Counting states

Phase space

$Z(E,N,V)$

Stirling formula

$\ln N! \approx N \ln N - N$

Equilibrium

$\frac{\partial}{\partial x} S(x) \overset{!}{=} 0$

$\frac{\partial S_1}{\partial V_1} = \frac{\partial S_2}{\partial V_2} = \frac{p}{T}$

$\frac{\partial E}{\partial S} = T$

E

N

N

$\frac{\partial E}{\partial V} = -p$

$\frac{\partial E}{\partial N} = \mu$

$E = \frac{d}{2} k_B T N$

Quantum corrections

Extensivity

$S = k_B \ln Z$

$\frac{1}{T} = \left(\frac{\partial S(E,N,V)}{\partial E} \right)$

1 st Aim:
Proof the 3 laws of thermodynamics

Microcanonical Ensemble

Thermodynamic potentials

$dS \geq \frac{1}{T} dE - \frac{\mu}{T} dN + \frac{p}{T} DV$

Legendre transform

$(E,N,V) \leftrightarrow (T,\mu,p)$

(Helmholtz) Free Energy

Gibb's (Free) Energy

$F(T,N,V) = U - TS$

$G(T,N,p) = U + pV - TS$

Exchange

2 nd Aim:
Derive ideal gas equation

Heat E

Work V

Mass N

Canonical Ensemble

$e^{-\beta H}$

Saddle point approximation

$\frac{\partial F}{\partial N} = \mu$

$\frac{\partial F}{\partial T} = -S$

$\frac{\partial F}{\partial V} = -p$

Quantum statistics

Fermi-Dirac statistics

Bose-Einstein condensation

Planck's law
(Black body radiation)
Ising model

Grand Canonical Ensemble

$z = e^{\beta\mu}$

$Z(T,\mu,V) = \sum_N z^N Z(T,N,V)$

3 rd Aim:
Probability factors for (grand) canonical ensembles

Maxwell's velocity distribution

Effusion

Ideal (classical) gas