Van't Hoff Equation

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This equation gives the quantitative temperature dependence of equilibrium constant (K). The relation between standard free energy change ($\Delta G°$) and equilibrium constant is

$$\Delta G^\circ = -RT\ln K \qquad (1)$$

We know that

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad (2)$$

Substituting (1) in equation (2)

$$-RT\ln K = \Delta H^\circ - T\Delta S^\circ$$

Rearranging

$$\ln K = \frac{-\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R} \qquad (3)$$

Differentiating equation (3) with respect to temperature,

$$\frac{d(\ln K)}{dT} = \frac{\Delta H^\circ}{RT^2} \qquad (4)$$

Equation 4 is known as differential form of van’t Hoff equation.

On integrating the equation 4, between T_1 and T_2 with their respective equilibrium constants K_1 and K_2.

Problem

For an equilibrium reaction K_p= 0.0260 at 25° C ΔH= 32.4 kJmol^{-1}, calculate K_p at 37° C

Solution:

T_1=25 + 273 = 298 K

T_2 = 37 + 273 = 310 K

ΔH = 32.4 KJmol^{-1} = 32400 Jmol^{-1}

R=8.314 JK^{-1} mol^{-1}

K_{P1}= 0.0260

K_{p2}=?

$$\log\frac{K_2}{K_1}=\frac{\Delta H^\circ}{2.303\,R}\left[\frac{T_2-T_1}{T_2T_1}\right]$$

$$\log\frac{K_2}{K_1}=\frac{32400}{2.303\times 8.314}\left(\frac{310-298}{310\times 298}\right)$$

$$=\frac{32400\times 12}{2.303\times 8.314\times 310\times 298}$$

$$=0.2198$$

$$\frac{K_2}{K_1}=\text{anti}\log 0.2198=1.6588$$

$$K_2=1.6588\times 0.026=0.0431$$