S. S. College. Jehanabad (Magadh University)

Department : Physics

Subject : Thermodynamics

Class : B.Sc(H) Physics Part I

Topic: Application of Maxwell's Thermodynamical Relation

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Joule-Thomson Cooling and Joule-Kelvin Coefficient

In Joule-Thomson porous plug experiment, if a gas at constant high pressure is forced through a porous plug to a region of constant low pressure, then there is a change in temperature of escaping gas. This is called the Joule-Thomson effect.

When the gas gets throttled, the gas gets wire drawn and it suffers expansion. Although there is a difference of pressure on two sides of the porous plug but the enthalpy H of the gas remains constant i.e.

$H = U + PV =$ a constant

differentiating

$dH = dU + PdV + VdP = 0$

$dQ = dU + PdV$ (First law of thermodynamics)

from second law

$dQ = TdS$ (Second law of thermodynamics)

substituting in the first law

$dQ = TdS + VdP = 0$ …(i)

dS is a perfect differential and S being a function of P and T i.e. $S = F(P, T)$, we have

$$dS = \left(\frac{\partial S}{\partial T}\right)_P dT + \left(\frac{\partial S}{\partial P}\right)_T dP$$

Substituting in equation (i)

$$T\left(\frac{\partial S}{\partial T}\right)_P dT + \left[T\left(\frac{\partial S}{\partial P}\right)_T + V\right]dP = 0$$

We know,

$$C_P = \left(\frac{\partial Q}{\partial T}\right)_P$$

$$= T\left(\frac{\partial S}{\partial T}\right)_P$$

Where *CP* is the specific heat at constant pressure.

We get

$$C_P dT = -\left[T\left(\frac{\partial S}{\partial P}\right)_T + V\right]dP \qquad \ldots\ldots\ (ii)$$

From Maxwell's fourth thermodynamical relation

$$\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$$

$$C_P dT = \left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]dP$$

which implies

$$dT = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]dP$$