Dynamic Equilibrium and le Chatelier's principle

A **reversible process** can move in either direction depending on the conditions. Most physical processes are easily reversible. Many chemical reactions are irreversible under ordinary conditions, but most reactions can be reversed under extreme conditions.
A reversible reaction will reach a dynamic equilibrium if sufficient time is allowed for the forward and reverse reactions to reach the same rate

A dynamic equilibrium exists when the forward rate of reaction equals the reverse rate of reaction. It occurs in a closed system and there is no change in overall macroscopic properties (eg temperature, pressure, concentration)

Le Chatelier's Principle - When a system in dynamic equilibrium is subjected to a change in conditions, the equilibrium will shift in the direction that minimises the change.

Temperature
If temperature is **increased**, the equilibrium will move to reduce the temperature so it will move in the **endothermic** direction.

If temperature is **reduced**, the equilibrium will move to increase the temperature that is in the **exothermic** direction.

Pressure only affects reactions involving gases where the number of gas molecules changes during the reaction.

If pressure is **increased**, the equilibrium will move to reduce the pressure so the equilibrium will move in the direction which **reduces** the number of **gas** molecules.

Concentration of chemicals

If more of a chemical is added to a reaction at equilibrium, the equilibrium will move in the direction which will use up the added chemical.

Summary

REACTANTS $\rightleftharpoons$ **PRODUCTS**

THE EFFECT OF PRESSURE ON THE POSITION OF EQUILIBRIUM	
INCREASE PRESSURE	MOVES TO THE SIDE WITH FEWER GASEOUS MOLECULES
DECREASE PRESSURE	MOVES TO THE SIDE WITH MORE GASEOUS MOLECULES

REACTION TYPE	ΔH	INCREASE TEMP	DECREASE TEMP
EXOTHERMIC	-	TO THE LEFT	TO THE RIGHT
ENDOTHERMIC	+	TO THE RIGHT	TO THE LEFT

THE EFFECT OF CHANGING THE CONCENTRATION ON THE POSITION OF EQUILIBRIUM	
INCREASE CONCENTRATION OF A REACTANT	EQUILIBRIUM MOVES TO THE RIGHT
DECREASE CONCENTRATION OF A REACTANT	EQUILIBRIUM MOVES TO THE LEFT
INCREASE CONCENTRATION OF A PRODUCT	EQUILIBRIUM MOVES TO THE LEFT
DECREASE CONCENTRATION OF A PRODUCT	EQUILIBRIUM MOVES TO THE RIGHT

Catalysts have no effect on the position of an equilibrium because they speed up the forward and the reverse reactions by the same amount.

Example of an industrially important equilibrium: [you do not need to learn the details]

The Haber Process

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

The reaction is carried out using:

- **A pressure of 150x atmospheric**
- **A temperature of 700K**
- **A catalyst of finely divided iron with metal oxide promoters**

Under these conditions, about 15% of the reactants are converted into ammonia. Cooling the hot gases under pressure causes ammonia to condense allowing it to be separated from the nitrogen and hydrogen which are recycled through the catalyst.
The conditions chosen are a compromise.

Temperature
The reaction to produce ammonia is exothermic so Le Chatelier's Principle indicates that a **low temperature would give the best yield.** However the activation energy for the reaction is high so it is very slow at low temperatures. 700K is a compromise.

Pressure
When ammonia is made, four gas molecules form two ammonia gas molecules so the **reaction is favoured by high pressure.** Reaction rate is also higher at increased pressure.
However very high pressures have cost and safety penalties that limit the pressure used.