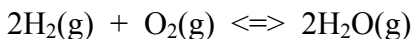


## EQUILIBRIUM CONTANTS

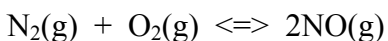
### MEANING OF VALUES



$$K_c = \frac{[\text{H}_2\text{O}]^2}{[\text{H}_2]^2[\text{O}_2]} = \frac{9.1 \times 10^{80}}{1}$$

Very little reactant relative to product.

Requires 200,000L of water vapor to locate 2 H<sub>2</sub> and 1 O<sub>2</sub> molecules.



$$K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]} = 4.8 \times 10^{-31} = \frac{4.8}{10^{31}}$$

Very little product relative to reactant.

In general for either K<sub>c</sub> or K<sub>p</sub>

K value very large

Reaction far toward completion

K value close to 1

Reactant and product concentrations nearly same

K value very small

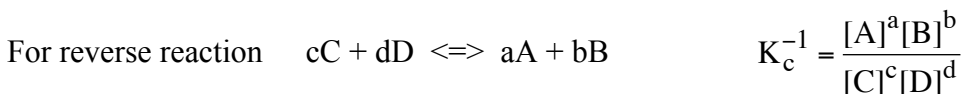
Hardly any products formed

## EQUILIBRIUM EXPRESSION

Equilibrium Expression for General Reaction

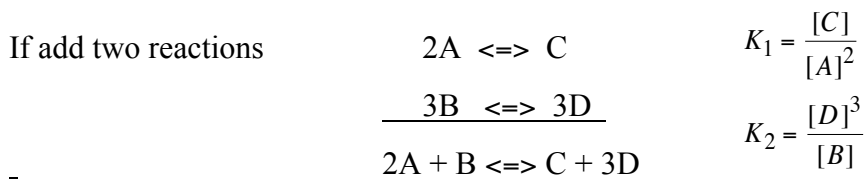


Also termed “mass action quotient” or “reaction quotient”



If double reaction, all coefficients are twice original value so (K<sub>c</sub>)<sup>2</sup>

If ½ reaction, all coefficients are ½ original value so (K<sub>c</sub>)<sup>1/2</sup>

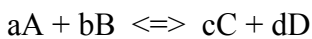


$$K = K_1 K_2 = \frac{[C]}{[A]^2} \times \frac{[D]^3}{[B]} = \frac{[C][D]^3}{[A]^2[B]}$$

## EQUILIBRIUM EXPRESSIONS

Relationship of  $K_p$  and  $K_c$

For a gaseous reaction the ratio of products to reactants in terms of pressure (atm) is  $K_p$



$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad \text{and} \quad K_p = \frac{P_C^c P_D^d}{P_A^a P_B^b}$$

$$PV = nRT \quad \text{so} \quad P = \frac{n}{V} RT = MRT$$

$$K_p = \frac{P_C^c P_D^d}{P_A^a P_B^b} = \frac{(M_C RT)^c (M_D RT)^d}{(M_A RT)^a (M_B RT)^b}$$

Factor out RT

$$K_p = (RT)^{\Delta n_{\text{gas}}} \left( \frac{M_C^c M_D^d}{M_A^a M_B^b} \right)$$

Therefore

$$K_p = (RT)^{\Delta n_{\text{gas}}} K_c \quad \text{where} \quad \Delta n_{\text{gas}} = (c+d) - (a+b)$$

## EQUILIBRIUM EXPRESSIONS

For the reaction:  $2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{ClNO}(\text{g})$ , write the  $K_c$  and  $K_p$  equilibrium expressions.

$$K_C = \frac{[\text{ClNO}]^2}{[\text{NO}]^2[\text{Cl}_2]}$$

$$K_P = \frac{P_{\text{ClNO}}^2}{P_{\text{NO}}^2 P_{\text{Cl}_2}}$$

At 500K, an equilibrium mixture contained 0.242 atm NO, 0.605 atm  $\text{Cl}_2$ , and 1.38 atm ClNO. Determine the  $K_p$  and  $K_c$  values.

To calculate  $K_c$  the relationship  $K_p = K_c(\text{RT})^{\Delta n}$  is used.

$$K_P = \frac{P_{\text{ClNO}}^2}{P_{\text{NO}}^2 P_{\text{Cl}_2}} = \frac{(1.38\text{atm})^2}{(0.242\text{atm})^2 (0.605\text{atm})} = 53.7\text{atm}^{-1}$$

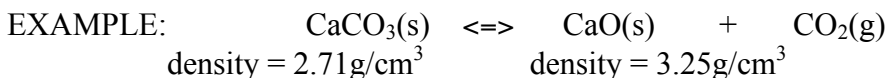
$$K_P = K_C (\text{RT})^{\Delta n \text{ gas}}$$

$$53.7\text{atm}^{-1} = K_C (0.08206 \text{ L} \cdot \text{atm/mol} \cdot \text{K} * 500\text{K})^{-1}$$

$$K_C = 2.20 \times 10^3 \text{ M}^{-1}$$

## HETEROGENEOUS EQUILIBRIA

Pure solids or pure liquids do not appear in equilibrium expression since their concentration is constant.



$$[\text{CaCO}_3] = \left( \frac{2.71\text{g}}{\text{cm}^3} \right) \left( \frac{1\text{mol}}{100.1\text{g}} \right) \left( \frac{1000\text{cm}^3}{1\text{L}} \right) = 27.1 \text{ mol/L}$$

$$[\text{CaO}] = \left( \frac{3.25\text{g}}{\text{cm}^3} \right) \left( \frac{1\text{mol}}{56.1\text{g}} \right) \left( \frac{1000\text{cm}^3}{1\text{L}} \right) = 57.9 \text{ mol/L}$$

$$K = \frac{[\text{CaO}][\text{CO}_2]}{[\text{CaCO}_3]}$$

$$\frac{K * [\text{CaCO}_3]}{[\text{CaO}]} = [\text{CO}_2] \quad \text{So } K_c = [\text{CO}_2] \quad \text{and} \quad K_p = P_{\text{CO}_2}$$