



Ammonia & The Haber Process

Ammonia (NH_3) is a covalent compound and is an extremely useful chemical. It is commonly used to make:

- Nitrogenous fertilisers which is very important in agriculture
- Household cleaning agents such as glass window cleaners, floor cleaners, etc
- Explosives for demolishing buildings and structures

Ammonia is manufactured industrially by the Haber Process. We will take a look at the details on this important industrial process later in the blog post.

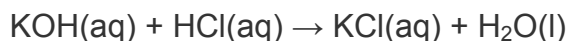
To learn this topic effectively, we shall structure our discussion into 3 parts, namely:

- Part 1: Reversible Reactions
- Part 2: Manufacturing of Ammonia by the Haber Process
- Part 3: Displacement of Ammonia from Ammonium Salts

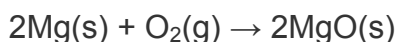
Part 1: Reversible Reactions

Many chemical reactions can proceed in one direction only. i.e. they cannot be reversed and they go towards completion. These are known as **irreversible reactions**.

e.g. Neutralisation reaction between acid and alkali



e.g. Combustion reaction



However, some chemical reactions can be reversible. i.e. reactions can go either directions and they reached an equilibrium, instead of going towards completion. These are known as **reversible reactions**.

At equilibrium, the forward and backward reactions do not stop; they continue, but at the same speed. Hence, there is no overall change in the amounts of reactants and products. A mixture of reactants and products is present and they are known to be in equilibrium.

A double arrow sign, \rightleftharpoons is used to indicate a reversible reaction.

Forward reaction refers to the reaction going from left to right.

Backward (or reverse) reaction refers to the reaction going from right to left.

e.g. Thermal decomposition of ammonium chloride, $\text{NH}_4\text{Cl(s)}$.

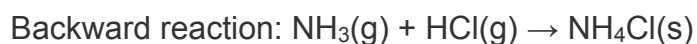
In fact, this is a reversible reaction and is represented by the following equation



Upon heating, solid ammonium chloride decomposes to form ammonia gas and hydrogen chloride gas.



Upon cooling, solid ammonium chloride is formed back.

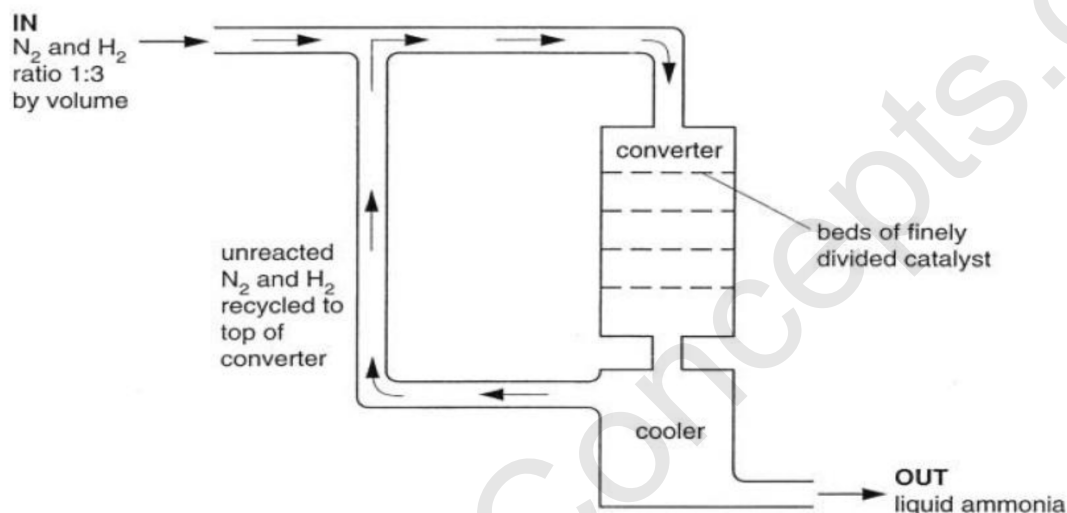


There are many other examples of reversible reactions.

The reaction between nitrogen and hydrogen to form ammonia is another example of a reversible reaction which will be tested in both the GCE O-Level Pure Chemistry Exam as well as IP Year 4 Chemistry Exam.

Part 2: Manufacturing of Ammonia by the Haber Process

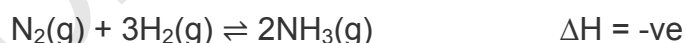
Ammonia is manufactured industrially by the Haber Process. The raw materials for the Haber Process are nitrogen gas and hydrogen gas.



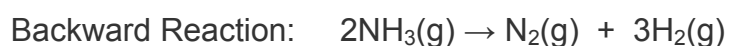
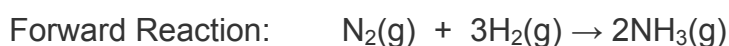
Raw Materials:

- N₂(g) is obtained from the Fractional Distillation of liquefied air
- H₂(g) is obtained from the Cracking of crude oil (petroleum)

Equation:



In reversible reactions, the forward and reverse reactions occur simultaneously.



Since the reaction is reversible, thus to have a good yield (amount) of ammonia gas, reaction conditions (temperature, pressure and the use of catalysts) are carefully controlled.

Conditions:

The nitrogen and hydrogen molecules are generally unreactive and thus there are no reaction between the two gases at room temperature and pressure.

For the two unreactive gases to react together, a high pressure and relatively high temperature are required. Finely divided iron catalyst is also needed to speed up the chemical reaction.

As we have discussed earlier, the reaction is reversible i.e. some of the ammonia molecules formed will decompose back to become nitrogen and hydrogen molecules. As such, reaction conditions (temperature and pressure) are carefully controlled by chemists and chemical engineers to ensure maximum yield of the product (ammonia gas) at a minimum cost.

1) Effect of Temperature

The lower the temperature, the higher will be the yield of ammonia, since the decomposition of ammonia back to hydrogen and nitrogen will be reduced.

Lower temperature, however, will also result in a slower rate of reaction.

Therefore, there is an optimal temperature that is being used.

2) Effect of Pressure

The higher the pressure, the higher will be the yield of ammonia.

Higher pressure will also increase the rate of reaction.

However, high pressure condition will be dangerous for people working in the manufacturing plant. More expensive equipments must be used to maintain high pressure.

Therefore, there is a limit to the amount of pressure that can be used.

3) Effect of Catalyst

Despite the high pressure and relatively high temperatures being used, the rate of reaction is still quite slow.

Therefore, a suitable catalyst is being used to speed up the rate of reaction.

Optimal Conditions in the Haber Process:

The best conditions used in the industry for obtaining the maximum yield of ammonia at minimum cost are:

- Pressure of 200 atm
- Temperature of 450 °C
- Presence of a finely divided iron catalyst

Note:

For students based in Singapore, do note that slightly different values have been quoted for the optimum pressure of the Haber Process, in both the two different Ministry of Education (MOE) approved Chemistry textbooks.

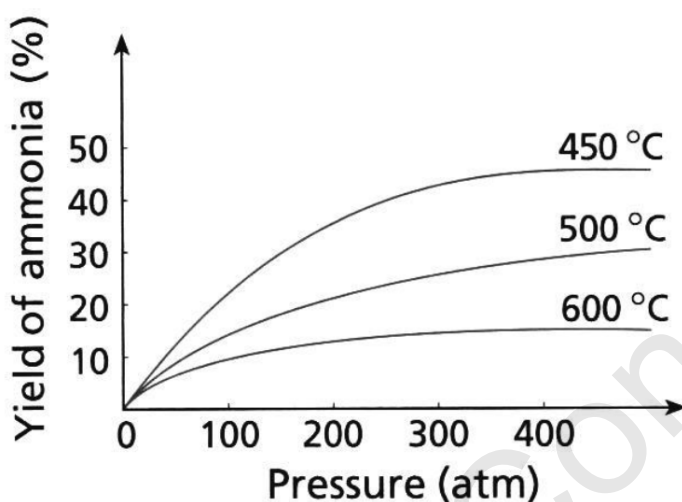
- Pearson's O-Level *All About Chemistry* reference textbook (2019 Edition) quoted 200 atm.
- Marshall Cavendish's O-Level *Chemistry Matters* reference textbook (2019 Edition) quoted 250 atm.

Schools will take reference from the approved textbooks so you will see that different GCE O-Level Pure Chemistry and IP Chemistry schools will use either one or the other values. Both are equally acceptable since there is a range of pressures (atm) which is being used industrially.

% Yield Graph

The following % Yield Graph might be given in your upcoming O-Level Pure Chemistry exam or IP Chemistry exam.

Note that you might even be asked to draw a simple graph to see how % Yield of ammonia is related to Temperature and Pressure.



Details in the Haber Process

1. Nitrogen and hydrogen are mixed in the ratio of 1:3 by volume
2. Mixture of gases is compressed to 200 atm and heated to 450 °C
3. Mixture of gases are passed over finely divided iron catalyst
4. Reaction is exothermic
5. Only about 10-15% of nitrogen is converted to ammonia i.e. % yield = 10-15%
6. A mixture of nitrogen, hydrogen and ammonia is obtained in the converter
7. Mixture of gases are then cooled in the cooling chamber (condenser)
8. Ammonia gas condenses to become liquid ammonia while hydrogen and nitrogen remains as gases
9. Unreacted hydrogen and nitrogen are pumped back (recycled) into the converter for further reaction.

Part 3: Displacement of Ammonia from Ammonium Salts

Ammonia can also be prepared in the Chemistry laboratory.

When an ammonium salt is heated with a strong alkali such as sodium hydroxide, potassium hydroxide and calcium hydroxide, ammonia gas is being displaced from the salt.



Loss of Nitrogen from Fertilisers in Agriculture

Calcium hydroxide and calcium oxide (quicklime) are widely used in agriculture to neutralise excess acidity in soil.

However, both calcium hydroxide and calcium oxide will react with nitrogen fertilisers to form ammonia gas, which then escapes into the atmosphere.



This causes the loss of nitrogen from fertilisers already added to the soil by farmers.

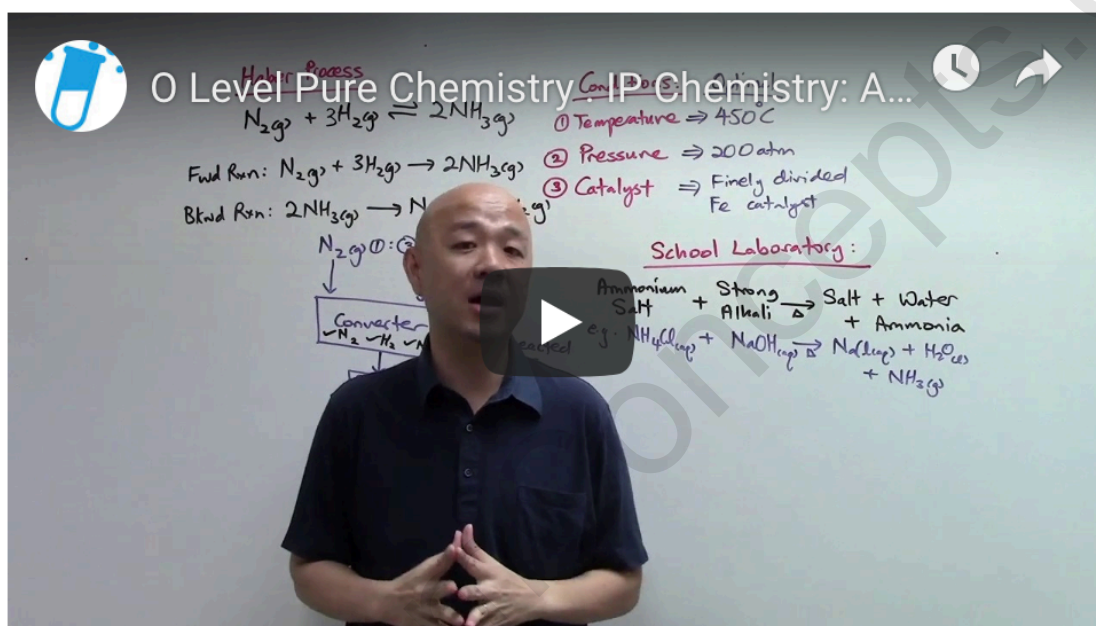
Thus, nitrogenous fertilisers and calcium hydroxide / calcium oxide should not be added to soil at the same time.

YouTube Video Tutorial on Ammonia

You can watch the YouTube Video below to have an even clearer idea about Ammonia.

Click on the following link for the video on [O-Level Chemistry . IP Chemistry: Ammonia and The Haber Process](#)

Length of Video: 9.59 minutes



Video: https://www.youtube.com/watch?time_continue=1&v=Nr9hQ4aNXGc

Alright, we have covered everything which is listed in the topic of Ammonia (it is sometimes also known the Nitrogen in the older Chemistry syllabus).

I hope you find the content easy for your understanding and if you have any questions, leave me a comment below. Feel free to share this blog post with your friends.

Subscribe to my blog to receive 2 updates per month sent to your email!

Source: <https://www.SimpleChemConcepts.com/o-level-chemistry-ammonia-and-the-haber-process/>