Equilibrium constant in Gaseous System : In gaseous reactions, the concentration of gases may also be expressed in terms of their partial pressure. For a gaseous reaction,

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

The equilibrium constant may be represented as

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

where P_A, P_B, P_C & P_D are the partial pressures of the gases A, B, C and D respectively. K_p is not always equal to K_c (equilibrium constant defined in terms of concentrations).

Relationship between K_p and K_c.

For the reaction,

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

the equilibrium constant for the reaction expressed in terms of the concentrations (mol/litre) may be expressed as:

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad \text{——— } (1)$$

If the equilibrium involves gaseous species, then the concentrations may be expressed in terms of partial pressure of the gaseous substances. Then equilibrium constant in terms of partial pressure may be written as:

$$K_p = \frac{P_C^c \cdot P_D^d}{P_A^a \cdot P_B^b} \quad \text{——} \ (2)$$

where P_A, P_B, P_C and P_D are partial pressure of the substance A, B, C, & D respectively. for ideal gas

$$PV = nRT \quad \text{——} \ (3)$$

$$P = \frac{n}{V} RT \quad \text{——} \ (4)$$

Where P is the Pressure in Pa, n is mole of gas, V is Volume in m^3 and T is temperature in Kelvin.

$$\frac{n}{V} = \text{Concentration}, (C)$$

we can also write

$$P = CRT \quad \text{——} \ (5)$$

[∵ At constant temperature, Pressure of the gas is Proportional to its Concentration, i.e.

$$P \propto C$$

$$\text{So, } P = CRT$$]

So for A, B, C, & D

$P_A = [A]RT$

$P_B = [B]RT$

$P_C = [C]RT$

$P_C = [D]RT$

where [A], [B], [C] & [D] are the molar Conc. of A, B, C and D respectively.

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substituting these values in expressions for K_p in eq (2)

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

$$K_p = \frac{([C]RT)^c \cdot ([D]RT)^d}{([A]RT)^a \cdot ([B]RT)^b}$$

$$K_p = \frac{[C]^c [D]^d (RT)^{c+d}}{[A]^a [B]^b (RT)^{a+b}}$$

$$K_p = \frac{[C]^c [D]^d}{[A]^a [B]^b} \cdot (RT)^{(c+d)-(a+b)}$$

$$\boxed{K_p = K_c \cdot RT^{\Delta n}}$$

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