Joule Expansion:

Joule expansion or free expansion

Let us have a thermally isolated system

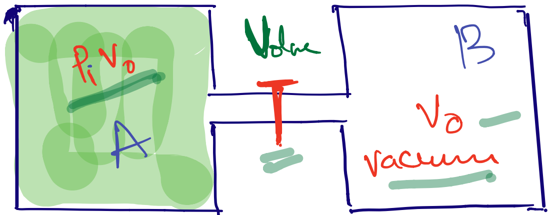


Fig 1

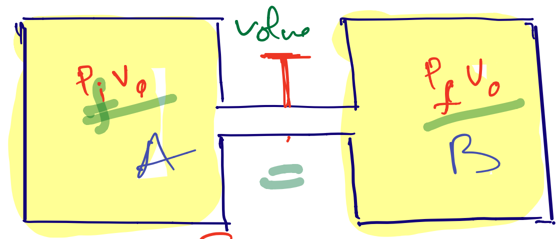


Fig 2

Joule expansion or free expansion

- Let 1 mole of gas is confined in Left Hand Side container

- The right hand side of container also has same volume V_0 but is evacuated

- Then the valve is opened and gas expands in both the chambers

- So now the volume $= 2V_0$
  Pressure $= P_f$
  Temperature T_f.

- So initially $P_i V_0 = RT_i$
  finally $P_f(2V_0) = RT_f$

— Since the system is thermally isolated $dQ = 0$ ✓

— Gas expands against vacuum so no external work is done so $dW = 0$ ✓

— So first law of thermodynamics says $dU = 0$ [from $dQ = dU + dW$]

— We know U is only function of T so $dU = 0 \Rightarrow dT = 0$ i.e. $\boxed{T_i = T_f}$

— which gives us $P_i V_0 = P_f 2V_0$

or $\boxed{P_f = \frac{1}{2} P_i}$

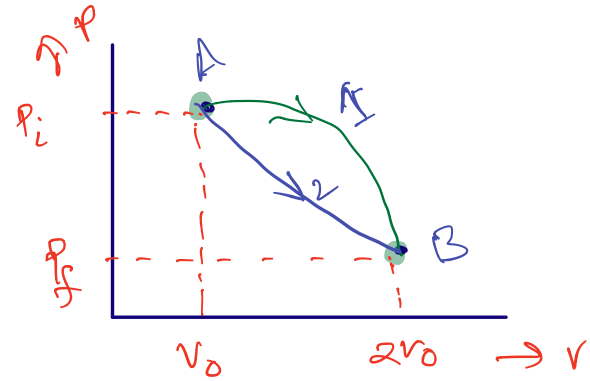
Let us now understand the change in entropy in such process.

Since the process is non static and irreversible process so $dS = dQ/T$ does not hold

Since entropy is a state function let us imagine a reversible isothermal process connecting initial and final process

1 = Joule free expansion

2 = isothermal reversible process.



So that we can estimate the change in entropy in the process.

$$\Delta S = S_2 - S_1 = \int_{V_0}^{2V_0} \frac{dQ}{T} = \int_{V_0}^{2V_0} \frac{du + PdV}{T}$$

$$= \int_{V_0}^{2V_0} \frac{PdV}{T} = R \ln 2V_0/V_0 \qquad PV = RT$$

or $\boxed{\Delta S = R \ln 2}$

So ΔS is necessarily positive

So entropy of the gas increases in an isothermal process even though there is no heat flow

This is same what we will get in the Joule free expansion as entropy is a function of state not the process.

System is isolated so no change of entropy associated with surrounding so the total change of entropy of universe in this process is same as given above (R ln 2)

$$\Delta S_U = R \ln 2$$

POINT TO BE NOTED

- Unlike energy, momentum and angular momentum in mechanical process
ENTROPY IS NOT CONSERVED except in reversible process

Similarly if we consider an other example where hot water is mixed with cold water in a closed chamber then energy remains conserved but not the ENTROPY. It is created in the process as its value increases

Entropy is always created in every process (except reversible) and once created the universe has to bear it for ever.

So

- Energy can neither be created nor destroyed

But

- Entropy cannot be destroyed but it can be created.