

$$Z = \sum_{\{\sigma_i\}} e^{-\beta H(\{\sigma_i\})} = \sum_{\sigma} \exp(\beta H(\sigma))$$

nonsingular function of the  $\sigma_i$ , i.e. analytic.

Pauli:  $f = \lim_{N \rightarrow \infty} \frac{\ln Z}{N}$

eg.  $Q=2$   $\uparrow, \downarrow$ ,  
with interaction on next page.

let  $F = -\frac{1}{\beta h} \ln Z$ .

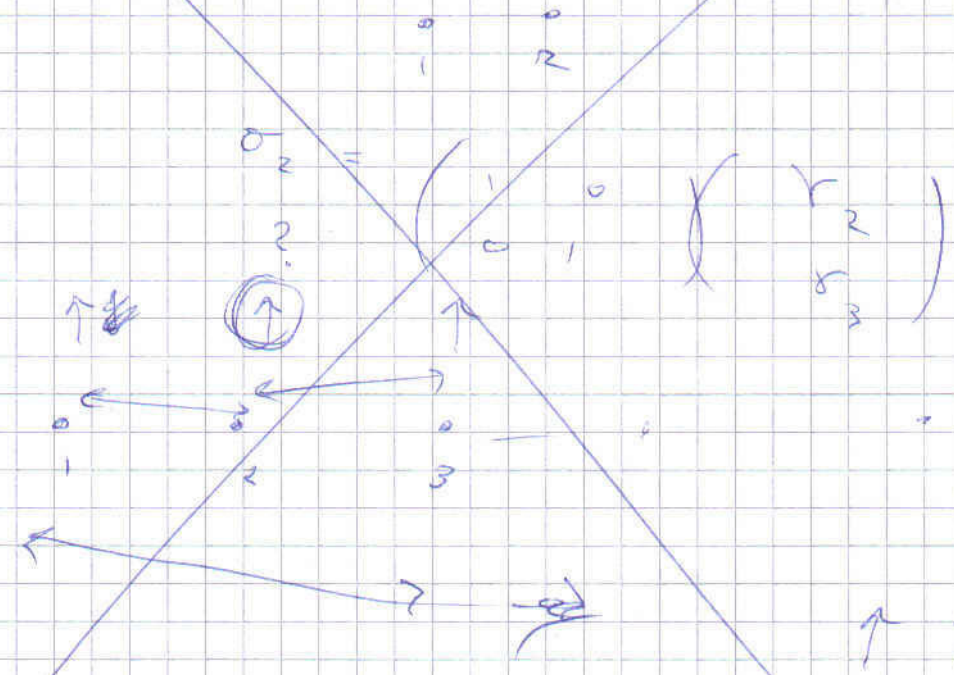
~~$\sigma_i$  are the states.~~

~~eg.  $\delta, \delta_1$~~



$Q=2$

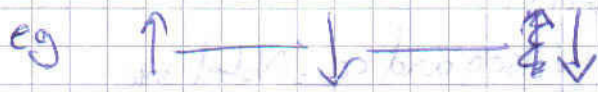
~~$Z_N = \sum_{\sigma_1, \sigma_2} \dots = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix}$~~



~~$Z_N = \dots$~~



eg  $H = - \sum \delta_i \cdot \delta_j$   $\uparrow \rightarrow 1$



we get  $-1$  from  $\downarrow \uparrow$   
and  $1$  from  $\downarrow \downarrow$   
total zero



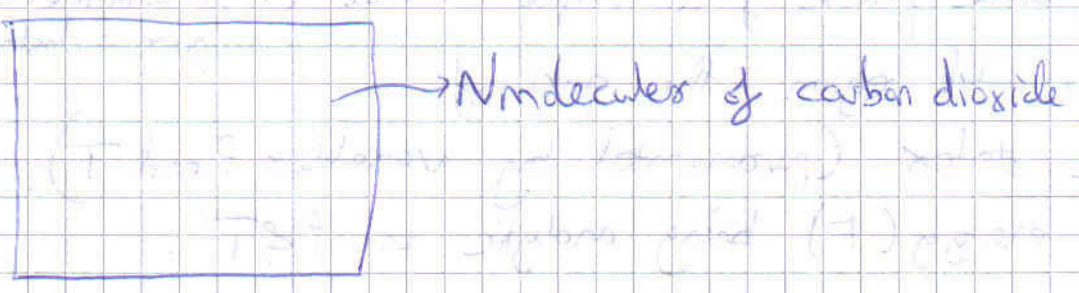
Note:  $-1$ 's were too in JS's talk.

Interaction of nearest neighbour.

eg Argon.  
 $P \uparrow$  pressure.

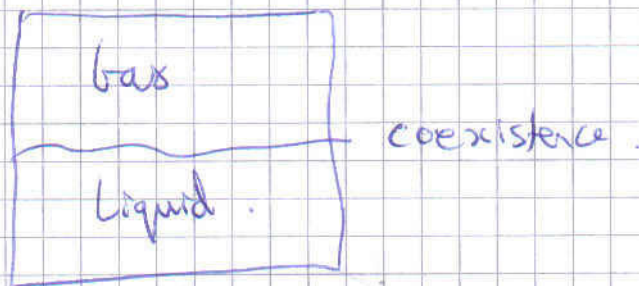
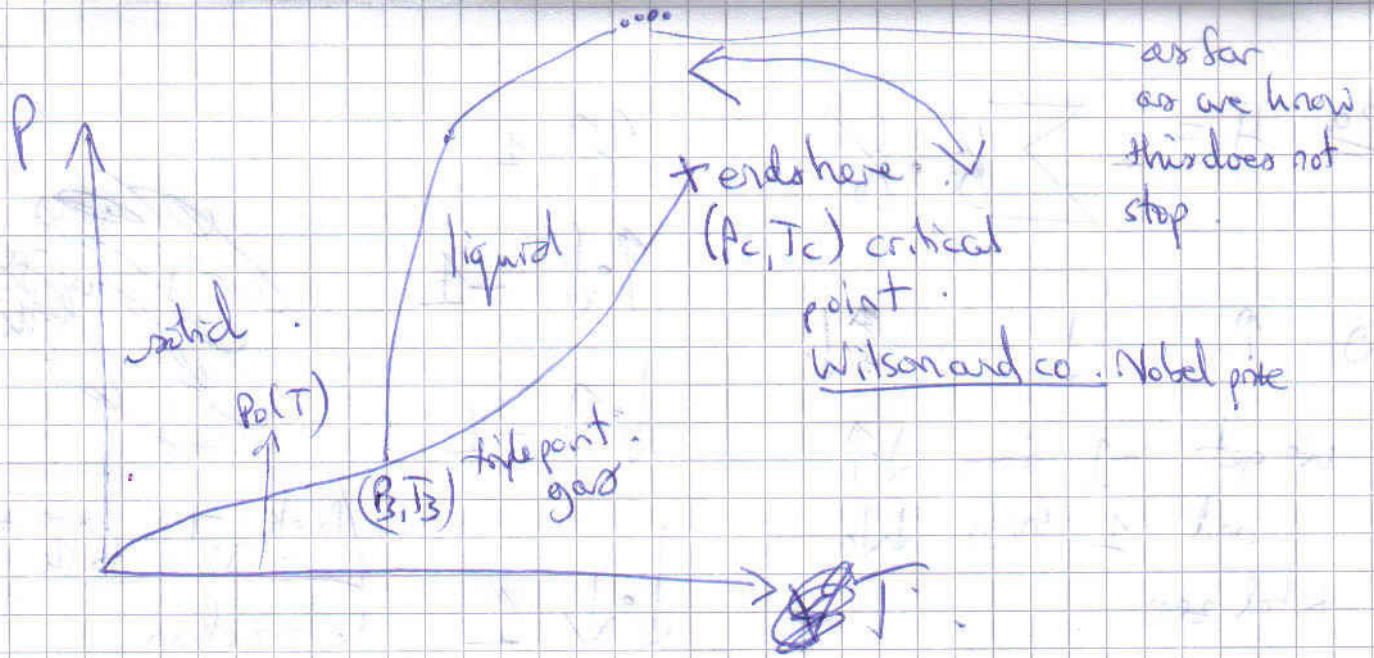


F can depend on  $p$ .  $P = \left( \frac{\partial F}{\partial V} \right)_T$   $\nwarrow$  constant temperature.  $F = \text{free energy}$ .



Note that  $T$  arose when we separated the differential equation in Paul's talk, so is common to both sides of the system  $\boxed{T|T}$ , so behaves in similar way to temperature. We can show  $T$  is "temperature" using the first and second Laws of Thermodynamics.





Above critical point, just have a fluid



A thermodynamic phase of a simple material (ie. one <sup>type of</sup> molecule, pure substance) is an open, connected region in the space of thermodynamic states (parametrized by variables  $P$  and  $T$ ) with the free energy ( $F$ ) being analytic in  $P$  &  $T$ .

$$F = F(p, T)$$

$$P = P(F, T)$$