

Physical Chemistry Comprehensive Formula Sheet

Master Reference for Thermodynamic, Kinetic, Quantum, and Electrochemistry Equations

1. Thermodynamics

First Law:

$$\Delta U = q + w$$

$$w = -P_{\text{ext}}\Delta V \text{ (Irreversible)} \quad w = -nRT \ln \left(\frac{V_2}{V_1} \right) \text{ (Reversible Isothermal)}$$

Enthalpy Heat Capacity:

$$H = U + PV, \quad \Delta H = \Delta U + \Delta(PV)$$

$$C_p - C_v = R \quad (\text{for ideal gas})$$

$$\Delta H_2 = \Delta H_1 + \int_{T_1}^{T_2} \Delta C_p dT$$

Entropy Second Law:

$$\Delta S = \int \frac{dq_{\text{rev}}}{T}, \quad \Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} \geq 0$$

$$\Delta S_{\text{iso}} = nR \ln \left(\frac{V_2}{V_1} \right) + nC_{v,m} \ln \left(\frac{T_2}{T_1} \right)$$

Gibbs Helmholtz Free Energy:

$$G = H - TS, \quad A = U - TS$$

$$dG = VdP - SdT \quad (\text{closed system, } \Delta W_{\text{non-PV}} = 0)$$

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

$$\Delta G^\circ = -RT \ln K_{eq}$$

2. Chemical Kinetics

Rate Laws Integrated Forms:

Order	Integrated Law	Half-life ($t_{1/2}$)
0	$[A] = [A]_0 - kt$	$\frac{[A]_0}{2k}$
1	$\ln[A] = \ln[A]_0 - kt$	$\frac{\ln 2}{k}$
2	$\frac{1}{[A]} = \frac{1}{[A]_0} + kt$	$\frac{1}{k[A]_0}$

Temperature Dependence (Arrhenius):

$$k = A \exp \left(-\frac{E_a}{RT} \right)$$

$$\ln \left(\frac{k_2}{k_1} \right) = \frac{E_a}{R} \left(\frac{T_2 - T_1}{T_1 T_2} \right)$$

3. Quantum Chemistry

Fundamental Relations:

$$E = h\nu = \hbar\omega, \quad \lambda = \frac{h}{p}$$

$$\hat{H}\psi = E\psi \quad (\text{Schrödinger Eq.})$$

Particle in a 1D Box ($0 \leq x \leq L$):

$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin \left(\frac{n\pi x}{L} \right)$$

$$E_n = \frac{n^2 h^2}{8mL^2}, \quad n = 1, 2, 3, \dots$$

4. Electrochemistry

Nernst Equation:

$$E = E^\circ - \frac{RT}{nF} \ln Q$$

At 298 K:

$$E = E^\circ - \frac{0.0591 \text{ V}}{n} \log_{10} Q$$

Thermodynamic Relations:

$$\Delta G = -nFE, \quad \Delta G^\circ = -nFE^\circ$$

$$\ln K = \frac{nFE^\circ}{RT}$$

5. Solutions Colligative Properties

Raoult's Law:

$$P_A = X_A P_A^\circ$$

Colligative Properties:

$$\Delta T_b = iK_b m$$

$$\Delta T_f = iK_f m$$

$$\Pi = icRT$$

Van 't Hoff Factor (i):

$$i = 1 + \alpha(v - 1)$$