

Ideal gas law: $PV = nRT$ Enthalpy: $H = E + PV$

Specific heats: $\Delta E = q_V = nc_V\Delta T$; $\Delta H = q_P = nc_P\Delta T$
 $c_V = (\text{\#d.f.}) \times (1/2 R)$ per mole
 $c_P = c_V + R$ for an ideal gas.

Water: $c_V = c_P = 1 \text{ cal/g}\cdot^\circ\text{C}$

Silver (Ag(s)): $c_V = c_P = 25.5 \text{ J/mol}\cdot\text{K}$

Work on ideal gas: $W = -\int PdV = -P_0(V_f - V_i)$ (isobaric process at P_0)
 $= -nRT_0 \ln(V_f/V_i)$ (isothermal process at T_0)
 $= nc_V(T_f - T_i)$ (adiabatic process ($q = 0$ and $PV^\gamma = K$; $\gamma = c_P/c_V$))

Entropy: $\Delta S = q/T$. For an isothermal process, $\Delta S = nR \ln(V_f/V_i)$.
 $S = k_B \ln \Omega$

Free energy: $G = H - TS$; $G = G^0 + RT \ln P$; $\Delta G = \Delta G^0 + RT \ln Q$

Equilibrium constant: $K_{eq} = e^{-\Delta G^0/RT} = e^{\Delta S^0/R} e^{-\Delta H^0/RT}$

Boltzmann Probability Distribution: $P(E) \propto \exp(-E/k_B T)$ for a single molecule, $\exp(-E/RT)$ for a mole.

Arrhenius Law for Rate Constant: $k = A \exp(-E_a/RT)$

Integrated Rate Laws: Zero order: $[A] = -kt + [A]_0$ First order: $\ln [A] = -kt + \ln [A]_0$
 Second order: $1/[A] = kt + 1/[A]_0$

Thermodynamic Data

	ΔH_f^0 (kJ/mol)	ΔG_f^0 (kJ/mol)	S^0 (JK ⁻¹ mol ⁻¹)		ΔH_f^0 (kJ/mol)	ΔG_f^0 (kJ/mol)	S^0 (JK ⁻¹ mol ⁻¹)
Br ₂ (l)	0	0	152	CH ₃ OH(g)	-201	-163	240
Br ₂ (g)	31	3	245	CH ₃ OH(l)	-239	-166	127
Br ₂ (aq)	-3	4	130	C ₂ H ₄ (g)	52	68	219
Br ⁻ (aq)	-121	-104	82	C ₂ H ₆ (g)	-85	-33	230
I ₂ (s)	0	0	116	C ₆ H ₁₂ O ₆ (s)	-1275	-911	212
C(s) graph	0	0	6	H ₂ (g)	0	0	131
C(s) dmd	2	3	2	H ₂ O (l)	-286	-237	70
CO(g)	-110	-137	198	H ₂ O (g)	-242	-229	189
CO ₂ (g)	-393	-394	214	N ₂ (g)	0	0	192
Cd(s)	0	0	52	NO (g)	90	87	211
Ag(s)	0	0	43	N ₂ O(g)	82	104	220
C ₃ H ₈ (g)	-104	-24	270	NO ₂ (g)	34	52	240
CH ₃ OH(g)	-201	-163	240	N ₂ O ₄ (g)	10	98	304
CH ₃ OH(l)	-239	-166	127	NH ₃ (aq)	-80	-27	111
CH ₄ (g)	-75	-51	186	NH ₃ (g)	-46	-17	193
H ₂ CO(g)	-116	-110	219	O ₂ (g)	0	0	205
Na(s)	0	0	51	O (g)	249	232	161
Na ⁺ (aq)	-240	-262	59	O ₃ (g)	143	163	239
NaBr (s)	-360	-347	84	H ₂ SO ₄ (aq)	-909	-745	20
K(s)	0	0	64	H ₂ SO ₄ (l)	-814	-690	157

Electrochemistry

$$\Delta G = -nFE$$

$$\Delta G = \Delta G^0 + RT \ln Q$$

$$E = E^0 - (0.0592/n) \log_{10} Q$$

$$\log_{10} K_{eq} = nE^0/0.0592$$

$$W_{elec} = q E$$

Electronegativities

C	2.5	H	2.1
S	2.5	Cu	1.9
F	4.0	O	3.5
N	3.0		

ZUMDAHL TABLE 11.1 HERE

Useful constants and conversions:

$$F = 96,485 \text{ coul/mole}$$

$$c = 3 \times 10^8 \text{ m/s}$$

$$N_0 = 6.02 \times 10^{23} \text{ molecules/mole}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ coul}^2/\text{J}\cdot\text{m}$$

$$1 \text{ nm} = 10^{-9} \text{ m}$$

$$1 \text{ cal} = 4.184 \text{ J}$$

$$e = 1.6 \times 10^{-19} \text{ coul/electron}$$

$$k_B = 1.38 \times 10^{-23} \text{ J/K}$$

$$1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$$

$$m_{\text{electron}} = 9.1 \times 10^{-31} \text{ kg}$$

$$1 \text{ Angstrom} = 10^{-10} \text{ m}$$

$$1 \text{ lit-atm} = 101.3 \text{ J}$$

$$1 \text{ Debye} = 3.336 \times 10^{-30} \text{ coul}\cdot\text{m}$$

$$R = 8.31 \text{ J/mole}\cdot\text{K}$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

$$1 \text{ Ampere} = 1 \text{ coul/sec}$$

Average bond energies (KJ/mole)

N-H	391	C-N	305	N=O	607
C \equiv C	839	C=N	615	N \equiv N	941
H-H	432	I-I	149	C=C	614
N-N	160	C-C	347	O=O	495
O-H	467	C-O	358	C=O	799

Atomic Radii (pm)

Cs	265
F	72
C	91
Cl	99

Quantum Mechanics

photon energy:

$$E = h\nu = hc/\lambda$$

Heisenberg Uncertainty:

$$\Delta p \Delta x \geq h/4\pi$$

DeBroglie Wavelength:

$$\lambda = h/mv$$

Schrödinger Equation

$$H\psi = E\psi : \quad (-\hbar^2/8\pi^2m)d^2\psi/dx^2 + V(x)\psi = E\psi$$

$$\text{H-atom: } V = -Ze^2/4\pi\epsilon_0r \quad E_n = -Z^2me^4/(8n^2h^2\epsilon_0^2) = 2.178 \times 10^{-18} (Z^2/n^2) \text{ (in Joules)} \quad a_0 = 0.0529 \text{ nm}$$

SAMPLE HYDROGENIC WAVEFUNCTIONS HERE

Dipole moment: $\mu = qR$

Melting Points and Heats of Fusion:

	<u>Melting Point</u>	<u>Enthalpy of Fusion (KJ/mol)</u>
O ₂	-218	0.45
HCl	-114	1.99
HI	-51	2.87
CCl ₄	-23	2.51
CHCl ₃	-64	9.2
NaF	992	29.3
NaCl	801	30.2

Intermolecular potential

(Lennard-Jones)
$$V = -aR^{-6} + bR^{-12}$$

$$\ln ((P_{\text{vap}}(T_1) / (P_{\text{vap}}(T_2)) = (\Delta H_{\text{vap}}/R)(1/T_2 - 1/T_1) \quad \text{Clausius-Clayperon Equation}$$

$$P = k_H\chi \quad \text{Henry's Law: } k_H = 413 \text{ atm (CH}_4 \text{ in water), } 1640 \text{ atm (CO}_2 \text{ in water), } 43400 \text{ atm (O}_2 \text{ in water)}$$

$$P(\text{solution}) = \chi(\text{solvent})P^0(\text{solvent}) : \text{Raoult's Law}$$