Commonly Used Formulas
Physics 213 2004-5

Mechanics

$F = ma = m\,dv/dt = dp/dt \qquad KE = \tfrac{1}{2} mv^2$

$F\,d_{cm} = \Delta(KE_{cm}), \qquad W_{on} = \Delta(KE_{cm}) + \Delta U = FD$

$F = m\,d^2u/dt^2 = -\kappa u\,, \quad u = A \sin \omega t\,, \quad \omega = (\kappa/m)^{1/2} = 2\pi f$

Ideal Gases

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

$U = \alpha NkT = \alpha\, nRT \qquad n = \#\text{ moles} = N/N_A$

$C_V = (dU/dT)_V = \alpha Nk = \alpha nR$

$c_V = \alpha R = (8.314\ \text{J/K})\alpha \qquad C_p = C_V + nR$

$pV = NkT = nRT \qquad c_p/c_V = (\alpha + 1)/\alpha = \gamma$

$p_{tot} = p_1 + p_2 + \ldots$

$Nk = nR$

$R = N_A k$

Classical Thermo and Heat Engines

$\Delta U = Q - W_{by} \qquad W_{by} = \int p\,dV$

$W_{by} = NkT \ln(V_f/V_i)$

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

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

$dQ = dU + p\,dV \qquad dS = dQ/T$

$\Delta S = \int (C/T)\,dT = C \ln(T_f/T_i) \qquad C = C_p \text{ or } C_V$

$W_{by} = Q_h - Q_c = \varepsilon Q_h \qquad \varepsilon = 1 - Q_c/Q_h \qquad \varepsilon_{carnot} = 1 - T_c/T_h$

	α	γ
●	3/2	5/3
●●	5/2	7/5

Diffusion and Heat Conduction

$x_{av}^2 = 2Dt \qquad r_{av}^2 = 6Dt \qquad D = (\ell^2/3\tau) = v\ell/3 \qquad \tau = \ell/v$

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

Spin Statistics

$M = (N_{up} - N_{down})\,\mu = m\mu$

$U = -\mathbf{M}\cdot\mathbf{B} = -MB = -m\mu B$

$\mu_e = 9.2848 \times 10^{-24}$ J/T $\quad M = N\mu \tanh(\mu B/kT)$

$\Omega(m) = 2^N \sqrt{\dfrac{2}{p\,N}}\; e^{-m^2/2N}$

$P(m) = \Omega(m)/2^N$

$$\Omega(N, N_{up}) = \frac{N!}{N_{up}!\,N_{down}!} = \frac{N!}{N_{up}!\,(N - N_{up})!}$$

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Bin Statistics and Entropy

$\Omega = M^N$ or $M^N/N! \qquad \ln N! \approx N \ln N - N$

$\sigma = \ln \Omega$

$1/kT = d\sigma/dU = \beta$

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

$1/T = dS/dU$

$\Omega = \dfrac{(q+N-1)!}{(N-1)!\,q!}\,, \quad q = \dfrac{U}{\varepsilon} = \dfrac{U}{hf}$

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

Boltzmann Statistics, Entropy of Ideal Gas

Boltzmann Distribution: $P_n = C \exp(-E_n/kT), \quad \Sigma P_n = 1$

Maxwell-Boltzmann Distribution: $P(E) = C\,E^{1/2} \exp(-E/kT), \quad \int P(E)\,dE = 1$

$\Omega = C(N)\,V^N U^{\alpha N} \qquad \Delta S = C_V \ln(T_f/T_i) + Nk \ln(V_f/V_i)$

$S = Nk\,(\ln(n_Q/n) + 5/2) \qquad n = N/V = \text{number density}$

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

$P_n = (1 - e^{-\varepsilon/kT})\,e^{-n\varepsilon/kT} \qquad \langle E \rangle = \varepsilon/(e^{\varepsilon/kT} - 1)$

Free Energy and Chemical Potential

$F = U - TS \qquad W_{by} \le F_i - F_f \qquad a\mu_A + b\mu_B = c\mu_C$ for $aA + bB$? cC

$\mu = dF/dN \qquad \mu = kT \ln(N/M) - \Delta$

$\mu_i = kT \ln(n_i/n_{Qi}) - \Delta_i$

$\dfrac{n_C^{\,c}}{n_A^{\,a}\,n_B^{\,b}} = \dfrac{n_{QC}^{\,c}}{n_{QA}^{\,a}\,n_{QB}^{\,b}}\,e^{c\Delta/kT}$

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

$p_Q = n_Q kT = (4.04 \times 10^4\,\text{atm})\,(m/m_p)^{3/2}\,(T/300\text{K})^{5/2} \qquad (n/n_Q = p/p_Q)$

$p = nkT$ with $n = N/V \qquad p = p_Q e^{-\Delta/kT} \qquad p(h) = p_o e^{-mgh/kT}$

Thermal Radiation

$J = \sigma_B T^4\,, \quad \sigma_B = 5.670 \times 10^{-8}\ \text{W/m}^2\,\text{K}^4 \quad \lambda_{max} T = 0.029$ m-K

Constants and Data:

0 K = –273.15 °C = –459.67 °F

$N_A = 6.022 \times 10^{23}$ / mole

$k = 1.381 \times 10^{-23}$ J/K $= 8.617 \times 10^{-5}$ eV/K

$R = 8.314$ J / mol·K $= 8.206 \times 10^{-2}$ l·atm / mol·K

1 atm $= 1.013 \times 10^5$ Pa $\qquad$ 1 liter $= 10^{-3}\ \text{m}^3$

$m_e = 9.109 \times 10^{-31}$ kg $\qquad m_p = 1836\, m_e$

$g = 9.8\ \text{m/s}^2 \qquad c = 2.998 \times 10^8$ m/s

$h = 6.626 \times 10^{-34}$ J·s $= 4.136 \times 10^{-15}$ eV·s

$\hbar = h/2\pi = 1.055 \times 10^{-34}$ J·s $\qquad$ 1 eV $= 1.602 \times 10^{-19}$ J

1 Calorie = 1000 calories = 4184J

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

$1\text{g} = 10^{-3}$ kg