PHYS 317 Fall 2023

Summary for Test 1

Ideal Gas:

$pV = NkT = \nu RT$ and microscopic picture

Equipartition Theorem:

$U_{\text{therm}} = N\frac{f}{2}kT$ (apply and determine f and derive for ideal gas)

1st Law of Thermodynamics:

$\Delta U = Q + W$ $W = -\int p\mathrm{d}V$

(pV diagrams, adiabat, isotherm, straight lines)

Heat Capacities and Enthalpy:

$C = \frac{Q}{\Delta T}$ $C_V = \left(\frac{\partial U}{\partial T}\right)_V$ $C_p = \left(\frac{\partial H}{\partial T}\right)_p$

$C = m\,c$

$H = U + pV$ (apply to reactions; if on exam, then table will be provided)

NOT on Test 1 (for Test 2)**Heat Conduction, Diffusion:** microscopic picture

Summary for Test 2

Heat Conduction, Diffusion: microscopic picture

Multiplicities:

systems: 2-state (paramagnet), Einstein solid, ideal gas (& similar)

list microstates; derive Ω, Ω_{tot}; apply Stirling formula and $\ln(1+x) \approx x$, know EXCEL commands; derive width of Ω_{tot} and know significance of sharp peak

NOT on Test 2: **Entropy:** $S = k \ln \Omega$ determine S, ΔS

2nd Law of Thermodynamics: major concept

SUMMARY FOR TEST 3

- $\Omega \rightarrow S \rightarrow T \longrightarrow U(T) \longrightarrow C_V$
  - Ideal Gas : derive Sackur-Tetrode equation; entropy of mixing; ...
  - Paramagnetism : $U(N, N_\uparrow)$, $M(N, N_\uparrow)$, $\Omega \rightarrow S$, interpret $S(U)$ etc.; full analytic solution $\Omega \ldots \rightarrow M(T)$ & $C_V(T)$ including math with sinh, cosh, tanh
  - Einstein Solid $\Omega \rightarrow \ldots C_V$
- Derivation of each term of

$$dU = TdS - pdV + \mu dN$$

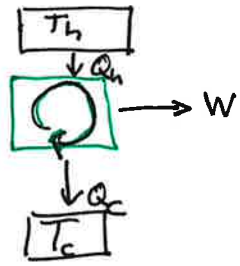
- $C_V, C_p \longrightarrow \Delta S = \int \frac{C\,dT}{T}$

all work from reading, class & HW 10 - 14

NOT : HW 15 & 16 ; Heat Engines & Refridgerators

SUMMARY FOR TEST 4

- Heat Engines & Refridgerators



$$e = \frac{W}{Q_h} = \frac{W_{by}}{Q_h}$$

- Thermodynamic Potentials U, F, H, G
  - thermodynamic identities: derive $dF = \dots$ etc. & Maxwell relations
  - derive $G = \mu N$ etc.
  - $dS_{tot} \geq 0$ $\xrightarrow[\text{derive}]{}$ $dG \leq 0 \rightarrow G$ minimum etc.
  - apply H, S, G etc. using table

- Phase Transitions
  - apply G minimum to exaples like diamond & water, liquid, steam
    including $p(T)$, $p(V)$, derive $G(p)$, $G(T)$, Clausius Clapeyron
  - van der Waals model: also $p(T)$, $p(V)$, $G(T)$, $G(p)$
    $\rightarrow p_c, T_c, V_c$ & $p(t,v)$

NOT: phase transitions of mixtures $G(x)$ & $T(x)$

SUMMARY FOR TEST 5

Phase Transitions: Mixtures ($G(x)$ curves & tangent & phase diagram)

Boltzmann Statistics:

derivations: const $T, V, N \rightarrow P(s) = \dfrac{e^{-E_s/kT}}{\sum_s e^{-E_s/kT}}$

const. $T, p, N \rightarrow P(s) = \dfrac{e^{-(E_s + pV_s)/kT}}{\sum_s e^{-(E_s + pV_s)/kT}}$

$$Z = \sum_s e^{-E(s)/kT}$$

$$\overline{X} = \frac{1}{Z} \sum_s X(s)\, e^{-E(s)\beta}$$

Applications:
- for specific small set of states
- paramagnet
- fluctuation dissipation thm $\quad C = \dots \quad \chi = \dots$
- show & use e.g. $\overline{E} = -\frac{1}{Z}\frac{\partial Z}{\partial \beta}$ & similar relations
- rotations
- equipartition theorem
- composite systems
- Maxwell distribution (derive $\bar{v}$, $\overline{v^2}$, v_{max} etc.)

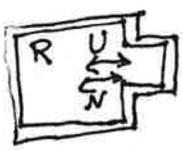
$F = -kT \ln Z \longrightarrow S, \mu$

- Harmonic Oscillator

NOT: ideal gas: $F \rightarrow \dots$

SUMMARY FOR TEST 6

$\left(Z_1 \to F = -kT \ln Z_1 \to S, \mu \right)$

- ideal gas: non-relativ. & relativ.
- Ising Model (Ferromagnet)
  - 1 dim. $Z \to U$ $(B=0)$
  - MF: derive self-consistent equ. & sketch to find solutions $(B=0$ and $B>0)$ (see HW31)
- Grand Canonical Distribution
  - derive 
  - apply: O_2, CO, hemoglobin, etc.
  - (apply →) Bosons & Fermions: microstates, derive $\bar{n}_{FD}$, $\bar{n}_{BE}$ or similar

NOT: Degenerate Fermigas

After Test 6 Topics:

Degenerate Fermi Gas: non-relativistic & relativistic

$$L = n\frac{\lambda}{2} \rightarrow \ldots \rightarrow N = \ldots$$

$$\varepsilon_F = \ldots$$

$$U = \ldots \qquad \rightarrow C$$

Blackbody Radiation:

$$U_{tot} = \sum_s E(s)\,P(s) = \ldots \rightarrow u(\varepsilon) \;\&\; u(\lambda)$$

$$N = \ldots$$

NOT: Bose-Einstein Condensation