

Manipulating Equilibrium Constant Expressions

Remember, for the reaction: $a A_{(aq)} + b B_{(aq)} \rightleftharpoons c C_{(aq)} + d D_{(aq)}$,

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

- Products in numerator, reactants in denominator
- Raise the stoichiometric value to the same factor for each species present
- Only gases and dissolved species appear in equilibrium constant expressions
- Solids and liquids do not appear in equilibrium constant expressions
- Remember to watch for units!

1. Do not include solids and liquids in equilibrium calculations, only gases and dissolved species

Example 1: $C_{(s)} + \frac{1}{2} O_{2(aq)} \rightleftharpoons CO_{(aq)}$

$$K_1 = \frac{[CO]}{[O_2]^{1/2}} = 4.6 * 10^{23} \text{ M}^{1/2} \text{ at } 25^\circ \text{C}$$

2. If doubling reaction, square K ; if tripling, cube K ; etc.

Example 2: $2 C_{(s)} + O_{2(aq)} \rightleftharpoons 2 CO_{(aq)}$

$$K_2 = \frac{[CO]^2}{[O_2]} = (K_1)^2 = (4.6 * 10^{23})^2 = 2.1 * 10^{47} \text{ M at } 25^\circ \text{C}$$

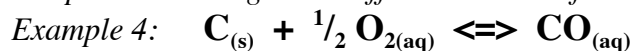
Also, if reaction*3, $K = (K_1)^3$; if reaction halved, $K = (K_1)^{1/2}$; etc.

3. If reactants and products are "flipped", take $1/K$ for new value..

Example 3: $CO_{(aq)} \rightleftharpoons C_{(s)} + \frac{1}{2} O_{2(aq)}$

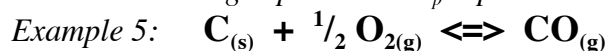
$$K_3 = \frac{[O_2]^{1/2}}{[CO]} = \frac{1}{K_1} = \frac{1}{4.6 * 10^{23}} = 2.2 * 10^{-24} \text{ M}^{-1/2} \text{ at } 25^\circ \text{C}$$

4. Temperature changes will affect the value of K by either adding or subtracting from the original value.



$$K_4 = \frac{[\text{CO}]}{[\text{O}_2]^{1/2}} = 9.7 \times 10^{23} \text{ M}^{1/2} \text{ at } 37^\circ \text{C}$$

5. Reactions in the gas phase use K_p expressions which are similar to K_c expressions

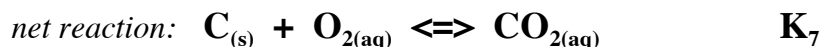
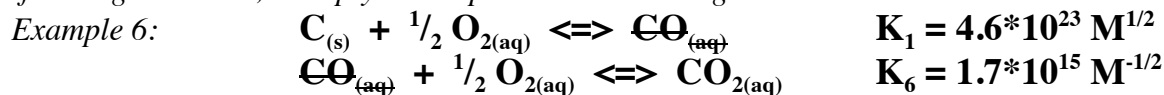


$$K_5 = \frac{P_{\text{CO}}}{P_{\text{O}_2}^{1/2}} = K_p, \text{ and if at } 25^\circ \text{C (298 K),}$$

$$K_p = K_c(\text{RT})^{\Delta n} = 4.6 \times 10^{23} (0.082057 \times 298)^{1-1/2} = 2.3 \times 10^{24} \text{ atm}^{1/2}$$

$R = \text{gas constant, } T = \text{Kelvin temperature, } P \text{ in atm}$

6. If adding reactions, multiply the respective K values together



Assume at 25°C :

$$K_7 = K_1 \cdot K_6 = \frac{[\text{CO}]}{[\text{O}_2]^{1/2}} * \frac{[\text{CO}_2]}{[\text{CO}][\text{O}_2]^{1/2}} = (4.6 \times 10^{23})(1.7 \times 10^{15}) = 7.8 \times 10^{38} \text{ unitless}$$