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GATE & Public Sectors

Chemical Technology CT

GATE 2015 Top Results

Chemical Engineering

1st Rank
Archhit Trichal

2nd Rank
Keval Pareta

GATE 2015 Result

Name
ARCHHIT TRICHAL

Registration Number
CH88041S1135

Gender
Male

Examination Paper
Chemical Engineering (CH)

Marks out of 100#	65.67			All India Rank in this paper	1
Qualifying Marks##	27.52 (General)	24.77 (OBC (NCL))	18.34 (SC/ST/PwD)	GATE Score	947

Highest Result in GATE 2015

Rank 1, 2, 7, 8.....

Total 39 Ranks under AIR 100

GATE 2014 Topper

Chemical Engineering

1st Rank
Sandeep Kumar

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Chemical Engineering (GATE & PSUs)

GATE 2015 Cut-off Marks				
BRANCH	**GENERAL**	**SC/ST/PD**	**OBC(Non-Creamy)**	**Total Appeared**
Chemical Engineering	27.52	18.34	24.77	15874

CONTENT

Syllabus : Chemical Technology: Inorganic chemical industries; sulfuric acid, NaOH, 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.

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, luse additives 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

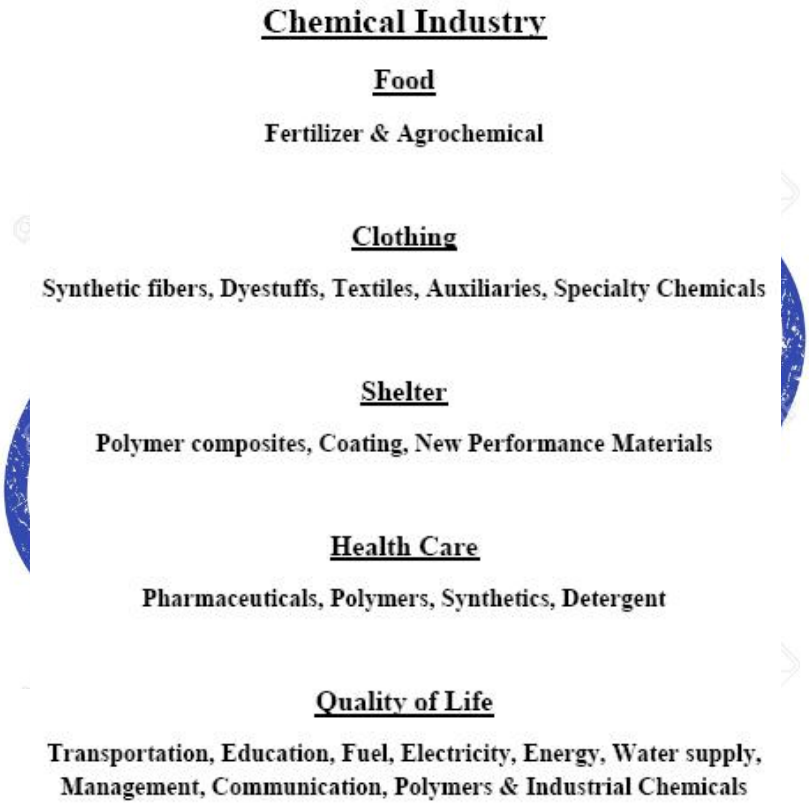
- Agriculture, chemical industry (ammonia and uses)

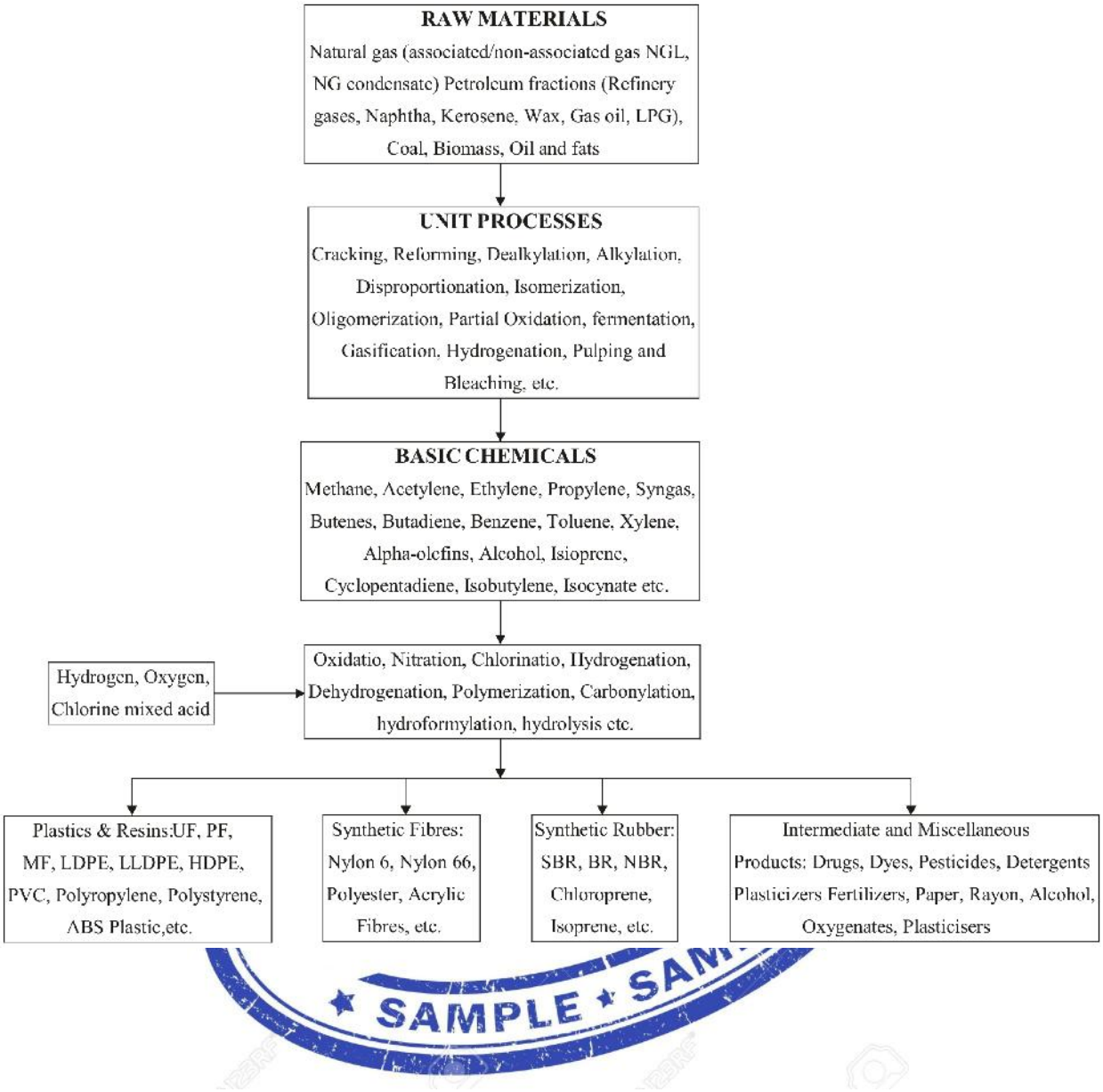
ix) Agrochemicals

- Pesticides

x) Minerals acids

- Chemical industry – organic and inorganic
-





CHAPTER-2

SULFUR & 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:

$SO_2, SO_3, H_2SO_4,$ Oleum $(H_2SO_4 + SO_3)$

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

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 which 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.

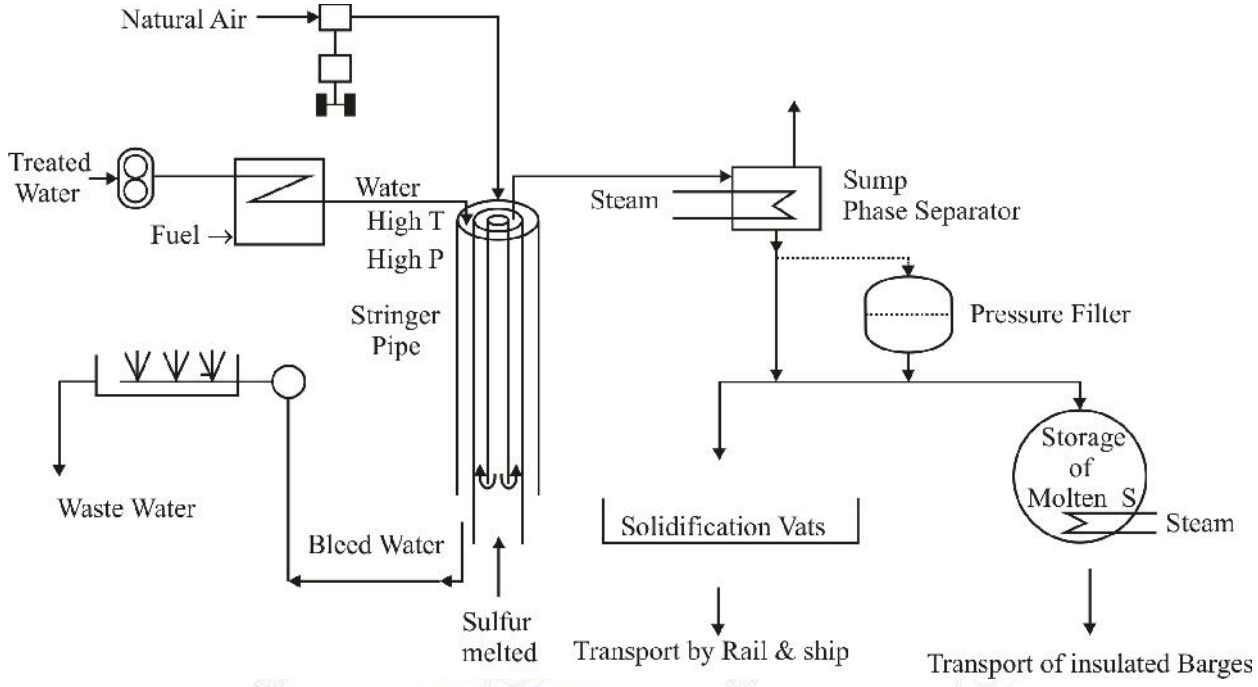


Figure-1

2. Oxidation Reduction of H_2S

Reference flow sheet Fig. 2.

Chemical Reaction

(*a*) $2H_2S + 3O_2 \rightarrow 3SO_2 + 2H_2O$

(*b*) $4H_2S + 2SO_2 \xrightarrow{Al_2O_3} S_6(g) + 4H_2O$

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.

(*iv*) Finally waste gas is scrubbed with molten sulfur.

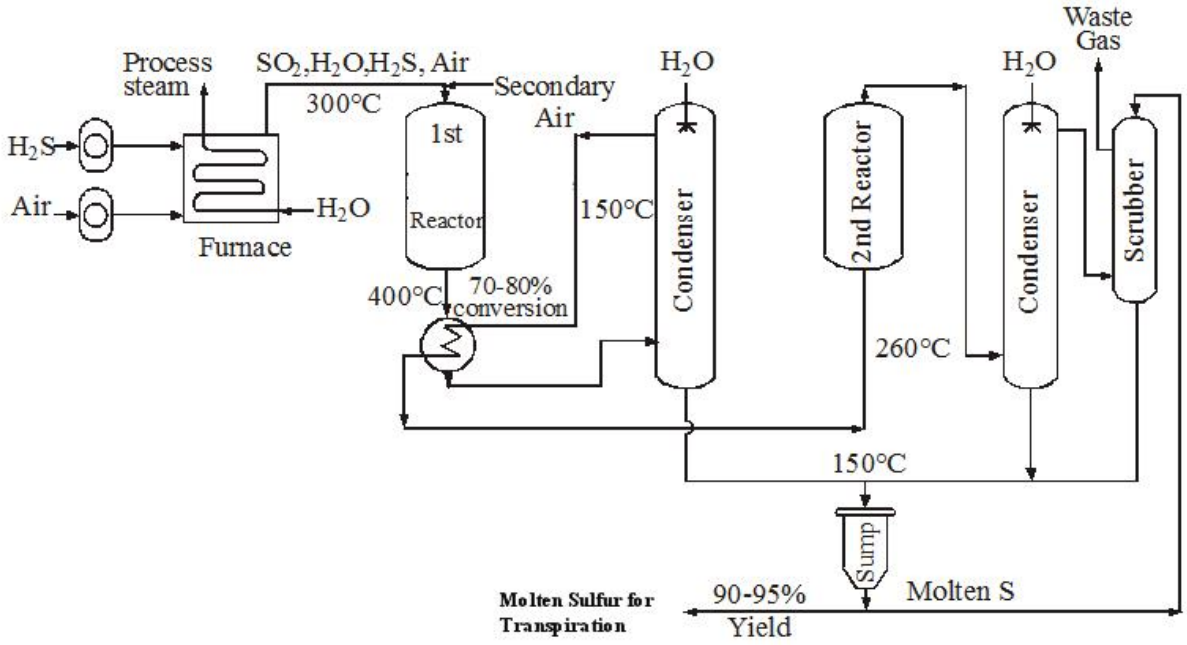


Figure-2

Major Engineering Problems:

(*a*) Two stage reactor design for exothermic reaction producing SO_2, oxidation of H_2S. 70 – 80% conversion is achieved first stage at 300 – 400º C range followed by 250 – 300º C operation in second reactor to obtain favorable equilibrium.

(*b*) Heat exchange for molten S handling.

(*c*) Corrosion

(*d*) Final clean up of stack gas.

3. Elemental Sulfur from Pyrites (Finish Process):

Chemical Reaction:

(*a*) Thermal Dissociation

$$FeS_2 \xrightarrow[1300°C]{1\,atm} \frac{1}{2}S_2(g) + FeS(l)$$

(*b*) General Combustion reaction

$$C + H + S + O_2 \rightarrow SO_2, H_2S, CO, H_2CO_2H_2O$$

(*c*) Sulfur recovery from gases $\rightarrow$ Hot stage

$$2\,COS + CS_2 + 2SO_2 \xrightarrow[\text{Catalyst}]{600^\circ C} S_6 + 3CO_2$$

(*d*) Sulfur recovery from gases $\rightarrow$ Cold stage

$$4\,H_2S + 2SO_2 \xrightarrow[280^\circ C]{Al_2O_3} 4\,H_2O + S_6$$

(*e*) Roasting of FeS (pyrrhotitc) for SO_2 recovery

$$2\,FeS + 3\frac{1}{2}O_2 \xrightarrow[1000^\circ C]{1\,atm} Fe_2O_3 + 2SO_2$$

Raw Material: Pyrites ore, limestone, fuel oil, water, electricity.

Process Description:

1. Pyrites ore is dried in a rotary kiln with flue gases and ground to 200 mesh. It is dispersed with hot combustion gases from oil burner at the top of a vertical circular shaft furnace. Heat of dissociation and fusion is transferred to the FeS_2 as it moves downward in the suspension. At the bottom of the vertical shaft the gases change 90º and move horizontally.

2. The liquid droplets of FeS are caught in the molten horizontal batch and silica gangue is trapped and fluxed with lime, floating on the top of the molten FeS matte. The liquid FeS is tapped periodically and granulated in water to produce 4 mm grains for further roasting operation.

3. Hot gases at 1,300ºC move through a high pressure heat recovery boiler section (70 atm, steam) cooling to 300ºC. Dust is separated by electrostatic precipitation.

4. The first step in combined S recovery is done in a high temperature catalytic reactor where carbon compounds with S are eliminated. The reaction gases still containing SO_2 and H_2S are cooled to 150ºC by passing through a low pressure heat recovery boiler (4.5 atm, gauge). This is followed by cold stage catalytic reaction where aluminium oxide catalyzes the $H_2S + SO_2$ to produce S_6 vapor.

5. After catalysis, sulfur gas is condensed as molten sulfur droplets in a spray condenser. The heat of fusion is recovered via low pressure steam boiler. The exist gases are next washed with water in another tower to further recover entrained and uncondensed sulfur.

6. The sulfur usually contains arsenic which attack the platinum catalyst in the $SO_2 \rightarrow SO_3$ contact process for H_2SO_4. It can be removed by contacting molten sulfur with milk of lime in a continuous autoclave.

7. Sulfur as SO_2 for sulfuric acid can be obtained by roasting the granulated FeS from the smelting furnace. Fluidized roasting at 1000ºC produce SO_2 gas which is cooled in waste heat boiler, cleaned by cyclone and electrostic precipitation. The hot cinder of iron oxide, suitable for blast furnace sinter cake are cooled on conveyor and shipped to steel plant.

Major Engineering Problems:

(*a*) Pyrites ore beneficiation

The process was developed for pyrites ore of Finland which have 1 – 5% SiO_2. Indian ore has 5 – 7% SiO_2 and require either floatation initially or extra limestone to flux or cut the silica. The latter is preferred since there is 30% loss of ore in beneficiation.

(*b*) Grinding:

The particle size range of 200 mesh was an economic balance between heat transfer rate from combustion gases plus residence time, as dictated by rate of fall of particle, tower high and grinding cost.

(*c*) Substitution of coal for fuel oil:

Low grade fuel oil is only available at high cost. Smelting with coal would represent a saving of 20% in the cost of sulfur produced. Uses of coal is being considered for pilot plant development in India. The question of using pulverized coal directly in the smelter burners or working with secondary combustion gases after ash has been removed must be resulted.

(*d*) Gaseous reaction in smelting furnace:

Complete combustion of fuel without excess air is desirable to avoid unbalance of the $H_2S, to SO_2$ ratio which can be shifted only minor change in the O_2/fuel ratio. The smelter feed system require close instrumental control.

(*e*) Two stage catalytic reactor Design:

Plant first operated only with cold stage so that COS and CS_2 remained unconverted to free sulfur by first using a high temperature. Catalyst these compounds can also be oxidized and S yields increased from 85 to 92%.

(*f*) Heat recovery and generation of electric energy:

Despite the initial endothermic smelting step and the high electrical energy usage for grinding, the overall process has excess heat energy which is converted via three stage of steam boiler heat recovery to electric energy with a net production of 1400 kWH/ton of S.

(H_2SO_4)

Method of Production

Classification of process

(*a*) Contact process

(*b*) Chamber process

Both processes are based on SO_2. Chamber process was first developed (1746) but product acid is of concentration less than 80%. Contact process fields 98%. H_2SO_4 and higher which can be diluted. If necessary, chamber process is virtually obsolete.

Contact H_2SO_4 Process:

1. Reference flow sheet

2. Chemical Reaction

(*a*) $S(s)+O_2(g)\rightarrow SO_2(g)$

(*b*) $SO_2(g)+\frac{1}{2}O_2(g)\xrightleftharpoons{V_2O_5}SO_3(g)$

3. Raw Materials:

(*a*) SO_2 is obtained from the following sources:

Sulfur, pyrites, (CuS, ZnS, PbS, MoS_2), waste H_2SO_4, H_2S sources.

(*b*) Catalyst: Most widely used catalyst is vanadium pentoxide dispersed on a porus carrier in pellet form. Platinum catalyst was previously used but it suffers from easy poisoning, fragility, rapid heat activation, high initial investment.

Process Description: Fig. 3.

1. Air SO_2 gas containing 7 – 10% SO_2 and 11 – 14%. O_2 is preheated by converter gas. It necessary and sent to first stage reactor of steel construction. This is the high temperature (500 – 600° C) stage, contains 30% of total catalyst and convert about 80% of SO_2.

2. The converter product is cooled by heat exchanger at 300° C and fed to a second stage where total yield is increased to 97% by operating at 400 – 450° C for favorable equilibrium.

3. High yield product gases are cooled to 150° C by water and air heat exchanger and absorbed in oleum fed at a rate to allow not over 91% rise in acid strength. Final scrubbing is done with a lower strength (97%) acid. Oleum concentration upto 40% can be made by tower absorption. Higher strength oleum upto 65% is prepared by distilling 20% oleum.

Major Engineering Problem:

(*a*) Design of multi stage catalytic converter for a highly exothermic reaction. Some design contains 3 or 4 stage rather than the conventional two stage operation for large capacity plant.

(*b*) Corrosion problem.

(*c*) Adaptation of process to various types of gas feeds.

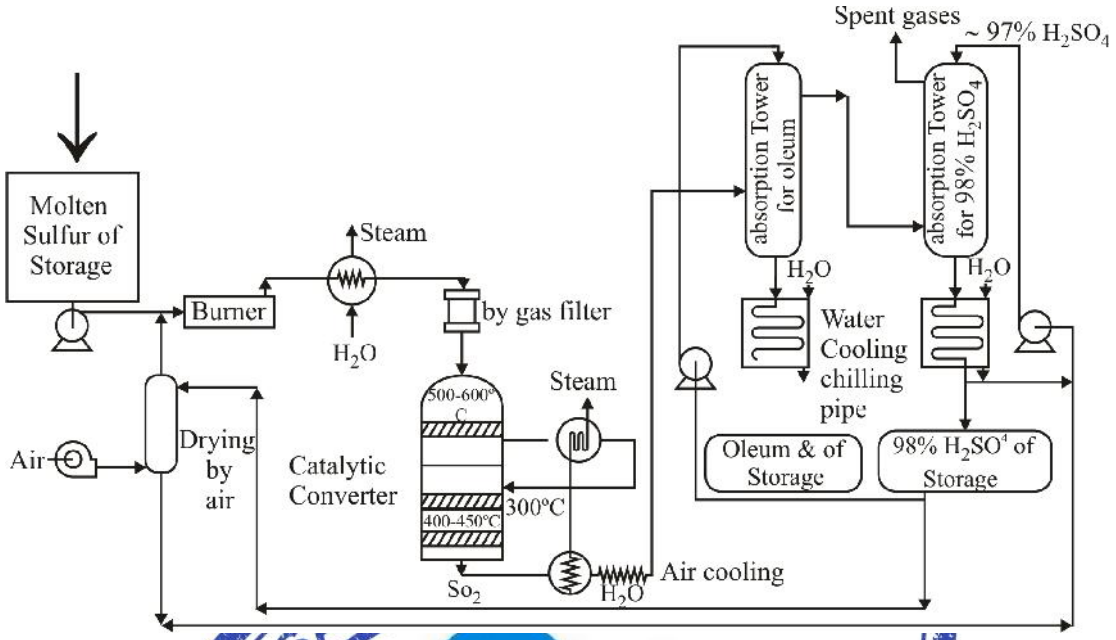


Figure-3

IMPORTANT POINTS TO REMEMBER

1. Sulfur (s) is the chemical elements that have the atomic number 16.
2. Sulfuric acid is a strong dibasic acid.
3. 20% Oleum means that in 100 Kg, there are 80 Kg of H_2SO_4 and 20Kg of SO_3
4. Cast iron is not suitable for use in oleum system.
5. LPG-liquified petroleum gas.
6. V_2O_5 catalyst used in H_2SO_4 production.

PRACTICE QUESTIONS

1. What is the chemical formula of oleum:

(*a*) SO_2 (*b*) SO_3 (*c*) H_2SO_4 (*d*) $(H_2SO_4 + SO_3)$

2. Frasch process is the process of mining is related to which industry:

(*a*) 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*) CO_2 (*b*) H_2SO_4 (*c*) NaOH (*d*) HNO_3

4. For contact H_2SO_4 process which catalyst preferred:

(*a*) Ni (*b*) Pt (*c*) V_2O_5 (*d*) Fe

5. Which is not advantage of V_2O_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 H_2S

(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) Al_2O_3 (c) H_2SO_4 (d) V_2O_5

9. 98% H_2SO_4 is obtained through

(a.) Contain process (b) Chamber process

(c.) Frasch process (d) None

10. Olcum is a mixture of

(a.) H_2SO_4 and H_2O

(b.) H_2SO_4 and SO_2

(c.) H_2SO_4 and SO_3

(d.) SO_3 and SO_2

ANSWER KEY

1	**d**	**2**	**c**	**3**	**b**	**4**	**c**	**5**	**d**
6	**b**	**7**	**d**	**8**	**b**	**9**	**a**	**10**	**c**

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