

Equilibrium Notes

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What is equilibrium? It is the term given to the point in a reversible chemical reaction when the forward reaction and the reverse reaction are both happening at the same rate.

A reversible reaction is one in which the forward reaction and reverse reaction both occur at the same time. The symbol for a reversible reaction is $\rightleftharpoons$

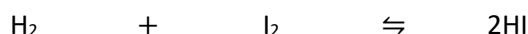
What is the forward reaction? This is the reaction where reactants react to produce products 😊

What is the reverse reaction? This is the reaction where the product or products breakdown to remake the reactants that they came from.

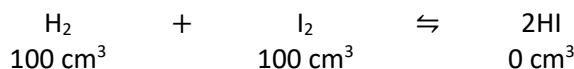
What is a dynamic equilibrium? When equilibrium is reached, the rate of the forward reaction is equal to the rate of the reverse reaction so there is no further change in composition of the equilibrium mixture in a closed system.

It has to be a closed system to have a dynamic equilibrium, as if it were an open system the gases could escape so equilibrium could not be achieved.

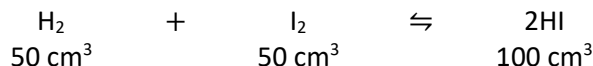
What does this mean for a reaction? Imagine that you have the following reaction:



Let's imagine that we had 100 cm³ of each reactant before the reaction.



At equilibrium we could see the following volumes.



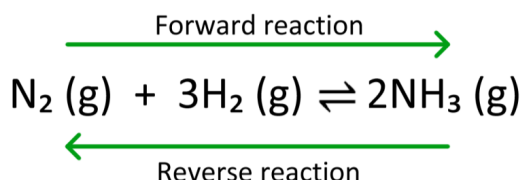
We can see here that there is now 100 cm³ on each side of the reaction. This reaction is now at equilibrium.

The Haber Process

What is the Haber process? It's the reaction of nitrogen gas and hydrogen gas to give ammonia gas, NH₃.

Why is it called the Haber process? It's named after the man who developed it, Fritz Haber.

Equation for the Haber process:



Where do we get the raw materials for the Haber process?

1. Nitrogen gas, N₂ (g), is obtained by the fractional distillation of liquid air.
2. Hydrogen gas, H₂ (g), can be made from natural gas/methane.

What are the conditions for Haber process?

Temperature: 450 °C.

Pressure: 200 atmospheres.

Catalyst: Finely divided/powdered iron.

What is the ammonia made used for? The main use of ammonia is to make ammonium nitrate which is widely used as a fertiliser to promote plant growth.

To get the best possible yield of ammonia, the conditions of the reaction must be controlled carefully. The conditions needed to obtain the best yield can be predicted using **Le Chatelier's Principle**.

Le Chatelier's Principle states that:

The **position of equilibrium** will shift so as to **counteract** the effect of any change in conditions.

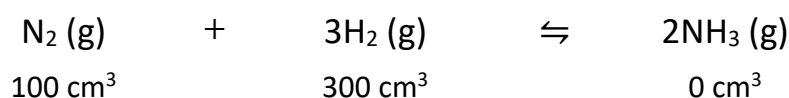
In simpler terms, if a change is made to a system that is at equilibrium, the position of equilibrium will move to **counteract** the change that was made. For the Edexcel GCSE we can be asked how changing the **pressure**, **temperature** and **concentration** can affect the position of equilibrium.

First though, what is the position of equilibrium? The position of equilibrium refers to the amounts of reactants and products in a reversible chemical reaction once it has reached equilibrium.

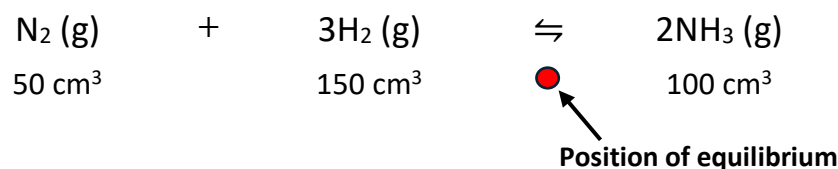
We could think of the position of equilibrium as an imaginary point that is half way between the two reactions that are happening in a reversible reaction, the forward and reverse reactions. Check out the example below 😊

Note: this isn't actually how the position of equilibrium works but this does make it easier to understand 😊.

Before the reaction begins...



When the reaction has reached equilibrium...



We notice that there is the same total volume of gas on each side of the reaction. So, the reaction is at equilibrium 😊
For this explanation we have put a circle to represent the position of equilibrium half way between reactants and the product.

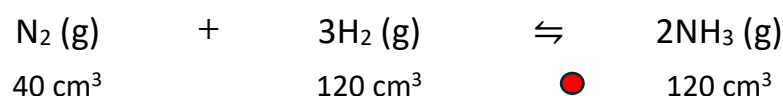
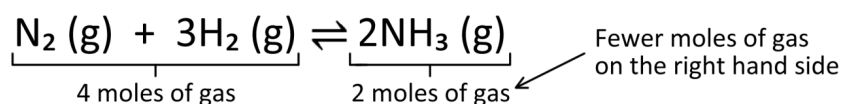
Ideally we want to make more of the product and not have the position of equilibrium be where it is. We would like it to **shift** to the right if we can. As Le Chatelier's Principle states, we can do this by changing the pressure, temperature and concentration in the reaction.

Changing the Pressure

How does changing the pressure affect the position of equilibrium? If the pressure is increased, the equilibrium position moves to the side of the equation with fewer moles. Do not say the side with less moles, say fewer.

There are **fewer** moles of gas on the right-hand side of the Haber process. So, by Le Chatelier's Principle, if the pressure of the reaction mixture is increased, the equilibrium will shift to the right to minimise the increase in pressure.

Equation for the Haber process:



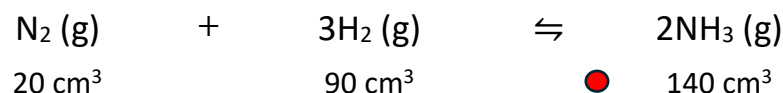
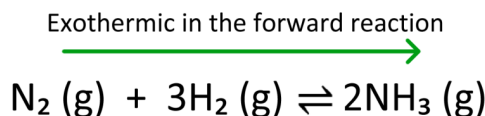
We notice that the position of equilibrium has shifted to the right 😊 so now we have more product. These figures are just for example the real reaction is a bit more fluid than this.

If the pressure is as high as possible, we get the best yield of ammonia. However, this high pressure can be dangerous. So, we use a compromise pressure of 200 atmospheres. This ensures a good enough yield in a fast-enough time.

Changing the Temperature

How does changing the temperature affect the position of equilibrium? By Le Chatelier's Principle, if the temperature of the equilibrium mixture is decreased in an exothermic reaction the equilibrium will shift to the right to minimise the decrease in temperature.

In a reversible reaction, if the reaction is exothermic in one direction, it is endothermic in the other direction. If the temperature is increased, the equilibrium position moves in the direction of the endothermic process (i.e. the left)

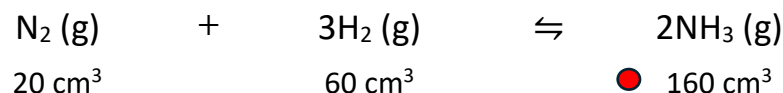


Here again we notice that the position of equilibrium has shifted to the right 😊 so now we have even more product.

If the temperature is as low as possible, we get the best yield of ammonia. However, the rate of reaction is too low. So, we use a compromise temperature of 450 °C. This ensures a good enough yield in a fast-enough time.

Changing the Concentration

If the concentration of a reactant (on the left) is increased, the equilibrium position moves in the direction away from this reactant, and so more of the products are produced (on the right). If one of the products is removed from a reaction (on the right), then the position of equilibrium moves to the right to make more of that product.



We notice that the position of equilibrium has shifted even further to the right 😊 so now we have even more product again.

We hope that helps to understand equilibrium and changing its position based on the conditions of the reaction 😊

Catalysts...

How does adding a catalyst affect the position of equilibrium? It doesn't! This question is a trap. They want to catch us out and get us to say it shifts left or right. Both are incorrect.

A catalyst does not alter the position of an equilibrium, but does speed up the rate at which equilibrium is reached.

This is because it speeds up both forward and reverse reactions equally. This means that a lower temperature can be used for a given rate of reaction and this will result in a higher yield. The catalyst used is finely divided iron.