

## Equilibrium Constants in Terms of Pressure, $K_p$

When the reactants and products are gases, the equilibrium constant can be expressed in terms of partial pressures ( $K_p$ ).



The relationship between  $K_p$  and  $K_c$  is given by the following equation:

$$K_p = K_c (RT)^{\Delta n}$$

$$\Delta n = \sum (\text{product coefficients}) - \sum (\text{reactant coefficients})$$

**Example:**  $3\text{H}_2(g) + \text{N}_2(g) \rightleftharpoons 2\text{NH}_3$   $K = 5.80 \times 10^2$ ,  $K_p = ?$

$$\Delta n = 2 - (3 + 1) = -2 \quad K_p = 5.80 \times (0.08206 \times 273)^{-2} = 4.34 \times 10^3$$

- If the number of gas molecules does not change in the reaction,  $K_p = K_c$  because  $\Delta n = 0$ .

## K for Heterogeneous Equilibria

The concentrations of solids, liquids, and the solvent are omitted from equilibrium expressions.



## Equilibrium Constants and Units

The more accurate expression for the equilibrium constant is given by using the activities of reactants and products.

$$K = \frac{(a_c)^c (a_d)^d}{(a_a)^a (a_b)^b}$$

For most undergraduate general chemistry courses, it is assumed that  $a = 1$  since the differences are small and can be neglected. Because activities have no units,  $K$  is traditionally shown without units.

## The Direction of Reaction and Quotient ( $Q$ )

To predict the direction of reaction before an equilibrium is reached, reaction quotient is used. It is similar to the expression for  $K$ , however, the actual concentrations are used.



- $Q < K$  Reaction has a tendency to form more products.
- $Q > K$  Reaction has a tendency to form more reactants.
- $Q = K$  Reaction is at equilibrium.

$$Q_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad Q_p = \frac{P_C^c P_D^d}{P_A^a P_B^b}$$

- If any reactant or product is missing in the initial mixture, the reaction will shift in the direction forming some of that component.

## Le Chatelier's Principle

If a chemical system at equilibrium is disturbed, the system shifts in a direction that minimizes the disturbance. This can be done in different ways.

### Changing Concentrations at Equilibrium

- Adding a reactant produces more product by consuming some of the reactant.
- Adding a product produces more reactant by consuming some of the product.



### Changing The Reaction Volume

- Decreasing the volume shifts the reaction to in the direction with less gas molecules.
- Increasing the volume shifts the reaction to in the direction with more gas molecules.



### Changing The Pressure

- The pressure can be changed in a few ways: 1) By decreasing the volume (see above), 2) By adding more substance to the mixture (see above), 3) By adding an inert gas.
- Adding an inert gas does not cause a shift in equilibrium because it does not alter the partial pressures of any of the reacting components.

### Changing The Temperature

Know the sign of  $\Delta H$  is different than what we write for heat!

For an endothermic reaction, treat the heat as a product.



For an exothermic reaction, treat the heat as a reactant.



# Chapter 12 Chemistry Study Guide

**Arshad Iqbal**



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