Equilibrium:

There are 2 types of equilibrium:

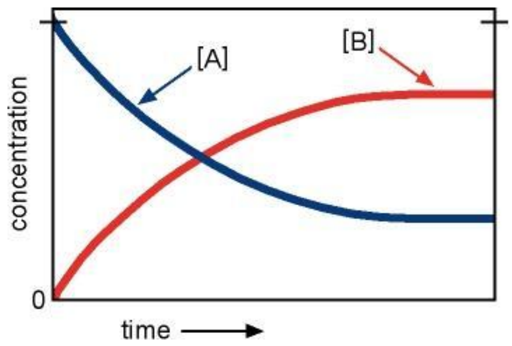
(a) **Dynamic equilibrium** = Where the rate of the forward reaction equals the rate of the backwards reaction.
(b) **Position equilibrium** = The point in a chemical reaction at which the concentrations of reactants and products are no longer changing.

Dynamic equilibrium:

There are 2 possible scenarios where this may happen in a chemical reaction.

Example 1:

A ⇌ B

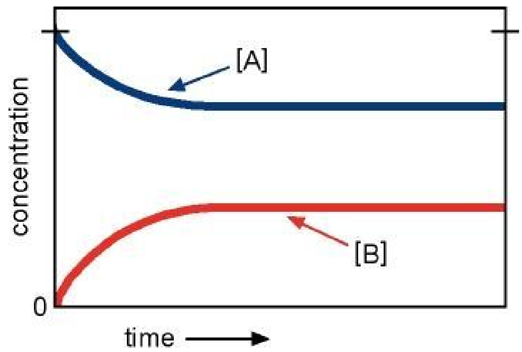


-At A, the position of the equilibrium is to the right.
-As time increases, the concentration of [A] decreases until it reaches equilibrium.
-At B, the position of equilibrium is to the left.
-As time increases, the concentration of [B] increases until it reaches equilibrium.
-[A] and [B] do not change.
-[A] and [B] reach equilibrium when the concentration of both [A] and [B] is constant.

Figure 1 *The concentration of reactants and products over time*

Example 2:

A ⇌ B



-At A, the position of equilibrium is to the left
-As time increases, the concentration of [A] decreases.
-At B, the position of equilibrium is to the right.
-As time increases, the concentration of [B] increases.
-[A] and [B] reach equilibrium when the concentration of both [A] and [B] is constant.

Figure 2 *The concentration of reactants and products over time*

Le Chatelier's Principal:

- Le Chântelier's principle states that 'when any change is made to the conditions of the equilibrium, the position of the equilibrium will move in the direction to counteract the change'.

There are 3 Factors that affect Equilibrium position:

1. Temperature
2. Pressure
3. Concentration

Let's go through an example question covering all conditions...

Temperature:

E.g.:

State and explain the effects on the position of the equilibrium if the temperature increases.

$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g) \qquad \Delta H = +57kJmol^{-1}$

1. As we can see from the equation the forward reaction is endothermic (energy is absorbed from the surroundings). Therefore ΔH is positive.
2. If the temperature increases, the system will act to make the system cooler = counteract the change.
3. To counteract the change, the equilibrium will favour the forward reaction because it is endothermic. The position of equilibrium will move to the right.

Pressure:

State and explain the effects on the position of the equilibrium if the Pressure increases.

$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g) \qquad \Delta H = +57kJmol^{-1}$

1. First of all, count the number of moles on both sides of the equation. On the equation above there are two moles on the right and one mole on the left.
2. If the pressure increases, the equilibrium will move to the left to oppose the change.
3. This is because there are fewer moles of gas on the reactant side.

Concentration:

State and explain the effects on the position of the equilibrium if the concentration of N_2O_4 increases.

$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g) \qquad \Delta H = +57kJmol^{-1}$

1. If the concentration of N_2O_4 increases, the system will act to counteract the change.
2. Hence, the equilibrium position will move to the right to restore dynamic equilibrium.

<u>Calculating mathematically the position of the equilibrium using Kc:</u>

<u>Key points to be noted:</u>

- If you see [ ] = concentration of an element
- You only use Kc values in an equilibrium question.
- The units are always different for every reaction so don't memorize the units. You will need to work them out in an exam.

<u>General formula: LEARN THIS!</u>

In the reaction:

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

[A] = concentration of A in $moldm^{-3}$

a = number of moles of A

Rules to remember when calculating Kc value:

- You must raise them to the power of their moles.
- You must remember to put square brackets around your reactants and products to show the examiner you are talking about concentration.
- If you change one variable, you must change the other reactant/product.
- Every Kc value has its own unique unit.

For example:

Calculate the Kc for this reaction below using the information provided.

N_2O_4 (g) $\rightleftharpoons$ $2NO_2$

$[N_2O_4]$ = 1 $moldm^3$ at equilibrium

$[NO_2]$ = 3 $moldm^3$ at equilibrium

<u>Method:</u>

1. Substitute the provided information into the Kc formula.
2. Raise the powers according to the number of moles.
3. Solve the equation to find Kc.

Write the expression:

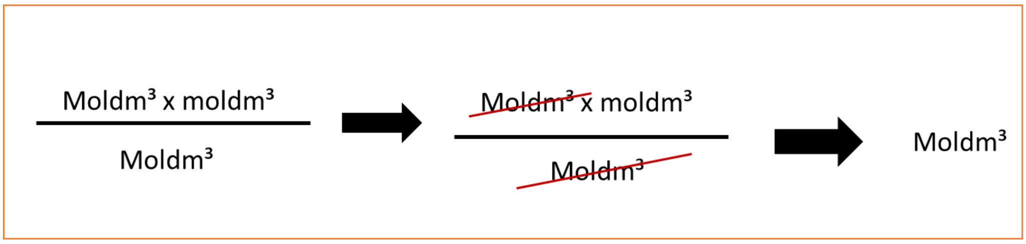
$$\frac{[NO_2]^2}{[N_2O_4]} = Kc$$

Full working out:

$Kc = (3)^2 / 1 = 9.0\ moldm^3$

Unit manipulation for Kc:

- **Every Kc value has its own unique units which is different for every reaction.**
- **To find the units of Kc, start by listing out the units like so...**



Value of Kc meaning:

1. If Kc is very large (about 1000), we will have mostly product species present at equilibrium which will give a forward direction to make the product.
2. If Kc is very small (about 0.001), we will have mostly reactant species present at equilibrium which will give a backward direction to make the reactant.
3. If Kc is between 0.001 and 1000, we will have a significant concentration of both reactant and product species present at equilibrium.

Exam techniques help sheet:

Structure of answer to an equilibrium question.

When writing your answer in the exam, you can use this guideline/method to write your answer, delete as appropriate:

1. **The equilibrium favours the forward/backward reaction.**
2. **The equilibrium will move to the left/right.**
3. **One sentence to explain why.**

(a)This is because the _____ reaction is endothermic/exothermic. (temperature)

(b) This is because there are fewer/more molecules of gas present.

(c) This is because the system will counteract the change.

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