



India's Best Institute for CHEMICAL ENGINEERING

# CHEMICAL ENGINEERING

REVISED AS PER GATE

# CHEMICAL TECHNOLOGY



# CHEMICAL ENGINEERING

**REVISED AS PER NEW GATE Syllabus**

**STUDY MATERIAL**

**CHEMICAL TECHNOLOGY**



**Chemical Technology (Syllabus)**

**Inorganic chemical industries (sulfuric acid, phosphoric acid, chlor-alkali industry), fertilizers (Ammonia, Urea, SSP and TSP); natural products industries (Pulp and Paper, Sugar, Oil, and Fats); petroleum refining and petrochemicals; polymerization industries (polyethylene, polypropylene, PVC, and polyester synthetic fibers).**

**CONTENT**

1. INTRODUCTION .....	03-04
2. SULFUR & SULFURIC ACID .....	05-12
3. FERTILIZER INDUSTRY .....	13-27
4. CHLOR-ALKALI INDUSTRY .....	28-36
5. INDUSTRIAL GASES & CEMENT INDUSTRY .....	37-44
6. NATURAL PRODUCT INDUSTRY.....	45-58
7. PULP AND PAPER INDUSTRY .....	59-65
8. PETROLEUM INDUSTRY .....	66-82
9. POLYMER INDUSTRY.....	83-90
10. CURRENT SCENARIO OF INDIAN CHEMICAL INDUSTRIES .....	91-92
11. PRACTICE SET-1 .....	93-97
12. Practice Set-2 & 3.....	98-110

## CHAPTER-1

## INTRODUCTION

1. Chemical and allied Industry have first rank among all manufacturing industry both in capital assets and importance to the country economy.
2. Chemical Industry plays important role in every part of life. For example foods, drugs, petroleum, and fertilizer industry
3. Chemical Industry is different than other industry as in chemical Industry we start from raw material and end up with consumer product through series of physical and chemical change.
4. During the study of chemical industry fundamentals of chemistry, thermodynamics, kinetics and economics are always valid.
5. Chemical processes are used to produce chemical products and which includes chemical transformation(s).
6. Specific products produced by the chemical and pharmaceutical include: aspirin, ibuprofen, paracetamol, naproxen, labetalol, etc
7. These active pharmaceutical ingredients (APIs) are produced by chemical reactions involving organic chemicals (organic chemistry).
8. These are chemically formulated products manufactured from basic chemicals which are used by and domestic consumers for specific purposes. For example: coatings, adhesives, pharmaceutical products, pesticides, cosmetics, disinfectants etc
9. Major feed stocks for chemical industries are coal, petroleum, biomass, oils and fats, sulphur, salts lime stone, rock phosphate etc.
10. Major chemicals products and their areas of application
  - i) **Plastics and polymers:** Agriculture water management, packaging, automobiles, telecommunications, health and hygiene, education.
  - ii) **Synthetic rubber:** Transportation industry, textile industry, industrial equipment living.
  - iii) **Synthesis fibre:** Non woven and woven fibre in automobile, hosiery, textile
  - iv) **Soap and synthetic detergents:** Health and hygiene domestic as well as industrial
  - v) **Industrial chemicals:** Drugs and pharmaceuticals pesticides, explosives, surface loading, dyes, ladditives adhesive oil fields, anti-oxides, chemicals, metal extraction, printing ink, paints
  - vi) **Sugar and alcohol:** Food alcoholic brewages, chemical feed store ethoxylate, bio fuel
  - vii) **Pulp and paper:** Letting and printing paper, culture paper, new paper, tissue paper, packaging paper.
  - viii) **Fertilizer:** Agriculture, chemical industry (ammonia and uses)
  - ix) **Agrochemicals:** Pesticides
  - x) **Minerals acids:** Chemical industry – organic and inorganic

**Chemical Industry:**

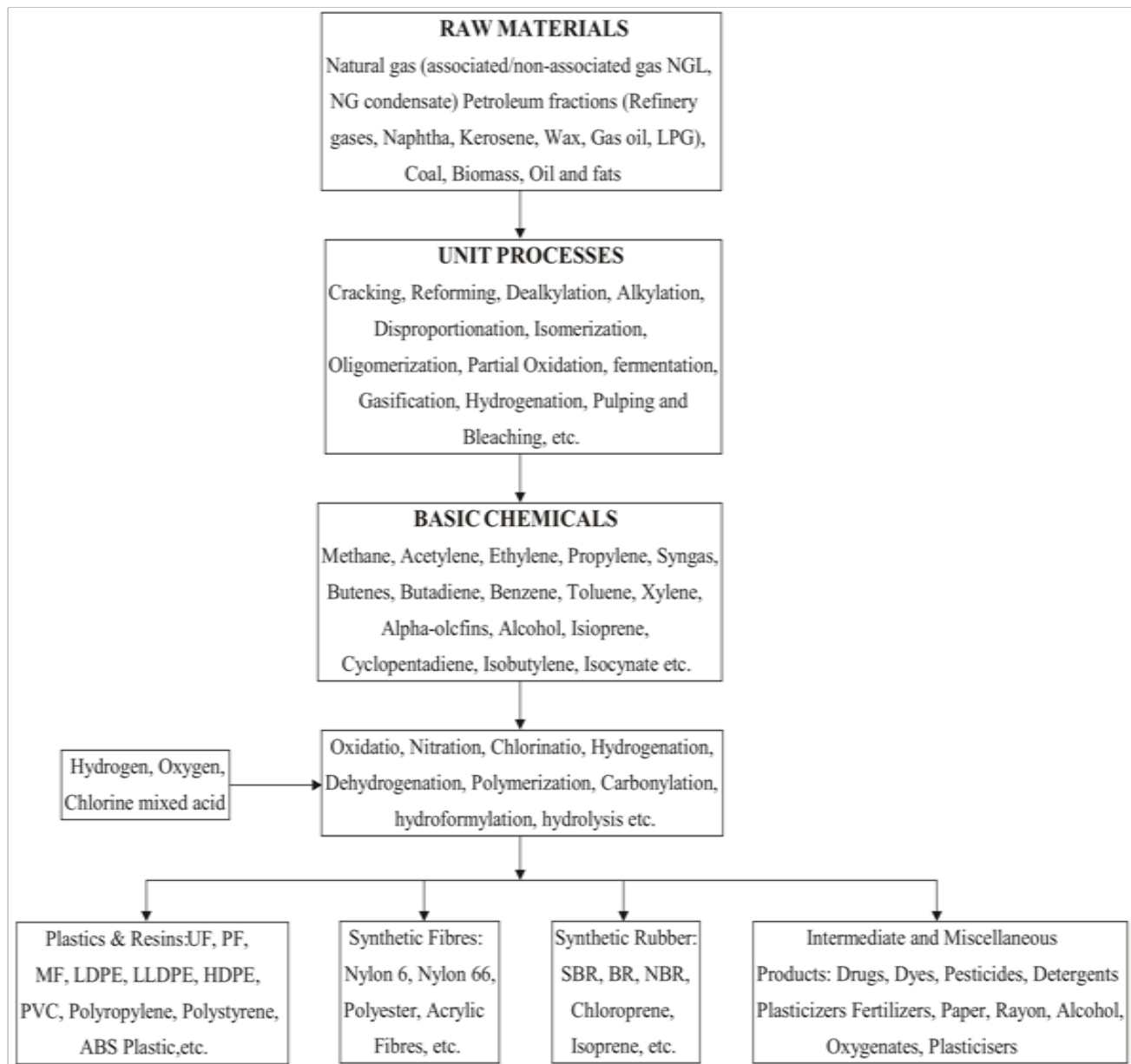
**Food:** Fertilizer & Agrochemical

**Clothing:** Synthetic fibers, Dyestuffs, Textiles, Auxiliaries, Specialty Chemicals

**Shelter:** Polymer composites, Coating, New Performance Materials

**Health Care:** Pharmaceuticals, Polymers, Synthetics, Detergent

**Quality of Life:** Transportation, Education, Fuel, Electricity, Energy, Water supply, Management, Communication, Polymers & Industrial chemicals



### Summary:

- Industrial production = f [Unit operation, unit process]
  - Unit operation → Physical treatment steps
  - Unit process → Chemical treatment steps.
- Operations that brings physical changes in raw materials is called as unit operations.
- Unit process brings chemical changes in raw materials.
- Industrial production = f[unit operation, unit process].

## CHAPTER-2

## SULFUR &amp; SULFURIC ACID

1. Sulfur (S) is the chemical element that has the atomic number 16. It is denoted with symbol (S).
2. It is an abundant, multivalent non metal. Sulfur in its native form is a bright yellow crystalline solid.
3. Its commercial uses are primarily in fertilizer, but it is also widely used in black gun powder, match sticks, insecticides and fungicides. It has m.p. 119° C.

**Consumption Pattern:**

**1. 80 – 90% of sulfur containing raw materials are converted to commercial oxidized forms:**

$\text{SO}_2, \text{SO}_3, \text{H}_2\text{SO}_4, \text{Oleum } (\text{H}_2\text{SO}_4 + \text{SO}_3)$

**2. End uses of elemental S are:**

- (a) 85 to 90% for sulfuric acid manufacture.
- (b) Rubber vulcanization agent
- (c) Gun powder, sulfur dyes
- (d) Paper and pulp.

**3. Application for Sulfuric Acid:**

- (a) Phosphate fertilizer
- (b) Petroleum refining
- (c) In organic chemicals and pigment
- (d) Copper leaching
- (e) synthetic rubber and plastic
- (f) Industrial organic chemicals
- (g) Pulps and paper

**Process:**

1. Elemental sulfur mining from salt domes
2. Hydrogen sulfide conversion from natural gas
3. Essential sulfur from ironpyrite

**1. Elemental Sulfur Mining by Frasch process****Raw Materials:**

- \* Sulfur deposits in salt domes
- \* Large supply of hot water.

**Process Description: (Fig. 1)**

1. Wells drilled into free sulfur bearing salt domes. Treated hot water is pumped into sulfur deposit melts with sulfur; water moves upward and outward to bleeder wells on outer periphery of area when it is aerated and discharged.



2. Molten sulfur sinks to bottom of casing and is jet pumped with compressed air to sump separation units and shipment or storage.
3. Filtration is sometimes used to remove carbonaceous and mineral matter.

### Major Engineering Problems:

- (a) Heat transfer in melting and shipping operations.
- (b) Finding suitable sources of treated water.
- (c) Corrosion.

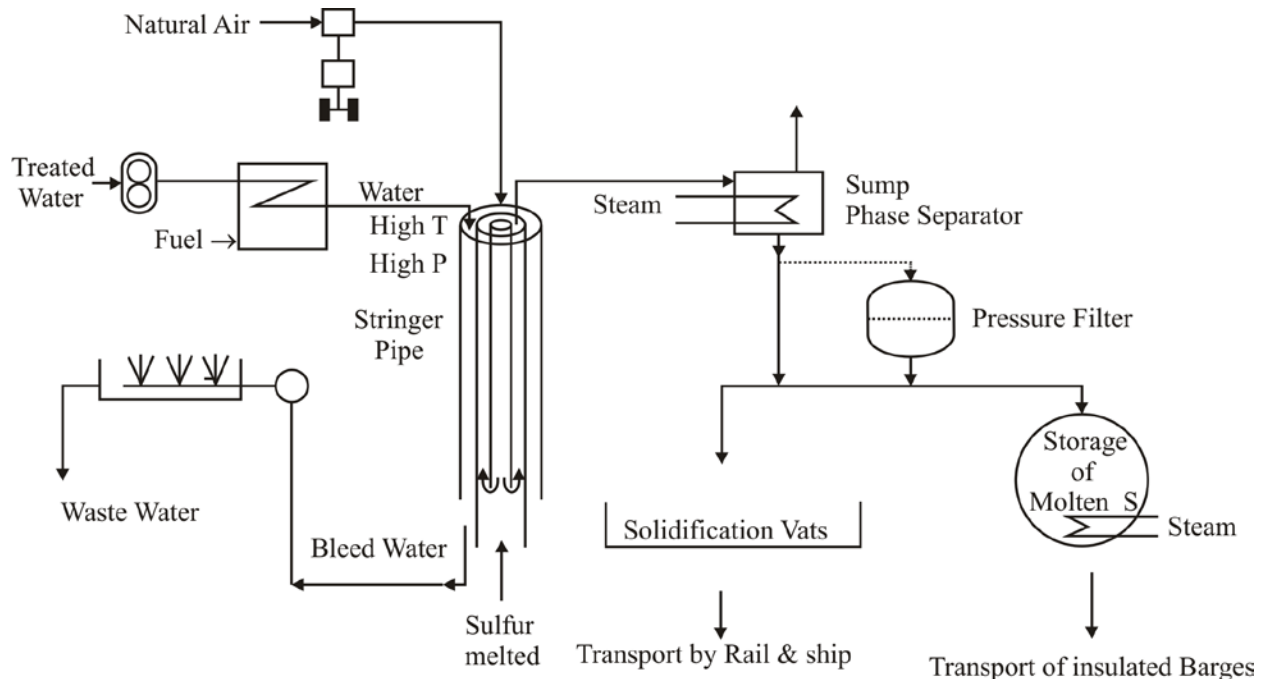
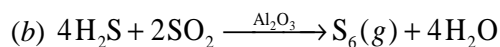
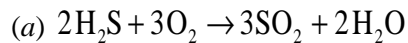


Figure-1

## 2. Oxidation Reduction of $H_2S$

Reference flow sheet Fig. 2.

### Chemical Reaction



### Raw Material

$H_2S$  from natural gas and petroleum refinery.

### Process Description:

- (i)  $H_2S$  and air is burned in a chemical reaction.
- (ii) The product  $SO_2$  oxidizes  $H_2S$  by reaction
- (iii) In two stage catalytic converter with inter cooling and condensing.

**Question-2: Which one of the following options represents the major components of oleum?**

- (A) Sulfuric acid and nitric acid  
(B) Concentrated sulfuric acid and petroleum jelly  
(C) Sulfuric acid and hydrochloric acid  
(D) Sulfuric acid and sulfur trioxide

**(GATE-2023: 2-Marks)**

**Answer: D**

Oleum ( $\text{H}_2\text{SO}_4 + \text{SO}_3 = \text{H}_2\text{S}_2\text{O}_7$ )

So, the major components of oleum is sulfuric acid and sulfur trioxide.

**Question-3:** In the production of  $\text{H}_2\text{SO}_4$  is equilibrium yield of  $\text{SO}_3$  is propotional to

- (a)  $P_T$                       (b)  $P_T^{3/2}$                       (c)  $P_T^{1/2}$                       (d)  $P_T^2$

Answer : ( C )

**Question-4:** Production of elemental sulfur from pyrite is known as :

- (a) Finnish process                      (b) Clause process  
(c)  $\text{H}_2\text{S}$  recovery                      (d) Frasch process

**Question-5:** Which of the following statement is not correct in contact process of  $\text{H}_2\text{SO}_4$  production.

- (a) Pt catalyst widely used for Contact process  
(b)  $\text{V}_2\text{O}_5$  relatively immune to poison  
(c) Low initial investment required for  $\text{V}_2\text{O}_5$  catalyst  
(d) High  $\text{SO}_2 / \text{O}_2$  input is required  $\text{V}_2\text{O}_5$  Catalyst

Ans: d

#### IMPORTANT POINTS TO REMEMBER

1. 20% Oleum means that in 100 Kg, there are 80 Kg of  $\text{H}_2\text{SO}_4$  and 20Kg of  $\text{SO}_3$
2. For  $\text{SO}_2$  oxidation equilibrium constant proportional to  $P_T^{-0.5}$ .
3.  $\text{V}_2\text{O}_5$  and Pt catalyst used in  $\text{H}_2\text{SO}_4$  production.
4. The sulfur usually contains arsenic As which attacks the vanadium or platinum catalyst in the  $\text{SO}_2$  to  $\text{SO}_3$  conversion in contact process for  $\text{H}_2\text{SO}_4$ .
5. 20% oleum means that in 100 kg, there are 80 kg of  $\text{H}_2\text{SO}_4$  and 20 kg of  $\text{SO}_3$
6. High  $\text{O}_2 / \text{SO}_2$  desired for  $\text{V}_2\text{S}_5$  catalyst in production of  $\text{H}_2\text{SO}_4$ .
7. Yield of  $\text{SO}_2$  proportional to  $P_T^{0.5}$  in  $\text{SO}_2$  oxidation.
8. Cast iron is not for use in oleum system.



<b>PRACTICE QUESTIONS</b>
---------------------------

1. What is the chemical formula of oleum:  
 (a)  $\text{SO}_2$             (b)  $\text{SO}_3$             (c)  $\text{H}_2\text{SO}_4$             (d)  $(\text{H}_2\text{SO}_4 + \text{SO}_3)$
2. Frasch process is the process of mining is related to which industry:  
 (a)  $\text{O}_2$  production            (b) Aluminium mining  
 (c) Sulfur mining            (d) Production of sugar
3. Chamber and contact process are related with which chemical production  
 (a)  $\text{CO}_2$             (b)  $\text{H}_2\text{SO}_4$             (c) NaOH            (d)  $\text{HNO}_3$
4. For contact  $\text{H}_2\text{SO}_4$  process which catalyst preferred:  
 (a) Ni            (b) Pt            (c)  $\text{V}_2\text{O}_5$             (d) Fe
5. Which is not advantage of  $\text{V}_2\text{O}_5$  catalyst?  
 (a) Relatively immune to poisons            (b) Low initial investment  
 (c) Only require 5% replacement per year            (d) None of these
6. Elemental S finds its major utilization in which of the field.  
 (a.) As a vulcanization agent  
 (b.) In sulphuric acid manufacture  
 (c.) Pulp and paper  
 (d.) Gun powder, sulphur dyes
7. Elemental S, can be obtained from which of the following method?  
 (a.) Frasch process  
 (b.) Oxidation reduction of  $\text{H}_2\text{S}$   
 (c.) Finish process  
 (d.) All of the above
8. Which of the following catalyst is used in finish process for recovering elemental S from pyrites?  
 (a.) Zn O            (b)  $\text{Al}_2\text{O}_3$             (c)  $\text{H}_2\text{SO}_4$             (d)  $\text{V}_2\text{O}_5$
9. 98%  $\text{H}_2\text{SO}_4$  is obtained through  
 (a.) Contact process            (b) Chamber process  
 (c.) Frasch process            (d) None
10. Oleum is a mixture of  
 (a.)  $\text{H}_2\text{SO}_4$  and  $\text{H}_2\text{O}$   
 (b.)  $\text{H}_2\text{SO}_4$  and  $\text{SO}_2$   
 (c.)  $\text{H}_2\text{SO}_4$  and  $\text{SO}_3$   
 (d.)  $\text{SO}_3$  and  $\text{SO}_2$

<b>ANSWER KEY</b>									
-------------------	--	--	--	--	--	--	--	--	--

<b>1</b>	<b>d</b>	<b>2</b>	<b>c</b>	<b>3</b>	<b>b</b>	<b>4</b>	<b>c</b>	<b>5</b>	<b>d</b>
<b>6</b>	<b>b</b>	<b>7</b>	<b>d</b>	<b>8</b>	<b>b</b>	<b>9</b>	<b>a</b>	<b>10</b>	<b>c</b>

## CHAPTER-3

## FERTILIZER INDUSTRIES

**Fertilizer Industry**

Nitrogen: requiring early stages of plant growth to promote development of stems and leaves

Phosphorous: early growth and accelerates seeding or fruit formation in later stages of growth

Potassium 'K' for the development of starches of potatoes and grains, sugar of fruits and vegetables and fibrous material of plants an ample supply of potassium in soil sometimes helps to prevent disease and lessen the effects of excessive nitrogen application.

K along N & P: Primary nutrients considered essential for plant growth.

**1. NITROGEN INDUSTRIES****i. Ammonia (NH<sub>3</sub>)****End uses of NH<sub>3</sub>**

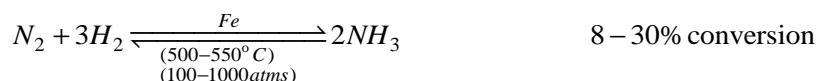
- 1) Direct application as fertilizer
- 2) Uses (for both fertilizers & plastics)
- 3) Ammonium phosphates
- 4) Nitric acid
- 5) Ammonium nitrate
- 6) Ammonium sulphate
- 7) Acrylonitrile

**Type of Nitrogen**

- 1) Mixed fertilizers (N, P, K)  
(expressed as wt% total N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O (e.g. 5 – 10 – 5))
- 2) Chemical nitrogen Fertilizers

**Method of production**

→ Based on pressure – catalytic reaction of N<sub>2</sub> and H<sub>2</sub>

**Grades**

- 1) Fertilizer Granular – coated  $\bar{C}$  non hygroscopic dust such as phosphate rock or limestone (40 – 42%N)
- 2) Liquor: mixture of urea in NH<sub>3</sub> sol (45% total N 30% NH<sub>3</sub> 15% urea)
- 3) Slow release: Contains low molecular weight urea polymers

**End uses**

- i) Solid fertilizer (53%)
- ii) Liquid fertilizer (31%)
- iii) Formaldehyde resins
- iv) Melamine

## **GATE-2023 Chemical Engineering**

*Congratulations !!!*

**8 Rank in Top 10**

*Congratulations !!!*

 <p><b>1</b> Rank ROHIT BHAGAT KALWAR</p>	 <p><b>2</b> Rank HARSHIT GUPTA</p>	 <p><b>3</b> Rank RAVI SHANKAR</p>	 <p><b>4</b> Rank ANANTHANARAYANAN POTTI S</p>
 <p><b>6</b> Rank BIBEKANANDA SAHOO</p>	 <p><b>6</b> Rank KARTIK DILIPKUMAR CHADDARWALA</p>	 <p><b>8</b> Rank SATYASHEKHAR VELAMALA</p>	 <p><b>10</b> Rank BIRUPAKHYA PATRO</p>
 <p><b>11</b> Rank RAKHAL BANERJEE</p>	 <p><b>13</b> Rank HARAPRASAD DASH</p>	 <p><b>17</b> Rank ARPIT BHARDWAJ</p>	 <p><b>18</b> Rank HATIF HAIDER KHAN</p>
 <p><b>18</b> Rank DINESH DEVHARE</p>	 <p><b>21</b> Rank ARAVIND B MENON</p>	 <p><b>24</b> Rank VUDDANTI GOUTHAM</p>	 <p><b>24</b> Rank NEELSINH RAJPUT</p>