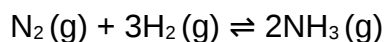


# Factors affecting chemical equilibrium.

- Equilibrium in chemical reactions is affected by several factors. Since equilibrium is achieved when the rate of the forward reaction equals the rate of the reverse reaction, any factor that can change these rates will affect equilibrium.
- One factor that affects equilibrium is concentration of reactants and products. By increasing or decreasing the concentration of any of the substances involved, the equilibrium position will change.
- Another factor that affects dynamic equilibrium is temperature. Depending on if the reaction is exothermic or endothermic, the shift will be toward the reactants or toward the products.
- If gases are involved in the reaction, another factor that affects dynamic equilibrium, is pressure.
- To begin we need to understand the term equilibrium position.
- The equilibrium position of a reversible reaction is a measure of the concentrations of the reacting substances at equilibrium.

For example

- Nitrogen gas is reacted with hydrogen gas to make ammonia gas.



- The equilibrium position is:
  - to the left if the concentrations of  $\text{N}_2$  and  $\text{H}_2$  are greater than the concentration of  $\text{NH}_3$  (more Nitrogen and hydrogen gas is produced)
  - to the right if the concentration of  $\text{NH}_3$  is greater than the concentrations of  $\text{N}_2$  and  $\text{H}_2$  (more ammonia gas is produced)

## Le Chatelier's Principle

- A scientist named Le Chatelier came up with a principle that will help us predict how these factors we mentioned can affect the position of the equilibrium.
- **Le Chatelier's principle states that if a system at equilibrium is subjected to any change, the system will adjust itself to oppose the applied change.**
- For example, if the temperature is increased, the position of equilibrium moves in the endothermic direction to reduce the temperature.

## Effect of changing pressure.

Pressure only affects equilibrium in reactions involving gases.

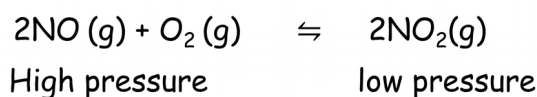
Pressure is caused by collision of the gas particles with the walls of the reaction vessel. The more the number of molecules present, the higher the number of collisions and hence the higher the pressure.

If the pressure of a gaseous reaction mixture is changed the equilibrium will shift to oppose that change (Le Chatelier's principle).

- ❑ If the pressure is increased the equilibrium will shift to favour the direction that has fewer molecules (lowers the pressure)
- ❑ If the pressure is decreased the equilibrium will shift to favour the direction that has more molecules. (increases the pressure)

### Example 1

Consider the following reaction involving gases.

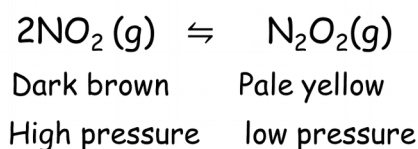


The left-hand side has higher pressure ( $2+1=3$  molecules) than the right side (2 molecules).

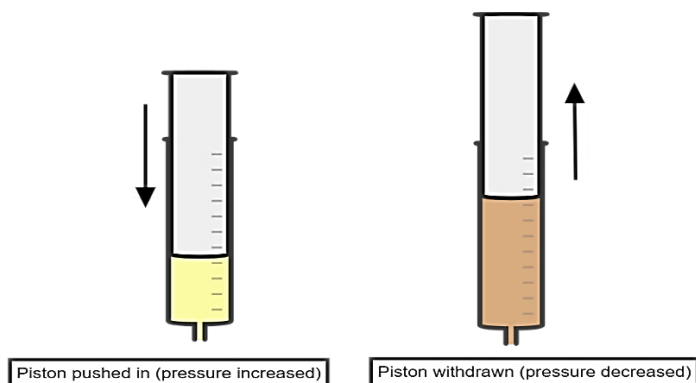
Applying pressure will favour the forward reaction since it reduces the pressure. A decrease in pressure favours the direction of reaction that forms more molecules.

### Example 2

The effect of changing pressure can be illustrated using the equilibrium established between nitrogen (IV) oxide and dinitrogen tetra oxide



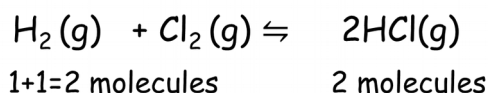
Consider what happens when the two gases are enclosed in a syringe.



- When the piston is pushed in, the volume of the gases is reduced hence increasing the pressure. The content of the syringe appear pale yellow.
- This shows that an increase in pressure favours the forward reaction which forms fewer molecules.

- When the piston is withdrawn slowly, the contents of the syringe darken as the volume increased therefore lowering the pressure.
- This shows that reverse reaction which forms more molecules is favoured by lowering the pressure.
- *What if the number of molecules of reactants equal the number of molecules of product?*
- If the number of molecules of reactants equals number of molecules of products, a change in pressure does not have any effect on the equilibrium.

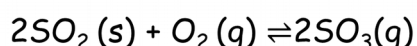
### Example 3.



Change in pressure will not affect the position of equilibrium but will help in the quick attainment of the equilibrium.

### Test yourself

Sulphur (IV) oxide reacts with oxygen to make sulphur trioxide in a reversible reaction:



Predict the effect of increasing the pressure

### Changing the temperature

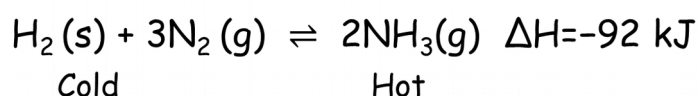
In a reversible reaction, if the reaction is exothermic in one direction, it is endothermic in the other direction.

According to Le Chatelier's principle, if the temperature of a reaction mixture is changed, the equilibrium will shift to oppose that change.

- ☐ If the temperature is increased the equilibrium will shift to favour the reaction which will reduce the temperature. The endothermic reaction is favoured.
- ☐ If the temperature is decreased the equilibrium will shift to favour the reaction which will increase the temperature. The exothermic reaction is favoured.

### Example 1

The equation below shows the equation for the production of hydrogen in Haber process



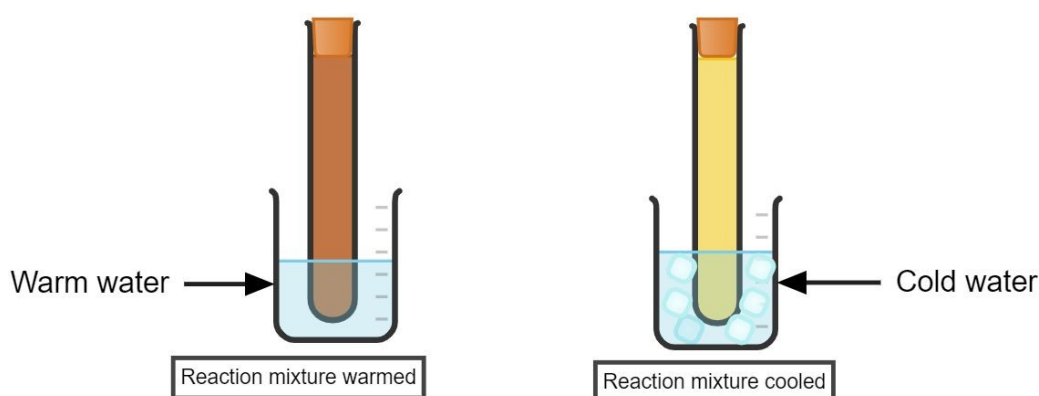
- ☐ If the forward reaction is exothermic, the backward reaction must be endothermic.

- Therefore, if the temperature is increased, the equilibrium position moves in the endothermic direction (to the left) to reduce the temperature. This means that less ammonia (NH<sub>3</sub>) will be produced.

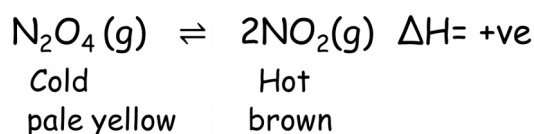
### Example 2

Consider a reaction in which copper turnings react with concentrated nitric (V) acid to produce brown nitrogen (IV) oxide gas (NO<sub>2</sub>)

The gas is collected in a test-tube fitted with a cork. The test-tube is warmed and then cooled and the colour changes observed in each case.



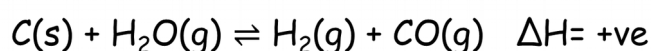
- When the mixture is heated, the dinitrogen tetraoxide molecules break up to form nitrogen (IV) oxide molecules. The mixture changes to brown colour.



- The forward reaction in the equation is endothermic since rising the temperature will favour the process that absorbs heat. In this case the equilibrium shifts from left to right and that is why the mixture becomes dark-brown.
- A decrease in temperature favours the reaction which liberates heat. Since reverse reaction is exothermic, the colour of the mixture becomes pale-yellow.
- Therefore it can be concluded that a change in temperature alters the position of equilibrium.

### Test yourself

Hydrogen can be manufactured by reacting carbon with steam:



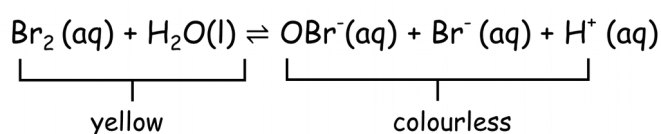
Predict the effect of increasing the temperature.

## 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.

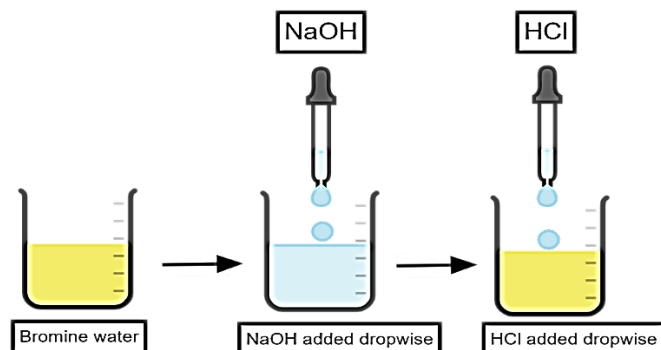
### Example 1

Bromine water is prepared by dissolving two drops of liquid bromine in a litre of water. The mixture is allowed to settle to attain equilibrium. The solution is yellow in colour.

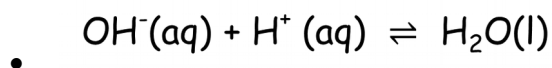


Each of the following solution was added into bromine water.

- Sodium hydroxide.
- Hydrochloric acid.



- The presence of bromine molecules makes the solution yellow.
- Adding sodium hydroxide (NaOH) will affect the position of the equilibrium.
- While neither sodium ions ( $\text{Na}^+$ ) nor hydroxide ions ( $\text{OH}^-$ ) are present on either side, the hydroxide ions will react with  $\text{H}^+$  ions to form water.



- The equilibrium will shift to the right hand side to replace the hydrogen ions that were removed. Thus the solution turns colourless.

- If hydrochloric acid was added to the equilibrium mixture, both hydrogen ions ( $\text{H}^+$ ) and chloride ions ( $\text{Cl}^-$ ) are being added.
- Hydrogen ions are on the right hand side of the equilibrium, therefore the equilibrium will shift to the left hand side to compensate, resulting in a higher concentration of reactants. This increases the intensity of the yellow colour.