**3 C Synthesis of Sulphuric Acid (the contact process)**

The contact process is the industrial manufacture of sulphuric acid from either sulphur, as shown in the chemical reaction below, or iron sulphide.

2S(s) + 3 O2 (g) + 2 H2O(l) → 2 H2S04 (l)

The contact process comprises three main steps:

* the production of sulphur dioxide
* a reversible reaction that converts the sulphur dioxide into sulphur trioxide
* the conversion of the sulphur trioxide into concentrated sulphuric acid.

Only the conversion from sulphur dioxide to sulphur trioxide is reversible; the other two processes are irreversible.

**Production of sulphur dioxide**

Sulphur dioxide is produced by burning sulphur in an excess of air:

S(s) + O2 (g) → SO2 (g)

Sulphur dioxide can also be produced by the combustion of sulphide ores, like pyrite, in an excess of air:

Using an excess of air means that the sulphur dioxide is already mixed with oxygen for the next stage.

**Converting sulphur dioxide into sulphur trioxide**

The conversion of sulphur dioxide into sulphur trioxide is a reversible reaction with the formation of sulphur trioxide being exothermic:

2S02 (g) + O2 (g) ⮀ 2 S03 (g) ΔH = -196 kJ mol- 1

***Optimising the yield***

According to Le Chatelier's principle, excess oxygen shifts the equilibrium to the right-hand (product) side to partially reduce the concentration of oxygen.

As highlighted above, the forward reaction to produce sulphur trioxide is exothermic (W = -196 kJ mor1). Therefore, according to Le Chatelier's principle the forward reaction will be favoured by a lower temperature as the equilibrium will shift to counter this by producing more heat through the exothermic reaction.

In the industrial process, the temperature is between 400 and 450°C, which is not very low. This is because as the temperature is reduced, the rate of the reaction decreases. To produce a sufficient amount of sulphur trioxide per day a compromise must be reached.

On the left-hand (reactant) side of the equilibrium there are three gaseous molecules compared to two gaseous molecules on the right-hand (product) side. Therefore, according to Le Chatelier's principle, increasing the pressure will shift the equilibrium to the right as the reaction will respond by partially reducing the pressure, i.e. favour the side of the reaction with fewer gaseous molecules.

As with the Haber process, increasing the pressure also has the advantage of increasing the reaction rate; however, the industrial process takes place between 1 and 2 atm. Even at this pressure the conversion to sulphur trioxide is almost 100%; therefore, there is no substantial economic advantage that can be achieved by increasing the yield compared to the expense incurred producing such high pressures.

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| **Condition of the reaction** | **Effect on yield** | **Effect on rate of reaction** |
| Increase concentration of Oxygen |  |  |
| Increased temperature |  |  |
| Decreased temperature |  |  |
| Increased Pressure |  |  |
| Decreased pressure |  |  |
| Use of a catalyst |  |  |

The use of a vanadium catalyst does not shift the equilibrium, as the rates of both the forward and reverse reactions are increased. Thus, the purpose of the catalyst is simply to increase the rate of formation of sulphur trioxide. Without the catalyst the rate of the reaction is so slow that virtually no sulphur trioxide is produced within a reasonable time. The effects of changing the conditions on the equilibrium yield and reaction rate, as well as the actual conditions, are shown in the table below.

# Converting sulphur trioxide to concentrated sulphuric acid

Because the reaction of sulphur trioxide with water is so uncontrollable, the sulphur trioxide must first be dissolved in concentrated sulphuric acid to form **oleum:**

S03 (g) + H2S04 (l) → H2S207 (l)

The oleum is then reacted in a much safer way to produce concentrated sulphuric acid:

**Questions.**

1. Write the chemical reactions for the production of Sulphuric acid. Include the state of each reagent and indicate which reaction does not go to completion (exists as an equilibrium).
2. Identify this reaction as exothermic or endothermic.
3. How does increasing the temperature of this reaction affect the rate and the yield of Sulphuric Acid?
4. Does increasing or decreasing the pressure of this reaction increase the yield of Sulphuric Acid?
5. What effect does a catalyst have on the rate and yield of this reaction?