Physical Chemistry Formula Sheet

Comprehensive Quick-Reference Guide

1. Thermodynamics

First Law:

$$\Delta U = q + w$$

$w = -P_{ext}\Delta V$ (Expansion work)

Enthalpy:

$$H = U + PV$$

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

For ideal gases: $\Delta H = \Delta U +$

Heat Capacity:

$$C_p - C_v = R$$

$$q = nC\Delta T$$

Entropy:

$$\Delta S = \int \frac{dq_{rev}}{T}$$

For phase change: $\Delta S = \frac{\Delta H_{trans}}{T_{trans}}$

Gibbs Free Energy:

$$G = H - TS$$

$$\Delta G = \Delta H - T\Delta S$$

Criterion for spontaneity at constant T, P: * $\Delta G < 0$ (Spontaneous) * $\Delta G = 0$ (Equilibrium) * $\Delta G > 0$ (Non-spontaneous)

Temperature Dependence:

$$\Delta G^\circ = -RT \ln K$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H^\circ}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

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2. Quantum Chemistry

Planck-Einstein Relation:

$$E = h\nu = \hbar\omega$$

De Broglie Wavelength:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Heisenberg Uncertainty Principle:

$$\Delta x \cdot \Delta p_x \geq \frac{\hbar}{2}$$

$$\Delta E \cdot \Delta t \geq \frac{\hbar}{2}$$

Time-Independent Schrödinger Eq.:

$$\hat{H}\psi = E\psi$$

Particle in a 1D Box:

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

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

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3. Chemical Kinetics

Rate Law: Rate $= k[A]^m[B]^n$

Integrated Rate Laws: * **Zero Order** ($[A]_t = [A]_0 - kt$)**:** $t_{1/2} = \frac{[A]_0}{2k}$ * **First Order** ($\ln[A]_t = \ln[A]_0 - kt$)**:** $t_{1/2} = \frac{\ln 2}{k} \approx \frac{0.693}{k}$ * **Second Order** ($\frac{1}{[A]_t} = \frac{1}{[A]_0} + kt$)**:** $t_{1/2} = \frac{1}{k[A]_0}$

Arrhenius Equation:

$$k = Ae^{-E_a/RT}$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{T_2 - T_1}{T_1T_2}\right)$$

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4. Electrochemistry

Nernst Equation:

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

At 298 K:

$$E = E^\circ - \frac{0.0591}{n}\log Q$$

Free Energy EMF:

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

Cell Equilibrium:

$$\log K = \frac{nE^\circ}{0.0591} \text{ (at 298 K)}$$

Conductivity: * **Molar Conductivity:**

$$\Lambda_m = \frac{\kappa \cdot 1000}{c}$$

* **Kohlrausch's Law:**

$$\Lambda_m^\circ = \nu_+\lambda_+^\circ + \nu_-\lambda_-^\circ$$

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5. Solutions Colligative Prop.

Raoult's Law:

$$P_A = X_A P_A^0$$

Boiling Point Elevation:

$$\Delta T_b = iK_b m$$

Freezing Point Depression:

$$\Delta T_f = iK_f m$$

Osmotic Pressure:

$$\Pi = iCRT$$

Van't Hoff Factor (i):

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

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6. Gases Molecular Velocities

Ideal Gas Law:

$$PV = nRT = Nk_BT$$

Van Der Waals Equation:

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

Molecular Speeds: * RMS Speed: $v_{rms} = \sqrt{\frac{3RT}{M}}$ * Average Speed: $v_{avg} = \sqrt{\frac{8RT}{\pi M}}$ * Most Probable: $v_{mp} = \sqrt{\frac{2RT}{M}}$