"Thermal Physics" Fall 2001
Formula and Fact Sheet (Version of 31 October 2001)
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$N_A = 6.0222 \times 10^{23}$ particles mol$^{-1}$
$k_B = 1.3806 \times 10^{-23}$ J K$^{-1}$
$R = 8.3143$ J mol$^{-1}$ K$^{-1}$
1 J = $2.39 \times 10^{-4}$ kcal
(T in °C) = (T in K) $-273.15$

1 atm = 1.01325 bar
1 Torr = 133.3 N m$^{-2}$ = 133.3 Pa
1 bar = $10^5$ N m$^{-2}$ = $10^5$ Pa
1 kcal = 4184 J
(T in °F) = $\frac{9}{5}$ (T in °C) $+32$

$$(1+x)^n = 1 + \frac{n}{1!}x + \frac{n(n-1)}{2!}x^2 + \cdots$$

$$x = x(y,z) \qquad \mathrm{d}x = \left(\frac{\partial x}{\partial y}\right)_z \mathrm{d}y + \left(\frac{\partial x}{\partial z}\right)_y \mathrm{d}z \qquad \left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y = -1$$

$$PV = nRT \qquad Pv = RT \qquad \left(P + \frac{a}{v^2}\right)(v-b) = RT$$

$$\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \qquad \kappa = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T \qquad Pv = A + \frac{B}{v} + \frac{C}{v^2} + \cdots$$

$$\mathrm{d}U = -\mathrm{d}'W_{ad} \qquad Q \equiv W - W_{ad} \qquad \mathrm{d}U = \mathrm{d}'Q - \mathrm{d}'W$$

$$\rho = \frac{m}{V} \qquad \mathrm{d}'W = \beta PV\mathrm{d}T - \kappa PV\mathrm{d}P \qquad \mathrm{d}'W = P\mathrm{d}V$$

$$\overline{C} = \frac{\Delta Q}{\Delta T} \qquad C = \frac{d'Q}{dT} \qquad c_V = \left(\frac{d'q}{dT}\right)_V \qquad c_P = \left(\frac{d'q}{dT}\right)_P$$

$$c_P - c_V = \left[\left(\frac{\partial u}{\partial v}\right)_T + P\right]\left(\frac{\partial v}{\partial T}\right)_P \qquad c_V = \left(\frac{\partial u}{\partial T}\right)_V \qquad c_P = \left(\frac{\partial h}{\partial T}\right)_P$$

$$c_P - c_V = -\left[\left(\frac{\partial h}{\partial P}\right)_T - v\right]\left(\frac{\partial P}{\partial T}\right)_V \qquad \eta \equiv \left(\frac{\partial T}{\partial v}\right)_u \qquad \mu \equiv \left(\frac{\partial T}{\partial P}\right)_h$$

$$c_P - c_V = R \qquad \gamma \equiv \frac{c_P}{c_V} \qquad Pv^\gamma = \text{Const.} \qquad Tv^{\gamma-1} = \text{Const.}'$$

$$w = \frac{1}{1-\gamma}[P_2v_2 - P_1v_1] \qquad w = c_v(T_1 - T_2) \qquad q = c_P(T_2 - T_1)$$

$$H = U + PV \qquad h = u + Pv \qquad \ell \approx \frac{\Delta Q}{\Delta m} \qquad \ell = h_i - h_j$$

$$\left(h_2 + \tfrac{1}{2}\nu_2^2 + gz_2\right) - \left(h_1 + \tfrac{1}{2}\nu_1^2 + gz_1\right) = q - w_{sh} \qquad \mathrm{d}H = \mathrm{d}'Q_P$$

$$P + \tfrac{1}{2}\rho\nu^2 + \rho gz = \text{Const.} \qquad u = u_o + c_v(T_2 - T_1) - \frac{a}{v}$$

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \qquad \eta = \frac{W}{Q_2} = 1 - \frac{T_1}{T_2} \qquad c = \frac{Q_1}{W} = \frac{T_1}{T_2 - T_1}$$

$$\eta(\text{Otto}) = 1 - \frac{Q_1}{Q_2} = 1 - \frac{1}{r^{(\gamma-1)}} \qquad r = \frac{V_a}{V_b}$$

$$\eta(\text{Joule}) = 1 - \left(\frac{P_a}{P_b}\right)^{(\gamma-1)/\gamma}$$

$dS \equiv \frac{d'Q_r}{T}$ $\quad$ $\Delta s = \frac{\ell}{T}$ $\quad$ $(\Delta s)_v = \int_{T_1}^{T_2} c_v \frac{dT}{T}$

$\Delta S \geq 0$ $\quad$ $dU = TdS - PdV$

$Tds = c_v dT + T\left(\frac{\partial P}{\partial T}\right)_v dv$ $\quad$ $(\Delta s)_P = \int_{T_1}^{T_2} c_P \frac{dT}{T}$

$Tds = c_P dT - T\left(\frac{\partial v}{\partial T}\right)_P dP$

$Tds = c_P \left(\frac{\partial T}{\partial v}\right)_P dv + c_v \left(\frac{\partial T}{\partial P}\right)_v dP$ $\quad$ $c_P - c_v = \frac{\beta^2 \, T \, v}{\kappa}$

$U$ $\quad$ $dU = TdS - PdV$ $\quad$ $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$

$H = U + PV$ $\quad$ $dH = TdS + VdP$ $\quad$ $\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$

$F = U - ST$ $\quad$ $dF = -SdT - PdV$ $\quad$ $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$

$G = U - TS + PV$ $\quad$ $dG = -SdT + VdP$ $\quad$ $\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$

$\left(\frac{dP}{dT}\right)_{s-l} = \frac{(s_s - s_l)}{(v_s - v_l)} = \frac{\ell_{s-l}}{T(v_s - v_l)}$ $\quad$ $g_1 = g_2$

$\lim_{T\to 0}\left(\frac{\partial \, \Delta G}{\partial T}\right)_P = 0$ $\quad$ $\lim_{T\to 0}\left(\frac{\partial \, \Delta H}{\partial T}\right)_P = 0$ $\quad$ $\lim_{T\to 0} S = 0$

$d'W = -\sigma \, dA$ $\quad$ $d'Q_T = \lambda \, dA_T$ $\quad$ $dU = T\,dS - P\,dV + \sigma\,dA$

$$dU = \left[T\left(\frac{\partial S}{\partial T}\right)_{P,A} - P\left(\frac{\partial V}{\partial T}\right)_{P,A}\right] dT + \left[T\left(\frac{\partial S}{\partial P}\right)_{T,A} - P\left(\frac{\partial V}{\partial P}\right)_{T,A}\right] dP + \left[\sigma + T\left(\frac{\partial S}{\partial A}\right)_{T,P} - P\left(\frac{\partial V}{\partial A}\right)_{T,P}\right] dA$$

$$dU = \left[C_{P,A} - PV\beta_{P,A}\right] dT + \left[PV\kappa_{T,A} - TV\beta_{P,A}\right] dP + \left[\sigma - T\left(\frac{\partial \sigma}{\partial T}\right)_{P,A} - P\left(\frac{\partial V}{\partial A}\right)_{T,P}\right] dA$$

$$dU = \left[\sigma - T\left(\frac{d\sigma}{dT}\right) - P\left(\frac{dV}{dA}\right)\right] dA$$

$$dU = \left[\sigma - T\left(\frac{d\sigma}{dT}\right)\right] dA$$

$S = -A \frac{d\sigma}{dT}$ $\quad$ $s = -\frac{d\sigma}{dT}$

$P_i - P_e = \frac{2\sigma}{r}$ $\quad$ $\ln \frac{p}{p_\circ} = \frac{v_\ell}{RT}(P - p_\circ)$ $\quad$ $r = \frac{2\,\sigma\,v_\ell}{RT \, \ln\left(\frac{p}{p_\circ}\right)}$

$E = -\frac{4}{3}\pi r^3 (\Delta g) + 4\pi r^2 \sigma$ $\quad$ $R_c = \frac{2\sigma}{\Delta g}$