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TOPIC 7.3: AMMONIA

THE ABOUT

CHAPTER ANALYSIS

TIME

- Relatively straight forward chapter
- 1 **key** concept

EXAM

- Usually tested in MCQs
- Tested together with chapters like Rate of Reaction & Energy Changes

WEIGHTAGE

- Light overall weightage
- Constitute to **1.5%** of marks for past 5 year papers

KEY CONCEPT

AMMONIA
RAW MATERIALS (H_2 & N_2)
HABER PROCESS

AMMONIA

Raw materials

Nitrogen and hydrogen are the raw materials that are used in the manufacturing of ammonia, via the Haber process.

Nitrogen is obtained through the process of **fractional distillation of liquid air.**

Hydrogen is obtained through the **cracking of crude oil**.

Iron would act as a **catalyst** to increase the rate of reaction.

AMMONIA

Ammonia (NH_3) is a **weak alkali** when it is in its aqueous state, as it partially dissociates in water to produce low concentration of OH^- ions.

$$NH_3\ (g) + H_2O\ (l) \rightleftharpoons NH_4^+\ (aq) + OH^-\ (aq)$$

$\rightleftharpoons$ **reversible reactions** will never be fully completed.

Displacement of ammonia from its salts

An alkali has the ability to displace the ammonia from an ammonium salt.

For example, potassium hydroxide **displaces ammonia** from ammonium carbonate when the solution is gently heated:

$$2KOH\ (aq) + (NH_4)_2CO_3\ (aq) \rightarrow K_2CO_3\ (aq) + \mathbf{NH_3\ (g)} + 2H_2O\ (l)$$

**Chemical reaction for alkali (acid & bases)!*

HABER PROCESS

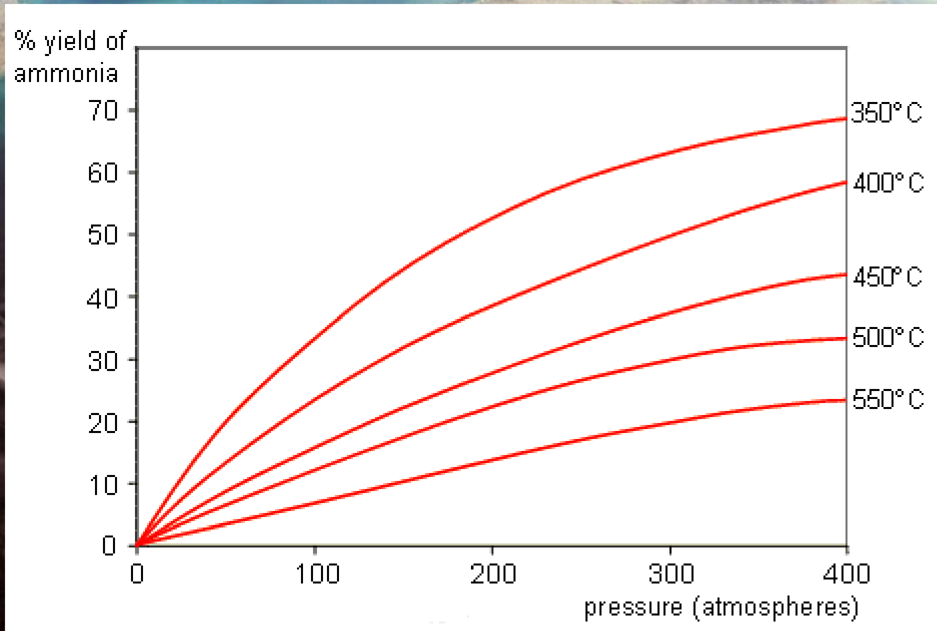
Haber process

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

In the process, nitrogen and hydrogen gases are mixed together in the ratio of 1:3.

Conditions

The Haber process is usually carried out at a **temperature of 450°C, at a pressure of 200 atm and with finely divided iron catalyst.**



HABER PROCESS

Analysis:

As seen from the graph, the **yield of ammonia increases when pressures are higher and temperatures are lower**.

Hence, to maximise the yield of ammonia, *theoretically*, the pressure levels should be increased and the temperature should be decreased.

However in reality, optimal conditions are kept at 450°C and pressure of 200 atm.

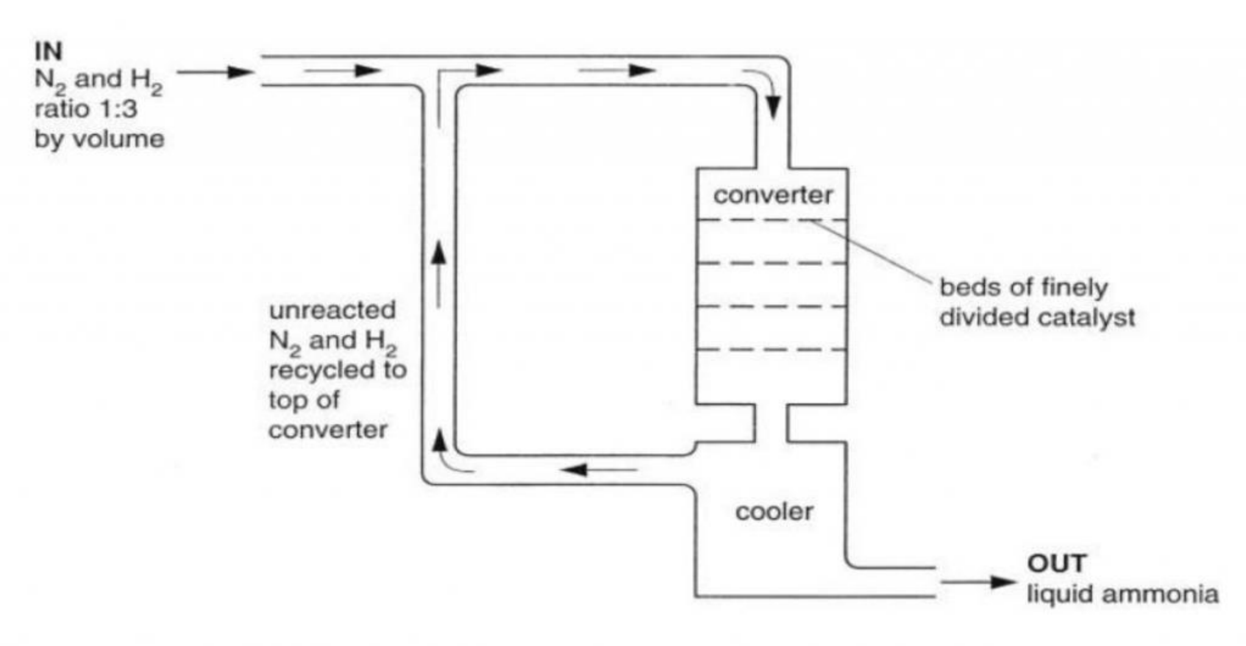
This is because:

- At pressures higher than 200 atm, the machines would be **more costly** and outweigh the benefits of that incremental yield. Also, there will be greater **safety risks at higher pressures.**

- At temperatures lower than 450°C, the **rates of reaction** would be **slowed down too much**. It would be more **cost efficient** to use a higher temperature to **increases the rate** despite lowering the percentage yield.

- Due to the **recycling of reactants, 98% of the reactants** are eventually **converted into ammonia**.

HABER PROCESS



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HABER PROCESS

- **Nitrogen and hydrogen gases** are mixed in a ratio of **1:3.**
- The mixture would be passed through a compressor, where a **pressure of 200 atm** is applied to the gas mixture and then passed through the converter **containing iron catalyst at 450°C to increase the rate of reaction.**
- **The ammonia gas formed would be directed into a cooler, condensing it into a liquid**, while **unreacted nitrogen and hydrogen gases are recycled**.
- The Haber process is **efficient and relatively cheap**, as the starting materials required (nitrogen, hydrogen and iron) are readily available at a low cost.
- **Heat is produced during the reaction (exothermic)**. It **maintains the temperature of the catalyst chamber.**

ADVANCED

things to note

Understanding Haber Process

Rate of reaction is more important than yield

Temperatures lower than 450°C will result in very **slow rates of reaction**. It is more **cost efficient** to use a higher temperature that **increases the rate of reaction**.

Only 15% of the reactants are converted into ammonia. But that is okay because **98% of the reactants** are eventually **reacted to form ammonia**.

Recall how 'pressure' increases rate of reaction

At a higher pressure, the reactants are brought closer together. There are **more reactants per unit volume**.

As a result, there are more collisions between reactants and thus a higher frequency of effective collisions. This causes the rate of reaction to increase.

Recall how 'temperature' increases rate of reaction

A higher temperature of a system means that:

1) Reactants have **higher kinetic energy and move faster**
2) The **fraction of reactant particles** in the system that have energy **more than or equal to the activation energy** is higher

These two factors increase the **frequency of effective collisions** and essentially result in an increase in the rate of reaction.

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