Physics 213 Formula Sheet

Fall 09
(09/16/09)

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} m^3

$h = 6.626 \times 10^{-34}$ 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 $m_p = 1836\, m_e = 1.673 \times 10^{-27}$ kg

$g = 9.8$ m/s^2

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

$U = \alpha NkT = \alpha nRT$

$C_V = \alpha Nk = \alpha nR$ n = # moles = N/N_A

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

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

$W_{by} = \alpha Nk\,(T_1 - T_2) = \alpha\,(p_1V_1 - p_2V_2)$

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

	α	γ
●	3/2	5/3
●●	5/2	7/5

Processes , Heat Engines, etc

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

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

Diffusion and Heat Conduction

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

$J_x = \kappa\, \Delta T/\Delta x$ $H_x = J A = \Delta T/R_{th}$

$R_{th} = d/\kappa A$

For an ideal gas: $D = (\ell^2/3\tau) = v\ell/3\tau = \ell/v$

Spins

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

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

SHO

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

Counting, Bin Statistics, Entropy

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

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

Equilibrium

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 $\sum_i (\Delta N_i)\mu_i = 0$ E.g.: $aA + bB \leftrightarrow cC \Rightarrow a\mu_A + b\mu_B = c\mu_C$

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

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

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/m^2 K^4

$\lambda_{max}T = 0.0029$ 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	28g

1g = 10^{-3} kg

These formulas might not be given to you on the exam equation sheet!

Fundamental Laws and definitions:

First law: $dU = dQ + dW$

For fluids: $W_{by} = \int p\,dV$

Second Law:

$d\sigma/dt \geq 0$

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

$\sum_i P_i = 1$

Entropy & Temperature:

$S = k\sigma = k \ln \Omega$

$$\frac{1}{T} \equiv \left(\frac{\partial S}{\partial U}\right)_{V,N}$$

Classical equipartition:

$\langle \text{energy} \rangle = \frac{1}{2} kT$ per quadratic term

Boltzmann:

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

Ideal gases:

$pV = NkT$ $\quad p_{tot} = p_1 + p_2 + \ldots$ $\quad C_p = C_V + Nk$