Thermodynamics

(Module -3)

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JOULE – THOMSON EFFECT

Statement: The phenomenon of change of temperature produced when a gas is made to expand adiabatically from a region of high pressure to a region of low pressure is known as the Joule – Thomson effect.

JOULE – THOMSON EFFECT

Joule and Thomson observed that when a compressed gas is forced through a porous plug into vacuum or a region of low pressure, under adiabatic conditions, it gets appreciably cooled. Hydrogen and Helium are exceptional as they get warmed up under similar conditions.

JOULE – THOMSON EFFECT

Inversion temperature

The temperature below which a gas becomes cooler on expansion is known as the Inversion temperature.

JOULE – THOMSON EXPERIMENT

A tube thoroughly insulated is fitted with a porous plug in the middle and two pistons A and B on the sides. The pressures on the left and right sides of the plug are kept at P_1 and P_2 respectively,

where $P_1 > P_2$.

JOULE – THOMSON EXPERIMENT

A volume V_1 of the gas enclosed between piston A and porous plug C at a higher pressure P_1 is forced very slowly through the porous plug by moving the piston A inwards and is allowed to expand to volume V_2 at a lower pressure P_2 by moving the piston B outwards.
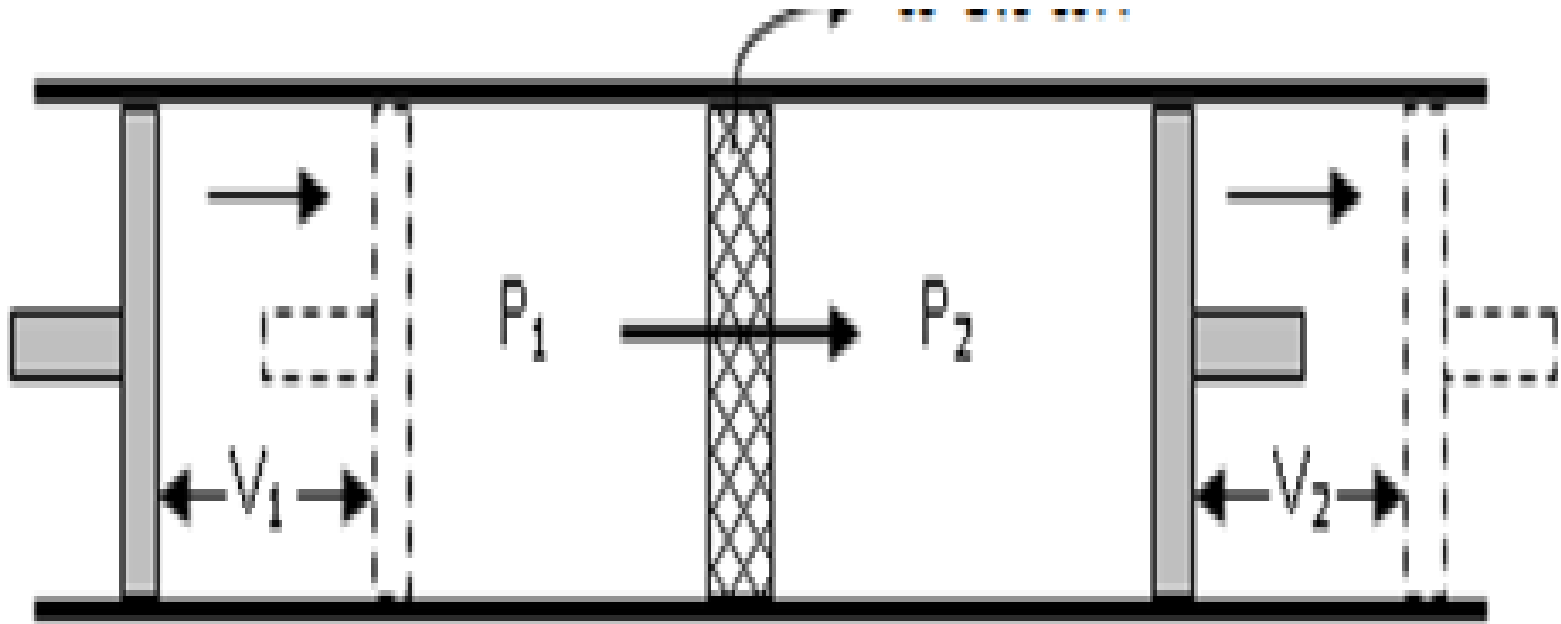
JOULE – THOMSON EXPERIMENT

The change in temperature is found by taking readings on the two thermometers and it was observed that when the experiment is done at room temperature, all gases (except H_2 and He) show a fall in temperature on expansion.

JOULE – THOMSON EXPERIMENT

JOULE – THOMSON EXPERIMENT

Since the process is carried out adiabatically,

$$Q = 0$$

According to first law of thermodynamics,

$$Q = \Delta E + W$$
$$0 = \Delta E + W$$
$$\Delta E = - W$$
$$W = - \Delta E$$

JOULE – THOMSON EXPERIMENT

$$\Delta E = - W$$

$$W = - \Delta E$$

Thus, the work done during the expansion of the gas under adiabatic conditions is at the expense of the internal energy. In other words, when the work of expansion is done adiabatically, the internal energy and hence temperature of the gas decreases.

JOULE – THOMSON EXPERIMENT

When a gas expands adiabatically through porous plug, the enthalpy of the system remains constant, while internal energy changes. In other words, adiabatic expansion of a gas takes place at constant enthalpy, such expansion is known as isoenthalpic.

$$\Delta H = 0.$$

Joule – Thomson coefficient

Joule – Thomson coefficient may be defined as the change in the number of degrees of temperature produced by a drop of one atmospheric pressure when the gas expands under conditions of constant enthalpy.

Joule – Thomson coefficient

It is expressed as,

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

Joule – Thomson coefficient

➤ If μ is positive (i.e., when dT and dP both are negative), the gas cools on adiabatic expansion. Most of the gases cools on expansion at room temperature.

Joule – Thomson coefficient

If μ is negative (i.e., when dT is positive and dP is negative), the gas warms up on adiabatic expansion at room temperature. Hydrogen and Helium warms up on expansion at room temperature.

Joule – Thomson coefficient

If $\mu = 0$ (i.e., when dT =0 for any value of dP), the gas neither cooled nor warms up on adiabatic expansion.

Joule – Thomson coefficient

The temperature at which the sign of μ changes is called **inversion temperature.**

The inversion temperatures of most of the gases are much higher than the room temperature and hence these gases undergo cooling on adiabatic expansion at room temperature.

Joule – Thomson coefficient

It has been found that at a particular pressure, every gas has a definite temperature at which μ = 0, below this temperature μ = +ve and above this temperature μ = -ve.

THANK YOU......