WJEC (Wales) Chemistry A-level

Topic 3.8 - Equilibrium Constants

Flashcards

Define dynamic equilibrium

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Dynamic equilibrium occurs in a reversible reaction when the rate of the forward reaction equals the rate of the backwards reaction. At equilibrium, the concentrations of reactants and products stay constant.

State le Chatelier's principle

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When a reaction at equilibrium is subjected to a change in concentration, temperature or pressure, the position of equilibrium will move to counteract the change.

Explain the difference between Kp and Kc

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Kc and Kp are both equilibrium constants.

Kc is found using molar concentrations in the calculation whereas Kp uses partial pressures. If you are dealing with a reaction in which all the substances are gaseous it is generally easier to use Kp.

For the reaction below, deduce an equation for Kc:

$2A + 3B \rightleftharpoons D + 4E$

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

Deduce the units for Kc where

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Deduce the units for Kc where $K_c = \frac{[D][E]^4}{[A]^2[B]^3}$

Replace the reactants/products in the Kc calculation with their units. Cancel any common units from the top and bottom of the fraction to find the units for Kc:

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

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

Deduce the units for Kc where

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Replace the reactants/products in the Kc calculation with their units. Cancel any common units from the top and bottom of the fraction to find the units for Kc:

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

$= (\text{mol dm}^{-3})^{-1} = \text{mol}^{-1}\text{dm}^3$

Why does Kc change when the temperature of a reversible reaction in a closed system is changed?

Why does Kc change when the temperature of a reversible reaction in a closed system is changed?

The Kc value is only valid for a certain temperature. When the temperature changes, the position of equilibrium shifts and so the equilibrium concentrations of the products and reactants changes. This leads to a change in Kc.

Consider a reversible reaction where the forward reaction is endothermic. How will increasing the temperature affect Kc?

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If the temperature is increased then the forward endothermic reaction will be favoured so the position of equilibrium will move towards the products. This means the concentration of products will increase and concentrations of reactants will decrease. This leads to an increase in Kc as in the calculation for Kc the number on the top of the fraction will be larger.

Consider a reversible reaction where the forward reaction is exothermic. How will increasing the temperature affect Kc?

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If the temperature is increased then the backwards endothermic reaction will be favoured so the position of equilibrium will move towards the reactants. This means the concentration of reactants will increase and concentrations of products will decrease. This leads to a decrease in Kc as in the calculation for Kc the number on the bottom of the fraction will be larger.

Explain why a compromised temperature of 450°C is used in the Haber process:

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

$$\Delta H = -46.2 \text{ kJ mol}^{-1}$$

Explain why a compromised temperature of 450°C is used in the Haber process:

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$, $\Delta H = -46.2$ kJ mol^{-1}

Since ΔH is negative we can deduce that the forward reaction is exothermic. Therefore, a low temperature is required to shift equilibrium towards the products, and increase the yield of product, but the temperature cannot be too low as this will lead to a very slow rate of reaction. Therefore, a compromised temperature is used so that the forward reaction is favoured but the rate of reaction is also relatively fast.

How does changing the concentration of a reactant or product affect the value of Kc?

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Changing the concentration of a reactant or product has no effect on Kc.

How does a catalyst affect the value of Kc?

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A catalyst has no effect on Kc. The catalyst will speed up the forward and backwards reactions at the same rate so the ratio of products to reactants will remain the same.

Consider a reversible reaction where the backwards reaction is exothermic. How could you increase the value of Kc?

Consider a reversible reaction where the backwards reaction is exothermic. How could you increase the value of Kc?

Kc will increase if the concentration of products increases. The forward reaction is endothermic and so to favour this direction, and hence increase the concentration of products, the temperature needs to be increased.

Define partial pressure and total pressure in relation to a mixture of gases

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Partial pressure - the pressure exerted by an individual gas in a mixture.

Total pressure - the sum of all the partial pressures of the individual gases in the mixture.

Define mole fraction

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The proportion of a gas mixture that is made up of a particular gas.

Give the formula to calculate mole fraction

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$$\text{Mole fraction of gas X} = \frac{\text{number of moles of gas X}}{\text{total number of moles of gas in the mixture}}$$

Give the formula to calculate partial pressure of a gas

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Partial pressure of gas X=

(mole fraction of gas X) x (total pressure of the mixture)

What are the units of partial pressure?

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kPa

For the following gaseous reaction, deduce an equation for Kp:

$$A + 3B \rightleftharpoons D + 2E$$

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

Deduce the units for Kp where

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Deduce the units for Kp where $Kp = \frac{(pD)(pE)^2}{(pA)(pB)^3}$

Substitute in the units for partial pressure and then perform cancellations:

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

The units for Kp are kPa^{-1}.

Why does Kp change when the temperature of a closed system reversible reaction is changed?

Why does Kp change when the temperature of a closed system reversible reaction is changed?

The Kp value is only valid for a certain temperature. When the temperature changes, the position of equilibrium shifts which changes the mole fractions of the gases present. This affects their partial pressures and so Kp changes.

Consider a reversible reaction where the forward reaction is exothermic. How will decreasing the temperature affect Kp?

Consider a reversible reaction where the forward reaction is exothermic. How will decreasing the temperature affect Kp?

If the temperature is decreased then the forward exothermic reaction will be favoured so the position of equilibrium will move towards the products. This means the molar fraction and partial pressure of the products will increase and the molar fraction and partial pressure of the reactants will decrease. This leads to an increase in Kp as in the calculation for Kc the number on the top of the fraction will be larger.

How will Kp be affected if the temperature is increased in the following reaction?

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

$$\Delta H = -197 \text{ kJ mol}^{-1}$$

How will Kp be affected if the temperature is increased in the following reaction?

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$, $\Delta H = -197$ kJ mol^{-1}

The forward reaction is exothermic. If the temperature is increased then the equilibrium shifts to the left (in the endothermic direction) to counteract the change. This means that less product is formed so the partial pressure of SO_3 will decrease while the partial pressure of SO_2 and O_2 will increase. This will cause Kp to decrease.

What is the significance of the magnitude of an equilibrium constant?

What is the significance of the magnitude of an equilibrium constant?

The magnitude of the equilibrium constant indicates where the position of equilibrium lies. The larger the value of Kp or Kc, the further towards the right (towards the products) the position of equilibrium lies.