

## The Meaning of $K_{eq}$

- If  $K_{eq} > 1$ , the forwards reaction or products are favoured; meaning the reaction essentially "goes to completion" and all or most of the reactants are used up to form the products.
- If  $K_{eq} < 1$ , the reverse reaction or reactants are favoured. The reaction does not occur to any great extent - most of the reactants remain unchanged, and there are few products produced.

Note: "Favoured" means that side of the equation has the higher number of moles and higher concentrations than the other.

Example: For the equilibrium system described by:  $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$

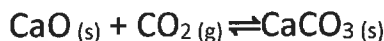
at a particular temperature the equilibrium concentrations of  $\text{SO}_2$ ,  $\text{O}_2$  and  $\text{SO}_3$  were 0.75 M, 0.30 M, and 0.15 M, respectively. Calculate  $K_{eq}$  and determine which reaction is favoured.

$$K_{eq} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} = \frac{[0.15]^2}{[0.75]^2 [0.30]} = \boxed{0.13}$$

Since  $K_{eq} < 1$ , the reverse reaction is favoured

## Key Points about $K_{eq}$

- Only gases and aqueous states are included in the equilibrium expression.   
 (Note: ions in solution are included in aqueous states)
- Solids or liquids are not included because while their amounts change during the reaction, their concentrations do not. They are instead assigned a value of 1.



$$K_{eq} = \frac{[\text{CaCO}_3]}{[\text{CaO}][\text{CO}_2]} = \frac{1}{[\text{CO}_2]}$$

Example: For the equilibrium system described by:  $\text{PCl}_5(\text{s}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g}) + \text{POCl}_3(\text{g})$

At equilibrium at  $100^\circ\text{C}$ , a 2.0L flask contains:

0.075 mol of  $\text{PCl}_5$     0.050 mol of  $\text{H}_2\text{O}$     0.750 mol of  $\text{HCl}$     0.500 mol of  $\text{POCl}_3$

Calculate  $K_{\text{eq}}$  for the reaction below and determine if the products or reactants are favoured.

$$K_{\text{eq}} = \frac{[\text{HCl}]^2 [\text{POCl}_3]}{[\text{PCl}_5] [\text{H}_2\text{O}]} = \frac{[\text{HCl}]^2 [\text{POCl}_3]}{[\text{H}_2\text{O}]} = \frac{[0.375]^2 [0.25]}{[0.025]} = \boxed{1.41}$$

calculate molarity first

$$[\text{HCl}] = \frac{0.750 \text{ mol}}{2 \text{ L}} = 0.375 \text{ M}$$

since  $K_{\text{eq}} > 1$  the products are favoured (slightly)

**\* Be able to manipulate the equation and solve for any part of the equilibrium expression. \***

Example:  $K_{\text{eq}} = 798$  at  $25^\circ\text{C}$  for the reaction:  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ .

In a particular mixture at equilibrium,  $[\text{SO}_2] = 4.20 \text{ M}$  and  $[\text{SO}_3] = 11.0 \text{ M}$ . Calculate the equilibrium  $[\text{O}_2]$  in this mixture at  $25^\circ\text{C}$ .

$$K_{\text{eq}} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$
$$[\text{SO}_2]^2 [\text{O}_2] = \frac{[\text{SO}_3]^2}{K_{\text{eq}}}$$
$$[\text{O}_2] = \frac{[\text{SO}_3]^2}{K_{\text{eq}} \cdot [\text{SO}_2]^2}$$
$$= \frac{[11]^2}{798 \cdot [4.2]^2} = \boxed{0.00860 \text{ M}}$$

does this make sense? Yes;  $K_{\text{eq}} \gg 1$  so few reactants are formed

**\* If asked to find  $K_{\text{eq}}$  for the reverse reaction at the same temperature, simply take the reciprocal of  $K_{\text{eq}}$  for the forwards reaction. \***

Example: For  $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$ ,  $K_{\text{eq}} = 280$  at  $600\text{K}$ . What is the value of the equilibrium constant for the reverse reaction at the same temperature?

$$K_{\text{eq}} = \frac{\text{products}}{\text{reactants}}$$

$$K_{\text{eq}_r} = \frac{\text{reactants}}{\text{products}}$$

$$\text{so } K_{\text{eq}_r} = \frac{1}{K_{\text{eq}_f}} = \frac{1}{280} = \boxed{0.0036}$$