The Industrial Production of

Sulfuric Acid

Ahmad Shah Idil; 12AB

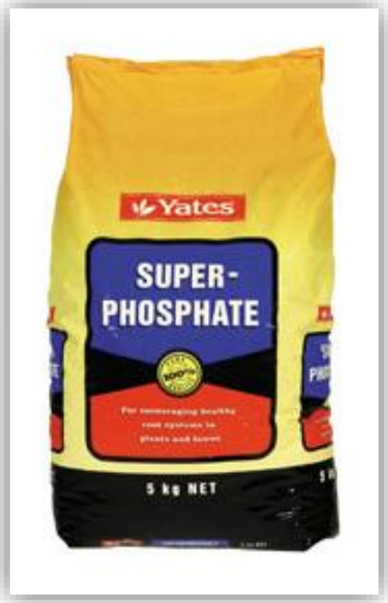
9.5.3 – Present information to **describe** the steps and chemistry involved in the industrial production of sulfuric acid and **analyse** the process to **predict** ways in which the output of sulfuric acid can be maximized.

Uses of Sulfuric Acid

Car Batteries

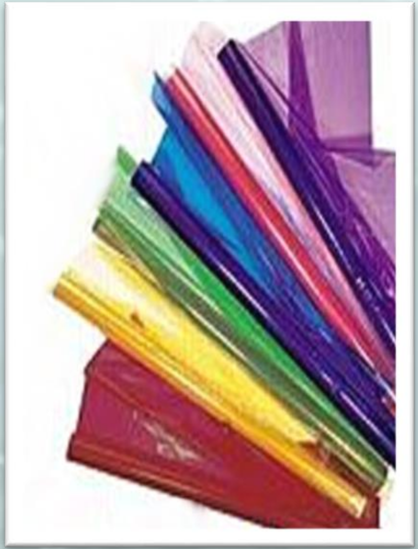
Dyes & Pigments

Fertilisers

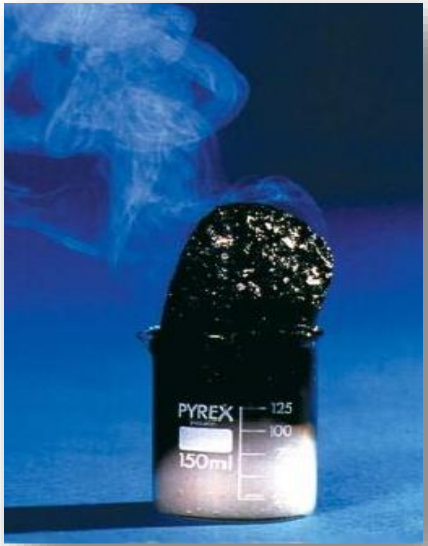


More Uses…

Explosives

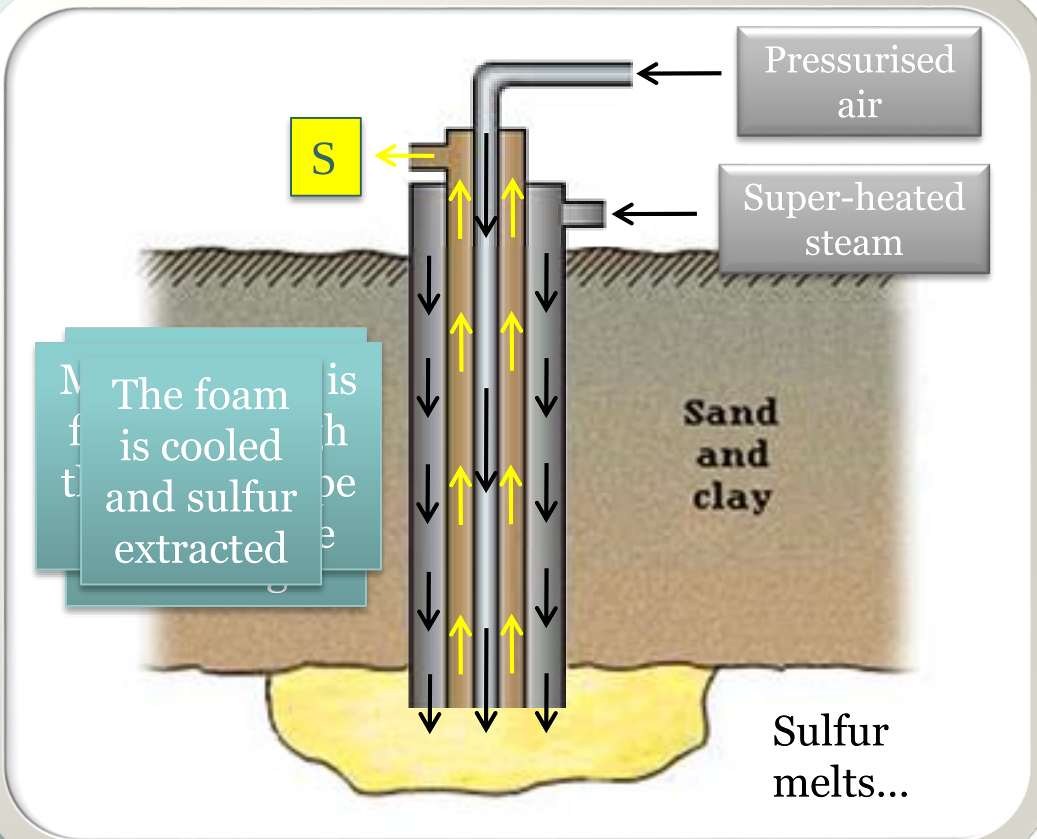


Cellophane

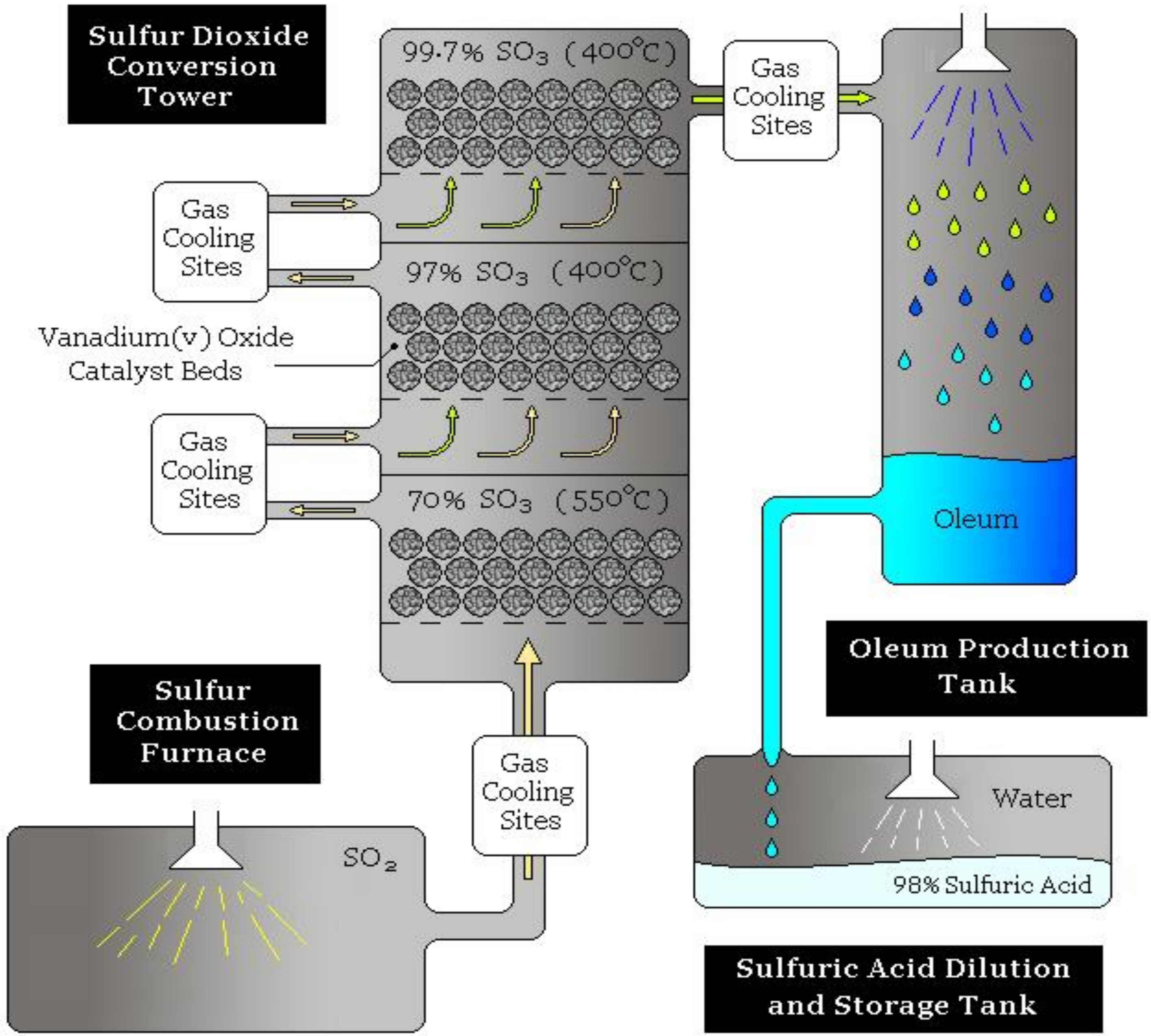


Dehydrating Agent

Sulfur Extraction



The Sulfur Product



Sulfur Dioxide Conversion Tower
99.7% SO_3 (400°C)
Gas Cooling Sites
Gas Cooling Sites
97% SO_3 (400°C)
Vanadium(v) Oxide Catalyst Beds
Gas Cooling Sites
70% SO_3 (550°C)
Oleum
Oleum Production Tank
Sulfur Combustion Furnace
Gas Cooling Sites
SO_2
Water
98% Sulfuric Acid
Sulfuric Acid Dilution and Storage Tank

Sulfur Combustion

- Sulfur is liquefied, and sprayed into a **combustion furnace** containing an excess of dry air at atmospheric pressure. The liquefaction of the sulfur greatly increases its surface area, and the excess air promotes the reaction.
- The resulting reaction is strongly exothermic and goes to completion:

$$S_{(l)} + O_{2(g)} \xrightarrow{\Delta} SO_{2(g)}$$

sulfur   oxygen   sulfur dioxide

Catalytic Conversion

- The conversion of sulfur dioxide (SO_2) into sulfur trioxide (SO_3) is the most difficult step of the process.
- This is because the conversion is an equilibrium reaction, and as such yield and rate considerations must be made:

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

sulfur dioxide | oxygen | sulfur trioxide

$$\Delta H = -99\,kJ/mol$$

Equilibrium Considerations

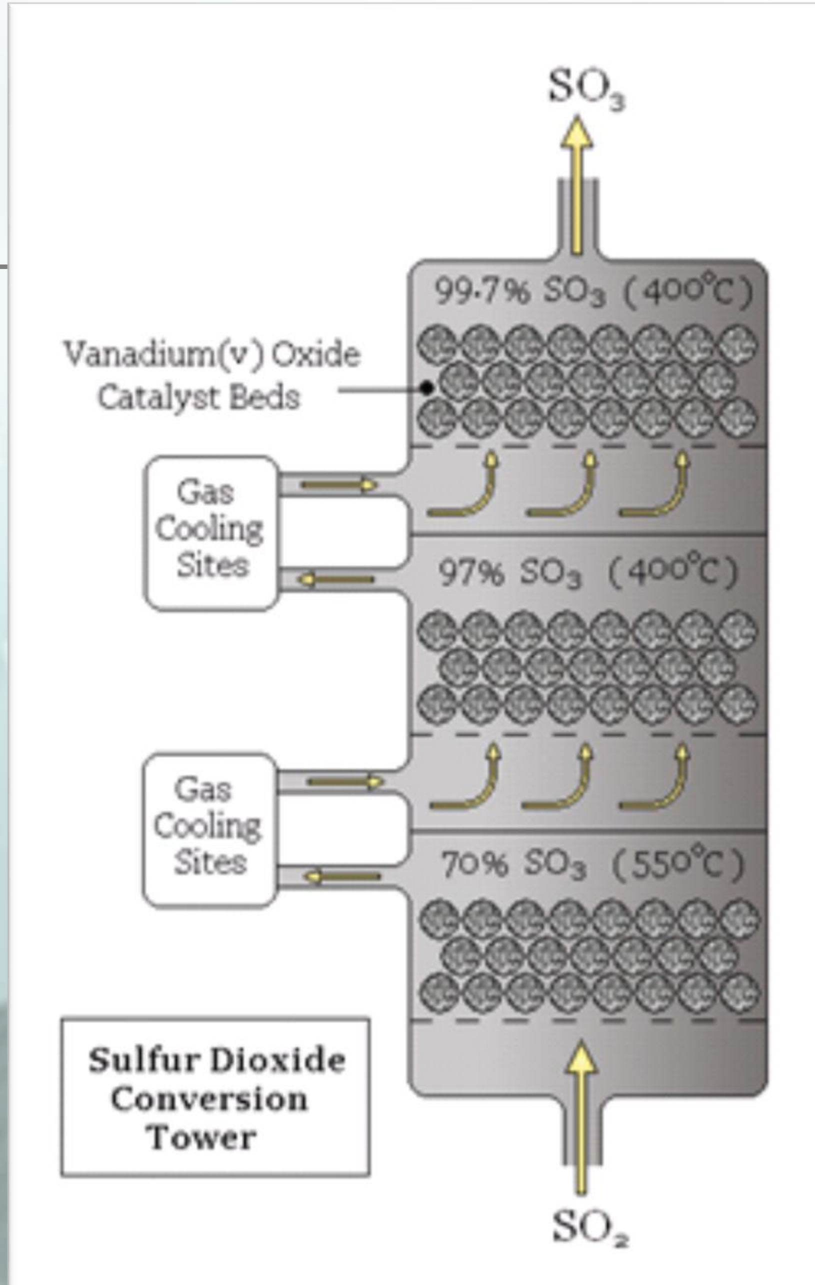
- According to the **Le Chatelier's Principle**, the output can be maximised by:
  - Using a LOW temperature; lower temperatures encourage the counter-acting heating effect of the exothermic forward reaction, to re-establish equilibrium with a higher yield.
  - Using HIGH pressure; there are 2 moles of product gas, compared to 3 moles of reactant gas, so a higher pressure will encourage the pressure-reducing forward reaction, as it produces less moles of gas.
  - Using an EXCESS of oxygen; this forces the equilibrium to the right, creating more product.
- However, these are PURELY equilibrium considerations, which only relate to yield. In an industrial process, the rate of reaction, is also important.

Rate Considerations

- In any chemical reaction, the rate of reaction **increases** as the temperature increases.
- This is because greater thermal energy means greater kinetic energy, which leads to more collisions between reactant molecules, and hence more reactions can occur.
- Hence, to **maximize** the output of sulfur trioxide:
  - A HIGH temperature favours a fast reaction
  - A CATALYST is used to speed up the reaction

The Compromise Reaction

- Through analysing the reaction, with all of the above, industrial chemists have decided on compromise conditions for this step of the contact process, in order to maximise the yield of sulfur trioxide, and hence the yield of sulfuric acid. The conditions are:
  - A pressure of a little above atmospheric (100 kPa; large pressures, are not used, even though it would increase the yield, because high pressure equipment is expensive and dangerous to build and maintain).
  - A small excess of oxygen.
  - A catalyst of vanadium(V) oxide is used.
  - Moderate temperature ranging from 400-550°C.



SO_3
99.7% SO_3 (400°C)
Vanadium(v) Oxide Catalyst Beds
Gas Cooling Sites
97% SO_3 (400°C)
Gas Cooling Sites
70% SO_3 (550°C)
Sulfur Dioxide Conversion Tower
SO_2

Oleum Production

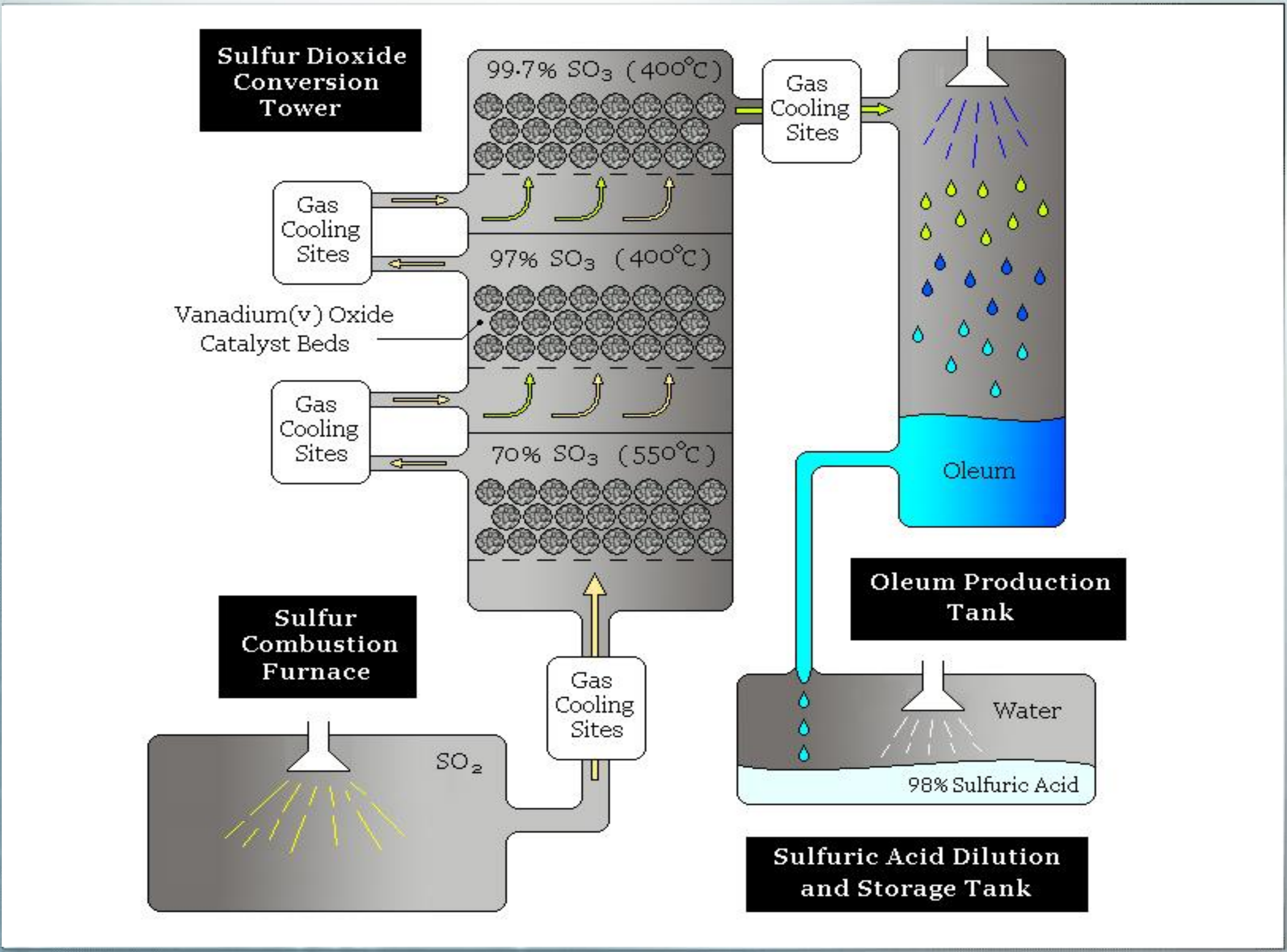
- Sulfur trioxide + water = BOOM (i.e. **not good**)
- Instead, the 99.7% SO_3 that leaves the conversion tower is dissolved into a stream of concentrated sulfuric acid, forming *oleum* ($H_2S_2O_7$).
- The sulfur trioxide dissolves very easily into sulfuric acid, and the reaction is stable:

$$\underset{\text{sulfur trioxide}}{SO_{3\,(g)}} + \underset{\text{sulfuric acid}}{H_2SO_{4\,(l)}} \longrightarrow \underset{\text{oleum}}{H_2S_2O_{7\,(l)}}$$

Final Dilution

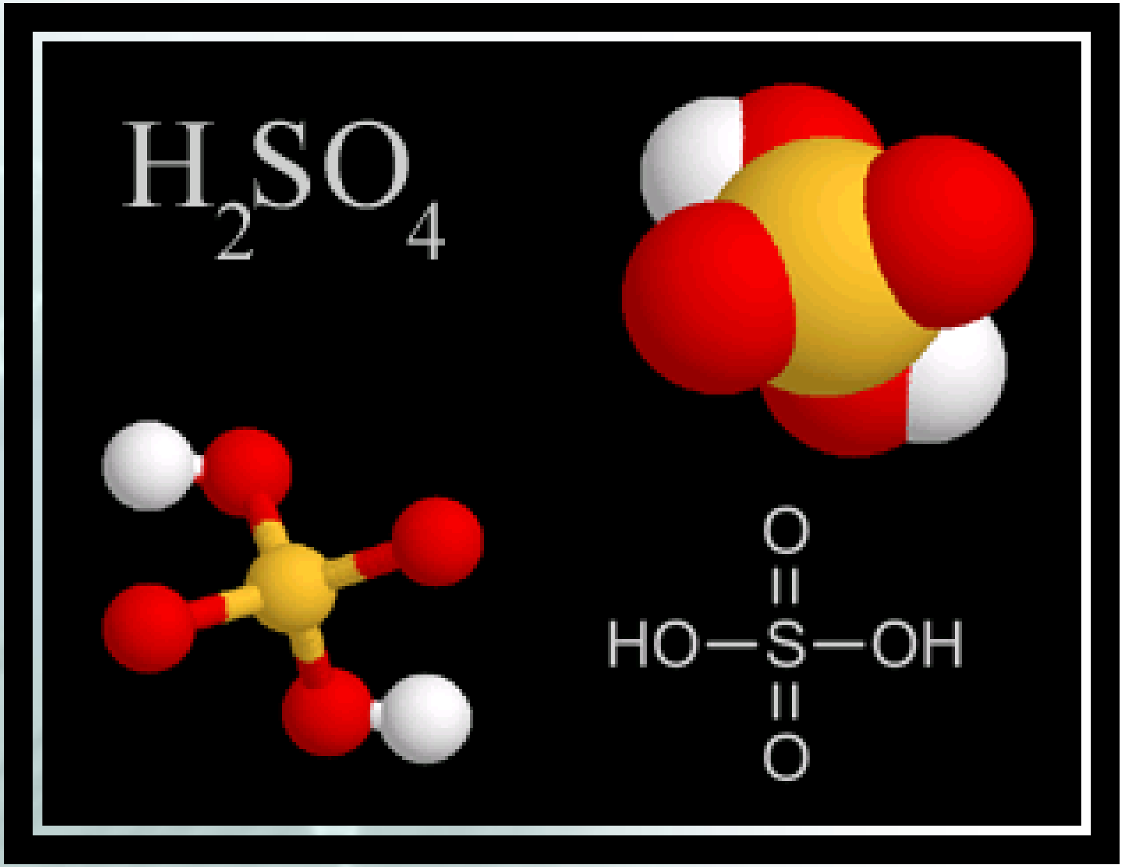
- Lastly, the oleum is diluted with distilled water
- This forms 98% concentration sulfuric acid
- This dilution is stable, and continuously carried out:

$$\underset{\text{oleum}}{H_2S_2O_{7\,(l)}} + \underset{\text{water}}{H_2O_{(l)}} \longrightarrow \underset{\text{sulfuric acid}}{2\,H_2SO_{4\,(l)}}$$



Sulfur Dioxide Conversion Tower
99.7% SO3 (400°C)
Gas Cooling Sites
Gas Cooling Sites
97% SO3 (400°C)
Vanadium(v) Oxide Catalyst Beds
Gas Cooling Sites
70% SO3 (550°C)
Oleum
Oleum Production Tank
Sulfur Combustion Furnace
Gas Cooling Sites
SO2
Water
98% Sulfuric Acid
Sulfuric Acid Dilution and Storage Tank

Final Product



References

Printed Material:

Farrelly, R., Garnett, P., Irwin, D., Vitlin, D. 2002, *Chemistry Contexts 2,* **Pearson Education Australia**, Sydney.

Roebuck, C. M. 2000, *Excel HSC: Chemistry*, **Pascal Press**, Singapore.

Smith, R. 2005, *Conquering Chemistry: HSC Course* (4^{th} edn.), **McGraw Hill Australia**, Sydney, pp. 330-336.

The New Encyclopædia Britannica, 1987, Vol. 16, *Sulphuric Acid* (15^{th} edn.), **Encyclopædia Britannica**, **Inc**, Chicago.

Electronic Data:

Encyclopædia Britannica, 2007, *Sulfuric Acid*, **Britannica Concise Encyclopedia**, viewed August 15, 2007, <http://concise.britannica.com/ebc/article-9379847/sulfuric-acid >

Encarta® 99 Encyclopedia, 1999, *Sulphuric Acid,* © 1993-1998 **Microsoft Corporation**. All rights reserved.

Encarta® 99 Encyclopedia, 1999, *Contact Process,* © 1993-1998 **Microsoft Corporation**. All rights reserved.

194.200.130.xxx, et al. 2001, *Sulfuric Acid*, Last updated 00:57, 16 August 2007, by 202.61.139.34 **The Wikipedia Foundation**, viewed 16 August, 2007. <http://en.wikipedia.org/wiki/Sulfuric_acid>