CL-304

Sulfur Production & its Derivatives

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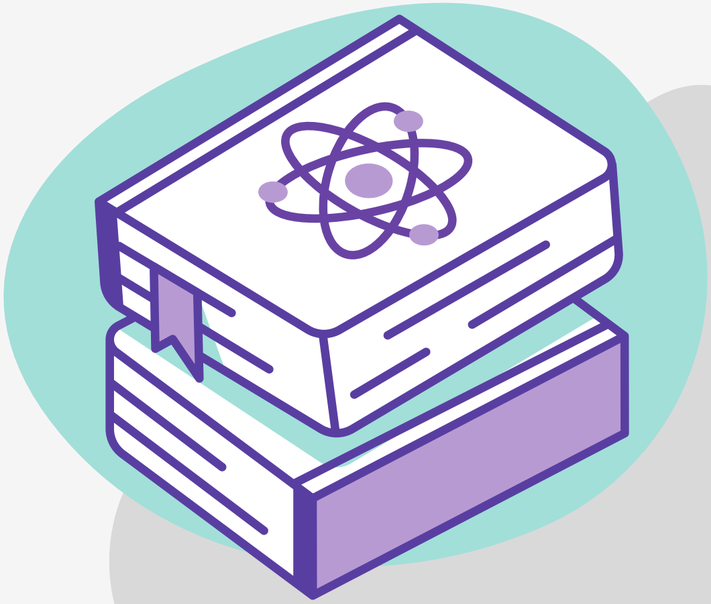
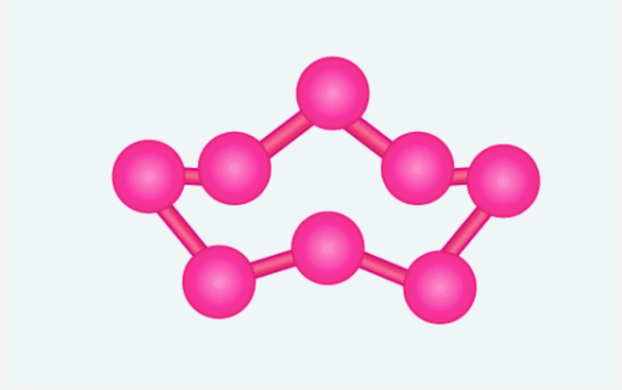
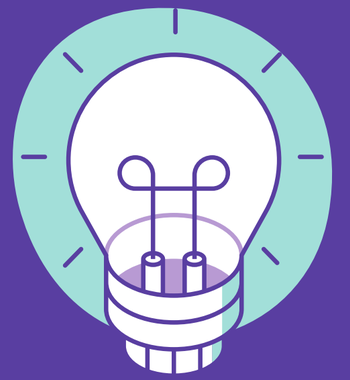


Sulfur



- Sulfur is a chemical element with the symbol 'S' and atomic number 16.
- It is a non-metallic, yellow, brittle solid that is odorless in its pure form.
- Major producers: United States, Russia, China, Canada, and Saudi Arabia.
- Under normal conditions, sulfur atoms form cyclic octatomic molecules with the chemical formula S8

Uses of Sulfur



Agriculture
Essential nutrient for plant growth; used in fertilizers.

Chemical Industry
Key raw material for sulfuric acid and various chemicals.

Petroleum Refining
Necessary for removing sulfur compounds from crude oil and natural gas.

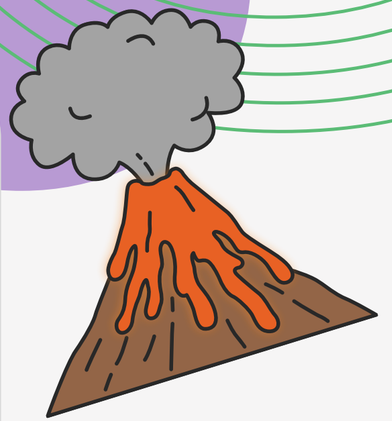
Mining and Metallurgy
Used in the extraction of metals and production of alloys.

Pharmaceuticals
Used in the production of drugs and antibiotics.

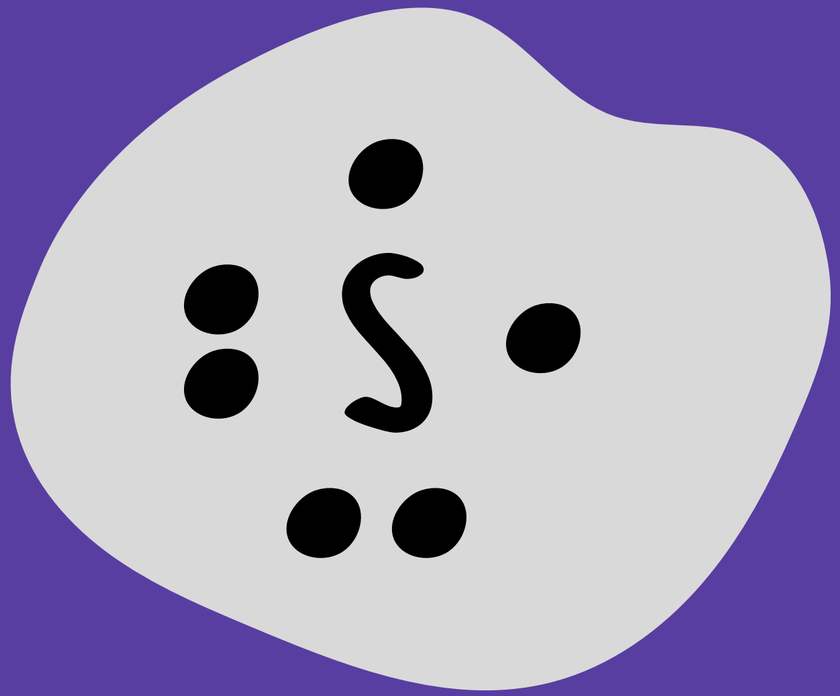
Food Industry
Used as preservatives in food and beverages.

Natural Sources of Sulfur

- **Volcanic Eruptions:** Significant contributor to atmospheric sulfur levels; common in volcanic regions like the Pacific Ring of Fire.
- **Hydrogen Sulfide** (H_2S) in Natural Gas and Crude Oil: Found in natural gas and crude oil reservoirs; separated and processed to recover elemental sulfur.
- **Sulfide Minerals in Metal Ores**: Present in ores like pyrite, galena, and sphalerite; extracted during mining and metallurgical processes.
- **Organic Sulfur in Biomass and Soil**: Found in plants, animals, and soils; released through decomposition and microbial activity.
- **Sulfate Minerals and Evaporites:** Found in sedimentary rocks and salt deposits; weathering and erosion contribute to sulfur content in soils and water bodies.

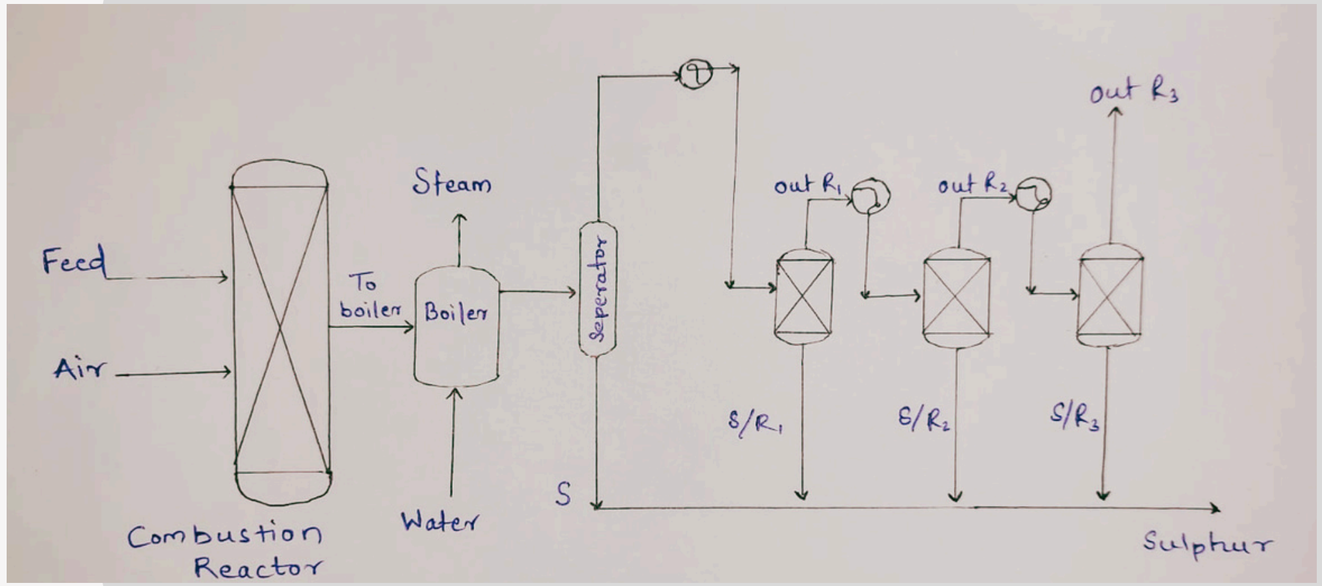


Sulfur Recovery from Natural Gas and Oil



- **Claus Process:** Widely used method involving thermal and catalytic reactions to convert hydrogen sulfide (H_2S) to elemental sulfur.
- **Amine Treating:** Chemical absorption process to remove H_2S and other sulfur compounds from natural gas and oil.
- **Tail Gas Treatment:** Purification process to recover sulfur from the tail gas of the Claus Process, increasing overall sulfur recovery efficiency.
- **Chelated Iron Process:** Chemical absorption using chelating agents to remove H_2S from gas streams, followed by regeneration of the chelating agent and sulfur recovery.

Claus Process



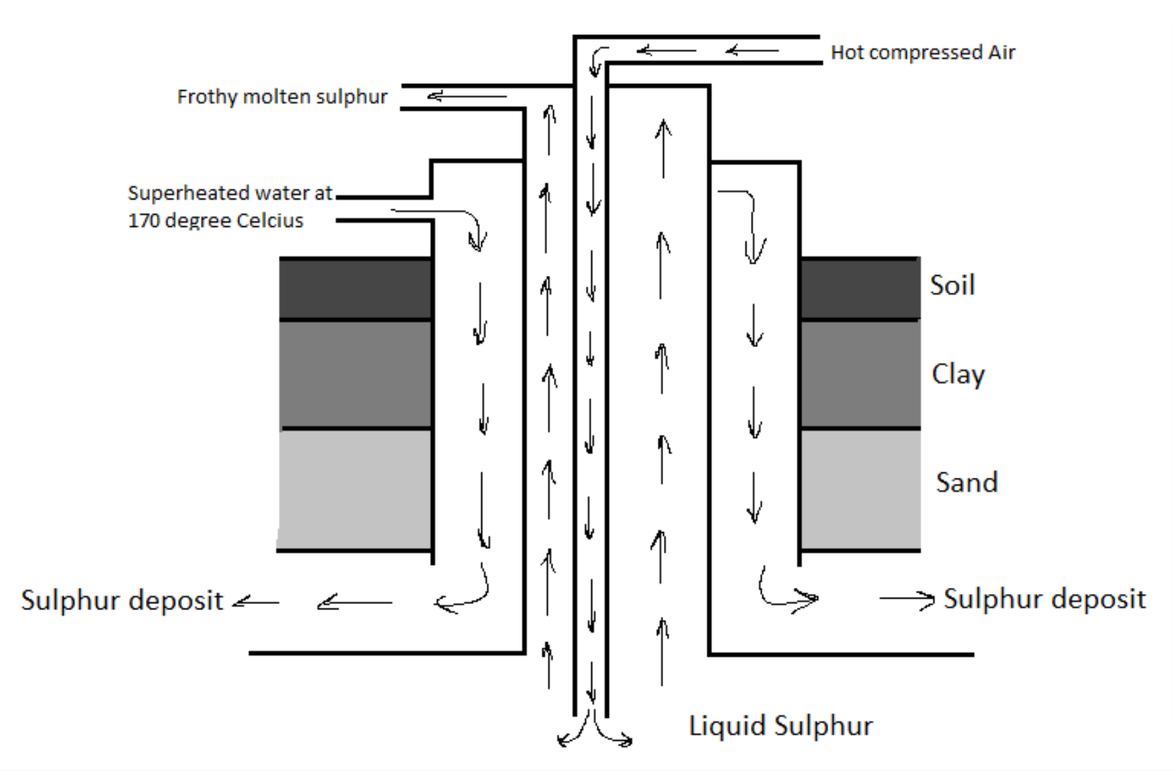
- Converts hydrogen sulfide (H2S) to elemental sulfur through a series of thermal and catalytic reactions.
- Typically recovers 95-99% of sulfur from hydrogen sulfide streams, making it a widely adopted method in the industry.
- It also has environmental benefits i.e. it reduces sulfur emissions and minimizes environmental impact by converting toxic H2S into useful elemental sulfur.

Tail Gas Treatment

Tail gas refers to the residual gas stream produced after the Claus Process. The tail gas contains unreacted hydrogen sulfide, sulfur dioxide, and other sulfur compounds

- Advanced Amine Scrubbing: Utilizes specialized amine solutions to capture and recover sulfur compounds from tail gas, improving overall sulfur recovery efficiency.
- Oxidative Tail Gas Treatment: Involves oxidation of residual sulfur compounds to elemental sulfur or sulfur dioxide, which can be recovered or safely vented.
- Cryogenic Separation: Uses low-temperature processes to condense and separate sulfur compounds from tail gas, allowing for higher purity and recovery rates.

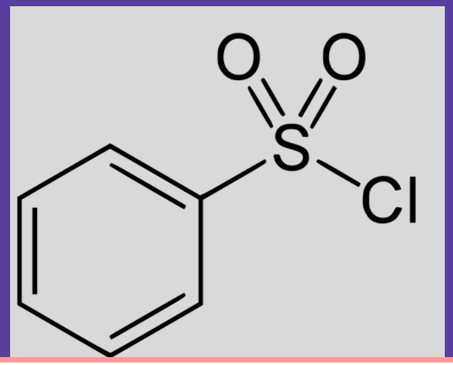
Frasch Process



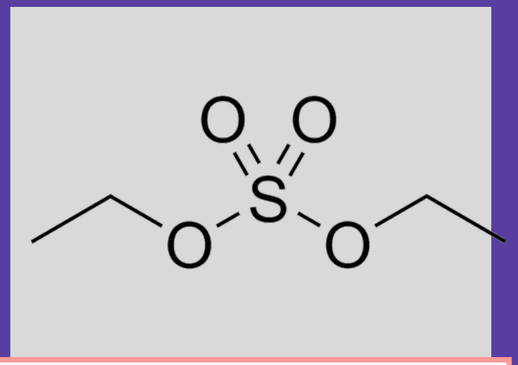
Ref. Vedantu

- In Frasch process we extract sulfur from underground deposits by taking advantage of the low melting point of sulfur.
- Superheated water (165 ˚C, 2.5-3 MPa) is injected into the deposit via the outermost tube.
- Sulfur (m.p. 115 ˚C) melts and flows into the middle tube.
- Water pressure alone is unable to force the sulfur into the surface due to the molten sulfur's greater density, so hot air is introduced via the innermost tube to froth the sulfur, making it less dense, and pushing it to the surface.

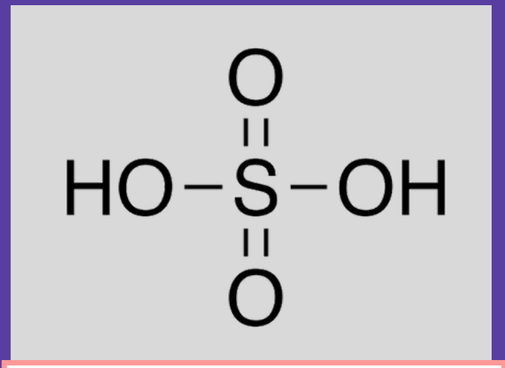
Sulphur Derivatives



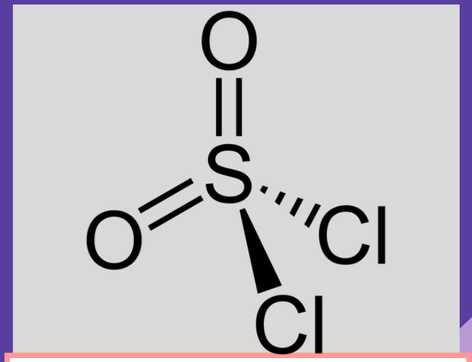
Benzene sulfonyl chloride



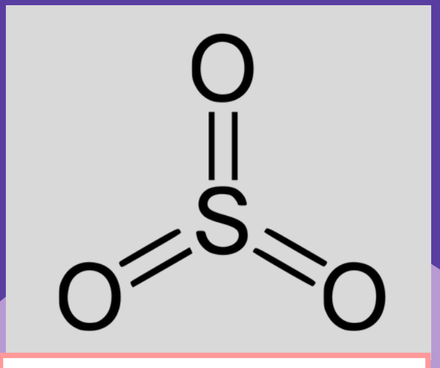
Diethyl sulfate



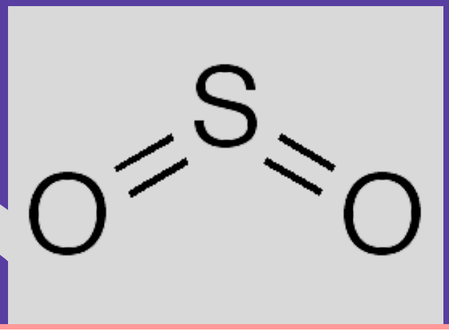
Sulfuric acid



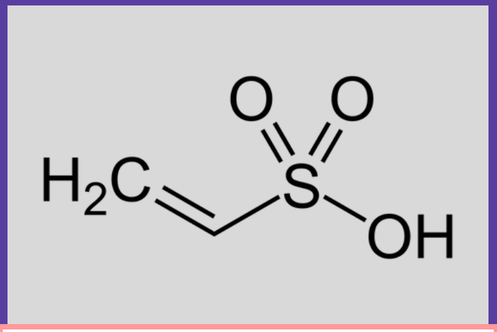
Sulfuryl chloride



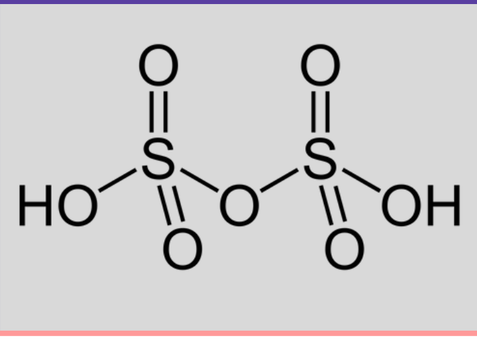
Sulphur trioxide



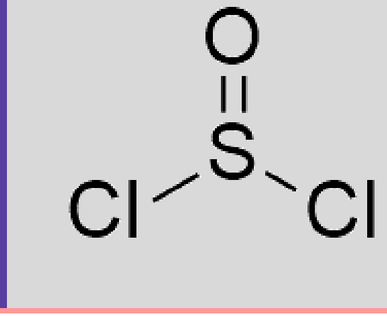
Sulfur dioxide



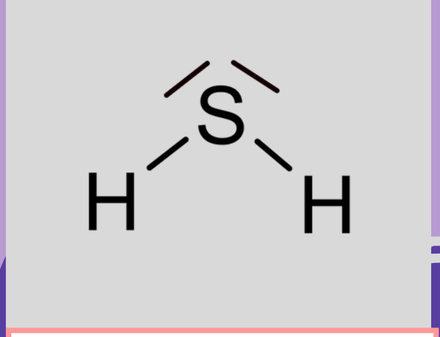
Vinyl sulfonate



Oleum 65%



Thionyl chloride



Hydrogen Sulphide

Sulphuric Acid

Sulfuric acid is a colorless, oily liquid with a high boiling point of 337°C and a density of 1.84 g/cm^3. Highly corrosive, it can cause severe burns and reacts violently with organic materials and certain metals. It is hygroscopic, absorbing water vapor for drying processes, and generates heat when mixed with water. Additionally, it is a diprotic acid, capable of donating two protons in acid-base reactions. The different production methods are **Contact Process, Lead Chamber Process, Wet Sulphuric Acid Process etc.**

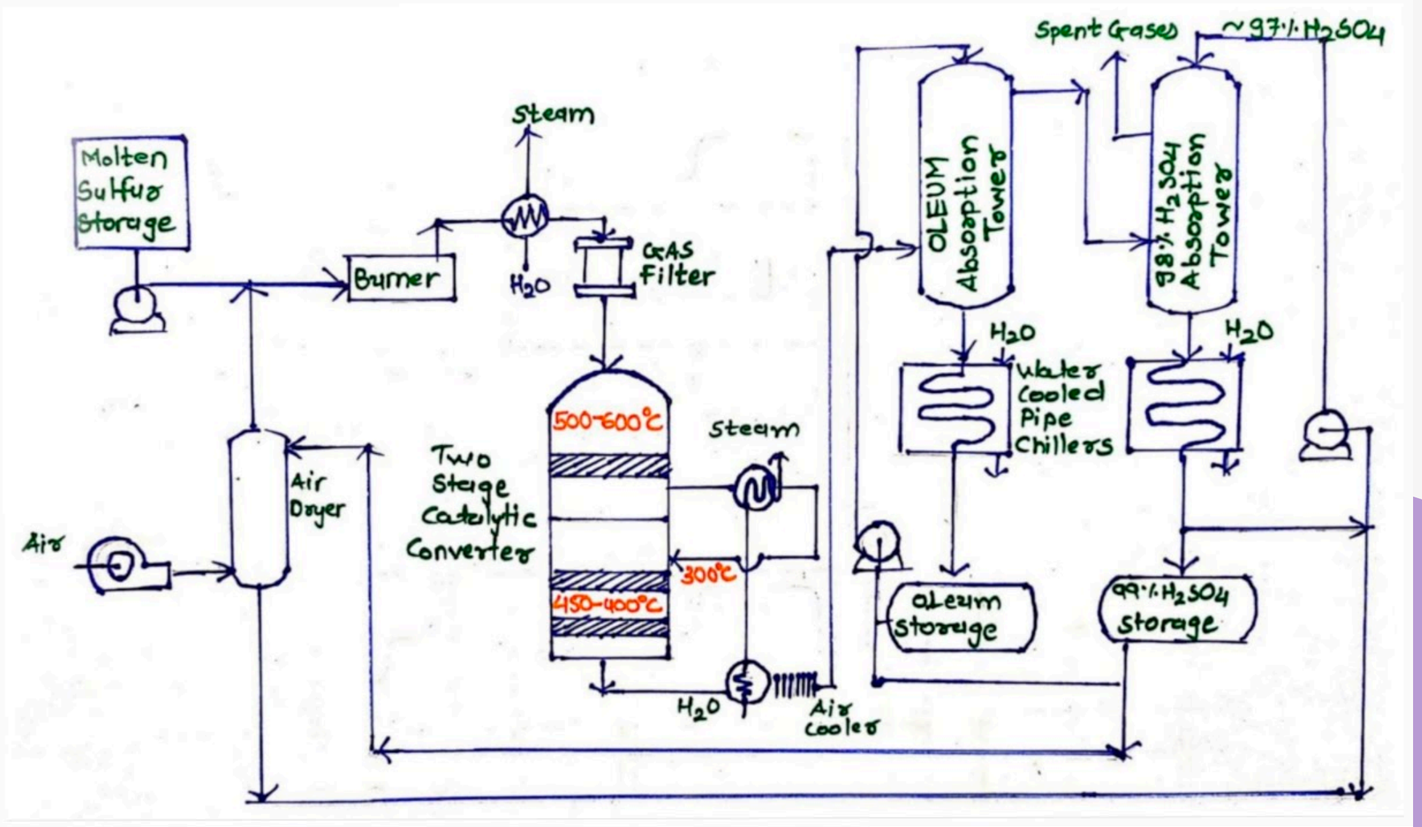
1. Contact Process:

- Sulfur dioxide (SO2) is oxidized to sulfur trioxide (SO3) using a vanadium(V) oxide catalyst.
- Operates at elevated temperatures typically around 400-450°C.
- The produced SO3 is absorbed in concentrated sulfuric acid to form oleum (fuming sulfuric acid).
- Oleum is diluted with water to produce various concentrations of sulfuric acid,

$$2SO_2 + O_2 \rightarrow 2SO_3$$

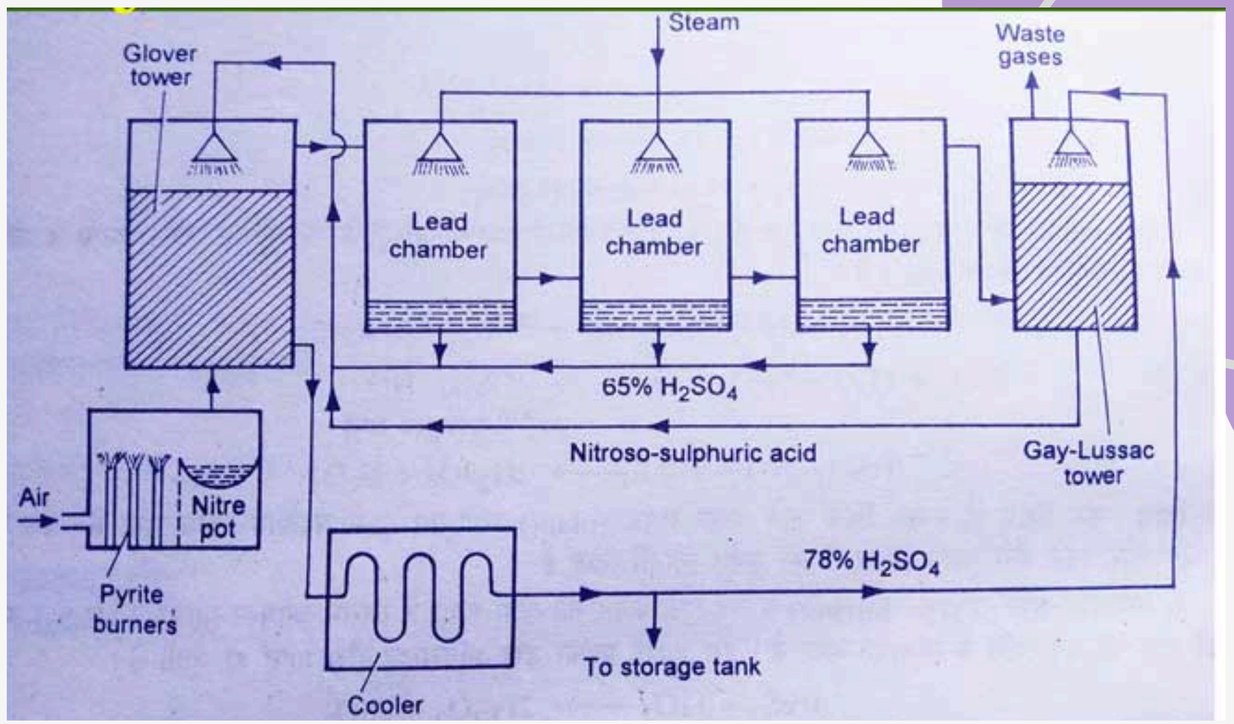
$$H2SO_4 + SO_3 \rightarrow H_2S_2O_7$$

$$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$$



2. Lead Chamber Process:

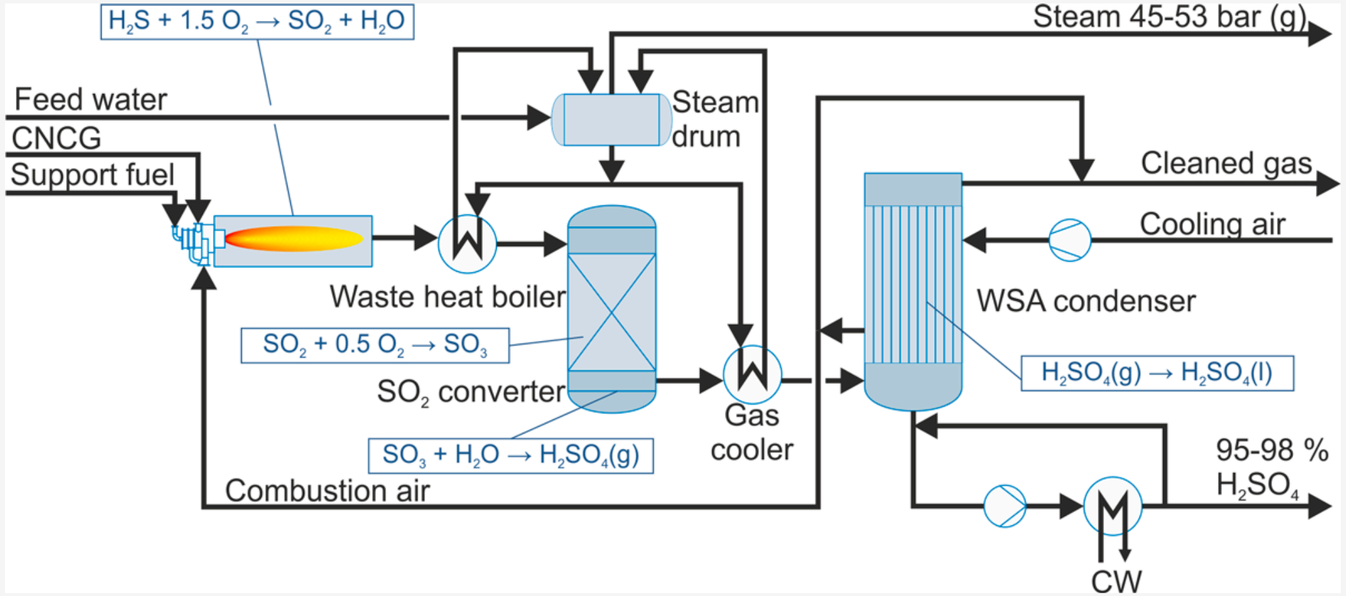
- Sulfur dioxide (SO2) reacts with nitrogen oxides in a lead-lined chamber to produce sulfur trioxide.
- Operates at moderate temperatures and atmospheric pressure.
- The produced sulfur trioxide is absorbed in water to form sulfuric acid.
- Traditional process largely replaced by the Contact Process but still used for specialized applications.



Ref. Chemistry Page

3. Wet Sulphuric Acid Process:

- Hydrogen sulfide (H2S) is oxidized to elemental sulfur using a vanadium-based catalyst.
- Operates at elevated temperatures, typically around 200-300°C.
- The produced elemental sulfur is further oxidized to sulfur dioxide and then to sulfur trioxide.
- Sulfur trioxide is absorbed in water to form sulfuric acid.
- Known for its high efficiency and ability to recover sulfur from various feedstocks.



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Hydrogen Sulphide

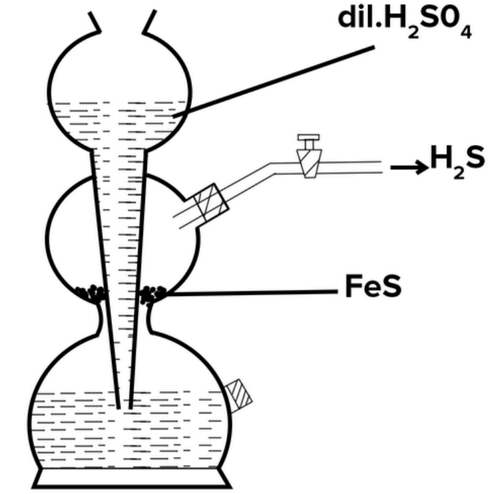
Hydrogen sulfide (H_2S) is a colorless, flammable gas with a characteristic foul odor resembling rotten eggs. It has a boiling point of -60.3°C and a density of 1.363 kg/m^3 at standard conditions. Highly toxic, even at low concentrations, it can cause respiratory issues and is considered a chemical hazard. H_2S is also corrosive to metals, especially in the presence of moisture. It is soluble in water and acts as a weak acid in aqueous solutions, capable of donating a proton in acid-base reactions.

1. Kipp's Apparatus Method:

- A metal sulfide, usually ferrous sulfide (FeS) or calcium sulfide (CaS), is placed in the upper chamber of the Kipp's apparatus.
- Dilute hydrochloric acid (HCl) or sulfuric acid (H_2SO_4) is added to the lower chamber.
- As the acid reacts with the metal sulfide, hydrogen sulfide gas (H_2S) is liberated and collected in the upper chamber of the apparatus.
- Reaction Equation:

  $FeS + 2HCl \rightarrow FeCl_2 + H_2S$

  $CaS + 2HCl \rightarrow CaCl_2 + H_2S$



Kipp's apparatus

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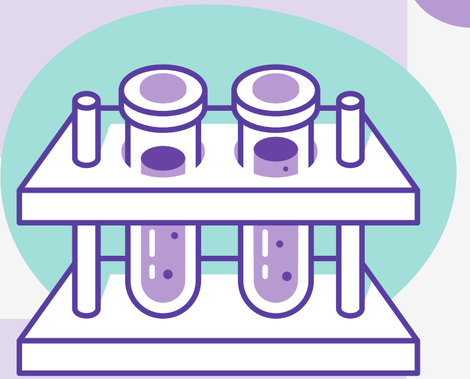
2. Thermal Decomposition of Metal Sulfides:

- Metal sulfides, such as copper sulfide (CuS) or lead(II) sulfide (PbS), are heated in a suitable apparatus or crucible to temperatures typically ranging from 500°C to 1000°C.
- As the metal sulfide decomposes, it produces the corresponding metal oxide and hydrogen sulfide gas.
- The hydrogen sulfide gas is then collected and purified using appropriate methods, such as gas washing or condensation.
- .Reaction Equation:

  $CuS \rightarrow CuO + H_2S$

  $PbS \rightarrow PbO + H_2S$



3. Industrial Processes :

- **Claus Process:**
  - Converts sulfur-containing compounds like H_2S and SO_2 in natural gas or crude oil into elemental sulfur and water through thermal decomposition and catalytic reactions.
- **Hydrodesulfurization (HDS) Process:**
  - Removes sulfur compounds from crude oil and refined petroleum products by reacting them with hydrogen in the presence of a catalyst, producing hydrogen sulfide (H_2S) as a by-product.
- **Acid Gas Removal Processes:**
  - Absorbs and removes acidic gases, including H_2S and CO_2, from natural gas and other gas streams using solvents or amine solutions, followed by regeneration to recover and purify the absorbed H_2S.

Sulphur Dioxide

Sulfur Dioxide (SO_2) is a colorless gas with a pungent odor, often described as similar to a burnt match or the smell of a struck matchstick. It has a boiling point of -10°C and a density of 2.927 kg/m^3 at standard conditions. SO_2 is a respiratory irritant and can cause breathing difficulties, especially in individuals with pre-existing respiratory conditions. It is also a chemical hazard and can be harmful to the environment. SO_2 is soluble in water and forms sulfurous acid, acting as an acidic oxide in aqueous solutions by donating protons in acid-base reactions.

1. Roasting of Metal Sulfide Ores:

- In metallurgical processes, metal sulfide ores, such as copper sulfide or zinc sulfide, are heated in the presence of oxygen to produce metal oxides and sulfur dioxide.
- The roasting process involves the thermal decomposition of metal sulfides to release sulfur dioxide gas.
- Reaction Equation:
  Metal Sulfide Ore+Oxygen→Metal Oxide+Sulfur Dioxide

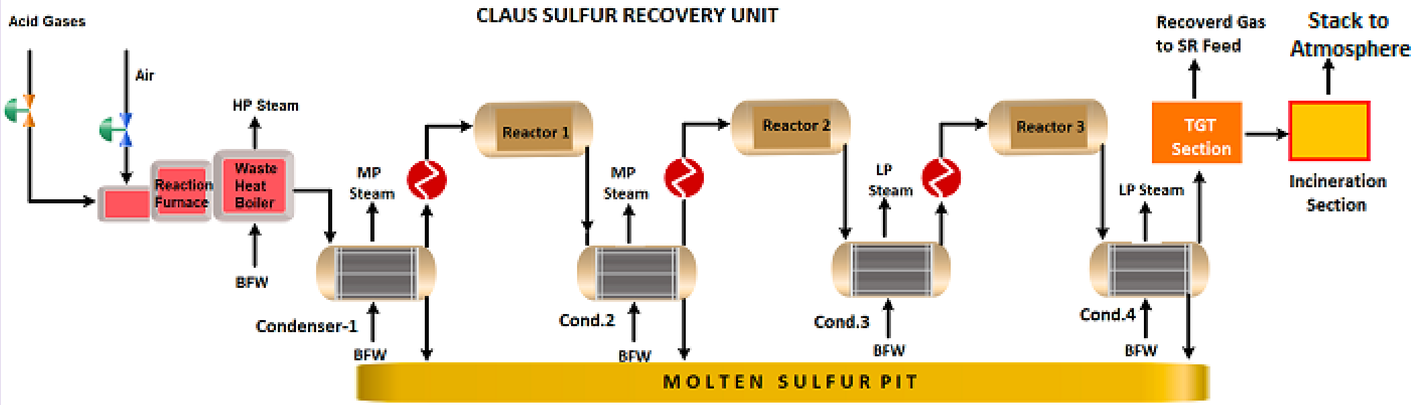
$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$
$$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$$
$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

2. Contact Process

The Contact Process is the most common industrial method for producing sulfur dioxide. It involves the combustion of sulfur to produce sulfur dioxide, which is then used to produce sulfuric acid in subsequent reactions.

3. Sulfur Recovery Units (SRU)

Sulfur Recovery Units are used in oil refineries and natural gas processing plants to convert hydrogen sulfide (H2S) into elemental sulfur and sulfur dioxide. The process involves the partial combustion of H2S to produce sulfur dioxide and water vapor, which can then be further processed to recover elemental sulfur.



Ref. The Petro Solutions

Reference

1. https://chemistrypage.in/preparation-of-sulfuric-acid
2. https://thepetrosolutions.com/sulfur-recovery-unit-sru/
3. Wikipedia
4. Chapter 8 - Sulfur Recovery Processes by Arthur L. Kohl, Richard B. Nielsen
5. https://www.nuroil.com/sulphur-production-and-uses.aspx
6. https://www.azelis.com/en/markets/fine-chemicals/products/sulphur-derivatives

Thank you for listening!