

THE CONTACT PROCESS

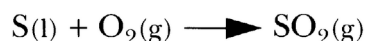
Sulfuric acid is made cheaply on a large scale by the **Contact process**. This is a multistep process which relies on the interplay between rate and equilibrium considerations for its success.

Four major steps are involved in the Contact process:

1. oxidation of S to SO_2
2. catalytic oxidation of SO_2 to SO_3
3. the absorption of the SO_3 by previously prepared sulfuric acid to produce oleum, $\text{H}_2\text{S}_2\text{O}_7$
4. the dilution of the oleum with water to make sulfuric acid.

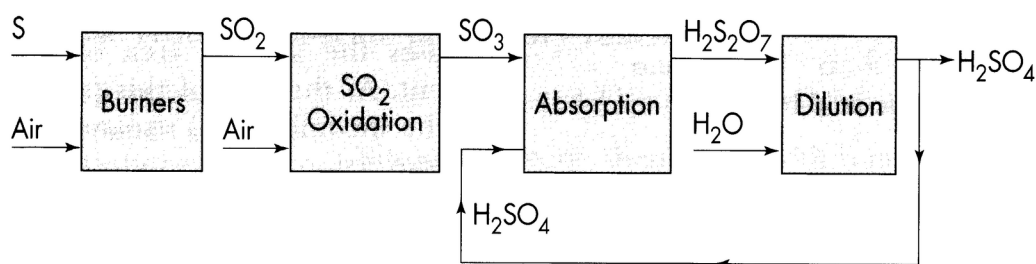
Oxidation of sulfur

To begin the Contact process, sulfur dioxide is required. This is usually obtained simply by burning elemental sulfur in air, according to:



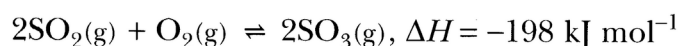
This reaction proceeds easily and complete conversion into sulfur dioxide is achieved. An unusual feature of this reaction, however, is that even in a large excess of air, the lower oxidation state oxide is obtained. Usually, where

an element has more than one oxide, a plentiful supply of air will produce the higher oxidation state oxide. This is the case for carbon (where the oxides concerned are CO and CO_2) and for phosphorus (P_2O_3 and P_2O_5). With sulfur, however, the higher oxide, SO_3 , does not form in excess air. Hence a special step in the Contact process is required to bring this about.



Oxidation of sulfur dioxide

The most critical step in the Contact process is the oxidation of the sulfur dioxide. The equation for this step is:



This reaction is a good example of the dilemma that is often faced by a chemical engineer. At normal temperatures, the value of the equilibrium constant is relatively high but the reaction rate is too slow. If, however, the temperature is increased to bring about a better rate, the yield of sulfur trioxide quickly begins to suffer. This is because the above reaction

is exothermic and, as temperature is increased, the value of its equilibrium constant therefore decreases.

Two of the most important industrial considerations (yield and rate) are therefore in conflict with one another. Hence, the ultimate design of the plant and its operating conditions must reflect a compromise between these two factors.

A closer look at plant design, however, reveals that we can lessen the effect of this compromise in a number of ways. These are:

- (a) Use a suitable catalyst to help obtain the rate required. This means that the temperature needed will be lower than that needed without a catalyst. The use of a lower temperature will thus increase the yield by indirectly increasing the value of the equilibrium constant.

In practice, a catalyst consisting of vanadium pentoxide, V_2O_5 , is used, operating at a temperature of around about 400°C .

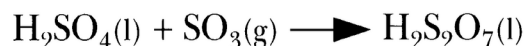
- (b) Use a moderate excess of air. According to Le Chatelier's principle, this will increase the amount of SO_3 produced.
- (c) Compress the gases so that the reaction is carried out at high pressure. Le Chatelier's principle predicts that if a system is pressurised, it will try to reduce such pressure. Consequently, there should be a tendency to reduce the number of particles that are present. In this case, this means that the equilibrium will shift to the right, as the forward reaction converts three molecules into two molecules, favouring the production of SO_3 .

In practice, however, the use of high pressures is not necessary. When all the above considerations are employed, the yield of SO_3 at atmospheric pressure is good enough to preclude the extra costs associated with high pressure equipment. This is an example of how the economics of a process are just as important as the chemistry when it comes to plant design.

- (d) Finally, as sulfur dioxide is a serious atmospheric pollutant, it is important that as much SO_2 be converted into SO_3 as possible. This also makes sound economic sense. To achieve this, the reacting mixture is passed over a number of 'beds' in which the V_2O_5 catalyst is present. The mixture is cooled in between one bed and the next to prevent the temperature rising too much and therefore affecting the yield. This arrangement is also good from a rate point of view as it increases the surface area of the catalyst, thus making it more efficient. At the end of this process, any unreacted SO_2 is recycled into the incoming SO_2 stream at the start of this step. The result is that conversion rates very close to 100% can be obtained.

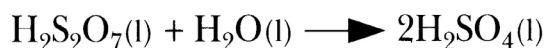
The absorption of sulfur trioxide

The step after conversion to SO_3 involves the absorption of this gas into previously prepared sulfuric acid. This is achieved by admitting the SO_3 to the base of a tall tower and admitting sulfuric acid to the top of the tower. The sulfuric acid, being a liquid, trickles down special vertical plates inside the tower. Oleum, or 'fuming sulfuric acid', is made on contact with the rising SO_3 , the equation being:



Dilution of oleum

The oleum thus produced is then mixed with the stoichiometric amount of water to make 98% sulfuric acid:



The direct reaction of SO_3 with water is not used in the absorption stage, owing to the large amounts of heat evolved. This would lead to the formation of sulfuric acid mist inside the absorption tower which would take a long time to settle out. In addition, SO_3 is more soluble in liquid sulfuric acid than it is in water.