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 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: $2\ SO_{2\,(g)} + O_{2\,(g)} \rightleftarrows 2\ SO_{3\,(g)}$

at a particular temperature the equilibrium concentrations of SO_2, O_2 and SO_3 were 0.75 M, 0.30 M, and 0.15 M, respectively. Calculate K_{eq} and determine which reaction is favoured.

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{[0.15]^2}{[0.75]^2[0.30]} = \boxed{0.13}$$

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

Key Points about K_{eq}

- Only gases and aqueous states (ions in solution) are included in the equilibrium expression.

- 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.

$$CaO_{(s)} + CO_{2\,(g)} \rightleftharpoons CaCO_{3\,(s)}$$

$$K_{eq} = \frac{[CaCO_3]}{[CaO][CO_2]} = \frac{1}{[CO_2]}$$

Example: For the equilibrium system described by: PCl_5 (s) + H_2O (g) ⇄ 2HCl (g) + $POCl_3$ (g)

At equilibrium at 100°C, a 2.0L flask contains:

0.075 mol of PCl_5 0.050 mol of H_2O 0.750 mol of HCl 0.500 mol of $POCl_3$

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

$$K_{eq} = \frac{[HCl]^2[POCl_3]}{[PCl_5][H_2O]} = \frac{[HCl]^2[POCl_3]}{[H_2O]} = \frac{[0.375]^2[0.25]}{[0.025]} = 1.41$$

calculate molarity first!

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

Since Keq > 1 the products are favored (slightly)

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

Example: K_{eq}= 798 at 25°C for the reaction: $2SO_2$ (g) + O_2 (g) ⇄ $2SO_3$ (g).

In a particular mixture at equilibrium, [SO_2]= 4.20 M and [SO_3]=11.0M. Calculate the equilibrium [O_2] in this mixture at 25°C.

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$[SO_2]^2[O_2] = \frac{[SO_3]^2}{K_{eq}}$$

$$[O_2] = \frac{[SO_3]^2}{K_{eq}\cdot[SO_2]^2} = \frac{[11]^2}{798\cdot[4.2]^2} = 0.00860\,M$$

does this make sense? Yes; Keq >>> 1 so few reactants are formed

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

Example: For CO (g) + H_2O (g) ⇄ CO_2 (g) + H_2 (g), K_{eq} = 280 at 600K. What is the value of the equilibrium constant for the reverse reaction at the same temperature?

$$K_{eq_f} = \frac{\text{products}}{\text{reactants}} \qquad K_{eq_r} = \frac{\text{reactants}}{\text{products}}$$

so $K_{eq_r} = \frac{1}{K_{eq_f}} = \frac{1}{280} = 0.0036$