

**Formulas:**

$T_3 = 273.16K = 0.01^\circ C$  ; water freezes/boils at  $T = 0^\circ C = 32^\circ F / T = 100^\circ C = 212^\circ F$   
 $1cal = 4.1868J$  ;  $N_A = 6.02 \times 10^{23}$

Thermal expansion:  $\Delta L = L\alpha\Delta T$  ;  $\Delta V = V\beta\Delta T$  ;  $\beta = 3\alpha$

Heat capacity and specific heat:  $Q = C\Delta T$  ;  $Q = cm\Delta T$

Heat of vaporization, fusion:  $Q = L_v m$  ;  $Q = L_f m$

First law of thermodynamics:  $\Delta E_{int} = Q - W$ ;  $dE_{int} = dQ - dW$  ;  $W = \int_{V_i}^{V_f} p dV$  work

Conduction:  $P_{cond} = \frac{Q}{t} = kA \frac{T_H - T_L}{L}$  ;  $R = \frac{L}{k}$  k,R=thermal conductivity, resistance

Radiation:  $P_{rad} = \sigma \epsilon AT^4$  ;  $\sigma = 5.67 \times 10^{-8} W / m^2 K^4$   $\epsilon = 1$  for black body

Ideal gas:  $PV = nRT = NkT = nN_A kT$  ;  $R = 8.31 J/molK$  ;  $k = 1.38 \times 10^{-23} J / K$

Pressure:  $P = \frac{Nm}{3V} (v^2)_{avg}$  Kinetic energy:  $K_{avg} = \frac{1}{2} m(v^2)_{avg} = \frac{3}{2} kT$

Internal energy:  $E_{int} = NK_{avg}$  ;  $C_V = \frac{3}{2} R$  for monoatomic gas;  $C_P = C_V + R$

$C_V, C_P$  = molar heat capacity at constant volume, pressure

$C_V = \frac{f}{2} R$  for polyatomic gases with f degrees of freedom per molecule

Adiabatic expansion of ideal gas:  $PV^\gamma = const$  ,  $TV^{\gamma-1} = const$  ;  $\gamma = C_P / C_V$

Distribution of molecular speeds:  $P(v) = 4\pi \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/(2kT)}$

Velocity distribution:  $F(v_x, v_y, v_z) = f(v_x)f(v_y)f(v_z)$ ,  $f(v_x) = \left(\frac{m}{2\pi kT}\right)^{1/2} e^{-mv_x^2/(2kT)}$

Mean free path:  $\lambda = 1 / (\sqrt{2}\pi d^2 N / V)$ , d=diameter ;  $v_{rms} = \sqrt{(v^2)_{avg}}$

**Entropy:**  $dS = dQ / T$  in a reversible process. S is a function of state.  $\Delta S = \int_i^f dQ / T$

$\Delta S \geq 0$  for a closed system. = if reversible process, > if irreversible process

Ideal gas:  $S(T, V) = nR \ln V + nC_V \ln T + const$

Heat engine:  $\epsilon = \frac{|W|}{|Q_H|}$  ; Carnot engine:  $\epsilon = 1 - \frac{|Q_L|}{|Q_H|} = 1 - \frac{T_L}{T_H}$

Refrigerator coefficient of performance  $K = \frac{|Q_L|}{|W|}$  ; Carnot refrigerator  $K_C = \frac{T_L}{T_H - T_L}$

Statistical view of entropy:  $S = k \ln W$ ;  $W = N! / (n_1! n_2! \dots)$ ;  $N! \approx N(\ln N) - N$

**Fluids:**  $\rho = m / V$ ,  $p = F / A$ ,  $1atm = 1.01 \times 10^5 Pa = 760torr$

Fluid at rest:  $p_2 + \rho g y_2 = p_1 + \rho g y_1$ ; gauge pressure =  $p - p_{atmospheric}$

Pascal's principle:  $\Delta p = F_1 / A_1 = F_2 / A_2$

Archimedes principle: buoyant force  $F_b = m_{fluid} g$