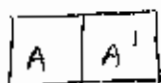


THEMAL + MECHANICAL INTERACTIONS:

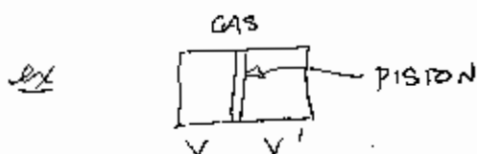


ISOLATED

- DEFINED BY E, X_α $\{ E', X_\alpha' \}$
 \downarrow
 $\alpha = 1 \dots n$

- BRING INTO CONTACT, ALLOW BOTH Q $\{$ ~~CHG~~ CHG IN X_α

- E', X_α' WILL DEP. ON E, X_α



$$E + E' = E^{(0)}$$

$$V + V' = V^{(0)}$$

$\{$ for sum: this discussion doesn't need the Q-S shg. in either; still know where will end up + new eqn

$\}$ FIXED

WANT:

(I) HOW DOES $\ln \Omega_{TOTAL}(E, X_\alpha)$ CHG?

$$\left(\ln \Omega_{TOT} = \ln \Omega_{TOT}(E, X_\alpha) \right) \uparrow \text{ (depends on } E, X_\alpha \text{ for sys. A)}$$

(II) WHAT NEW EQUIL. CONDS? $\{$ COULD GUESS $\}$

EXPECT $\Omega_{TOT}(E, X_\alpha)$ HAS SHARP PEAK AT $\tilde{E}, \tilde{X}_\alpha$

$$\Rightarrow \bar{E}, \bar{X}_\alpha = \tilde{E}, \tilde{X}_\alpha$$

**
 ex: $V=0 \rightarrow$
 no states;
 grows rapidly
 as V^N
 **

PLOT: CP. X_α FIXED, NOT INSULATED $\Rightarrow Q$

skip \rightarrow not obvious (E \neq CONST) some cross restricted curve

$\{ X_\alpha$ FREE, INSULATED $\Rightarrow W \}$

X_α FREE, NOT INSULATED $\Rightarrow Q \{ W$

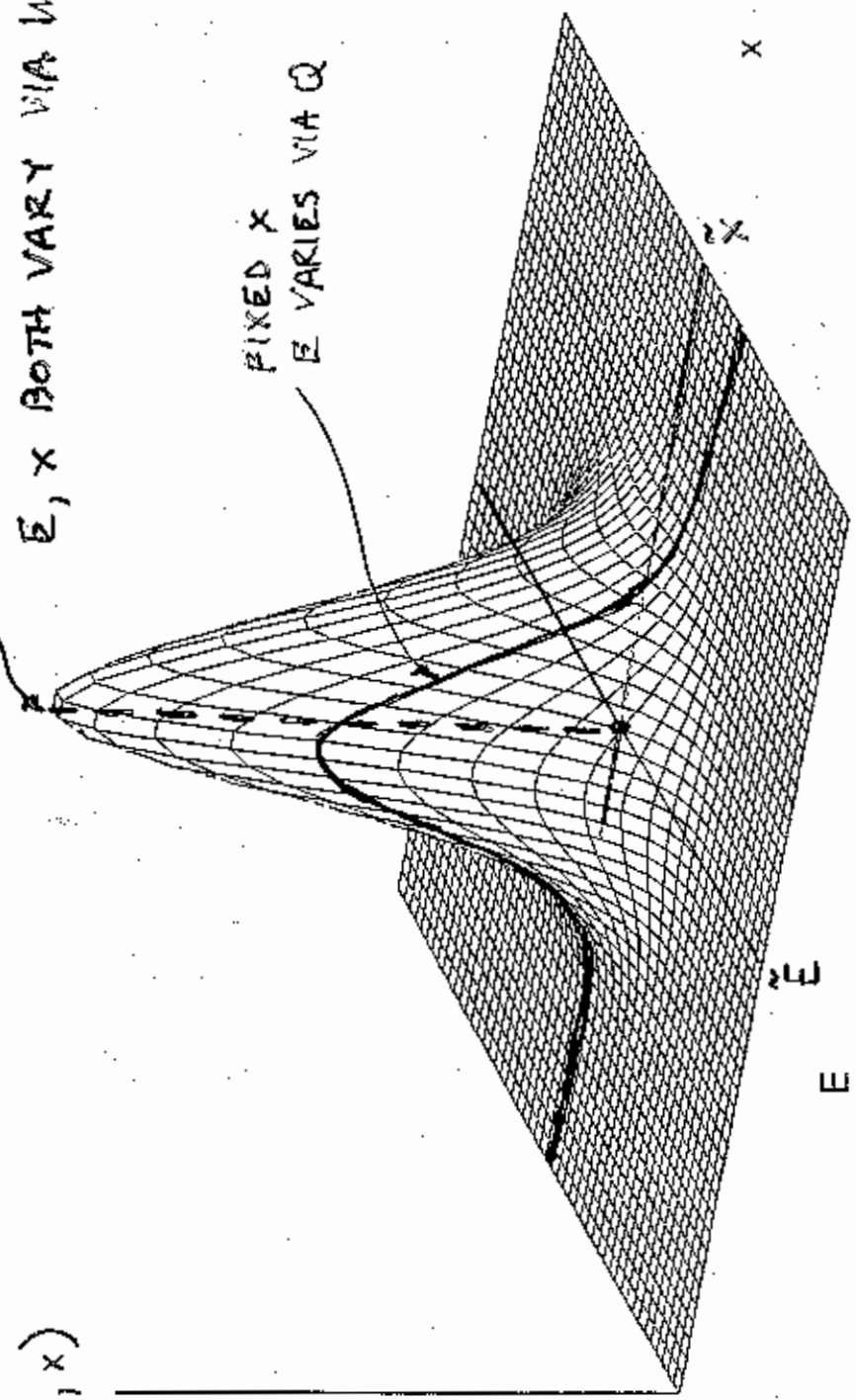
skip
 plot

sheng

MAX Ω WHEN
 E, x BOTH VARY VIA W, Q

FIXED x
 E VARIES VIA Q

$$\Omega_{\text{total}}(E, x)$$



(I) CHG IN $\ln \Omega$ (FOR A)

{ in general: put in contact, system moves quickly, forms a new equilibrium eventually reaches new equilibrium: very diff \bar{E}, \bar{X}_α . Cant use stat. reasoning to describe interim, but if move slowly from one to other (ex: slow chg in V, sequence of diff sys at diff T's),

new equlib is macro state -> can use as

=> FOR SMALL CHG IN MACRO PARAMS:

$$\bar{E} \rightarrow \bar{E} + d\bar{E}$$

$$\bar{X}_\alpha \rightarrow \bar{X}_\alpha + d\bar{X}_\alpha$$

SMALL ON MACRO SCALE BUT \gg FLUCTUATIONS

=> MOVE FROM Ω_{TOT} PEAKED AT " TO " "

in system, some more, some less, but not by much

IF QUASI-STATIC:

- STAY IN EQUIL

- USE STATISTICAL REASONING

$$d \ln \Omega(\bar{E}, \bar{X}_\alpha) = \underbrace{\frac{\partial \ln \Omega}{\partial \bar{E}}}_{\beta} d\bar{E} + \sum_{\alpha} \underbrace{\frac{\partial \ln \Omega}{\partial \bar{X}_\alpha}}_{\beta \bar{X}_\alpha} d\bar{X}_\alpha$$

just math

$$= \beta (d\bar{E} + \sum_{\alpha} \bar{X}_\alpha d\bar{X}_\alpha)$$

$$= \beta (d\bar{E} + dW)$$

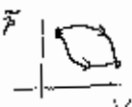
(remember W, Q diff for ave)

$$\frac{1}{kT} dS = \frac{1}{kT} dQ$$

$$\Rightarrow \boxed{dS = \frac{dQ}{T}} \text{ Q-S}$$

- FOR 'SMALL CHGS IN $\bar{E} \neq \bar{X}_\alpha$

- EXACT DIFF: $\int_A^B \frac{dQ}{T}$ INDEP. OF PATH

{ mention pV plot

 Q NOT SAME, $S \frac{dQ}{T}$

(classical thermo: this is how learned of existence of S)

(skip this pg; already covered)

PROPERTIES OF ENTROPY:

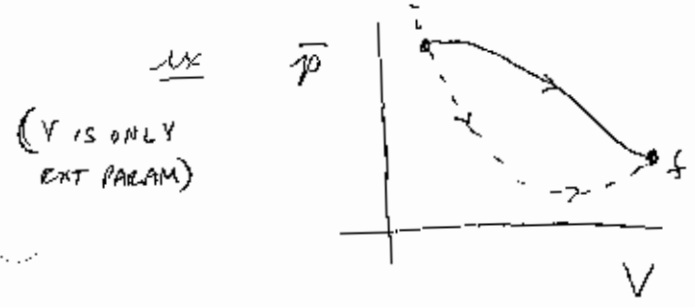
(1) EXACT DIFF: DIFF. BETWEEN FN S FOR 2 MACROSTATES
 $ds = \frac{dQ}{T}$ (ds is, dQ is NOT)

S hard to measure, dQ, T easy to measure

(2) FINITE DIFF:

$$S_f - S_i = \int_i^f ds = \int_i^f \frac{dQ}{T} \text{ (EQUIL)}$$

- INDEP. OF HOW GO FROM INITIAL TO FINAL STATE (ANY SYSTEM)
- INITIAL & FINAL STATES PERFORM CHANGES QUASI-STATICALLY



$\int_i^f dQ$ DEPENDS ON PATH *

$\int_i^f \frac{dQ}{T}$ DOES NOT " } SURPRISING! **

(cf p-problem 2.11)
 $\Delta E, \Delta S$ IND. OF PATH
 Q NOT

TO EVALUATE:

- IN GEN. WILL BE IN CONTACT WITH OTHER SYSTEMS: $dW, dQ \neq 0$
- STAY IN EQUIL AT EACH STEP:

$\Omega(E, V) \rightarrow$ DETERMINES \bar{p}, T FOR EACH \bar{E}, V UNIQUELY
 \rightarrow CAN COMPUTE $dQ = d\bar{E} + dW$ AFTER EACH SMALL STEP

- GET SAME RESULT

- ** - USEFUL TOOL EVEN IF DON'T GET FROM i TO f Q-S:
 - S_i, S_f PROPERTIES OF i, f STATE, NOT HOW GOT THERE
 - CAN CALC. S_f FROM S_i FOR Q-S PROCESS \Rightarrow SAME RESULT

* from i to f dW (by sys.) = area under curve
 $\Delta E = 0 \quad Q = \Delta E + W = W \quad \therefore$ higher path has $Q >$ lower path

** even if didn't know what S was, could stumble onto its existence by this observation
 if $\frac{dQ}{T}$ indep of path, there must be some fn. S whose $\Delta S = \int \frac{dQ}{T}$



SPECIAL CASES:

(1) HEAT RESERVOIR:
(BATH)



(a) $T' \sim \text{CONST}$ $T \rightarrow T'$ (b) $Q' \ll \bar{E}' \rightarrow$ SMALL EFFECT ON A' ; TREAT Q-S

$$\Delta S' = \int \frac{dQ'}{T'} \cong \frac{1}{T'} \int dQ' = \frac{Q'}{T'} = \frac{-Q}{T'}$$

{ BUT WILL SEE IN HW: $\Delta S > \frac{Q}{T'}$ }

how can I raise T a finite amt but Q-S?

(2) INSULATED:

$dQ = 0$ (ADIABATIC)

$\Rightarrow dS = 0$

FINITE (Q-S) CHG IN $X_\alpha \Rightarrow \Delta S = 0$

- \Rightarrow Q-S WORK CHGS E , LEAVES # ACCES. STATES FIXED
- \Rightarrow REVERSIBLE (CAN UNDO VIA Q-S CHG) (no dS , no dR)

IN GENERAL:


NON Q-S PROCESS: $\Delta S > 0$
NOT REVERSIBLE

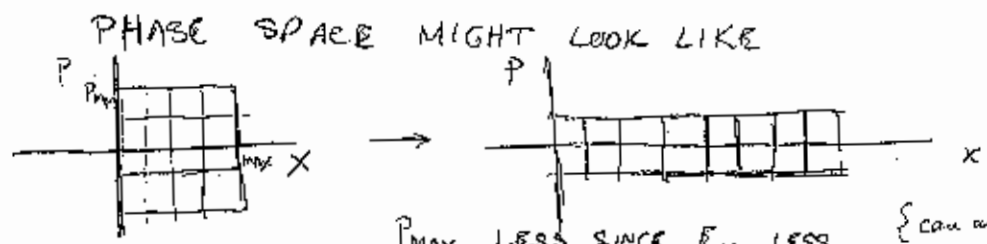
(my thoughts:)

IMPORTANCE OF Q-S PROCESS IN $dS = \frac{dQ}{T}$

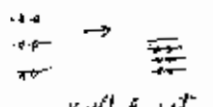
$\Rightarrow \Delta S = 0$ IF INSULATED



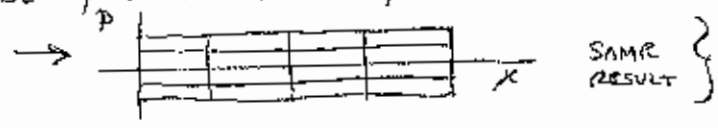
- Q-S:
- (a) LET PISTON MOVE OUT SLOWLY, UNDER EFFECT OF \bar{p} (ie particles bounce off)
 - (b) EACH BOUNCE  LOSES E TO PISTON
 - (c) $\Delta E = -W = -\int \bar{p} dV$ (work by sys.)
 - (d) $\Delta S = 0$ \therefore NEWLY AVAIL. STATES FROM INCR. IN X COMPENSATED EXACTLY BY LESS E AVAIL. TO GET TO CERTAIN STATES
 - (e) ex: CLASSICAL SYS. w/ 1 DOF (NOT 3N DOF)



P_{MAX} LESS SINCE E_{MAX} LESS
 S CONST SINCE # CELLS CONST
 \Rightarrow REVERSIBLE

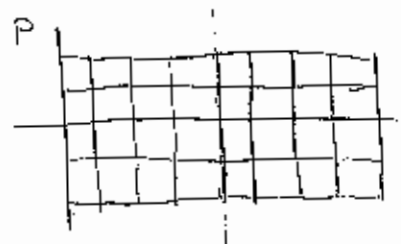
{ can also picture QM: state level drops, but less E avail to get to them: ex-angle $\frac{2\pi v}{\lambda}$

 full E set can reach gently?

for me: { OR COULD CHANGE δp & $\delta x \Rightarrow h_0 = \delta p \delta x$ CONST:



VS NOT Q-S: REMOVE WALL / MOVE ABRUPTLY

- (a) NO TIME FOR MOLECULES TO BOUNCE
 \Rightarrow CAN'T REMOVE E $\Rightarrow \Delta E = 0$
- (b) NO LOSS OF AVAIL. E, TWICE AS MANY δx 'S (P_{MAX} CONST)



(c) $\Delta S > 0$

(II) GEN. EQUIL

simple connection, could in general be more complicated f.e. 3.20

EQUIL: BOTH E, X_a VARY. \rightarrow MAX BOTH

EX. $X_a = V$: $A \leftrightarrow A'$ $E^{(0)} = E + E'$ $V^{(0)} = V + V'$ ($E^{(0)}, V^{(0)}$ FIXE)

$\Omega_{TOT}(E, V) = \Omega(E, V) \Omega'(E', V')$ (for partic. E)

$\ln \Omega_{TOT} = \ln \Omega + \ln \Omega'$

$S_{TOT} = S + S'$

MAX Ω_{TOT} (or S_{TOT}): $d \ln \Omega_{TOT} = d(\ln \Omega + \ln \Omega') = 0$
 ALLOW E & V TO CHG; (require to req. all partial der. vanish)

A: $d \ln \Omega = \frac{\partial \ln \Omega}{\partial E} dE + \frac{\partial \ln \Omega}{\partial V} dV = \beta dE + \beta \bar{p} dV$

(Ω chgs because: (a) more E makes more states avail
 (b) chg V chgs how many states are at partic. E) $\left. \begin{matrix} \frac{\partial \ln \Omega}{\partial X_a} = \beta \bar{X}_a \text{ from before} \end{matrix} \right\}$

A': $d \ln \Omega' = \beta' dE' + \beta' \bar{p}' dV' = -\beta' dE - \beta' \bar{p}' dV$

($dE' = -dE, dV' = -dV$)

MAX: $(\beta - \beta') dE + (\beta \bar{p} - \beta' \bar{p}') dV = 0$ $\left. \begin{matrix} \frac{\partial \ln \Omega}{\partial E} = 0 \\ \frac{\partial \ln \Omega}{\partial V} = 0 \end{matrix} \right\}$

dE, dV INDEP \Rightarrow $\beta = \beta'$
 $\bar{p} = \bar{p}'$

\Rightarrow THERMAL EQUIL.
 \Rightarrow MECH. EQUIL.

AT $E = \tilde{E} = \bar{E}$
 $V = \tilde{V} = \bar{V}$

$\left. \begin{matrix} \text{in gen: } T \text{ equal} \\ \text{true } \Rightarrow ? \\ \text{required } \bar{X} \text{ " } \\ dV = -dV \end{matrix} \right\}$

** (surprising that $\bar{p} = \bar{p}'$ comes just by counting states:

sp. $\bar{p}' > \bar{p}$ (but $\beta = \beta'$) $\Rightarrow \frac{\partial \ln \Omega'}{\partial V'} > \frac{\partial \ln \Omega}{\partial V}$

key: $\frac{\partial \ln \Omega}{\partial V} = \beta \bar{p}$

but note: if \bar{p} 's diff, the same chg in V does work at diff rate for 2 sp.
 \Rightarrow one will gain E faster than other loses it
 \Rightarrow more avail. states; also explains why β is involved 2 cons?

\Rightarrow rate at which Ω' gets avail states squeezed into $E + dE'$ greater than for $\Omega \Rightarrow$ more states avail if V' incr., V decr.)

GEN. PROPERTIES OF S:
 SHAPE OF $\ln \Omega(E)$ OR $S(E)$ (FOR INDIV SYS):

3.12
21

HAVE (USUALLY)

$$\beta = \frac{\partial \ln \Omega(E)}{\partial E} > 0 \quad \left(= \frac{1}{kT} \Rightarrow T > 0 \right)$$

$$-\lambda = \frac{\partial^2 \ln \Omega}{\partial E^2} < 0 \quad (\text{signal = possibility})$$

(else no max when put in contact, no equil position)
 (for me: need this true at all E can always put 2 ident sys. together w/ any amt of E -- NOT TRUE IF

$$\Rightarrow \boxed{\frac{\partial S}{\partial E} > 0 \quad \frac{\partial^2 S}{\partial E^2} < 0}$$

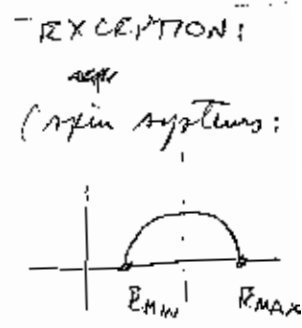
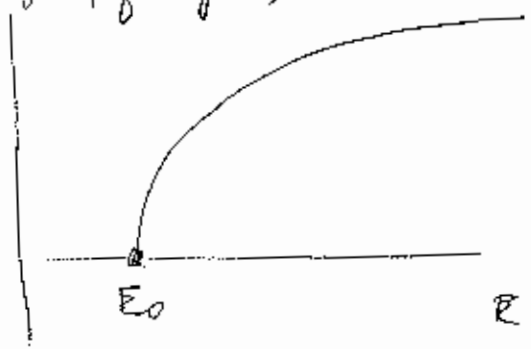
ALSO, AT $E = E_0$ (GND ST)
 $\Omega(E_0) = 1$ (a few)
 $\ln \Omega(E_0) = 0$ (small #)

$$\boxed{S(E_0) = 0} \quad (\text{a few degrees})$$

CLASSICAL:
 N IDEAL GAS
 $\Omega \propto V^N$ EVEN IF $E \approx 0$
 BUT $S = k \ln \Omega \propto N \ln V$ indep of type of gas

SHAPE

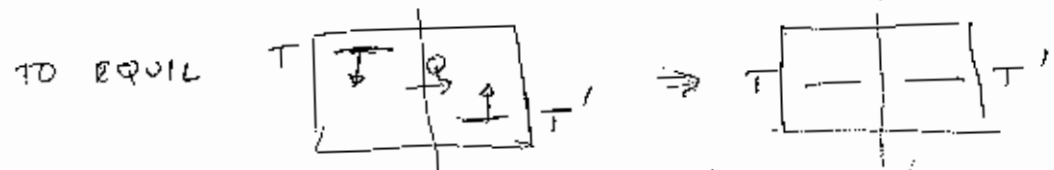
$$S(E) = k \ln \Omega(E)$$



EXCEPTION:
 spin systems:

* ALSO: $-\lambda = + \frac{\partial \beta}{\partial E} < 0 \quad \frac{\partial \beta}{\partial E} = \frac{\partial}{\partial E} \left(\frac{1}{kT} \right) = - \frac{1}{kT^2} \frac{\partial T}{\partial E}$

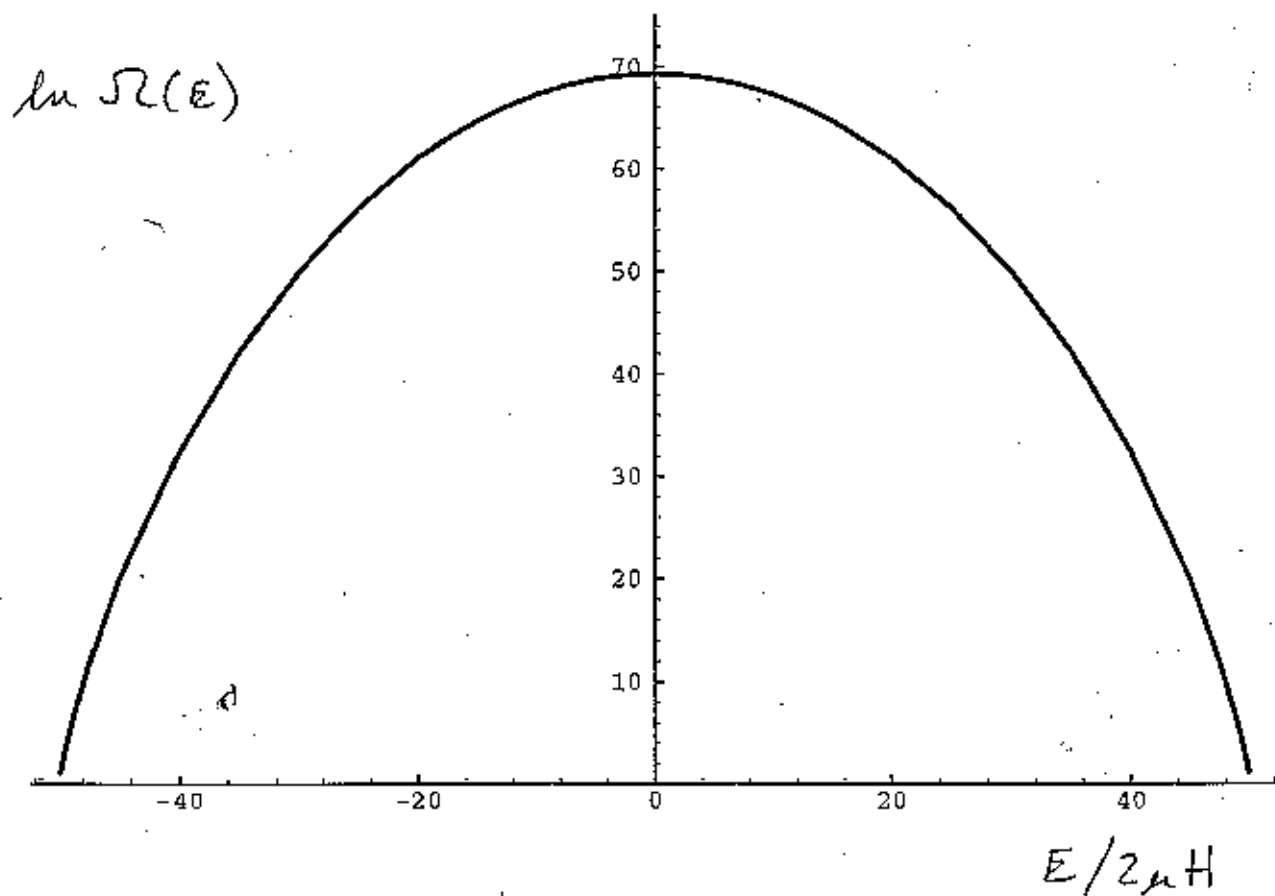
$$\Rightarrow \boxed{\frac{\partial T}{\partial E} > 0} \quad \text{ie } T \text{ inc. w/ } E$$



(ANOTHER WAY TO SEE NECESSARY FOR REACHING NEW EQUIL)

ship

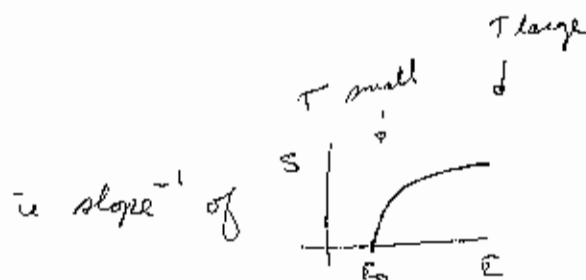
SPIN SYSTEM (REF 2.4)

 $\ln \Omega(E)$ $N = 100$ 

T vs S vs E

$$\beta \equiv \frac{1}{kT} = \frac{\partial \ln \Omega}{\partial E} = \frac{1}{k} \frac{\partial S}{\partial E}$$

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



MOD - LARGE E:

$$\Omega \sim E^f$$

$$S \sim k + \ln E$$

$$\frac{\partial S}{\partial E} \sim \frac{k}{E}$$

slope decr. w/ E

$$kT \sim E/f$$

(AT EQUIL)

as before

VERY SMALL E:

$$E \rightarrow E_0 \text{ (NEED QM)}$$

VERY ROUGHLY $\Omega \sim (E - E_0)^f$

{ we were assuming E large when did stat; removed grid at E0; if kept in would find this }

as above $\Rightarrow kT \sim \frac{E - E_0}{f} \rightarrow 0 \text{ AS } E \rightarrow E_0$ { OR $kT \sim \Delta E$ per particle }

{ CRUDE: had in mind fair amt of E to go around; will do better in the }

my est:

BETTER: f DISTINGUISHABLE PARTICLES

$\Delta E = \text{EXCITE. E FOR 1 "}$

$$E = E_0 \Rightarrow \Omega = 1 \quad S = -\infty$$

$$E = E_0 + \Delta E \text{ (enough to excite 1)}$$

$$\Rightarrow \Omega = f$$

$$\frac{\partial S}{\partial E} \sim \frac{\Delta S}{\Delta E} \sim \frac{k \ln f}{\Delta E}$$

$$kT \sim \frac{\Delta E}{\ln f}$$

ln f ~ order 1 (or 55 or 100)

ex: ATOM IN 1 LITER BOX

$$L = 10^{-1} \text{ m}$$

$$kT \sim \frac{\Delta E}{\ln f} \sim \frac{\frac{\pi^2}{L^2} \frac{h^2}{m_p} \frac{1}{4t}}{\ln f} \sim \frac{\pi^2 (10^2 \text{ m}^{-2}) (1 \times 10^{-30} \text{ J-s})^2}{10^{-27} \text{ kg}} \frac{1}{5t}$$

$$\sim 10^{-40} \text{ J}$$

$$\text{(or } 10^{-24} \text{ } ^\circ\text{K)}$$



\Rightarrow

$$T \rightarrow 0^+ \text{ AS } E \rightarrow E_0, S \rightarrow 0$$

{ for me :

even better:

f indisting. particles

n units of $\Delta E \Rightarrow E = E_0 + n\Delta E$

n units in f slots

$$\Omega \sim \binom{f}{n} = \frac{f!}{n!(f-n)!}$$

$$\ln \Omega \sim \ln f! - \ln n! - \ln (f-n)!$$

$$\sim f \ln f - n \ln n - (f-n) \ln (f-n)$$

$$\ln \Omega \sim n \ln f \quad \text{if } n \ll f$$

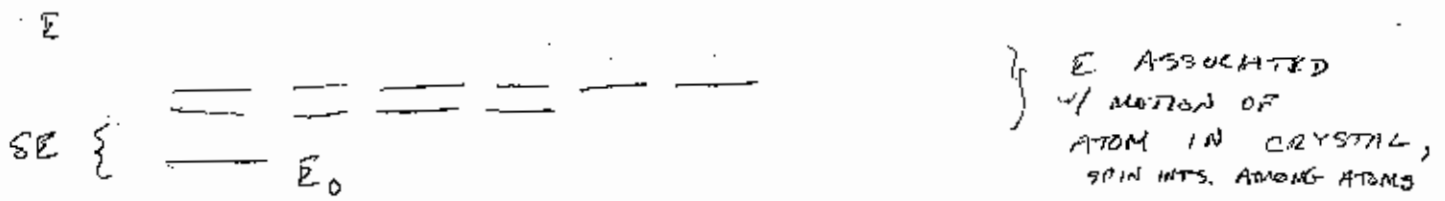
$$S = k \ln \Omega \sim k n \ln f = \frac{k E \ln f}{\Delta E}$$

$$\frac{\partial S}{\partial E} \sim \frac{k \ln f}{\Delta E}$$

$$kT \approx \frac{\Delta E}{\ln f} \quad \left. \vphantom{\frac{\Delta E}{\ln f}} \right\}$$

$E \rightarrow E_0$
 $T \rightarrow 0$ PRACTICAL
LIMIT FOR S

ATOMS IN SOLID (AS IN BOX)



$E \rightarrow E_0$ $S \rightarrow 1$ $S \rightarrow 0$ $T \rightarrow 0$
IN PRACTICE: ^{OFTEN} VERY HARD TO FORCE MACRO SYS. INTO EXACT GND ST:

EX: NUCLEI HAVE SPIN S
ORIENTATIONS FOR EACH NUCLEUS: $S_z = -S\hbar, (-S+1)\hbar, \dots, +S\hbar$
TOTAL # POSSIBLE: $(2S+1)^N$ $2S+1$ ($S = \frac{1}{2} \rightarrow 2$)

INTS. FOR SPINS

- EACH NUCLEUS INTERACTS WEAKLY w/ B FROM NEIGHBORING PARTICLES
- WEAK FORCES \rightarrow SMALL E DIFFS (DEPENDS ON $\frac{1}{M_{NUCLEUS}}$)
- ~~FERRO MAGNET~~: LOW E HDS ALL $\uparrow \uparrow \uparrow$ LINED UP (local freedom to atoms)

TRUE SPECTRUM:



$\Omega(E) \sim \Omega(\text{SPINS}) \cdot \Omega(\text{ATOM})$

$\Rightarrow S = kN \ln(2S+1) + S_{\text{ATOM}}$

HOW DOES S DROP w/ E?

$E \rightarrow E_0, T \rightarrow 0$ IN STAGES:

IF $SE \approx E_0$ $S \rightarrow kN \ln(2S+1)$ $T \sim 1^\circ K$
 $S_{\text{ATOM}} \rightarrow 0 \Rightarrow S$ GOES TO CONST SO $\ln(2S+1)$ OF $2S+1$
 $S \rightarrow 0$ $T \sim 10^{-6} K$

THIS STEP VERY HARD

Overall $kT \sim E$ avoid big diff
low kT low number that count to...

MORE THERMO LAWS

(FORMULATED BEFORE MICRO (STATISTICAL) DESCRIPTION)

2ND (a) THERMALLY ISOLATED SYSTEM GOES FROM ONE MACRO STATE TO ANOTHER

$$\Delta S \geq 0$$

(even if do work on it)

(b) NOT ISOLATED BUT Q-S :

$$dS = \frac{\delta Q}{T}$$

(NOTE: Q-S ALSO MEANS SLOW CHG IN TEMP, SLOW FLOW OF Q; SLOW CHG IN EXT. PARAMS)

NOT Q-S: dS WILL BE GREATER

3RD $A \rightarrow S$ $T \rightarrow T_0$ $S \rightarrow S_0$

INDEP. OF PARAMS OF PARTICULAR SYSTEM

(S_0 OFTEN 0 IN PRINCIPLE CONST IN PRACTICE)

if its $S_0 \neq 0$, its because its something like nuclear spin, and cant get to it (ie cant rotate E avail. to be small enough to limit) ; doesnt matter what you're doing ; system ; V, P, \dots

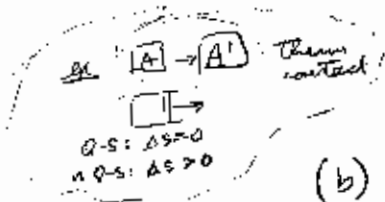
→ LAWS FORMULATED BY OBSERVATION, BEFORE STATISTICAL

DESCRIPTION (S WAS SUBTLE) (presumably detected its existence by noting $\int \frac{\delta Q}{T}$ was indep of path \therefore had to be some fun $S \Rightarrow \Delta S = \int \frac{\delta Q}{T}$. Then can always measure relative S)

* COULD ALSO MENTION

0TH: A IN THERM. EQ. w/ C
B " " " " C \Rightarrow A w/ B

1ST: $\Delta \bar{E} = -W + Q$ (E CONS.)

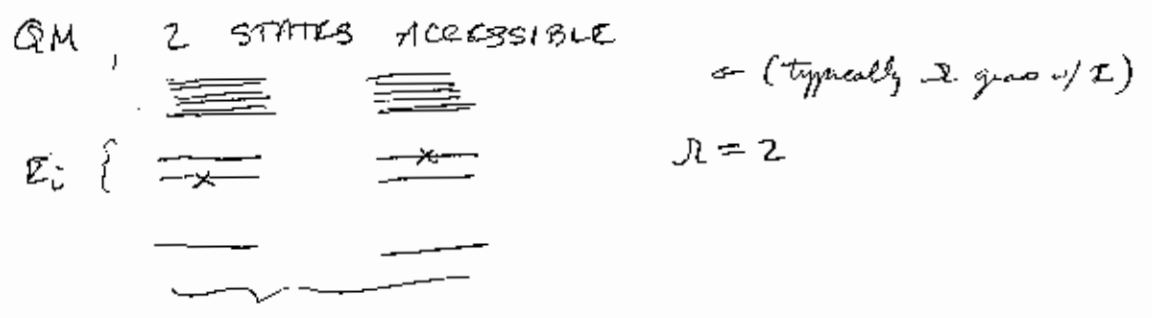


MORE ON 2ND LAW:

$\Delta S \geq 0$ IF THERMALLY ISOLATED;
 0 ONLY IF Q-S (i.e. REVERSIBLE) (INCL WORK ON/BY)

- OBVIOUS IF REMOVE CONSTRAINT (BY DEFN)
- WORK: LESS OBVIOUS \Rightarrow WHAT IF DO POS. W? LOWE E \Rightarrow LESS STATES AVAIL?

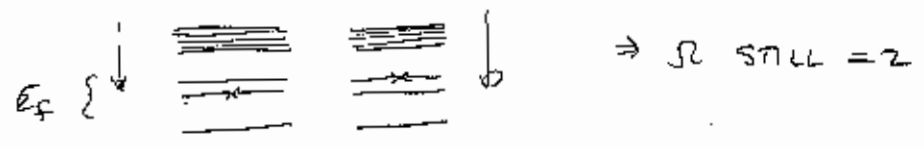
SIMPLIFIED CASE:



2 SYS IN ENSEMBLE; EACH CAN BOUNCE BETWEEN 2 AVAIL STATES, BUT SAME # IN EACH

Q-S WORK W BY, SYS:

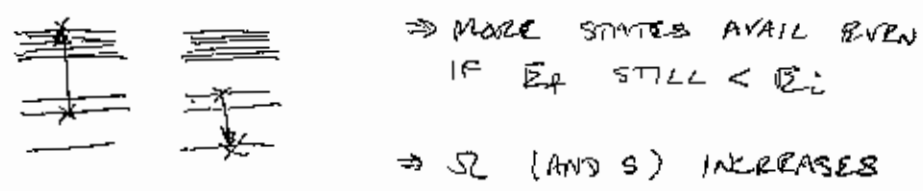
- QM: LEVELS CHG, STATES STAY OUT
- E_f ALSO DECREASES BY W



- ENSEMBLE: INDIV. SYS CAN STILL BOUNCE BETWEEN, BUT HAVE REMOVED JUST ENOUGH ENERGY SO STAY IN THESE STATES

R STILL 2

NON-QS: CAUSE TRANSITIONS AS WELL AS DROP LEVELS



\Rightarrow MORE STATES AVAIL EVEN IF E_f STILL $< E_i$

CLASSICAL 8CS:

OF GAS IN PREVIOUS DISCUSSION

- AS EXPAND; NEED TO DO Q-S SO PULL OUT ENOUGH E_v TO COMPENSATE INCR IN X VIA W
- ANY MORE RAPID EXPANSION \Rightarrow PULL OUT LESS E (PARTICLES CAN'T CATCH UP)
 $\Rightarrow \Delta S > 0$
- CONTRACT; IF Q-S, PUT IN JUST ENOUGH E VIA W TO COMPENSATE DECR. IN X
- ANY MORE RAPID CONTRACTION \Rightarrow DO MORE W (PARTICLES BOUNCE OFF FASTER MOVING WALL)
 \Rightarrow TOO MUCH E IN
 $\Rightarrow \Delta S > 0$

4.10 Adiabatic Processes

The above reasoning—in particular, the derivation of Equation (4.13) and the consequent identification of TdS with dQ in a reversible process—is somewhat abstract, and we will now consider how it applies to the system of spin 1/2 nuclear magnets discussed in Chapter 3. In particular, we show for this model that a process that is *adiabatic* in the quantum mechanical sense (which will be explained) is necessarily isentropic.

Consider first a single isolated spin in a magnetic field B , in a particular state (say, spin up), with energy $-\mu B$. Now we *slowly* change B . In order to produce a transition (a *spin flip*) to the spin down state, whose energy is $+\mu B$, quantum mechanics tells us that we need a component of the field oscillating at the frequency corresponding to the energy separation of the states; that is, $\frac{2\mu B}{\hbar}$. If B were to change rapidly, it could have a Fourier component at this frequency, but we will assume that B changes sufficiently slowly that no such high frequency field is present. Then the spin must stay in whatever state it began in, even though the energy of this state is changing. The energy needed is supplied (or taken up) by the electromagnetic field. Such a slow change, in which the occupation of quantum states does not change, is called an *adiabatic* change.

Now suppose that we have a collection of spins isolated from its surroundings. Although in our model we neglected the interaction between them, the spins must interact weakly if they are to come into equilibrium with each other. The interaction occurs because the motion of one spin in the field generates a high frequency magnetic field of just the right frequency to cause a neighboring spin to flip; this spin-spin interaction ensures that the whole assemblage of spins reaches its equilibrium condition of maximum Ω . However, the quantum mechanics of this interaction tells us that if one spin flips \uparrow to \downarrow , the other has to flip from \downarrow to \uparrow (see Figure 4.5), so that the total spin is conserved. Although there is a change of microstate,

¹¹See L. R. G. Treloar, *Physics of Rubber Elasticity* (Oxford University Press, 1958) for a fuller treatment.

$$\uparrow\downarrow \Rightarrow \downarrow\uparrow$$

Figure 4.5. Mutual spin flip, conserving total spin.

the macrostate does not change, so that Ω (and hence S) does not change. While this is a very specific model, it illustrates the general result, which we justify in Chapter 5, that an adiabatic change is isentropic.

In general, a process is adiabatic in the quantum mechanical sense if it does not change the average occupancy of the quantum states. Ω is unchanged, so that such a process does not change the entropy and is called an isentropic process. An adiabatic process in this sense is always possible in principle. Here we have shown this for a spin system, which has discrete energy levels; the case of continuous levels, as in a gas, will be dealt with later (see Example 9.2).