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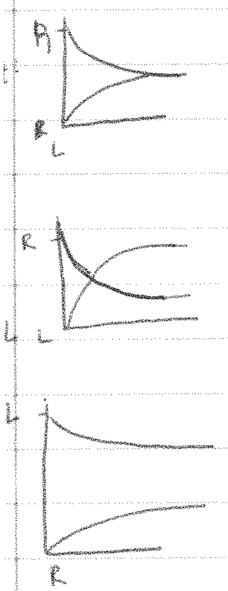
THE EQUILIBRIUM CONSTANT

<u>candy demo</u> from 02/06



- At equilibrium, concentrations of reactants + products are constant
- Equilibrium concentrations don't depend on initial

$N_2O_4(g) \rightleftharpoons 2NO_2(g)$ b/c the ratio of $[NO_2]^2$ to N_2O_4 remains constant no matter what equilibrium concentrations of product and reactants.

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

$$[NO_2]^2 : [N_2O_4]$$

(*) THE LAW OF MASS ACTION

$$\ldots + aA + bB \rightleftharpoons cC + dD + \ldots$$

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

PRODUCT

stoich coefficient

REACTANT

Bracket represent concentration in M ($M = \frac{mol}{L}$)

$\boxed{\text{Practice: At } 500^\circ C}$

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

$[N_2] = .921\ M$, $[H_2] = .763\ M$, $[NH_3] = .157\ M$

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.157)^2}{(0.921)(0.763)^3}$$

<u>no unit</u>, but # in M.

K is always unitless.

$= 0.0603 \rightarrow$ less reactant than product b/c less than 1.

$\boxed{\text{Practice \#2}}$ $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

* Note that these aren't solutions, they are <u>gases</u>.

$$K_p = \frac{P_C^{\,c}\,P_D^{\,d}}{P_A^{\,a}\,P_B^{\,b}}$$

Pressures are in atm (1 atm = 1.013 bar)

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How K_p and K_c are related?

Ideal Gas Law : $PV = nRT$

$$P = \frac{n}{V} RT$$

$$P_A = \left(\frac{n}{V}\right)_A RT = [A]RT$$

$$\frac{mol}{L} = [A]$$

$$K_p = \underbrace{\frac{[C]^c [D]^d}{[A]^a [B]^b}}_{K_c} (RT)^{\underbrace{c+d-(a+b)}_{\Delta n}}$$

change in number of moles going from reactants to products.

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

Practice: What is Δn for Haber-Bosch RXN?

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

moles = 2 - (3+1)

moles = -2

>> Types of Equilibrium <<

1) Homogeneous equilibrium (involve reactant + product in same phases)

$$H_2O_{(g)} + CO_{(g)} \rightleftharpoons H_{2(g)} + CO_{2(g)}$$

• Pure substances Do not appear in K_c & K_p

2) Heterogeneous (reactants + products in diff phases)

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

$$\Delta \quad CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

$$K_c = \frac{\cancel{[CaO]}[CO_2]}{\cancel{[CaCO_3]}} = CO_2 \quad \& \quad K_p = P_{CO_2}$$

ex) $PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)} \therefore K_c = [Cl^-]^2 * [Pb^{2+}]$

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Value of K: indicates extent of RXN.

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

$K \ll 1$ means bottom greater so, [react] >> [prod]

This equilibrium lies to the left.

ex) endothermic RXN ($+\overset{\text{large}}{\Delta H}$)

$K = 10^{18}$ ← $K \gg 1$ means [react] << [prod] This equilibrium lies to the Right.

ex) exothermic RXN ($-\overset{\text{large}}{\Delta H}$)

$K \approx 1$ means [react] ≈ [prod]

ex) $H_2O_{(g)} + CO_{2(g)} \rightleftharpoons H_{2(g)} + CO_{2(g)}$ K = 24, intermediate value of K.