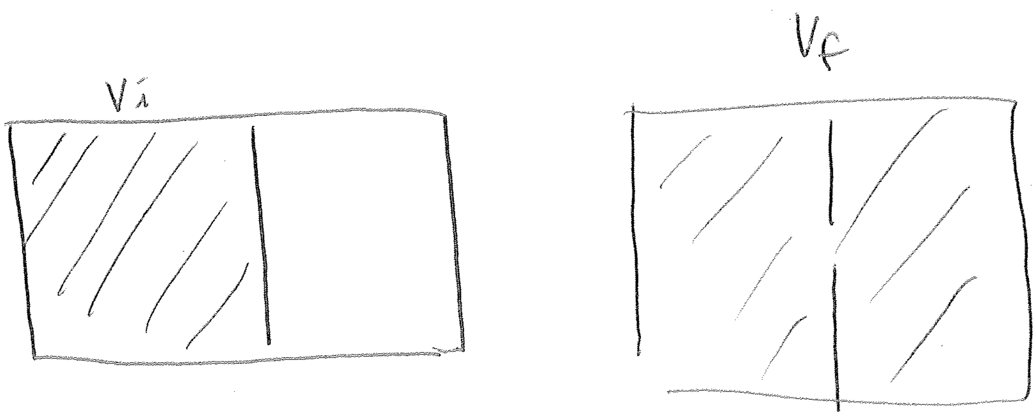
ENTROPY OF IDEAL GAS

$$S = Nk\left[\ln\left(\frac{V}{N}\left(\frac{4\pi m U}{3Nh^2}\right)^{3/2}\right) + \frac{5}{2}\right]$$

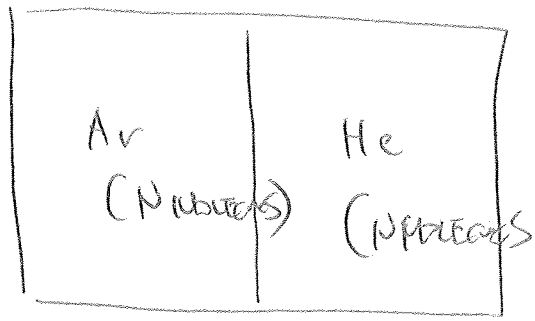


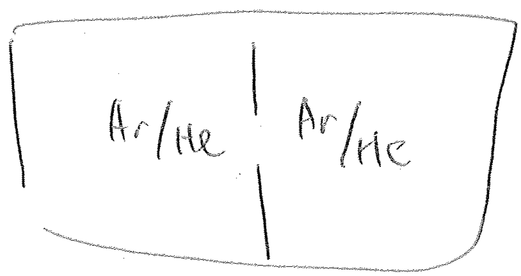
$$S_i = Nk\left[\ln\left[\frac{V_i}{N}\left(\frac{4\pi m U}{3Nh^2}\right)^{3/2}\right] + \frac{5}{2}\right]$$

$$S_f = Nk\left[\ln\left[\frac{V_f}{N}\left(\frac{4\pi m U}{3Nh^2}\right)^{3/2}\right] + \frac{5}{2}\right]$$

$$S_f - S_i = Nk\left[\ln\frac{V_f}{V_i}\right]$$

$$\Delta U = Q + W = 0 + \underline{\underline{0}}$$ NOT PUSHING ON ANYTHING





ENTROPY?

$$\Delta S_{He} = Nk \ln \frac{V_f}{V_i} = Nk \ln 2$$

$$\Delta S_{Ar} = Nk \ln \frac{V_f}{V_i} = Nk \ln 2$$

$$\Delta S_{TOTAL} = \Delta S_{He} + \Delta S_{Ar} = 2Nk \ln 2$$

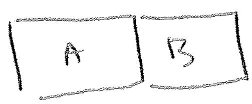
REVERSIBLE PROCESS — ENTROPY STAY THE SAME

IRREVERSIBLE PROCESS — ENTROPY INCREASES

~~IE ISO~~

ISOTHERMAL COMPRESSION AND EXPANSION OF GAS

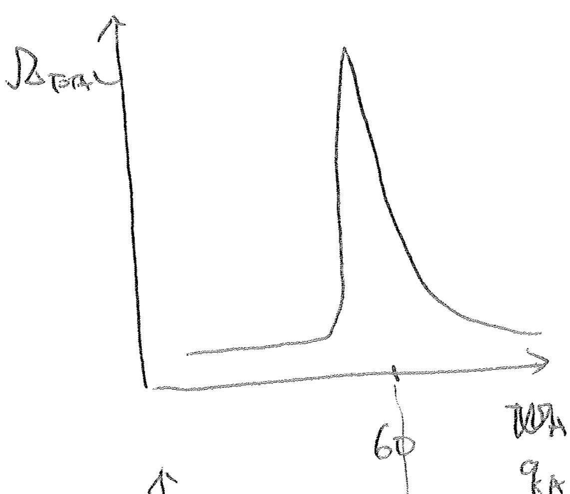
CHAPTER 3 (REMINDER EXAM IN TWO WEEKS)



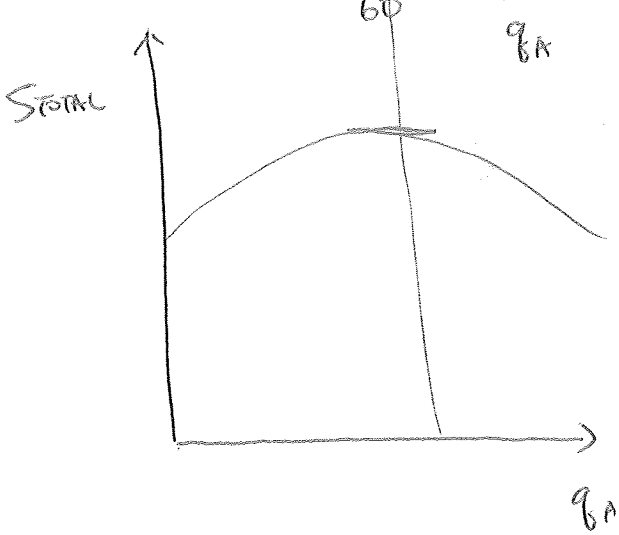
$q_{TOTAL} = 100$

$N_A = 300$

$N_B = 200$

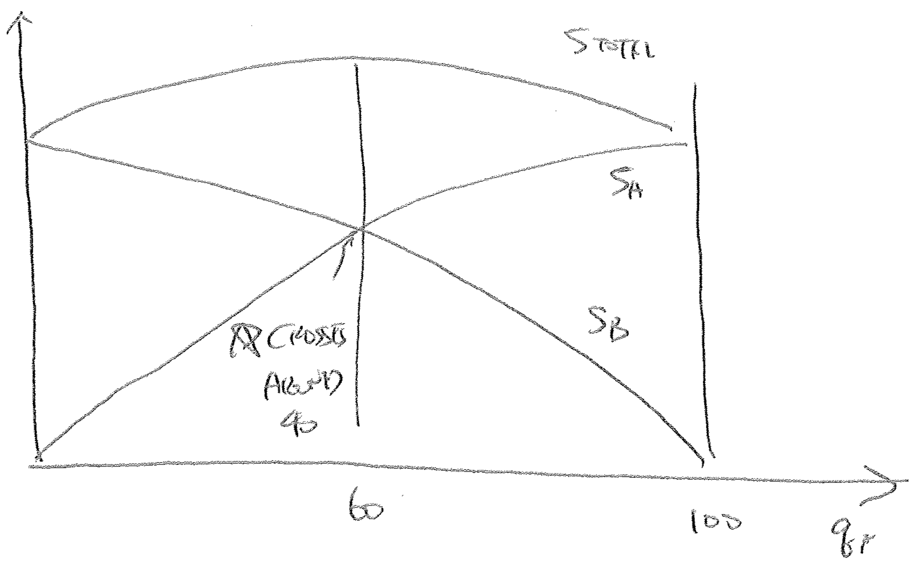


$$\frac{d\Omega_{TOTAL}}{d\,q_A} = 0$$



$$\frac{d\,S_{TOTAL}}{d\,q_A} = 0$$

WE CAN REALLY CALCULATE THIS!



$$\frac{\partial S_{TOTAL}}{\partial q_A} = 0 \quad \text{so} \quad \frac{\partial S_{TOTAL}}{\partial U_A} = 0$$

$$S_{TOTAL} = S_A + S_B$$

$$\frac{\partial S_A}{\partial U_A} + \frac{\partial S_B}{\partial U_B} = 0$$

$$\frac{\partial S_A}{\partial U_A} = -\frac{\partial S_B}{\partial U_A}$$

$$U_A + U_B = U_{TOTAL}$$

$$dU_A + dU_B = 0 \Rightarrow dU_A = -dU_B$$

So $\frac{\partial S_A}{\partial U_A} = \frac{\partial S_A}{\partial U_B}$ AT EQUILIBRIUM

$S = J/K$

$U = J$

$\frac{S}{U} = 1/K?$

WE WILL ASSERT $\frac{1}{T} = \frac{\partial S}{\partial U}$

EINSTEIN SOLID

$S = Nk \left[\ln(q/N) + 1 \right]$

$U = q h\nu = q\varepsilon$

$S = Nk \left[\ln U - Nk \ln(\varepsilon N) + Nk \right]$

$T = \left(\frac{\partial S}{\partial U} \right)^{-1} = \left(\frac{Nk}{U} \right)^{-1}$

$\underline{U = NkT}$ EXACTLY CORRECT

TRY FOR IDEAL GAS

~~$\Omega \propto V^{N} U^{3N/2}$~~

~~$S = Nk \ln V + Nk \ln U^{3/2}$~~

$$S = Nk\left[\ln\left(\frac{V}{N}\left(\frac{4\pi m U}{3Nh^2}\right)^{3/2}\right) + \frac{5}{2}\right]$$

$$\frac{S}{Nk} = \ln V + \ln U^{3/2} + \underline{f(N)}$$

SOME FUNCTION OF N

$$\frac{\partial S}{\partial U} = Nk\,\frac{3}{2}\,\frac{U^{1/2}}{U^{3/2}} = \frac{3}{2}\frac{Nk}{U} = \frac{1}{T}$$

$$U = \frac{3}{2}NkT$$

USE OF ENTROPY

HEAT CAPACITY

$$C_V = \left(\frac{\partial U}{\partial T}\right)_{N,V}$$

FOR EINSTEIN SOLID AT HIGH TEMP

$U = NkT$ $\quad$ $C_V =$ ~~kT~~ Nk

FOR MONOATOMIC GAS

$U = \frac{3}{2}NkT \quad C_V = \frac{3}{2}Nk$

IN GENERAL

PROCEDURE IS

1. FIND Ω
2. $S = k \ln \Omega$
3. $\frac{1}{T} = \frac{\partial S}{\partial U}$
4. FIND $U(T)$
5. $\frac{\partial U}{\partial T} = C_V$

HOW TO MEASUR ENTROPY

$$\frac{\partial S}{\partial U} = \frac{1}{T}$$

$$\partial S = \frac{\partial U}{\partial T} = \frac{Q+W}{T}$$

IF $W=0$ ($dV=0$)

$$\boxed{\partial S = \frac{Q}{T}}$$

EASY TO USE IF TEMP DOES NOT CHANGE

BUT IF TEMP CHANGES BUT $dV=0$

$$Q \quad dU = C_V\, dT$$

$$dS = \frac{C_V\, dT}{T}$$

EXAMPLE 200g OF WATER IS HEATED FROM 20°C TO 100°C

WHAT IS THE INCREASE IN ENTROPY

200g OF WATER → $C = 200\ \text{cal}/K$ OR $840\ J/K$

$$\Delta S = \int_{T_i}^{T_f} \frac{C_v\, dT}{T} = (840\ J/K) \ln T \Big]_{T_i}^{T_f}$$

$$= \text{840 } J/K \ln \frac{373}{293}$$

$$\Delta S = 200\ J/K$$

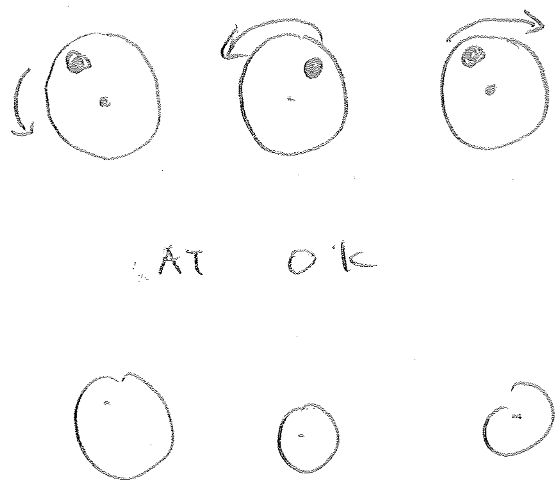
C_v CAN BE MEASURED ACCURATELY DOWN TO NEAR 0K

✓ $$S_f - S(0) = \int_0^{T_f} \frac{C_v\, dT}{T}$$

$S(0) \Rightarrow \quad \Omega(0) = 1 \quad \ln 1 = 0 \quad S(0) = 0$

<u>THIRD LAW</u> $\quad S(0) = 0$

2. RESIDUAL ENTROPY



MANY WAYS TO ARRANGE THIS