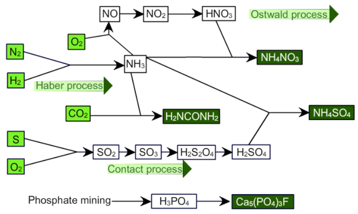
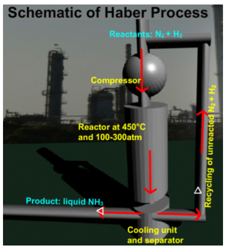
FERTILISERS MEMO

Industrial production of fertilisers





Overview

1 Why is nitrogen important to plants? **Nitrogen is found in all proteins, and so it is an essential nutrient.**

2. In what forms can plants absorb nitrogen?
Dissolved urea, nitrate, nitrite and ammonium ions.

3 Complete to summarise the industrial processes.

Process	Reactants	Products of step 1	Products of step 2	Final products
Haber	**$N_2 + H_2$**	not applicable		**NH_3**
Ostwald	**$NH_3 + O_2$**	**NO**	**NO_2**	**HNO_3**
Contact	**$S + O_2$**	**SO_2**	**SO_3**	**H_2SO_4**

Haber Process

4 What is the purpose of the Haber Process?
To produce **ammonia (NH_3)** from **nitrogen (N_2)** and **hydrogen (H_2).**

5 Write a balanced equation for the Haber Process's reversible reaction. **$N_2 + 3H_2 \rightleftharpoons 2NH_3$**

6 Name some uses of ammonia. **As a cleaning agent. As a coolant in some air conditioners. To manufacture nitrogen fertilisers.**

7 Name two conditions which must be met for a reaction to reach equilibrium.
- **reversible reaction** - **closed system**

8 Name two characteristics of equilibrium.
- **rates of forward and reverse reactions are equal to one another**
- **the concentrations of reactants and products remain constant**

9 In the Haber Process an iron oxide catalyst is usually used. Ruthenium can also be used. What does a catalyst do to a reaction, and how does it do this? **It speeds up a reaction by lowering its activation energy. It does this by serving as a binding site on which the reaction can occur.**

10 Circle the correct option (True / False) for each of the following.

i A catalyst speeds up the Haber Process's forward reaction more than the reverse. [True / **False**]

ii A catalyst will cause more product to be formed. [True / **False**]

iii A catalyst will decrease the time it takes to reach equilibrium because it speeds up both forward and reverse reactions. [**True** / False]

iv A catalyst speeds both forward and reverse reactions equally [**True** / False]

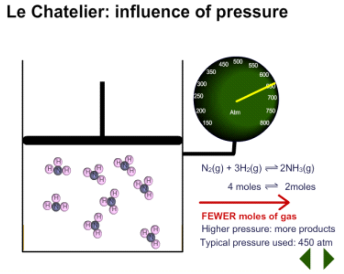
11 Link each element from Column A with its corresponding element in Column B.
Write the letter from A next to each item in B in the last column.

Column A	Column B	A
a dynamic equilibrium	absorbs heat	**b**
b endothermic	a measure of the average kinetic energy of particles	**i**
c exothermic	disturbs equilibrium, favours increased crowding, more molecules	**e**
d Le Chatelier's principle	273 K and 101,3 kPa	**k**
e decrease in pressure	disturbs equilibrium, favours exothermic reaction	**g**
f increase in pressure	releases heat	**c**
g removing heat	a state in which forward and reverse reactions occur at equal rates	**a**
h adding heat	force per area, in gases related to rate of particle collisions	**j**
i temperature	disturbs equilibrium, favours decreased crowding, fewer molecules	**f**
j pressure	disturbs equilibrium, favours endothermic reaction	**h**
k STP	when a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance	**d**

Le Chatelier: Effect of pressure

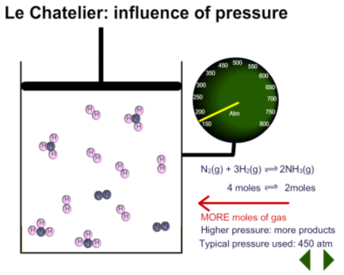
12 Complete the explanation by filling the gaps or choosing from the options. Do this before, or after, but not during, watching the animations. Mark during re-watching.

Increased pressure



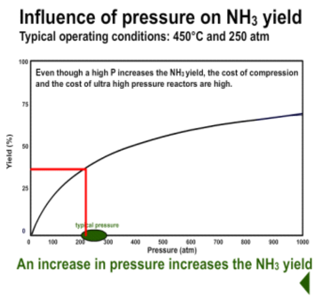
According to **Le Chatelier's** principle, when a system which is in equilibrium is disturbed, it will respond in such a way as to **counteract** the disturbance. An increase in pressure [de/**in**]creases the crowding of gaseous molecules. The system will respond by [**de**/in]creasing their crowding. Crowding is decreased in gases when [**fewer**/more] molecules are formed. In the Haber Process the [**forward**/reverse] reaction makes fewer molecules than the [forward/**reverse**] reaction. In the forward reaction **2** molecules of ammonia are made from every **4** molecules of reactants (**1** N_2 and **3** H_2 molecules). Consequently, an increase in pressure **disturbs** equilibrium for a while by making the [**forward**/reverse] reaction occur at a higher rate than the [forward/**reverse**] reaction. This causes [**more**/less] ammonia to be formed and [more/**less**] nitrogen and hydrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again **equal** to one another, and the amounts of reactants and products will [change/**remain constant**]. However, compared to before the pressure was applied, there will now be [**more**/less] ammonia present at equilibrium. The equilibrium constant value, Kc, however, will be [higher than/lower than/**the same as**] it was in the original equilibrium.

Decreased pressure



Decreasing pressure [**de**/in]creases the crowding of gaseous molecules. The system will respond by [de/**in**]creasing their crowding. Crowding can be increased by forming [fewer/**more**] molecules. In the Haber Process, that means that for a while the [forward/**reverse**] reaction will occur at a higher rate than the [**forward**/reverse] reaction. The reverse reaction changes every 2 molecules of ammonia into **4** molecules (**1** nitrogen and **3** hydrogen molecules). This causes the amount of ammonia present to [**de**/in]crease and the amount of nitrogen and hydrogen to [de/**in**]crease. While this is happening the system [is/**is not**] in equilibrium. After a while a new dynamic equilibrium will be reached, in which the rates of both forward and reverse reactions will **equal** one another, and the amounts of reactants and products will remain **constant**. However, compared to before the pressure was decreased, there will now be [more/**less**] ammonia present at equilibrium. The equilibrium constant value, Kc, however, will be [higher than/lower than/**the same as**] it was in the original equilibrium.

Optimum pressure



In the Haber Process, we want to make as much **ammonia** as possible. We want the dynamic equilibrium to be such that a lot of [reactant/**product**] is formed. A(n) [de/**in**]crease in pressure will cause more products to form. We need as [low/**high**] a pressure as it is safe and economical to use. We say we need to use an **optimal** pressure: the pressure for which we get a good yield for a reasonable price while still being safe. Pressures between 200 and 300 atmospheres are typically used in the Haber Process.

Le Chatelier: Effect of temperature

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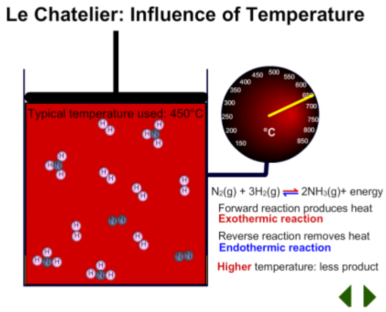


Heating

Heating a reaction up increases the **kinetic** energy of the particles, and so causes them to react more [slowly/**rapidly**] with one another. Additionally, heat can have an effect on disturbing the **equilibrium** of a reaction.

In the Haber Process the forward reaction is [**exo**/endo]thermic and the reverse is [exo/**endo**]thermic. This means that as nitrogen and hydrogen react with one another to form ammonia, heat is [absorbed/ **released**], but as ammonia breaks up into hydrogen and nitrogen, heat is [**absorbed**/released]. According to Le Chatelier's principle, when a system which is in equilibrium is disturbed, it will respond in such a way as to counteract the disturbance. So if heat is added to a system in the Haber Process, the [exo/**endo**]thermic [forward/**reverse**] reaction is favoured to [**absorb**/release] some of that heat and so [**cool the system back down**/heat the system back up]. Both the forward and reverse reactions occur at [lower/**higher**] rates than before the heat was added, due to the additional kinetic energy of all the particles, but the [forward/**reverse**] reaction will have been speeded up to a greater extent than the [**forward**/reverse] reaction. So for a while, the system will not be in **equilibrium** as the [forward/**reverse**] reaction occurs more rapidly than the [**forward**/reverse] reaction. This will [in/**de**]crease the amount of ammonia present, and [**in**/de]crease the amount of hydrogen and nitrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again **equal** to one another, and the amounts of reactants and products will remain **constant**. However, compared to before the heat was added, there will now be [**less**/more] ammonia present at equilibrium. A new equilibrium constant, Kc, [higher than/**lower than**/the same as] that of the original equilibrium, is reached.

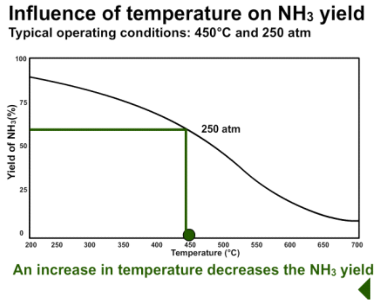
Cooling

Cooling a system that is in equilibrium has two effects. Firstly, by [**de**/in]creasing the kinetic energy of all the molecules, it [**reduces**/increases] the rates of both the forward and reverse reactions. Secondly, it has the effect of disturbing the **equilibrium** by favouring the [**exo**/endo]thermic reaction until a new equilibrium is reached with [the same/**a different**] equilibrium constant.

If heat is removed from a system in the Haber Process, the [**exo**/endo]thermic [**forward**/reverse] reaction is favoured to [cool the system back down/**heat the system back up**]. For a while, the system will not be in **equilibrium** as the [**forward**/reverse] reaction occurs more rapidly than the [forward/**reverse**] reaction. This will [**in**/de]crease the amount of ammonia present, and [in/**de**]crease the amount of hydrogen and nitrogen. After a while a new dynamic equilibrium is reached. The rates of forward and reverse reactions are again **equal** to one another, and the amounts of reactants and products will remain **constant**. However, compared to before the system was cooled, there will now be [less/**more**] ammonia present at equilibrium. A new equilibrium constant, Kc, [**higher than**/lower than/the same as] that of the original equilibrium, is reached.

Optimum temperature

In the Haber Process, we want to get a high ammonia yield. We want a dynamic equilibrium which makes as much ammonia product as possible. Consequently, we need to use a fairly [high/**low**] temperature. However, this causes a problem, namely **it causes both reactions to be slow, and so it takes a long time for equilibrium to be reached.** Therefore, a compromise is made, and a temperature of approximately 450°C is often used.



Units of pressure and temperature

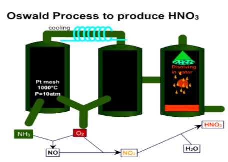
14 Complete for units of pressure.

Unit		Pressure at sea level at 0°C
Name	**Symbol**	
bar	**bar**	**1 bar**
atmospheres	**atm**	**1 atm**
kilopascals	**kPa**	**101,3 kPa**
millimeters mercury	**mm Hg**	**760 mm Hg**

15 Kelvin is the SI (Standard International) unit for temperature. Complete for conversions.

Temperature in degrees Celsius (°C)	Temperature in Kelvin (K)
0	**273**
-273	0
100	**373**
-27	200
25	**298**

Ostwald Process



16 What is the purpose of the Ostwald Process?
To produce **nitric acid (HNO_3)** from **ammonia (NH_3)**.

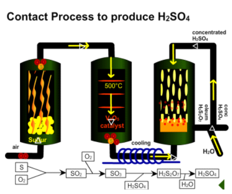
17 How is the product of the Ostwald Process useful for the fertiliser industry?
Nitric acid can be used to make nitrate fertilisers.

18 Why doesn't it matter that the platinum catalyst used is very expensive?
It can be used over and over again because it is not used up. Catalysts speed up reactions without themselves being changed in the process.

Complete.

Step 1	Step 2	Step 3
$NH_3 + O_2$ ↓ **platinum** catalyst **NO** →	**NO** + O_2 ↓ NO_2 →	$NO_2 + H_2O$ ↓ HNO_3

Contact Process



20 What is the purpose of the Contact Process?
To produce **sulfuric acid (H_2SO_4)** from **S + O_2**.

21 Name some uses of sulfuric acid. **manufacture of fertilisers, electrolyte in car batteries, as a dehydrating (a drying) agent**

22 Complete.

Step 1	Step 2	Step 3	Step 4
$S + O_2$ ↓ SO_2 →	$SO_2 + O_2$ ↓ V_2O_5 catalyst SO_3 →	$SO_3 + H_2SO_4$ ↓ $H_2S_2O_7$ →	$H_2S_2O_7 + H_2O$ ↓ $2H_2SO_4$