Pressure, Concentration and K

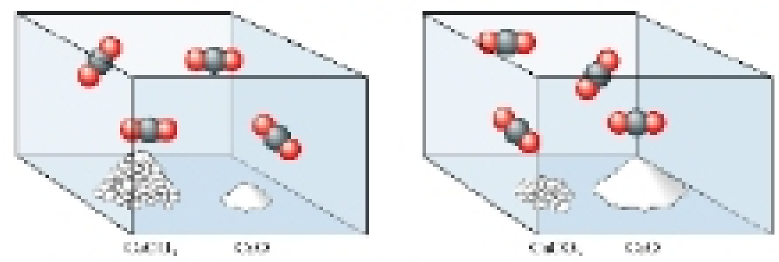
$N_{2\,(g)} + O_{2\,(g)} \quad 2\,NO_{(g)}$

$$K_c = \frac{a^2_{[NO]}}{a_{[N_2]}a_{[O_2]}} \qquad K_p = \frac{a^2_{P_{NO}}}{a_{P_{N_2}}a_{P_{O_2}}}$$

Heterogeneous Equilibria

$CaCO_3\,(s) \quad CaO\,(s) + CO_2\,(g)$

For pure solids and liquids, activity = 1.0



The position of an equilibrium involving a pure solid or liquid **does not depend** upon the amounts of pure solid or liquids present. The **activity of a pure solid or liquid is always equal to 1**, so the "concentration" does not appear in the *K* expression.

Heterogeneous Equilibria

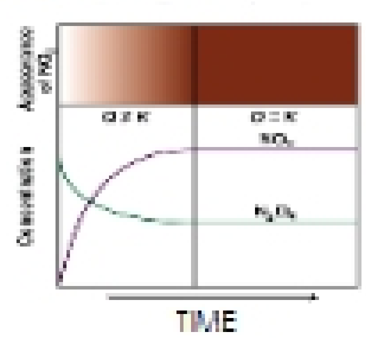
$CaCO_3\,(s) \quad CaO\,(s) + CO_2\,(g)$

$$K_c = a_{[CO_2]} = \frac{[CO_2]}{1\text{ M}}$$

$$K_p = a_{P_{CO_2}} = \frac{P_{CO_2}}{1\text{ atm}}$$

Equilibrium Calculations

- The reaction quotient (Q) is defined as the value of the expression for K (known as the "law of mass action") at any time during the reaction.



- We can compare Q to K to determine in which direction the reaction is proceeding.

Equilibrium Calculations

Q has same form as K, but the **concentrations are the actual concentrations at any time (t)** rather than the concentrations after equilibrium is reached.

Three cases when we can compare Q to K:

- If Q=K, the system is at equilibrium
- If Q<K, then the reaction will proceed toward products
- If Q>K, then the reaction will proceed toward reactants

Example

For the following reaction K_p = 3.81 at 773 K.

N_2 (g) + 3 H_2 (g) 2 NH_3 (g)

If P(NH_3)=0.063 atm, P(N_2)=0.0043 atm, and P(H_2)=0.035 atm, is the reaction at equilibrium? If not, in which direction will the reaction proceed in order to establish equilibrium?

Example

PCl_5 (g) PCl_3 (g) + Cl_2 (g)

If the initial pressure of PCl_5 was 0.500 atm, and the total pressure at equilibrium is 0.830 atm, what is K_p?

Example

Consider the equilibrium:

CO(g) + H_2O(g) = CO_2(g) + H_2(g)

0.250 mol CO and 0.250 mol H_2O are placed in a 125 mL flask at 900 K. What is the composition of the equilibrium mixture if K_c = 1.56?

Example

The reaction between nitrogen and oxygen to form nitric acid proceeds according to the following reaction:

$N_2\ (g) + O_2\ (g) \rightleftharpoons 2\ NO(g)$

$K_c = 4.1 \times 10^{-4}$ at 2000 K

Initially 0.500 moles of N_2 and 0.860 moles of O_2 are put into a 2.00 L vessel. Calculate the concentrations of all the species at equilibrium.

Example

Phosgene decomposes into CO and Cl_2 when heated according to the equation.

$COCl_2\ (g) \quad CO\ (g) + Cl_2\ (g)$

$K_c = 8.3 \times 10^{-4}$ at 360°C

Calculate the concentration of all species at equilibrium if 5.00 moles of phosgene are placed into a 10.0 L flask.

Example

Hydrogen iodide decomposes at moderate temperatures by the reaction:

$2\ HI\ (g) \rightleftharpoons H_2\ (g) + I_2\ (g)$

When 4.00 mol HI were placed in a 5.00 L vessel at 458°C, the equilibrium mixture was found to contain 0.442 mol I_2. What is the value of K_c ?

Le Châtelier's Principle

"If a change in conditions (a "stress") is imposed on a system at equilibrium, the equilibrium position will shift in a direction that tends to reduce that change in conditions."

$A + B \qquad C + D + \text{Energy}$

For example, in the reaction above:

If **more A or B is added** you will force the reaction to **produce more product**; if **either is removed**, the reaction will shift to **form more reactants**.

If **C or D is added** you will force the reaction to **form more reactants**, if **either is removed**, the reaction will shift to **form more products**.

If it is **heated** (energy added) you will **get more reactants**, and if **cooled, more products**.