

Physics 213 Formula Sheet

Fall 2010

Constants, Data, Definitions

- 0 K = -273.15 °C = -459.67 °F
- $N_A = 6.022 \times 10^{23}$ / mole
- $k = 1.381 \times 10^{-23}$ J/ K = 8.617×10^{-5} eV / K
- $R = kN_A = 8.314$ J / mol·K = 8.206×10^{-2} l·atm / mol·K
- 1 atm = 1.013×10^5 Pa 1 liter = 10^{-3} m³
- STP → T = 0°C; p = 1 atm
- $h = 6.626 \times 10^{-34}$ J·s = 4.136×10^{-15} eV·s
- $\hbar = h/2\pi = 1.055 \times 10^{-34}$ J·s
- 1 eV = 1.602×10^{-19} J
- $c = 2.998 \times 10^8$ m/s
- $\mu_e = 9.2848 \times 10^{-24}$ J/T $\mu_p = 1.4106 \times 10^{-26}$ J/T
- $m_e = 9.109 \times 10^{-31}$ kg $m_p = 1836 m_e$
- $g = 9.8$ m/s² = 1.673×10^{-27} kg

Fundamental Laws/Principles:

First law: $dU = dQ + dW$

Second Law: $d\sigma/dt \geq 0$

$$P_i \propto \Omega_i \equiv e^{\sigma_i}$$

Classical equipartition <energy> = 1/2 kT per quadratic term

Entropy & Temperature: $S = k\sigma = k \ln \Omega$; $\frac{1}{T} \equiv \left(\frac{\partial S}{\partial U} \right)_{V,N}$

Heat Capacities: $C_V \equiv (\partial U / \partial T)_V$; $C_p \equiv (\partial (U + pV) / \partial T)_p$

Special properties of α -ideal gases

$U = \alpha NkT = \alpha nRT$ $pV = NkT$ $p_{tot} = p_1 + p_2 + \dots$

$C_V = \alpha Nk = \alpha nR$ $C_p = C_V + Nk$ $n = \# \text{ moles} = N/N_A$

$c_p/c_v = (\alpha + 1)/\alpha = \gamma$ $W_{by} = NkT \ln(V_f/V_i)$

$VT^\alpha = \text{const.}$, or $pV^\gamma = \text{const.}$, $\gamma = (\alpha + 1)/\alpha$

$W_{by} = \alpha Nk (T_1 - T_2) = \alpha (p_1 V_1 - p_2 V_2)$

$\Delta S = C_V \ln (T_f/T_i) + Nk \ln (V_f/V_i)$

	α	γ
●	3/2	5/3
●●	5/2	7/5

Processes, Heat Engines, etc

$\Delta U = Q - W_{by}$ $W_{by} = \int pdV$

Quasistatic: $dS = dQ/T$ so $\Delta S = \int (C/T) dT$

$dQ = dU + pdV$

$\epsilon_{Carnot} = 1 - T_C/T_H$

Diffusion and Heat Conduction

$D = (\ell^2/3\tau) = v \ell / 3$ $\tau = \ell / v$

$\langle x^2 \rangle = 2Dt$ $\langle r^2 \rangle = 6Dt$

$J_x = \kappa \Delta T / \Delta x$, $\kappa = D_{HC}$ where $c = C_V / V$

$H_x = J A = \Delta T / R_{th}$ $R_{th} = d / \kappa A$ $\Delta L / L = \alpha \Delta T$

$T_A(t) = T_f + (T_{A0} - T_f) e^{-t/\tau}$, $\tau = R_{th} C_A$

Spins

$\Omega(N, N_{up}) = \frac{N!}{N_{up}! N_{down}!} = \frac{N!}{N_{up}! (N - N_{up})!}$; $\Omega(m) = 2^N \sqrt{\frac{2}{\pi N}} e^{-m^2/2N}$; $P(m) = \Omega(m) / 2^N$

$M = (N_{up} - N_{down}) \mu \equiv m\mu$, $M = N\mu \tanh(\mu B / kT)$

SHO

$P_n = (1 - e^{-\epsilon/kT}) e^{-n\epsilon/kT}$; $\langle E \rangle = \epsilon / (e^{\epsilon/kT} - 1)$ $\epsilon = hf$; $\Omega = \frac{(q + N - 1)!}{q!(N - 1)!}$

Counting, Bin Statistics, Entropy

Ω	Occupancy (N << M)		
	Unlimited	Single	Dilute
Distinct	M^N	$\frac{M!}{(M-N)!}$	M^N
Identical	$\frac{(N+M-1)!}{N!(M-1)!}$	$\frac{M!}{(M-N)!N!}$	$\frac{M^N}{N!}$

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

Equilibrium

Boltzmann: $P_n = \frac{d_n e^{-E_n/kT}}{Z}$; $Z \equiv \sum_i d_i e^{-E_i/kT}$

Free energies: $F \equiv U - TS$ $G \equiv U - TS + pV$

Chemical potential:

$\mu = \left(\frac{\partial F}{\partial N} \right)_{V,T} = \left(\frac{\partial G}{\partial N} \right)_{p,T}$; equilibrium $\sum_i (\Delta N_i) \mu_i = 0$

$\mu_i = kT \ln(n_i/n_{Ti}) - \Delta_i$ (ideal gas)

$n_Q = (2\pi mkT/h^2)^{3/2} = (10^{30} \text{ m}^{-3}) (m/m_p)^{3/2} (T/300K)^{3/2}$

Semiconductors $n_e n_h = n_i^2$; $n_i = n_Q e^{-\Delta/2kT}$

Thermal Radiation

$J = \sigma_B T^4$, $\sigma_B = 5.670 \times 10^{-8}$ W/m² K⁴ $\lambda_{max} T = 0.0029$ m-K

Particle	mass/mol
N ₂	28g
O ₂	32g
He	4g
Ar	40g
CO ₂	44g
H ₂	2g
Si	28g
Ge	73g
Cu	64g
Al	27g
1g = 10 ⁻³ kg	

$aA + bB \leftrightarrow cC \Rightarrow$
 $a\mu_A + b\mu_B = c\mu_C$
 $\frac{n_c^c}{n_A^a n_B^b} = \frac{n_c^c}{n_A^a n_B^b} e^{c\Delta/kT}$