

WJEC Chemistry A-level

3.8: Equilibrium Constants

Detailed Notes

Welsh Specification

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The Kc Constant

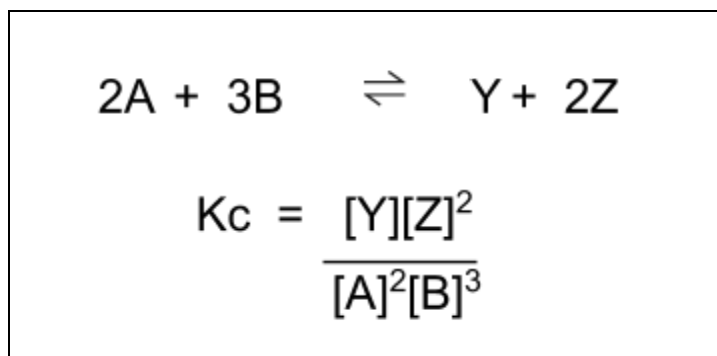
For **reversible reactions**, there is an **equilibrium constant**, Kc, that indicates the position of equilibrium for a reaction at a certain temperature. Kc for a given reaction always has the same value unless the **reaction conditions**, and therefore the position of equilibrium, is changed.

Calculating Kc

In order to find the value of Kc, the **concentrations** of the species present in the reaction at the **point of equilibrium** needs to be known.

Kc is equal to the **concentration of the products** divided by the **concentration of the reactants** - and any variation in the number of moles, raises that species to a **power** with the same value as the number of moles.

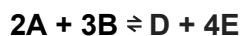
Example:



This equilibrium constant has varying units depending on the chemical reaction. It can be calculated by **substituting the units** into the Kc expression. Some of these then **cancel** to give the **overall units** of Kc for that reaction. The units for the **above reaction** can be calculated to be $\text{mol}^{-2}\text{dm}^6$. If the units **cancel completely** then Kc has **no units**.

Example:

Consider the following reaction:



$$K_c = \frac{[D][E]^4}{[A]^2[B]^3}$$

Then we have:

To work out the units, we substitute units into each position of A, B, D and E:

$$K_c = [(\text{mol dm}^{-3})(\text{mol dm}^{-3})^4] / [(\text{mol dm}^{-3})^2(\text{mol dm}^{-3})^3]$$

All the units cancel so Kc has **no units**.





Temperature Changes and Kc

The value of Kc is **not affected by concentration** change or use of a **catalyst**, however it is affected by changing the reaction **temperature**. This is because the **equilibrium position** will change, resulting in different concentrations of reactants and products.

Example:



*In this reaction, the forward reaction is endothermic.
This means that an increase in temperature will favour the forward reaction, and will increase the production of products.*

This will cause the value of Kc to increase as the concentration of the products at equilibrium will increase.

$$\uparrow K_c = \frac{[Y][Z]^2 \uparrow}{[A]^2[B]^3}$$

Similarly, if the **temperature** is changed so that the production of **reactants is favoured**, the value of **Kc will decrease** as the concentration of **reactants increases** (*dividing by a bigger number will decrease the outcome number*).

The Kp Constant

Kp is the equilibrium constant used for **gaseous equilibria**. All reactants and products must be in a **gaseous state** in order for Kp to be calculated.

Calculating Kp

Within a gaseous system, each gas has a **partial pressure**. These partial pressures allow the value of Kp for a gaseous equilibrium to be found. The **sum** of these partial pressures gives the **total system pressure**.

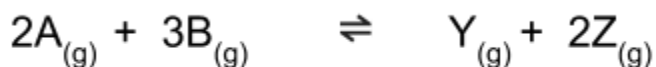




The **molar fraction** of a substance and the **total pressure** of the system are used to calculate **partial pressures**. The **units** for partial pressure are generally **kPa** - the same units of the total pressure.

$$\text{Partial Pressure of A} = \frac{\text{Moles of A}}{\text{Total Moles}} \times \text{Total Pressure}$$

K_p can then be calculated from the partial pressures of species present in the reaction:



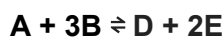
$$K_p = \frac{(pY)(pZ)^2}{(pA)^2(pB)^3}$$

It is similar to **K_c** in that any variation in moles raises the **partial pressure to a power** of equal quantity to the number of moles.

K_p also has **varying units** which are determined in the same way as for **K_c** - by **substitution** into the equation for **K_p**.

Example:

Consider the following reaction:



Then we have:

$$K_p = \frac{(pD)(pE)^2}{(pA)(pB)^3}$$

To work out the units, we substitute units into each position of A, B, D and E:

$$K_p = [(kPa)(kPa)^2] / [(kPa)(kPa)^3] = kPa^{-1}$$

The units for **K_p** are **kPa⁻¹**.

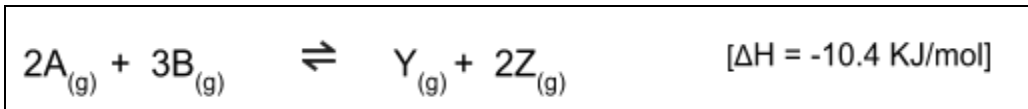




Temperature Changes and Kp

The value of Kp for a reaction can change depending on whether the reaction is **endothermic** or **exothermic**. This is because **changing the temperature** could favour the forwards or backwards reaction depending on which way around they are.

Example:



*In this reaction, the forwards reaction is exothermic.
This means that an increase in temperature will favour the backwards
reaction, and will increase the production of reactants.*

*This will cause the value of Kp to decrease as the partial pressure
of the reactants will increase
(dividing by a bigger number will decrease the outcome number).*

$$\downarrow K_p = \frac{(p_Y)(p^2_Z)}{(p^2_A)(p^3_B)} \uparrow$$

Likewise, if the **temperature** is changed so that the production of **products is favoured**, the value of **Kp will increase** as partial pressures of products increase.

