as sludge from bottom.

In the design of a ideal sedimentation tank, one of the

controlling parameters is the settling velocity of the particle to be removed.

The settling properties can be categorized into four classes.

① Type-I Settling :- It is characterized by particles that settle discretely at a constant settling velocity. They settle as individual particles & do not flocculate during settling.

Examples are sand & grit (a mixture of abrasive particles)

Stokes law is applied for determining settling velocity

$$V_s = \frac{g(S_s - S) d^2}{18 \mu}$$

② Type-II Settling :- It is characterized by particles that flocculate during sedimentation. These types of particles occur in alum or iron coagulation. There is no mathematical relationship that can be used to describe type-II settling. The Stokes eqn cannot be used because the flocculating particles are continually changing in size & shape.

③ Type III & Type IV Settling :- When the water contains a high conc. of particles (for ex,  $>10000 \text{ mg/l}$ ) both type III (hindered or zone settling) & Type IV (compressing settling) occur along with discrete & flocculating settling. Zone settling occurs in actual sludge sedimentation.

With a high particle conc. the free area b/w the particles is reduced. This causes greater interparticle fluid velocities, which reduces the settling velocities. Liquid tends to move up through the interstices b/w the particles. As a result, that particles that are in contact with one another tend to settle as a zone or blanket.

As settling continues, a compressed layer of particles begins to form. The particles are in contact & do not really settle.

A more correct way to visualize the phenomena is the flow of water out of a mat of particles that is being compressed. Thus, it is called compression sapping. ⑥

### Q3. Water pollutants can be divided as follows:

(1) **oxygen demanding wastes:** organic wastes such as animal manure and plant debris that can be decomposed by aerobic bacteria comes under this. The amount of oxygen dissolved in water is used by aerobic bacteria to decompose these waste and so reduces the DO of water,

This causes fish and other form of oxygen consuming aquatic life to die. These wastes comes from sewage, paper mills, food processing facilities.

(2) **Plant nutrients:** these waste contains the plant nutriens like nitrate, phosphate and ammonium ions, which are soluble in water. This comes from agricultural runoff and urban fertilizers and can cause excessive growth of algae and other aquatic plan, which die, decay and deplete DO of water and kill aquatic life, restirc solar penetration in aquatic system. Drinking water with excessive levels of nitrates lowers the oxygen carrying capacity of the blood and can kill unborn child and infants (blue baby syndrome).

(3) **Disease causing agents:** these are the waste comes from sewage, animal and human waste. It includes bacteria, viruses, protozoa, and other biological MO which causes disease. They affect the human health who drinks from such waters.

#### ④ Inorganic Chemicals :-

These pollutants include ~~metals~~ metals such as mercury, lead, cadmium, & nickel which are highly toxic, comes from human activities, mine drainage, & leaching of mining wastes. These pollutants can ~~be~~ be concentrated by hydrological process & may become hazardous to ecosystem & human health.

non-metallic salts :- Salts such as selenium & arsenic are toxic as well as NaCl at high conc. be toxic for plants & animals.

Acids :- These are released by industries like metal smelting, leather tanning also by coal & oil combustion, produces  $H_2SO_4$ ,  $HCl$ ,  $HNO_3$ , which are very hazardous to atmosphere & sculpture. Corrosion of metals, power coop yields, various health problem are common effect of these pollutants.

#### ⑤ Organic Chemicals :-

Pollutants like oils, gasoline, plastics, detergents, pesticides come under this category. The ~~main~~ sources are industrial processing, runoff of pesticides, landfills & dumps. These pollutants harms human health by causing nervous system damage, reproductive disorders, cancers & also harms wildlife.

#### ⑥ Sediment :-

It is soil that comes with rivers into aquatic system. It fills lakes & reservoirs, clog & fill lakes, carry pesticides, bacteria & other harmful substance & may disrupt aquatic environment.

#### ⑦ Radioactive materials :-

These are the isotopes of iodine, radon, uranium etc., comes from nuclear power plants, mining & processing of uranium & other ores, nuclear weapons production. It can cause birth defects, certain cancers etc.

(8) Heat: raising or lowering water temperature from normal levels can adversely effect water quality and aquatic life. Water cooling and some industrial plants are the source for heat in aquatic system. It lowers the DO levels and makes aquatic organisms more vulnerable to disease.

## Unit-II

**Q4.** Synthesis gas is generally considered to be a variable mixture of CO and H<sub>2</sub> for synthesis of organic compounds. There are cases where CO is not needed and these specific cases are so labeled:

Ammonia synthesis gas

Hydrogenation of coal

All synthesis gasses contain hydrogen.

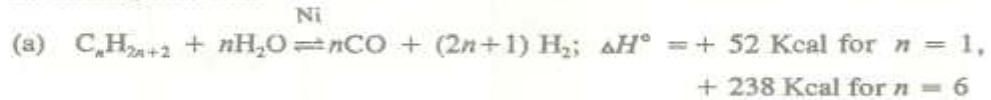
### 3.2. Reforming of Hydrocarbons by Steam

#### 3.2.1. Reference flow sheet: Figure IIB-6

Based on ICI steam-naphtha reforming process

#### 3.2.2. Chemical reactions

- Reforming reactions



- Water gas shift reaction



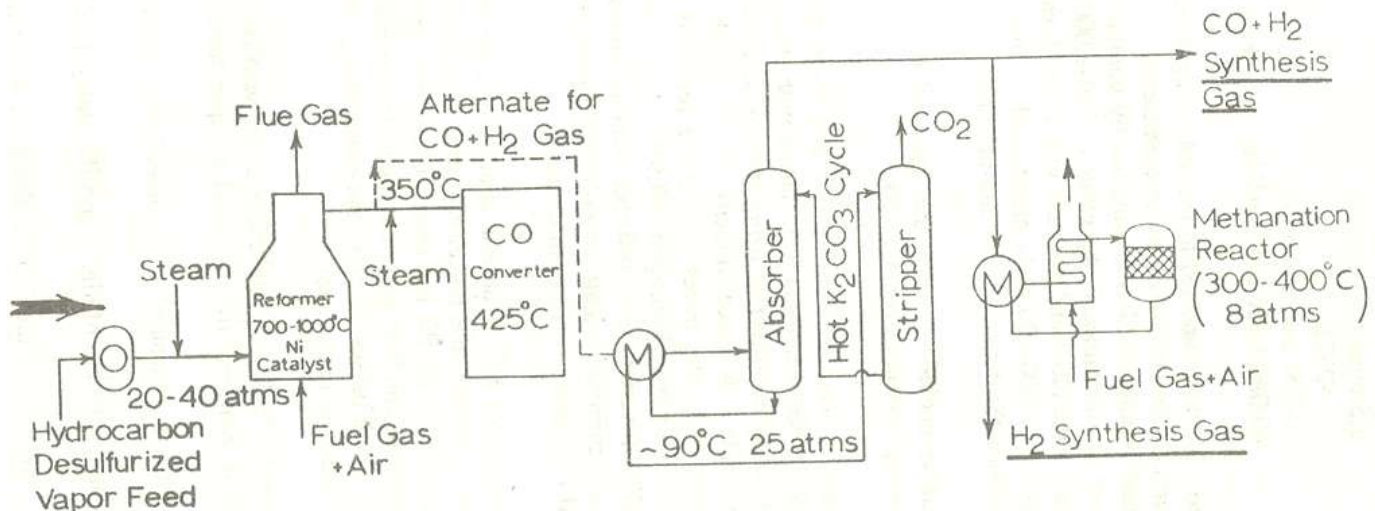
#### 3.2.3. Raw materials

- Refinery naphtha or off-gases
- Air (optional)
- Steam
- Small make-up quantities of nickel and promoted iron oxide catalyst, ethanolamines, and ammoniacal cuprous formate

#### 3.2.4. Quantitative requirements

(a) Basis: 100 Nm <sup>3</sup> of hydrogen of 99. + % purity	
Naphtha	21.9 kg
Steam	560 kg

(A) Reforming for preparation of synthesis gas containing H<sub>2</sub> with or without CO.



Fuel (as naphtha)	22.3 kg
Cooling water	6.5 tons
Electricity	1.4 KWH
(b) Plant capacities:	10-200 tons/day of H <sub>2</sub>
	80,000-1,680,000 Nm <sup>3</sup> /day of synthesis gas

#### Process description

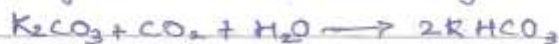
The hydrocarbon feed is mixed with steam and fed to the reforming furnace. The nickel catalyst is packed in vertical tubes of 3-4 inches in diameter and about 20-25 feet long. Heat for the endothermic reaction is supplied by combustion gas. The reaction temperature must be maintained in the range of 700-1,000°C; high temperature alloy steel is used for the tubes and the steel wall of the furnace is refractory lined. A space velocity of 500-600/hr is maintained. After the reformer, the process takes three alternates depending on end-products.

- *For CO-H<sub>2</sub> synthesis gas*  
The effluent reformer gas is cooled to 35°C and pumped to a hot potassium carbonate scrubbing system to remove CO<sub>2</sub>.
- *For H<sub>2</sub> gas*  
A water-gas shift converter is used to remove CO and form more hydrogen by reaction 3.2.2(c). Reformer gas is quenched with steam to give 350°C input gas to a catalytic converter using iron oxide catalyst promoted with chromium oxide. A space velocity of 100-200/hr is maintained. After scrubbing CO<sub>2</sub>, the traces of CO are removed by methanation reaction. For high purity hydrogen (99.9%), one or two additional stages of the shift converter, CO<sub>2</sub> absorber combination are added with either ammoniacal cuprous formate or molecular sieves used to remove residual CO and CO<sub>2</sub> down to 10 ppm or less.
- *For NH<sub>3</sub> synthesis gas*  
The correct amount of nitrogen for NH<sub>3</sub> synthesis is added via air and the oxygen is burned out by hydrogen in a nickel catalyzed combustion chamber inserted immediately following the reformer. Gases are cooled to 350°C by a water quench tower and then passed to the shift converter. Except for the additional N<sub>2</sub> which passes through, the remainder of the process is the same as for hydrogen preparation.

Q5.

LPG production mainly based upon the principle of separation of C<sub>2</sub>-C<sub>4</sub> fractions from the rest of fractions.

LPG - The oil field gases contain carbon dioxide & hydrogen sulfide, together known as acid gases. Because these gases are corrosive, poisonous, etc so they are removed first before further processing. These gases can be removed by benzfield process, which



Absorption:-

A stream of combined gases consisting of gases from ADU, isomerisation, & alkylation, refinery off gases is first washed to remove the suspended impurities. The gas are then passed into dryer containing any suitable adsorbent to remove moisture. Gas from dryer is compressed to 10 atmos pressure & chilled & sent into the absorber. In the absorber C<sub>2</sub> & C<sub>4</sub> fractions are absorbed in lean oil. Small amount of light ~~gas~~ absorbed in oil separated in deethanizer. The bottom product of deethaniser is sent to the debutanizer where the top fraction of the column consist the mixture of butane & propane. Bottom products contains solvent &

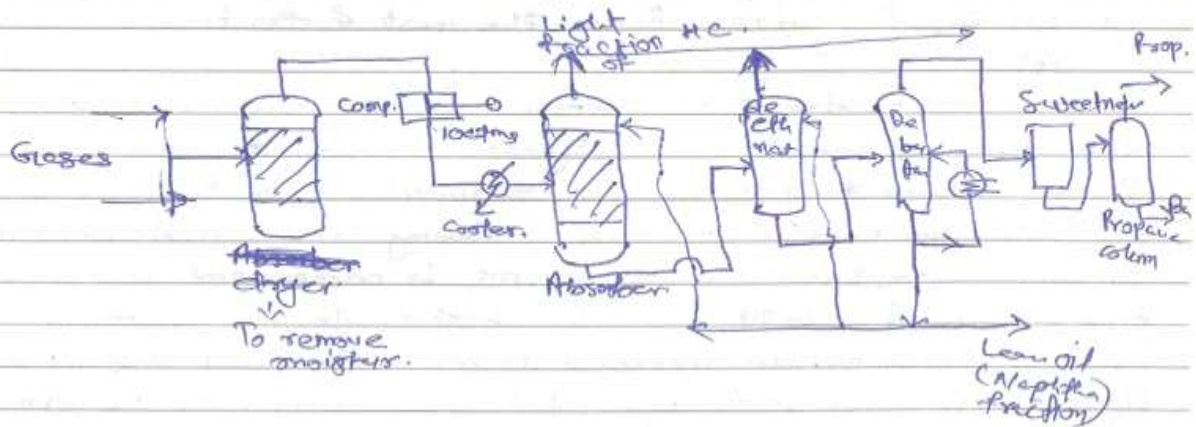
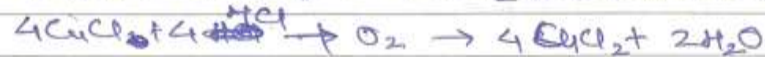
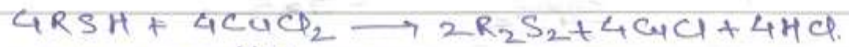
other HCs higher than C<sub>4</sub> fraction, this bottom fraction is lean oil (naphtha fraction), which is cooled & sent to the distillation absorber. The C<sub>3</sub>-C<sub>4</sub> mixture is sweetened & chilled & fed to propane column.

Propane-butane mix is sold as LPG.

C<sub>3</sub>-C<sub>4</sub> mixture has impurities of which has to be like sulfur compounds & of like hydrogen sulfide, carbonyl sulfide, carbon disulfide, & sulfonyl chloride.

Removal of these sulfur compound is known as sweetening.

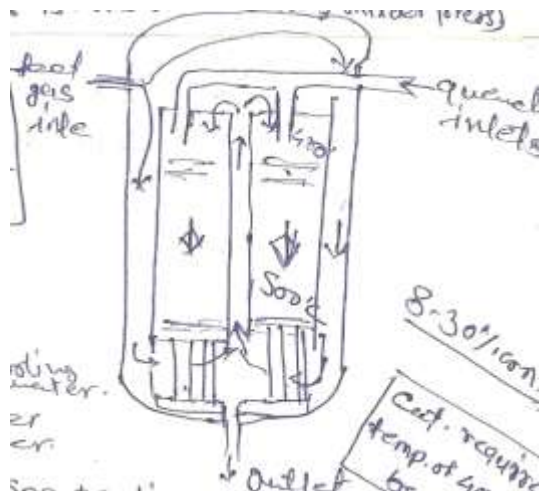
(i) Oxidizing ~~on~~ mercaptans & ~~to~~ disulfides.



### Unit-III Q6.

Description:- Ammonia synthesis gas is compressed to the operating press (100-1000 atm). It is sent through a filter to remove compression oil & additionally through a high temp. guard converter (converts CO & CO<sub>2</sub> to CH<sub>4</sub> & removes traces of H<sub>2</sub>O, H<sub>2</sub>S, P & As). This is done by catalyst.

The relatively cool gas is added along to outside of converter tube walls to provide cooling so that carbon steel can be used for the thick wall pressure vessel & internal tubes. The preheated gas flows next through the inside of the tube which contain promoted porous iron catalyst at 500-550°C. The NH<sub>3</sub> product, with a 8-30% conversion depending on the process conditions, is removed by condensation, first with water & then NH<sub>3</sub> refrigeration. The unconverted N<sub>2</sub>-H<sub>2</sub> mixture is recirculated to allow an 85-90% yield.



**Process Variables:** The industrial conditions for producing ammonia the temperature must be 450°C to 500°C. The FORWARD reaction (to form ammonia) is exothermic (it gives out heat).

Ammonia is produced at the atmospheric pressure of 100 atm because it is too expensive to make a high-pressure chemical plant. Running the reaction at 200 atm is the highest pressure with the greatest return value.

With a reversible reaction, a catalyst which increases the rate will increase the rate of both the forward and the backward reaction. This is useful because the catalyst will, cause the reaction mixture to reach its equilibrium composition more quickly. The catalyst will not change the equilibrium composition of the substance.

Q7.

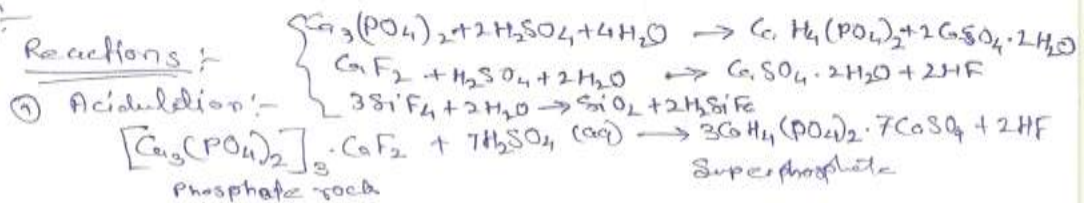
## Calcium Phosphate

There are two grades

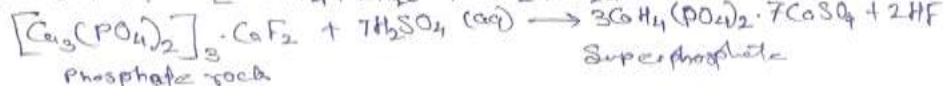
- ① Superphosphate :- made by reacting phosphate rock with ~~H<sub>2</sub>PO<sub>4</sub>~~ <sup>sulfuric acid</sup>; contains ~~B<sub>2</sub>O<sub>5</sub>~~ contains 16-20% P<sub>2</sub>O<sub>5</sub>
- ② Triple superphosphate :- made by reacting phosphate rock with phosphoric acid; contains 42-50% P<sub>2</sub>O<sub>5</sub>.

Superphosphate :-

Reactions :-



① Acidulation :-



② SiO<sub>2</sub> removal :-



Raw mat. :- 30-35% P<sub>2</sub>O<sub>5</sub> & 62-70% H<sub>2</sub>SO<sub>4</sub>

Quantitative Requirement :-

1 ton of superphosphate

Phosphate Rock → 0.5-0.6 ton, sulfuric acid → 0.3-0.4 t

Capacity → 100-1400 tons/day

Process Description :-

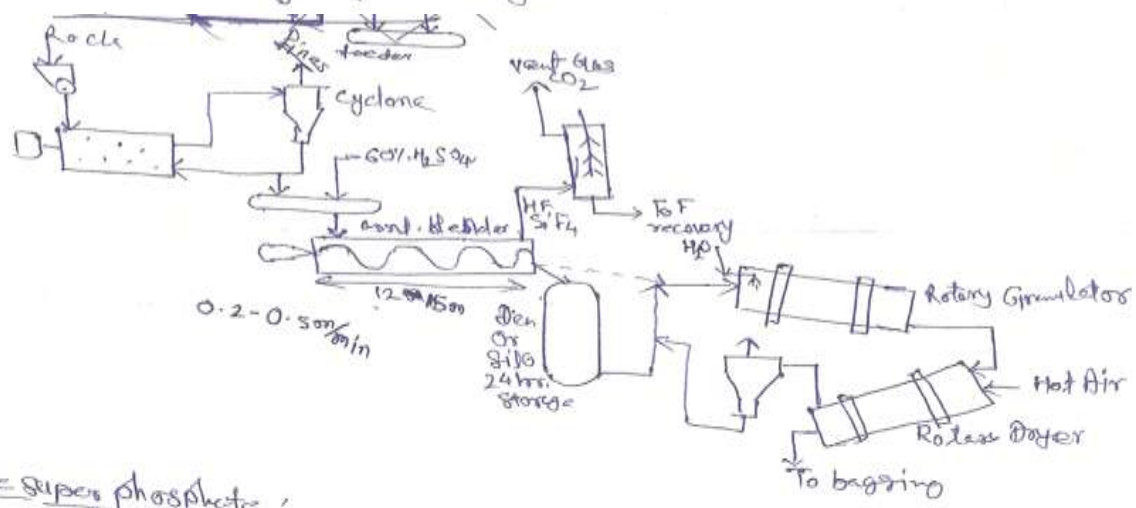
Phosphate rock lumps are crushed in jaw crusher & ground to -100 mesh in a hammer or ring mill. A continuous feed of sulfuric acid & powdered rock phosphate is sent to a steel trough, lead lined & brick lined, covered with a hood to collect SiF<sub>4</sub> & HF fumes. The rotating mechanism, made of cast iron blocks on a square shaft, moves the product gradually forward at the rate of 0.2 to 0.5 meter/min through the 12-15 meters reactor-conveyor

unit. With proper grinding & acid control, the reaction is effectively complete & can be sent directly to a granulator.

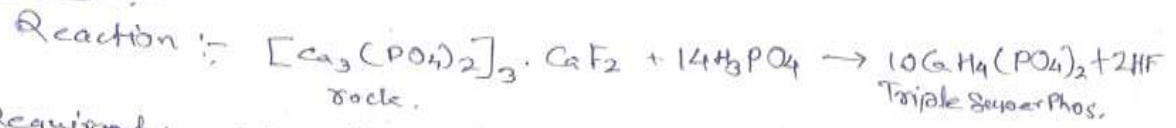
The SiF<sub>4</sub> & HF fumes along with CO<sub>2</sub> are scrubbed in water & the fine silica is removed by NaCl. according to

The porous, crumbly mat. from the den is mixed with rock dust from the grinding sections of the plant & fed to the inside of a slopy rotary drum. Water is sprayed on the tumbling solids to form free-flowing granules & to enhance the acidulation reaction.

Product is dried in a rotary dryer & packaged in 50-kg plastic lined jute bags.

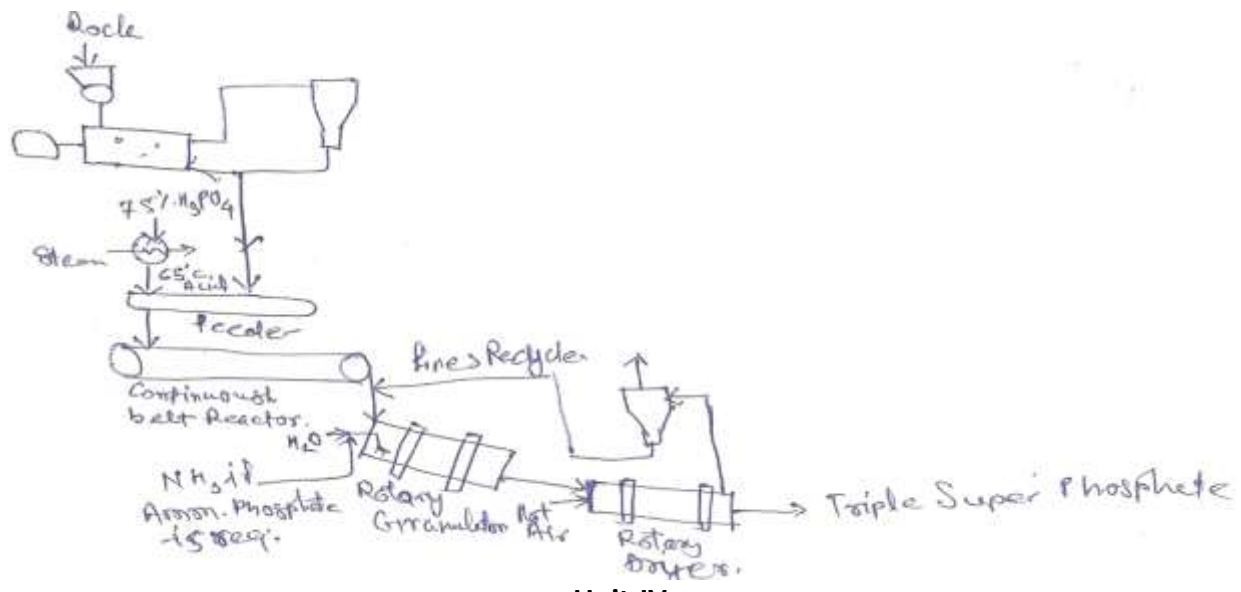


Triple super phosphate :-

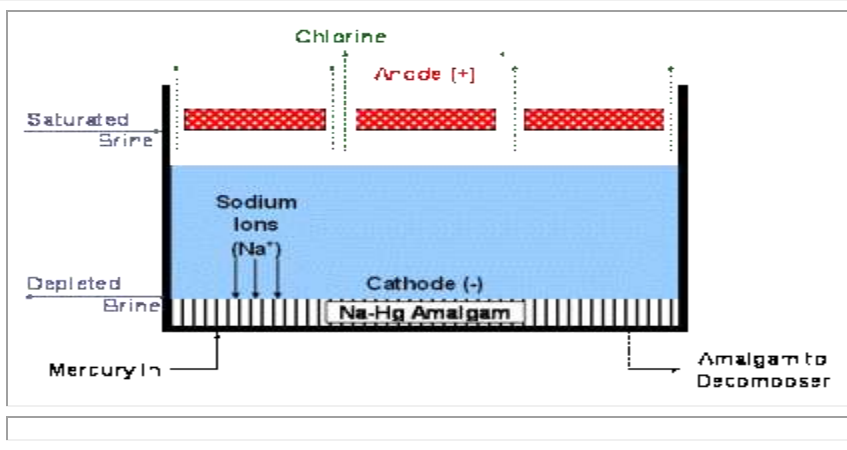


- Required :- 1 ton of T.S.P.  
 rock - (32% P<sub>2</sub>O<sub>5</sub>) 0.45 ton.  
 Phosphoric Acid (56% P<sub>2</sub>O<sub>5</sub>) 0.62 ton

Description :- The acid at 60-70% mixed with ground rock in a continuous mixer & passed to a continuous belt where reaction is completed in 15-20 min. The product is next granulated, dried & bagged.



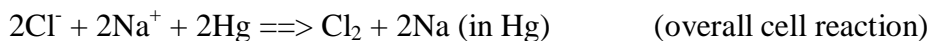
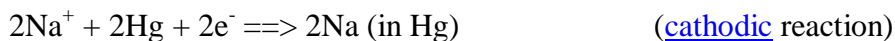
## Q8. Types of Cell used for manufacturing of caustic soda: Mercury cells



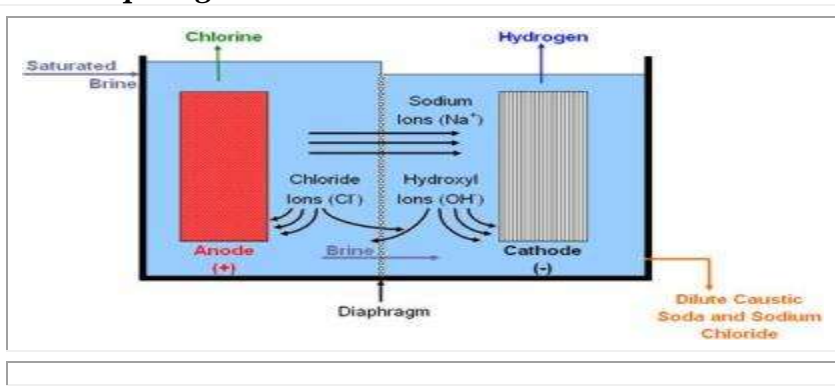
The mercury cell has steel bottoms with rubber-coated steel sides, as well as end boxes for brine and mercury feed and exit streams with a flexible rubber or rubber-coated steel cover. Adjustable metal [anodes](#) hang from the top, and mercury (which forms the [cathode](#) of the cell) flows on the inclined bottom. The [current](#) flows from the steel bottom to the flowing mercury.

[Saturated](#) brine fed from the end box is electrolyzed at the anode to produce the chlorine gas, which flows from the top portion of the trough and then exits. The sodium ion

generated reacts with the mercury to form sodium amalgam (an alloy of mercury and sodium), which flows out of the end box to a vertical cylindrical tank. About 0.25% to 0.5% sodium amalgam is produced in the cell. The sodium amalgam reacts with water in the decomposer, packed with graphite particles and produces caustic soda and hydrogen. Hydrogen, saturated with water vapor, exits from the top along with the mercury vapors. The caustic soda then flows out of the decomposer as 50% caustic. The unreacted brine flows out of the exit end box. Some cells are designed with chlorine and [anolyte](#) outlets from the end box, which are separated in the depleted brine tank. The mercury from the decomposer is pumped back to the cell.



## Diaphragm cells



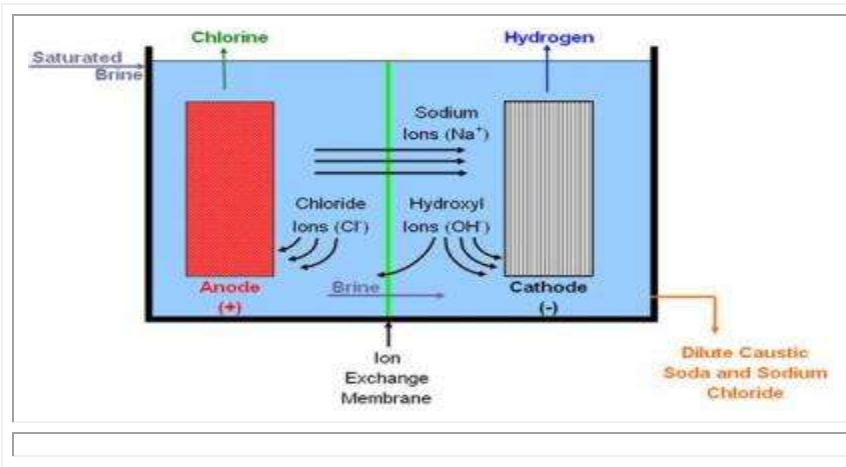
The diaphragm cell is a rectangular box with metal [anodes](#) supported from the bottom with copper-base plates, which carries a positive [current](#). The [cathodes](#) are metal screens or punch plates connected from one end to the other end of the rectangular tank. Asbestos, dispersed as a slurry in a bath, is vacuum deposited onto the cathodes, forming a [diaphragm](#). [Saturated](#) brine enters the anode compartment and the chlorine gas liberated at the anode during electrolysis, exits from the

anode compartment. It is saturated with water vapor at a partial pressure of water over the [anolyte](#). The sodium [ions](#) are transported from the anode compartment to the cathode compartment, by the flow of the solution and by [electromigration](#), where they combine with the hydroxyl ions generated at the cathode during the formation of the hydrogen from the water [molecules](#). The [diaphragm](#) resists the back [migration](#) of the hydroxyl ions, which would otherwise react with the chlorine in the anode compartment. In the cathode compartment, the concentration of the sodium hydroxide is ~12%, and the salt concentration is ~14%. There is also some sodium chlorate formed in the anode compartment, dependent upon the [pH](#) of the anolyte.

## Membrane cells



In a membrane cell, an [ion-exchange membrane](#) separates the [anode](#) and [cathode](#) compartments. The separator is generally a bi-layer membrane made of perfluorocarboxylic and perfluorosulfonic acid-based films, sandwiched between the anode and the cathode. The saturated brine is fed to the anode compartment where chlorine is liberated at the anode, and the sodium ion [migrates](#) to the cathode compartment. Unlike in the diaphragm cells, only the sodium ions and some water migrate through the membrane. The unreacted sodium chloride and other inert ions remain in



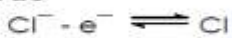
the [anolyte](#). About 30-32% caustic soda is fed to the cathode compartment, where sodium ions react with hydroxyl ions produced during the course of the hydrogen gas evolution from the water [molecules](#). This forms caustic, which increases the concentration of caustic solution to ~35%. The hydrogen gas, saturated with water, exits from the [catholyte](#) compartment. Only part of the caustic soda product is withdrawn from the cathode compartment. The remaining caustic is diluted to ~32% and returned to the cathode compartment.

Reactions in membrane and diaphragm cell:

**At cathode**



**At Anode**



## Q9. (i) Major engineering problem

### Absorption units

The absorption units should be constructed to permit the downward travel of growing sodium bicarbonate crystals. This is done by having each unit simulate a very large single bubble cap with down sloping floors. The absorption is carried out in towers filled with liquid. Hence CO<sub>2</sub> must be compressed. Due to the compression the partial pressure and solubility of CO<sub>2</sub> increased at the end of carbonating cycle.

### Making tower

Sodium bicarbonate formed in the making tower is drawn off as a suspension, it is necessary to ensure that the precipitated sodium bicarbonate is easily filterable and efficiently washable. It is carried out by regulating the temperature and concentration in the making tower. During the precipitation cycle, the temperature gradient is maintained at 20°C at the both ends and 45°C in the middle and fine crystals of sodium bicarbonate are allowed to grow. The temperature is increased from 20°C to 45-55°C by heat of reaction and reduced by using coils.

### Development of suitable calcining equipment

Moist sodium bicarbonate will cake on sides of kiln, preventing effective heat transfer through shell. Kiln must be equipped with heavy scraper chain inside and wet filter cake must be mixed with dry product to avoid caking. These problems can be avoided by using fluidized bed calciner.

### Filtration unit

Filtration should be carried out by using vacuum on the drum filter. It helps in drying the bicarbonate and in recovering ammonia

### Ammonia recovery

Ammonia recovery costs 4-5 times that of Na<sub>2</sub>CO<sub>3</sub> inventory so losses must be kept low. By proper choice of equipment design and maintenance, losses are less than 0.2% of recycle load or 0.5%/kg product or 1kg/ton of sodium carbonate.

### Waste disposal

Large quantities of CaCl<sub>2</sub>-NaCl liquor is generated during the process. The uses of these liquor is to be find out or dispose it as waste.

### (ii) USES of HCl acid:

Hydrogen chloride and the aqueous solution, muriatic acid, find application in many industries.

- Anhydrous HCl is consumed for its chlorine value, whereas aqueous hydrochloric acid is often utilized as a non-oxidizing acid.

- Used in metal cleaning operations, chemical manufacturing, petroleum well activation, and in the production of food and synthetic rubber.
- Used for the manufacture of chlorine and chlorides, e.g. Ammonium chloride used in dry cell.
- In the manufacture of glucose from corn starch.
- For extracting glue from bones and purifying boneblack.
- A saturated solution of zinc chloride in dilute HCl is used for cleaning metals before soldering or plating.
- It is also used in medicine and as laboratory reagent.
- Aqua regia used for dissolving metal

## Unit-V

Q10.

### 2. Cement Rock Beneficiation

Much of the locally available limestone has too high a silica and iron content for direct use in cement manufacture. These undesirable constituents can be removed by ore dressing or beneficiation methods which are based on fluid mechanics and adsorption.

4.2.1. Reference flow sheet: Figure IJK-1

4.2.2. Quantitative requirements

(a) Basis: 1 ton of low-grade limestone

Water 2-3 tons

Reagents 50-200 grams

Electricity 2.5 KWH

(b) Plant capacities: 300-1,000 tons/day

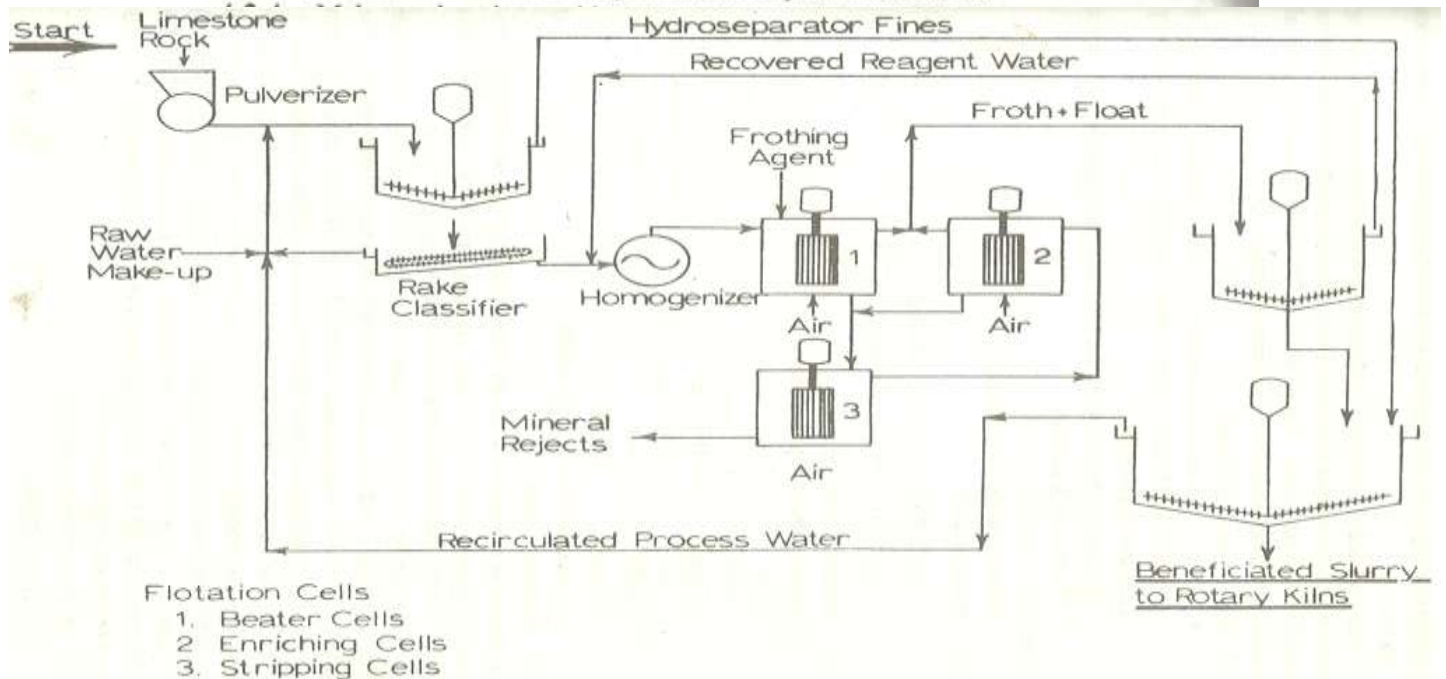
4.2.3. Process description

The operations are grinding, classification, flotation and thickening.

Rock is wet-ground, fed to a hydroseparator where the overflow goes directly to the

final thickener, being of satisfactory composition. If not, it is subjected to flotation separation as well as the coarse material which must be floated to remove silica, mica and talc.

Flotation is based on the ability of a collecting agent to wet certain minerals causing these to be entrained in an air froth which rises to the surface and overflows the flotation cell into the thickener cascade. In these latter units the flotation liquor is recycled and the beneficiated cement rock slurry is fed directly to cement kilns.



Q11. Types of glass:

### 1. Soda-lime or soft glasses

The raw materials are silica (sand), calcium carbonate and soda ash. Their approximate composition is  $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$ . About 90% of all glasses produced belong to soda lime glass. The low cost, low melting point soda-lime glass has resistant to de-vitrification and to water. However, they have poor resistance to common reagents like acids.

Uses: They are used as window glass, electric bulbs, plate glass, bottles, jars, building blocks and cheaper tablewares, where high temperature resistance and chemical stability are required.

## 2. Potash-lime or hard glasses

Silica (sand), calcium carbonate and potassium carbonate are the basic raw material for potash lime glass. Their approximate composition is  $K_2O.CaO.6SiO_2$ . They possess high melting point and have good resistance to acids, alkalis and other solvents compare to ordinary glasses.

Uses: These glasses are costlier than soda-lime glasses and are used for chemical apparatus, combustion tubes, etc., which are to be used for heating operations.

## 3. Lead glass

Instead of calcium oxide, lead oxide is fused with silica. As much as 80% of lead oxide is incorporated for dense optical glasses. In addition,  $K_2O$  is used instead of sodium oxide. So, its approximate composition is  $K_2O.PbO.6SiO_2$ . Lead glass is more expensive than ordinary lime-soda glass, but it is much easier to shape and to work with. Lead glass has a lower softening temperature and higher refractive index than soda glass.

Uses: Lead glasses are used for optical lenses, neon sign tubing, cathode ray tubes, art objects because of their high luster. High lead content glasses are used for extra dense optical glasses, for windows and shields to protect personnel from X-rays and gamma rays in medical and atomic energy fields respectively.

## 4. Borosilicate glass or Pyrex glass

It is the most common of the hard glasses of commerce which contain virtually only silica and borax with a small amount of alumina and still less alkaline oxides. Borosilicate glass has the following composition.

Component	SiO <sub>2</sub>	B <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	Na <sub>2</sub> O
Percentage	80.5	13	3	3	0.5

Borosilicate glasses have a very much higher softening point and excellent resistivity to shock.

Uses: They are used in pipelines for corrosive liquids, gauge glasses, superior laboratory apparatus, chemical plants, television tubes, electrical insulators etc.

## 5. Alumino-silicate glass

They possess exceptionally high softening temperature and having the typical constituent as follow

Component	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	B <sub>2</sub> O <sub>3</sub>	MgO	CaO	Na <sub>2</sub> O & K <sub>2</sub> O
Percentage	55 22	7	9	5	1	

Uses: combustion tubes, gauge glasses for high-pressure steam boilers, and in halogen-tungsten lamps capable of operating at temperature as high as 750°C.

## 6. Optical glasses

They contain phosphorus and lead silicate, together with a little cerium oxide, is capable of absorbing harmful UV light. In general optical glasses have low melting points and are relatively soft. Their chemical resistant and durability are appreciably lower than those of ordinary glasses.

Uses: Used for manufacture of lenses.

## 7. Insulating glass

It is a transparent unit prepared by using two or more plates of glass separated by 6-13 mm thick gap, filled up with dehydrated air and then thematically sealing around the edges. This provides a high insulation against heat.

Uses: It is used as thermal insulating materials

## 8. Laminated glass

It is made by pressing or bonding together two or more sheets /plates of glass with one or more alternating layer of bonding material like plastic resin, asphalt or synthetic rubber.

It is shock-proof, i.e. it can with stand sudden changes of temperature and pressure without breaking.

9. A bullet-resistant laminated glass is manufactured by pressing together several layers of glass with vinyl resins in alternate layers. Ordinary, thickness of such glass varies from 12.7 mm - 76.5 mm. Even thicker types are made for specific uses.

Uses: As safety glass in aircrafts, automobiles, helicopters, submarines. Bullet resistant lamination glass finds application in making automobile wind screens, looking windows etc

## 10. Glass wool

It is a fibrous wool-like material composed of intermingled fine threads or filaments of glass which is completely free from alkali. Glass filaments are obtained by forcing molten mass of glass through small orifice of average diameter of 0.005 - 0.007mm continuously. which is sent to rapidly revolving drum resulting in wool like form. It has low electrical conductivity and does not absorb moisture and it is completely heat proof. Uses: It is employed for heat insulation purpose, e.g., insulation of metal pipe lines, motors, vacuum cleaners, walls and roofs of houses.

## 11. Photochromic glass

Large number of microscopic particles of silver halides trapped in the three dimensional silicate networks in fixed concentration. On exposure light, temporary colour centers consisting of silver particles only are produced and these add quickly producing total darkness. The intensity of darkness depends upon the concentration of silver.