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| **Uses and Production of Ammonia (Haber Process)** |
| **Key Concepts**  In 1909 [Fritz Haber](http://www.ausetute.com.au/nobelpri.html) established the conditions under which nitrogen, N2(g), and hydrogen, H2(g), would combine using   * medium temperature (~500oC) * very high pressure (~250 atmospheres, ~25,500kPa) * a [catalyst](http://www.ausetute.com.au/enerprof.html) (a porous iron catalyst prepared by reducing magnetite, Fe3O4). Osmium is a much better catalyst for the reaction but is very expensive.   This process produces an ammonia, NH3(g), [yield](http://www.ausetute.com.au/yield.html) of approximately 10-20%.  The Haber synthesis was developed into an industrial process by Carl Bosch.  The reaction between nitrogen gas and hydrogen gas to produce ammonia gas is an [exothermic](http://www.ausetute.com.au/enthchan.html) [equilibrium reaction](http://www.ausetute.com.au/equilibrium.html), releasing 92.4kJ/mol of energy at 298K (25oC).   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | N2(g) nitrogen | + | 3H2(g) hydrogen | heat, pressure, catalyst  http://www.ausetute.com.au/../images/eqlarrow.gif | 2NH3(g)  ammonia | http://www.ausetute.com.au/../images/capdelta.gifH = -92.4 kJ mol-1 |   OR   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | N2(g) nitrogen | + | 3H2(g)  hydrogen | heat, pressure, catalyst  http://www.ausetute.com.au/../images/eqlarrow.gif | 2NH3(g)  ammonia | + 92.4 kJ mol-1 |   By [Le Chetalier's Principle](http://www.ausetute.com.au/lechatsp.html):   * increasing the pressure causes the equilibrium position to move to the right resulting in a higher yeild of ammonia since there are more gas molecules on the left hand side of the equation (4 in total) than there are on the right hand side of the equation (2). Increasing the pressure means the system adjusts to reduce the effect of the change, that is, to reduce the pressure by having fewer gas molecules. * decreasing the temperature causes the equilibrium position to move to the right resulting in a higher yield of ammonia since the reaction is exothermic (releases heat). Reducing the temperature means the system will adjust to minimise the effect of the change, that is, it will produce more heat since energy is a product of the reaction, and will therefore produce more ammonia gas as well However, the rate of the reaction at lower temperatures is extremely slow, so a higher temperature must be used to speed up the reaction which results in a lower yield of ammonia.  |  |  |  |  |  | | --- | --- | --- | --- | --- | | The [equilibrium expression](http://www.ausetute.com.au/equicons.html) for this reaction is: | |  |  | | --- | --- | | Keq = | [NH3]2 | | [N2][H2]3 | | | As the temperature increases, the equilibrium constant decreases as the yield of ammonia decreases. | |  |  | | --- | --- | | **Temperature (oC)** | **Keq** | | 25 | 6.4 x 102 | |  | | | 200 | 4.4 x 10-1 | |  | | | 300 | 4.3 x 10-3 | |  | | | 400 | 1.6 x 10-4 | |  | | | 500 | 1.5 x 10-5 | |   [Rate](http://www.ausetute.com.au/reactrate.html) considerations:   * A catalyst such as an iron catalyst is used to speed up the reaction by lowering the [activation energy](http://www.ausetute.com.au/enerprof.html) so that the N2 bonds and H2 bonds can be more readily broken. * Increased temperature means more reactant molecules have sufficient energy to overcome the energy barrier to reacting (activation energy) so the reaction is faster at higher temperatures (but the yield of ammonia is lower as discussed above).  A temperature range of 400-500oC is a compromise designed to achieve an acceptable yield of ammonia (10-20%) within an acceptable time period.  |  |  | | --- | --- | | At 200oC and pressures above 750atm there is an almost 100% conversion of reactants to the ammonia product.  Since there are difficulties associated with containing larger amounts of materials at this high pressure, lower pressures of around 200 atm are used industrially.  By using a pressure of around 200atm and a temperature of about 500oC, the yield of ammonia is 10-20%, while costs and safety concerns in the biulding and during operation of the plant are minimised | http://www.ausetute.com.au/../images/rorampre.gif |   During industrial production of ammonia, the reaction never reaches equilibrium as the gas mixture leaving the reactor is cooled to liquefy and remove the ammonia. The remaining mixture of reactant gases are recycled through the reactor. The heat released by the reaction is removed and used to heat the incoming gas mixture.  **Uses of Ammonia**   |  |  | | --- | --- | | **Industry** | **Use** | | **Fertilser** | production of:   * ammonium sulfate, (NH4)2SO4 * ammonium phosphate, (NH4)3PO4 * ammonium nitrate, NH4NO3 * urea, (NH2)2CO,also used in the production of barbiturates (sedatives), is made by the reaction of ammonia with carbon dioxide | | |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | CO2  carbon dioxide | + | 2NH3  ammonia | http://www.ausetute.com.au/../images/eqlarrow.gif | H2NCOONH4  ammonium carbonate | heat, pressure  http://www.ausetute.com.au/../images/eqlarrow.gif | (NH2)2CO  urea |   </TD< TR> | | |  | | | **Chemicals** | synthesis of:   * nitric acid, HNO3, which is used in making explosives such as TNT (2,4,6-trinitrotoluene), nitroglycerine which is also used as a vasodilator (a substance that dilates blood vessels) and PETN (pentaerythritol nitrate). * sodium hydrogen carbonate (sodium bicarbonate), NaHCO3 * sodium carbonate, Na2CO3 * hydrogen cyanide (hydrocyanic acid), HCN * hydrazine, N2H4 (used in rocket propulsion systems) | |  | | | **Explosives** | ammonium nitrate, NH4NO3 | |  | | | **Fibres and Plastics** | nylon, -[(CH2)4-CO-NH-(CH2)6-NH-CO]-,and other polyamides | |  | | | **Refrigeration** | used for making ice, large scale refrigeration plants, air-conditioning units in buildings and plants | |  | | | **Pharmaceuticals** | used in the manufacture of drugs such as sulfonamide which inhibit the growth and multiplication of bacteria that require *p*-aminobenzoic acid (PABA) for the biosynthesis of folic acids, anti-malarials and vitamins such as the B vitamins nicotinamide (niacinamide) and thiamine. | |  | | | **Pulp and Paper** | ammonium hydrogen sulfite, NH4HSO3, enables some hardwoods to be used | |  | | | **Mining and Metallurgy** | used in nitriding (bright annealing) steel, used in zinc and nickel extraction | |  | | | **Cleaning** | ammonia in solution is used as a cleaning agent such as in 'cloudy ammonia' | |