

Theory of Joule-Thomson expansion

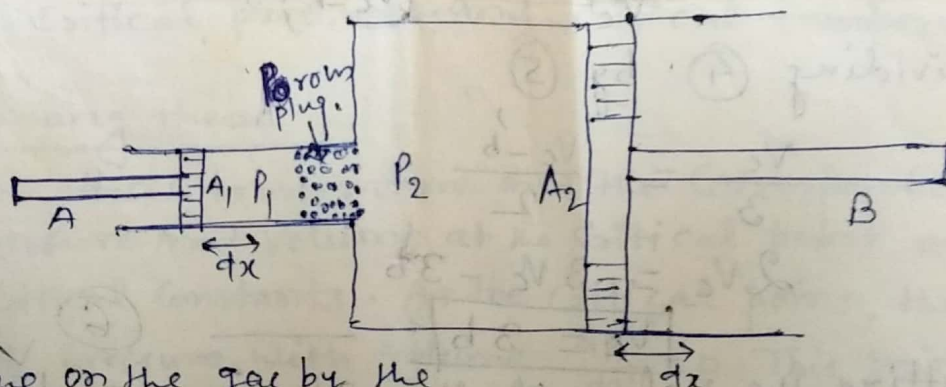
or

Theory of Porous plug experiment

The gas is allowed to pass through the porous plug from the high pressure side to the low pressure side. The velocity of the gas as it emerges from the porous plug is very high and there is increase in the kinetic energy of the molecules.

Consider one gram molecule of a gas to the left and to the right of the porous plug.

Let P_1, V_1 and P_2, V_2 represent the pressure and volume on the two sides of the porous plug. When the piston A is moved through a certain distance dx , the piston B also moves through the same distance dx .



□ The work done on the gas by the piston A = $P_1 A_1 dx = P_1 V_1$.

The work done by the gas on the piston B = $P_2 A_2 dx = P_2 V_2$

Thus, the net external work done by the gas is

$$P_2 V_2 - P_1 V_1$$

If w is the work done by the gas in separating the molecules against their inter-molecular attractions, the total amount of work done by the gas

$$= (P_2 V_2 - P_1 V_1) + w$$

No heat is gained or lost to the surroundings. There are three possible cases:

(i) Below the Boyle temperature; ✓

$$P_1 V_1 < P_2 V_2$$

and $P_2 V_2 - P_1 V_1$ is +ve. w must be either positive or zero. Thus a net +ve work is done by the gas and there must be cooling when the gas passes through the porous plug.

(ii) At the Boyle temperature if P_1 is not very high

$$P_1 V_1 = P_2 V_2$$

$$P_2 V_2 - P_1 V_1 = 0.$$

The total work done by the gas in this case is w . Therefore, cooling effect at this temperature is only due to the work done by the gas in overcoming inter-molecular attractions.

(iii) Above the Boyle temperature,

$$P_1 V_1 > P_2 V_2$$

$$P_2 V_2 - P_1 V_1 \text{ is } -ve$$

Thus, the observed effect will depend upon whether $(P_2 V_2 - P_1 V_1)$ is greater or less than w

If $w > (P_1 V_1 - P_2 V_2)$, cooling will be observed.

If $w < (P_1 V_1 - P_2 V_2)$, heating will be observed.

Thus, the cooling or heating of a gas due to free-expansion through a porous plug from a high pressure to a low pressure side will depend on (i) the deviation from Boyle's law (ii) work done in overcoming inter-molecular attractions.