Temperature Effects on Equilibrium: A Study Guide

Show that

\[
\frac{\Delta H}{R} \ln K = - \frac{d(1/T)}{dT}
\]

Solution

Since

\[
\Delta G = -RT \ln K, \\
\ln K = -\frac{\Delta G}{RT}
\]

Differentiate both sides with respect to \((1/T)\) in the above equation gives,

\[
\frac{d(\ln K)}{d(1/T)} = -\frac{1}{R} \frac{d \Delta G}{d(1/T)} = \frac{-\Delta H}{RT^2}
\]

DISCUSSION

If \(K_1\) and \(K_2\) are the equilibrium constant at \(T_1\) and \(T_2\) respectively, show further that

\[
\ln \left(\frac{K_1}{K_2}\right) = -\frac{\Delta H}{R} \left(\frac{1}{1/T_1} - \frac{1}{1/T_2}\right).
\]

This is achieved by definite integral. This relationship indicates that the plot of \(\ln (K)\) versus \(1/(T)\) is a straight line, and the slope is \(-\Delta H / R\). Thus, \(\Delta H\) can be determined by measuring the equilibrium constant at different temperatures.

\[
101,300 \text{ N m}^{-2} \\
23.756 \text{ mmHg} = 3166 \text{ Pa} \\
760 \text{ mmHg}
\]

\[
G^0 = 8.312 \text{ J} \times 298 \ln(3166) \\
= 20.0 \text{ kJ/hr}
\]

DISCUSSION

This example illustrates the evaluation of Gibb's energy when the equilibrium constant is known.

Contributors and Attributions

- Chung (Peter) Chieh (Professor Emeritus, Chemistry @ University of Waterloo)