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CHAPTER 14 CHEMICAL EQUILIBRIUM

reversible reaction $Rate_{FWD} = Rate_{REV}$

physical $H_2O_{(s)} \rightleftharpoons H_2O_{(l)}$

chemical $aA + bB \rightleftharpoons cC + dD$

EQ. constant $K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$ "Law of mass-action"

DEPENDS ON (T)

$\uparrow K$, $\uparrow$[PRODUCTS] @ EQ

$\downarrow K$, $\downarrow$[PRODUCTS] @ EQ

HOMOGENEOUS EQ – all the reacting chemicals are in the same phase

conc. $2\ NO_{2\,(g)} \rightleftharpoons N_2O_{4\,(g)}$

$K_c = \frac{[N_2O_4]}{[NO_2]^2}$

$P = \left(\frac{n}{V}\right)RT$ → M $P \propto M$

$K_p = \frac{P_{N_2O_4}}{P^2_{NO_2}}$ → partial pressures

$K_c \neq K_p$ usually

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$K_c \neq K_p$ usually

$$a\,A_{(g)} \rightleftharpoons b\,B_{(g)}$$

$$K_c = \frac{[B]^b}{[A]^a} \qquad K_p = \frac{P_B^{\,b}}{P_A^{\,a}}$$

$$P_B = \frac{n_B}{V}RT \qquad P_A = \frac{n_A}{V}RT$$

$$K_p = \frac{\left(\frac{n_B}{V}\right)^b}{\left(\frac{n_A}{V}\right)^a}(RT)^{b-a} \Rightarrow \boxed{K_p = K_c(RT)^{\Delta n}}$$

Δn = moles of gas products − moles of gas reactants

(if $\Delta n = 0$, $K_c = K_p$)

$$2\,CO_{(g)} + O_{2\,(g)} \rightleftharpoons 2\,CO_{2\,(g)}$$

$$K_c = \frac{[CO_2]^2}{[CO]^2[O_2]} \qquad K_p = \frac{P_{CO_2}^{\,2}}{P_{CO}^{\,2}\cdot P_{O_2}} = K_c(RT)^{-1}$$

AQUEOUS SYSTEM

$[H_2O] = 55.5\,M$ — treat as a constant (omit)

$$NO_{2\,(aq)}^- + H_2O_{(l)} \rightleftharpoons HNO_{2\,(aq)} + OH^-_{(aq)}$$

$$K_c = \frac{[HNO_2][OH^-]}{[NO_2^-]} \quad (K_b!)$$

example

A) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$

K_c @ 191°C = 0.00326 $\qquad K_p = ?$

$$K_p = K_c (RT)^{\Delta n} = (0.00326)\left(\left(0.0821 \frac{atm \cdot L}{mol \cdot K}\right)(464K)\right)^1$$

$$K_p = 0.124$$

B) If, at EQ, $P_{PCl_5} = 3.50 \text{ atm}$, $\qquad P_{PCl_3} = ?$

$P_T = ?$

$X = ?$

$$K_p = \frac{P_{PCl_3} \cdot P_{Cl_2}}{P_{PCl_5}}$$

$P_A = X_A P_T$

$$K_p \cdot P_{PCl_5} = P_{PCl_3} \cdot P_{Cl_2}$$

$$X_A = \frac{P_A}{P_T}$$

$$(0.124)(3.50 \text{ atm}) = x^2$$

$$x = P_{PCl_3} = P_{Cl_2} = 0.659 \text{ atm}$$

$$P_T = 3.50 \text{ atm} + 0.659 \text{ atm} + 0.659 \text{ atm} = 4.82 \text{ atm}$$

$$X_{PCl_5} = \frac{3.50 \text{ atm}}{4.82 \text{ atm}} = 0.726$$

$$X_{PCl_3} = \frac{0.659 \text{ atm}}{4.82 \text{ atm}} = 0.137 = X_{Cl_2}$$