Gas Laws

$$\frac{p_1V_1}{T_1}=\frac{p_2V_2}{T_2} \qquad Z_c=\frac{p_cV_c}{RT_c} \qquad Z=\frac{V_m}{V_m^o}$$

$$p=\frac{nRT}{V-nb}-a\left(\frac{n}{V}\right)^2 \qquad pV_m=RT \qquad p_r=\frac{8T_r}{3V_r-1}-\frac{3}{V_r^2}$$

$$pV_m=RT\left(1+B'p+C'p^2+...\right)$$

$$pV_m=RT\left(1+\frac{B}{V_m}+\frac{C}{V_m^2}+...\right) \qquad T_r=\frac{T}{T_c} \qquad V_r=\frac{V_m}{V_c} \qquad p_r=\frac{p}{p_c}$$

$$T_c=\frac{8a}{27Rb} \qquad V_c=3b \qquad p_c=\frac{a}{27b^2} \qquad T_B=\frac{a}{bR}$$

$$\frac{T_B}{T_c}=\frac{27}{8}$$

First Law of Thermodynamics

$$KE=\frac{3}{2}RT \qquad \Delta U=U_f-U_i \qquad \Delta U=w+q$$

$$w=-\int_{V_i}^{V_f}pdV \qquad w=-p_{ex}\Delta V \qquad w=-nRT\ln\left(\frac{V_f}{V_i}\right)$$

$$dU=C_VdT \qquad C_V=\frac{3}{2}R \qquad dH=C_pdT \quad \text{(constant } p\text{)}$$

$$H=U+pV \qquad T_a\left(\frac{V_a}{V_b}\right)^{\frac{1}{c}}=T_b \qquad c=\frac{C_v}{nR}$$

$$\gamma=\frac{C_p}{C_v}=1+\frac{1}{c} \qquad p_aV_a^{\gamma}=p_bV_b^{\gamma}$$

$$\Delta\boldsymbol{H}_{rxn}^{\circ}=\Sigma n_p\Delta\boldsymbol{H}_f^{\circ}(\text{products})-\Sigma n_r\Delta\boldsymbol{H}_f^{\circ}(\text{reactants})$$

$$\Delta\boldsymbol{C}_p^{\circ}=\Sigma n_p\Delta\boldsymbol{C}_p^{\circ}(\text{products})-\Sigma n_r\Delta\boldsymbol{C}_p^{\circ}(\text{reactants})$$

$$dU=\pi_TdV+C_VdT \qquad \left(\frac{\partial U}{\partial T}\right)_p=\alpha\pi_TV+C_V \qquad \left(\frac{\partial H}{\partial T}\right)_V=\left(1-\frac{\alpha\mu}{\kappa_T}\right)C_p$$

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p \qquad \mu = \left(\frac{\partial T}{\partial p}\right)_H \qquad \kappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T$$

$$\mu_T = -\mu C_p \qquad C_p - C_V = \frac{\alpha^2 VT}{\kappa_T}$$

Second Law of Thermodynamics

$$S \geq 0 \qquad \Delta S = \frac{dq_{rev}}{T} \qquad \Delta S = nR\ln\left(\frac{V_f}{V_i}\right)$$

$$\Delta S = nR\ln\left(\frac{p_i}{p_f}\right) \qquad dS = \frac{dH_{pt}}{T_{pt}} \qquad S(T_f) = S(T_i) + C_p \ln\frac{T_f}{T_i}$$

$$\Delta S = C_v \ln\left(\frac{T_f}{T_i}\right) + nR\ln\left(\frac{V_f}{V_i}\right)$$

Third Law of Thermodynamics

$$S(T_f) = S(0) + \int_i^f \frac{C_{p,solid}dT}{T} + \frac{dH_{fus}}{T_m} + \int_i^f \frac{C_{p,liq}dT}{T} + \frac{dH_{vap}}{T_b} + \int_i^f \frac{C_{p,gas}dT}{T}$$

$$\Delta S^o = \Sigma\, nS^o \text{ (products)} - \Sigma\, nS^o \text{ (reactants)}$$

Spontaneity

$$A = U - TS \qquad G = H - TS \qquad dU = TdS - pdV$$

$$dA = dU - TdS \qquad dG = dH - TdS \qquad dw_{max} = dA$$

$$G(p_f) = G(p_i) + nRT\ln\left(\frac{p_f}{p_i}\right) \qquad -p = \left(\frac{\partial U}{\partial V}\right)_S \qquad T = \left(\frac{\partial U}{\partial S}\right)_V$$

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial p}{\partial S}\right)_V \qquad \left(\frac{\partial p}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T \qquad V = \left(\frac{\partial G}{\partial p}\right)_T$$

$$\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p \qquad \left(\frac{\partial V}{\partial T}\right)_p = -\left(\frac{\partial S}{\partial p}\right)_T \qquad -S = \left(\frac{\partial G}{\partial T}\right)_p$$

$$\left(\frac{\partial G/T}{\partial T}\right)_p = -\frac{H}{T^2} \qquad \ln\phi = \int_0^p \frac{Z-1}{p}dp \qquad \phi = \frac{f}{p}$$

Chemical Equilibria

$$\mu = \left(\frac{\partial G}{\partial n}\right)_{p,T} \qquad \ln K = -\frac{\Delta_r G^\theta}{RT} \qquad \Delta_r G = \left(\frac{\partial G}{\partial \xi}\right)_{p,T}$$

$$\Delta_R G = \mu_B - \mu_A \qquad G = G^\theta + RT \ln\left(\frac{p}{p^\theta}\right)$$

$dG = \mu_A dn_A + \mu_B dn_B$

$$Q = \prod_J p_J^{\nu_J} \qquad \Delta_R G = \Delta_R G^\theta + RT \ln Q \qquad \Delta_R G^\theta = -RT \ln K$$

$$0 = \sum_J \nu_J J \qquad \mu = \mu^\theta + RT \ln p \qquad \chi_J = \frac{n_J}{n}$$

$$\Delta_{mix} G = nRT(\chi_A \ln \chi_A + \chi_B \ln \chi_B) \qquad \Delta_{mix} S = -nR(\chi_A \ln \chi_A + \chi_B \ln \chi_B)$$

$$a = \frac{p}{p*} \qquad K = \left(\prod_J a_J^{\nu_J}\right)_{equilibrium} \qquad \gamma = \frac{a}{\chi}$$

$$\ln K_2 - \ln K_1 = \frac{-\Delta_r H^\theta}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad \Delta_R G = RT \ln \frac{Q}{K}$$

$$dG = Vdp - SdT + \mu_A dn_A + \mu_B dn_B + \ldots \qquad dU = TdS - pdV + \mu_A dn_A + \mu_B dn_B + \ldots$$

$$\mu_J = \left(\frac{\partial U}{\partial n_J}\right)_{S,V} \qquad \mu_J = \left(\frac{\partial H}{\partial n_J}\right)_{S,p} \qquad \mu_J = \left(\frac{\partial U}{\partial n_J}\right)_{V,T}$$

Colligative Properties

$$\ln(1 - \chi_B) = \frac{\Delta_{vap} H}{R}\left(\frac{1}{T} - \frac{1}{T*}\right) \qquad \Delta T = K_b b \;\; \Delta T = K_f b \qquad \Delta T = \frac{RT*^2}{\Delta_{vap} H}\chi_B$$

$$\Delta T = \frac{RT*^2}{\Delta_{fus} H}\chi_B \qquad \ln \chi_B = \frac{\Delta H_{fus}}{R}\left(\frac{1}{T^*} - \frac{1}{T}\right) \qquad \Pi = \left(\frac{n_B}{V}\right)RT$$

$$\Pi = [B]RT$$

$$\Pi = [B]RT(1 + B[B] + C[B]^2 + \ldots)$$

Electrochemistry

$$V = \frac{-e^2}{4\Pi\varepsilon_0 r} \qquad \phi = \frac{q}{4\Pi\varepsilon_0 r} \qquad \Delta_{solv}G^\theta = -\frac{z_i^2 e^2 N_A}{8\Pi\varepsilon_o r_i}\left(1-\frac{1}{\varepsilon_r}\right)$$

$$a = \gamma\frac{b}{b^\theta} \qquad \Delta_{solv}G^\theta = -\frac{z_i^2}{r_i(in\ pm)}\left(6.86\times10^4 kJ/mol\right) \qquad \mu = \mu^{ideal} + RT\ln\gamma$$

$$\mu_i = \mu_i^{ideal} + RT\ln\gamma_\pm \qquad \gamma_\pm = \sqrt{\gamma_+\gamma_-}\ \ \gamma_\pm = \left(\gamma_+^p\gamma_-^q\right)^{1/s} \qquad s = p+q \qquad \phi = \frac{z_i e}{4\Pi\varepsilon r}e^{-r/r_D}$$

$$I = \frac{1}{2}\sum_i z_i^2\left(b_i/b^\theta\right) \qquad I = \frac{1}{2}\frac{\left(z_+^2 b_+ + z_-^2 b_-\right)}{b^\theta} \qquad \log\gamma_\pm = -\left|z_+ z_-\right| AI^{1/2}$$

$$\ln\gamma_\pm = -\frac{A\left|z_+ z_-\right|I^{1/2}}{1+BI^{1/2}} \qquad \Delta G = w = -nFE \qquad E_{cell} = E^\theta - \frac{RT}{nF}\ln Q$$

$$E_{cell} = E^\theta - \frac{0.059}{n}\log Q \qquad E_{cell} = -\frac{RT}{nF}\ln Q \qquad E^\theta = \frac{0.059}{n}\log K$$

$$E^\theta = \frac{RT}{nF}\ln K$$

Phase Change

$$T = \frac{\Delta H_f^o}{\Delta S_f^o} \qquad \mu = \left(\frac{\partial G}{\partial n}\right)_{p,T} \qquad -S = \left(\frac{\partial G}{\partial T}\right)_p$$

$$-S_m = \left(\frac{\partial\mu}{\partial T}\right)_p \qquad V_m = \left(\frac{\partial\mu}{\partial p}\right)_T \qquad \Delta\mu = \frac{M\Delta p}{\rho}$$

$$p = p^* e^{V_{m,l}\Delta P/RT} \qquad p = p^*\left(1+\frac{V_{m,l}\Delta P}{RT}\right) \qquad \frac{p-p^*}{p^*} = \frac{V_{m,l}\Delta P}{RT}$$

$$H = U + pV \qquad dU = w + q \qquad dU_m = -pdV_m + TdS_m$$

$$\frac{dp}{dT} = \frac{\Delta_{trs}S}{\Delta_{trs}V} \qquad p = p^* + \frac{\Delta_{fus}H}{T^*\Delta_{fus}V}\left(T-T^*\right) \qquad \frac{dp}{dT} = \frac{\Delta_{vap}H}{T\Delta_{vap}V}$$

$$\ln\frac{p}{p^*} = -\frac{\Delta_{sub}H}{R}\left(\frac{1}{T}-\frac{1}{T^*}\right) \qquad F = C - P + 2 \qquad \ln\frac{p}{p^*} = -\frac{\Delta_{vap}H}{R}\left(\frac{1}{T}-\frac{1}{T^*}\right)$$

$$y_A = \frac{\chi_A p_A^*}{\chi_A (p_A^* - p_B^*) + p_B^*} \qquad p = \frac{p_A^* p_B^*}{y_A (p_B^* - p_A^*) + p_A^*} \qquad n_\alpha l_\alpha = n_\beta l_\beta$$

$$S^E = \Delta_{mix} S - \Delta_{mix} S^{ideal} \qquad \Delta_{mix} G = nRT\left(\chi_A \ln \chi_A + \chi_B \ln \chi_B\right) \qquad H^E = n\beta RT \chi_A \chi_B$$

$$\beta = \frac{w}{RT} \qquad \ln \frac{\chi_A}{1-\chi_A} + \beta(1 - 2\chi_A) = 0$$

Molecular Motion

$$f(E) = Ke^{-E/kT} \qquad f(v_x) = \left(\frac{m}{2\pi kT}\right)^{1/2} e^{\frac{-mv_x^2}{2kT}} \qquad f(v) = 4\pi\left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{\frac{-m}{2kT}v^2}$$

$$\bar{c} = \left(\frac{8RT}{\pi M}\right)^{1/2} \qquad c^* = \left(\frac{2RT}{M}\right)^{1/2} \qquad c = \left(\frac{3RT}{M}\right)^{1/2}$$

$$\mathsf{N} = \frac{nN_A}{V} \qquad V_{coll} = \sigma \bar{c}_{rel} \Delta t \qquad \lambda = \frac{kT}{\sqrt{2}\sigma p}$$

$$z = \frac{p}{kT} \sigma \bar{c}_{rel} \qquad \lambda = \frac{\bar{c}}{z} \qquad Z_W = \frac{p}{(2\pi mkT)^{1/2}}$$

$$\frac{Rate_A}{Rate_B} = \sqrt{\frac{M_B}{M_A}} \qquad p = \frac{\Delta m}{A_o \Delta t}\left(\frac{2\pi RT}{M}\right)^{1/2}$$

Transport

$$J(matter) = -D\frac{d\mathsf{N}}{dz} \qquad J(E) = -\kappa \frac{dT}{dz} \qquad J(x-momentum) = -\eta \frac{dv_x}{dz}$$

$$D = \frac{1}{3}\lambda \bar{c} \qquad \kappa = \frac{1}{3}\bar{c}\lambda C_{V,m}[A] \qquad \eta = \frac{1}{3} M \lambda \bar{c}[A]$$

Kinetics

$$-\frac{d[A]}{dt} = k[A]^0 = k \qquad -\frac{d[A]}{dt} = k[A]^1 \qquad -\frac{d[A]}{dt} = k[A]^2$$

$$[A] = -kt + [A]_0 \qquad \ln[A] = -kt + \ln[A]_0 \qquad \frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$\tau = \frac{[A]_0}{2k} \qquad \tau = \frac{\ln 2}{k} \qquad \tau = \frac{1}{[A]_0 k}$$

$$\ln\left(\frac{[B]/[B]_0}{[A]/[A]_0}\right)=(B_0-A_0)kt \qquad K=\frac{k}{k'} \qquad [A]=\frac{k'+ke^{-(k'+k)t}}{k'+k}[A]_0$$

$$\frac{d[intermediate]}{dt}=0 \qquad k=Ae^{-E_a/RT} \qquad \ln\left(\frac{k_2}{k_1}\right)=\frac{E_a}{R}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)$$

Spectroscopy

$$\lambda=\frac{c}{\nu} \qquad \tilde{\nu}=\frac{\nu}{c} \qquad T=\frac{I}{I_0}=10^{-\varepsilon[J]l}$$

$$A=\varepsilon[J]l \qquad \mu=\frac{m_1m_2}{m_1+m_2} \qquad \nu=\frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$$

$$\varepsilon_v=\left(\mathrm{v}+\frac{1}{2}\right)h\nu \qquad \varepsilon_v=\frac{1}{2}h\nu \qquad V(r)=D_e\left[1-e^{-a(R-R_e)}\right]^2$$

$$\mathrm{v}_{\max}=\frac{1}{2x_e}-1 \qquad P_i=\omega_iKe^{-\varepsilon_i/kT} \qquad \varepsilon_r=\frac{\hbar^2}{2\mu r^2}J(J+1)$$

$$\omega_J=2J+1 \qquad \Delta\varepsilon_r=\frac{\hbar^2}{I}(J+1) \qquad I=\mu r^2$$

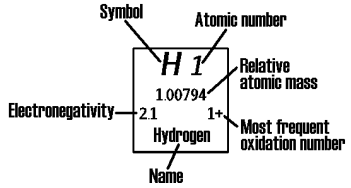
$$J_{\max}=\left(\frac{IkT}{\hbar^2}\right)^{1/2}-\frac{1}{2} \qquad \varepsilon_P=\nu-2BJ \qquad B=\frac{\hbar}{4\pi I}$$

$$\varepsilon_R=\nu+2B(J+1)$$

Conduction

$$H=\frac{-h^2}{8\pi^2m}\left\{\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right\}+V(x,y,z) \qquad H=\frac{-h^2}{8\pi^2m}\left\{\frac{\partial^2}{\partial x^2}\right\}+V(x)$$

$$P=\left(e^{(E-\mu)/kT}+1\right)^{-1} \qquad \hbar\omega=e\phi-KE$$



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	*H 1* 1.00794 2.1 1+ Hydrogen																	*He 2* 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.