Modern chemical manufacture

Manufacture of ammonia by Haber's process

Under ordinary conditions, nitrogen and hydrogen do not react. The process of manufacturing of ammonia by combining hydrogen and nitrogen gas in the ratio 1:3 by volume at 450°C under 200 to 500 atmospheric pressure in the presence of promoted iron as catalyst is called Haber's process. This process is used to manufacture the ammonia on industrial scale.

Principle:

When a mixture of nitrogen and hydrogen gas in 1:3 ratio by volume is heated at a temperature of 450°C and 200 to 500 atmospheric pressure in presence of promoted iron as catalyst then ammonia gas is produced.

$$N_{2(g)} + 3H_{2(g)} \underset{\substack{200\text{-}500\ \text{atm} \\ \text{promoted iron}}}{\overset{450^0C}{\rightleftharpoons}} 2NH_{3(g)} + 22.08\ \text{kcal}$$

Conditions for maximum yield of ammonia

1. Temperature:

Low temperature is required as reaction is exothermic. Although low temperature gives high percentage of ammonia, the reaction is too slow. From economic point of view, optimum temperature of about 450°C is required.

2. Pressure:

At high pressure, more reactants reacts together to give good yield of product. So high pressure (200 to 500 atmospheric pressure) is favorable for this reaction.

3. Concentration:

For the maximum yield of ammonia, more concentration of nitrogen and hydrogen is required.

4. Catalyst:

To attain the equilibrium fast, promoted iron is required as catalyst.

5. Purity of gas:

Presence of impurities may cause catalyst poisoning. So pure nitrogen and hydrogen should be supplied.

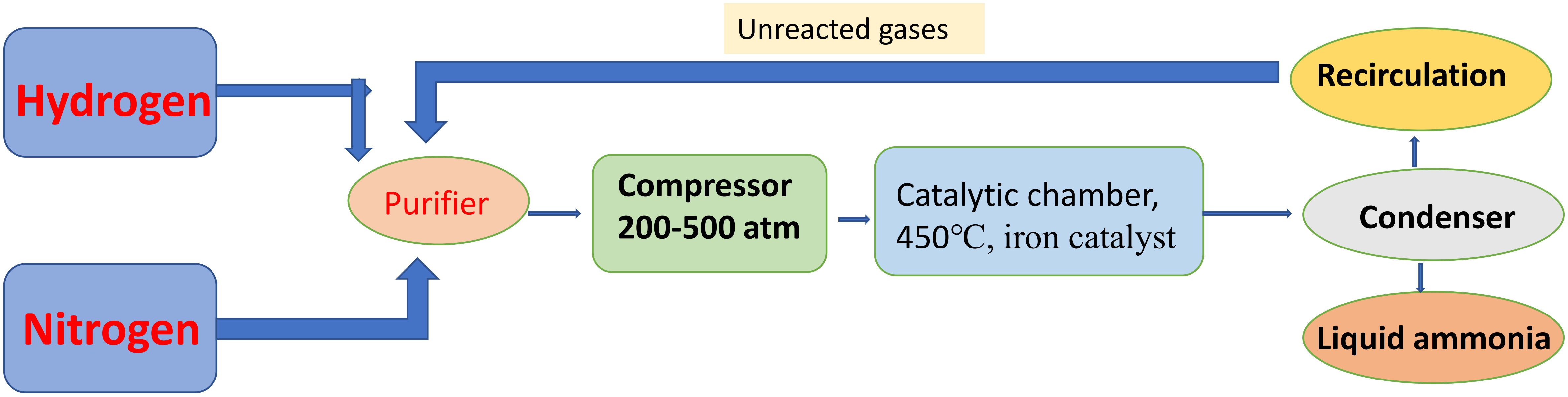


Fig: Flow-sheet diagram of manufacture of ammonia by Haber's process

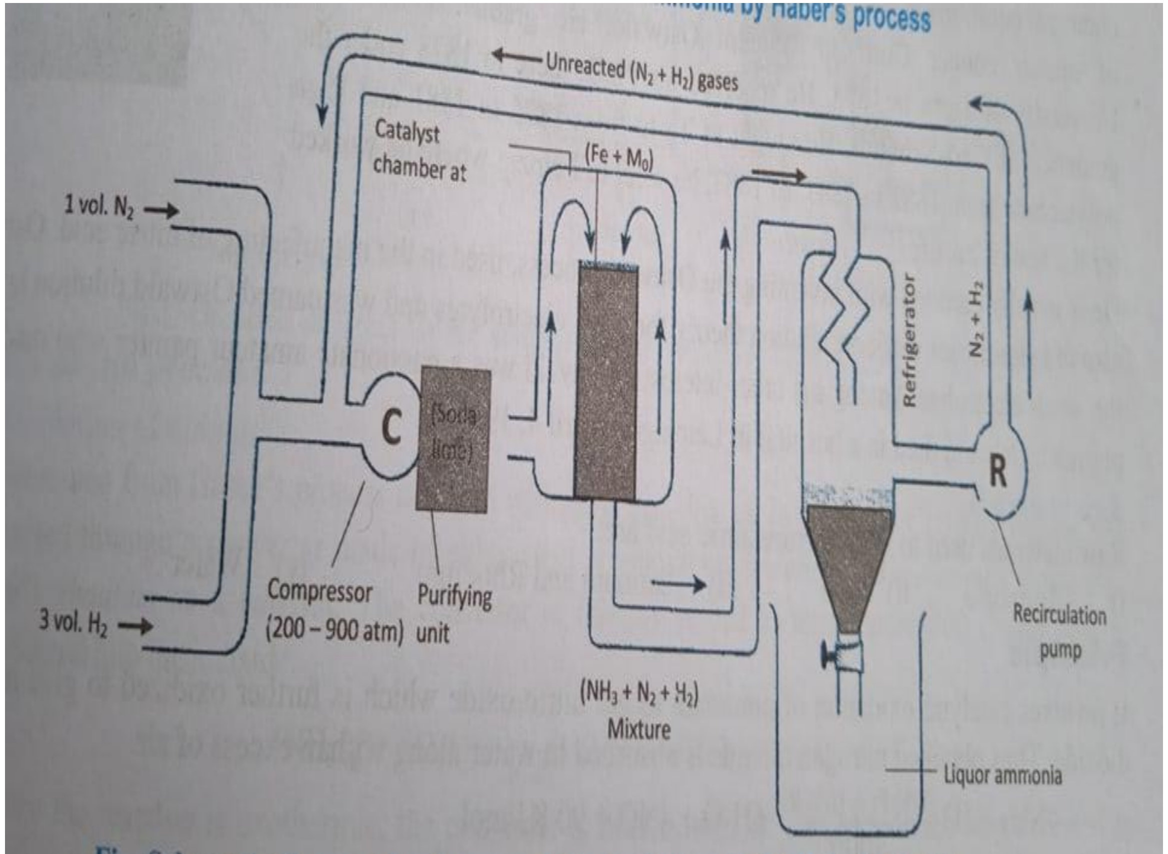
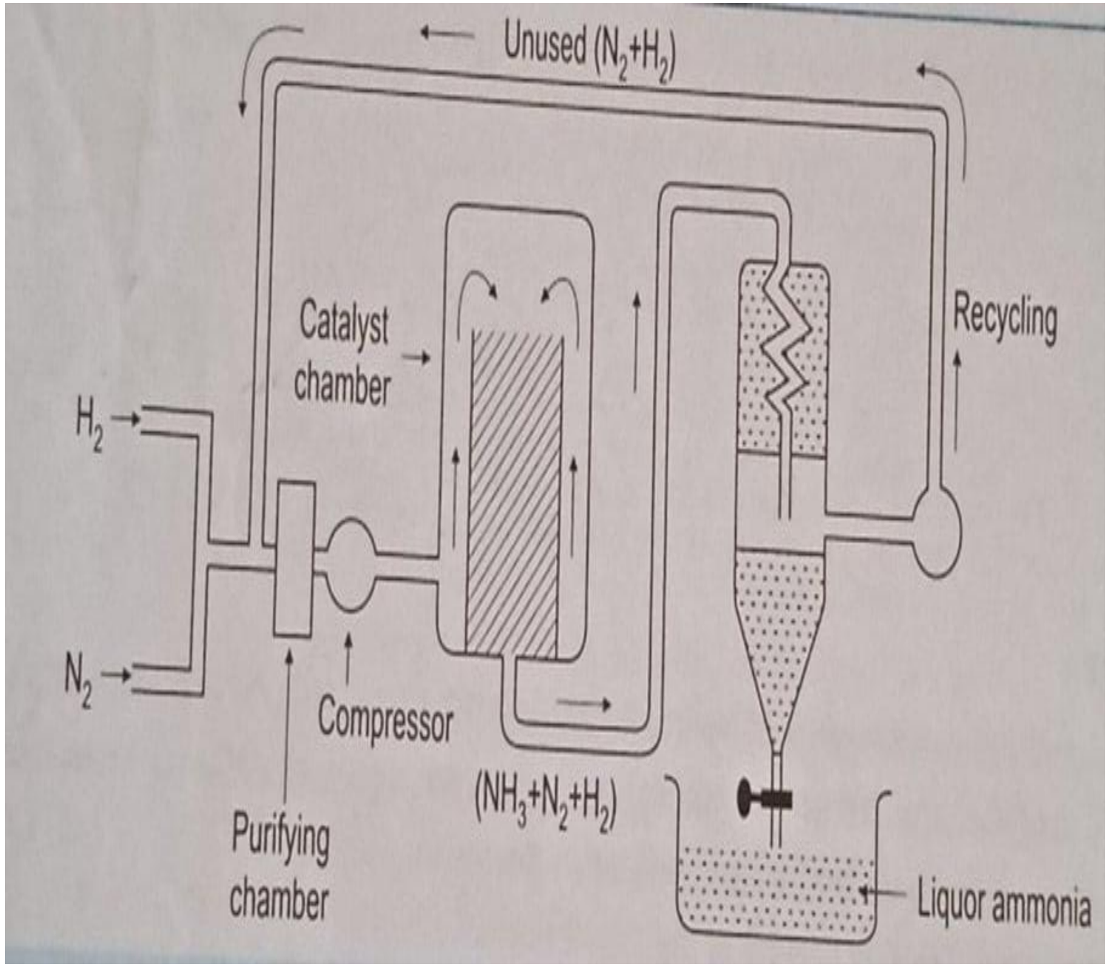


Fig: Schematic diagram for the manufacture of ammonia by Haber's process



Details of the process

Production of H_2 and N_2: Hydrogen gas required is either obtained by electrolysis of water or from water gas ($CO + H_2$) where CO is removed by fractional liquefaction. While nitrogen is obtained from the fractional distillation of liquid air.

Compressor: The nitrogen and hydrogen in the ratio 1:3 by volume are compressed to purifying unit at a pressure of 200 – 900 atmosphere usinga compressor pump.

Purifying unit: The compressed gas is then passed into a soda-lime tower (mixture of sodium hydroxide and calcium oxide, called soda-lime). It absorbs CO_2 and moisture.

$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

Catalyst chamber: It is a vertical, cylindrical steel vessel with thick walls able to withstand high gaseous pressure. It is packed with finely divided promoted iron containing Al_2O_3, K_2O, and ZrO as a *promoter*. The instrumentation and selection of suitable catalysts for Haber's process were developed by *Carl–Bosch* and it issometimes called *Haber–Bosch ammonia synthesis*. The chamber is heated electrically to about 500^0C to initiate the reaction. Since the reaction is exothermic, heat is produced which keeps the reaction going. Under conditions of these temperatures and pressure, only about 15% of reactant gases are converted into ammonia.

Condenser: The gas obtained from the catalyst chamber contains ammonia along with unreacted hydrogen and nitrogen. The mixture is then passed through a condenser where ammonia gets condensed and collected in a receiver while unreacted H_2 and N_2 pass out uncondensed. Such condensed ammonia is called *liquor ammonia*.

Recirculation: The uncondensed (unreacted nitrogen and hydrogen) gas is recirculated through the catalyst converter by a *recirculation pump* and reprocessed to get more ammonia.