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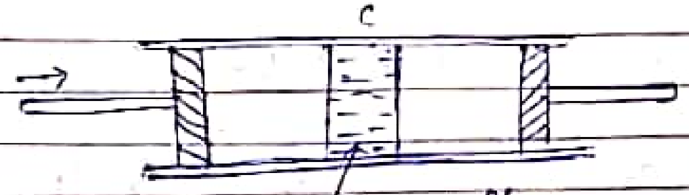
Joule-Thomson Effect : 9-1 (H & S) Paper-II

When a gas under constant pressure is forced through an insulated porous plug to a region of lower constant pressure its temperature changes. This is called the "Joule Thomson effect." The change in temperature is proportional to the pressure difference between the two sides of the plug. At ordinary temperatures, all gases except hydrogen and helium, show a cooling effect while hydrogen and helium show a heating effect.



Let us consider a mass of fluid passing through the porous plug C. The fluid during its passage through the pores becomes throttle. This is always the case whenever a fluid has to escape through a partly obstracted passage. This gas suffers a volume expansion. The plug is surrounded by the non-conducting jacket. So that no heat enters or leaves the fluid, the process of throttling is adiabatic. During this adiabatic throttling the enthalpy of the system remains the same i.e.

$$H = U + PV \quad \text{—— (1)}$$

On differentiation, we get

$$dH = dU + PdV + VdP$$
$$= TdS + VdP \quad \text{—— (2)}$$

Since

$$TdS = dU + PdV$$

Let $S \equiv S(T, P)$, thus

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

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Then

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

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

But

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

and from Maxwell's equation

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

so that

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

or $$dT = \frac{1}{C_P} dH + \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right] dP \quad \text{--- (3)}$$

Regarding T as a function of H and P

$$dT = \left(\frac{\partial T}{\partial H}\right)_P dH + \left(\frac{\partial T}{\partial P}\right)_H dP \quad \text{--- (4)}$$

~~From (3)+(4)~~ Comparisions from (3) & (4)

$$\left(\frac{\partial T}{\partial H}\right)_P = \frac{1}{C_P}$$

$$\mu \equiv \left(\frac{\partial T}{\partial P}\right)_H = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right] \quad \text{--- (5)}$$

Eqn. (5) is known as differential Joule-Thomson effect.

Specific heat C_P is always greater than zero, then from (5) it is clear that if

$$\left(\frac{\partial V}{\partial T}\right)_P < \frac{V}{T}$$

Then

$$\left(\frac{\partial T}{\partial P}\right)_H < 0.$$

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Thus the temperature of the system under going adiabatic throttling increases.

If

$$\left(\frac{\partial V}{\partial T}\right)_P > \frac{V}{T}$$

Then

$$\left(\frac{\partial T}{\partial P}\right)_H > 0$$

Thus the temperature of the system undergoing adiabatic throttling decreases.

If

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

Then

$$\left(\frac{\partial T}{\partial P}\right)_H = 0$$

i.e during adiabatic throttling the temperature of the system does not change.

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