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PHYSICAL CHEMISTRY ULTIMATE CHEAT SHEET

1. Thermodynamics & Thermochemistry

First Law of Thermodynamics:

$$\Delta U = q + w$$

Work (PV): $w = -\int P_{\text{ext}} dV$

- Reversible Isothermal: $w = -nRT\ln(\frac{V_2}{V_1})$
- Irreversible: $w = -P_{\text{ext}}(V_2 - V_1)$
- Adiabatic ($q = 0$): $w = \Delta U = nC_v\Delta T$
- Reversible Adiabatic: $PV^\gamma = \text{const}, \quad \gamma = C_p/C_v$

Enthalpy & Heat Capacity:

$$H = U + PV, \quad C_p - C_v = R$$

$$\Delta H = nC_p\Delta T, \quad \Delta U = nC_v\Delta T$$

Entropy & Second Law:

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

$$\Delta S_{\text{ideal gas}} = nC_v\ln(\frac{T_2}{T_1}) + nR\ln(\frac{V_2}{V_1})$$

Gibbs Free Energy & Spontaneity:

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

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

$\Delta G < 0 \implies$ Spontaneous process.

2. Chemical & Ionic Equilibrium

Equilibrium Constants:

$$K_p = K_c(RT)^{\Delta n g}$$

$$\text{van 't Hoff Equation: } \frac{d\ln K}{dT} = \frac{\Delta H^\circ}{RT^2}$$

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

Ionic Equilibrium & pH:

$$\text{pH} = -\log[\text{H}^+], \quad \text{pOH} = -\log[\text{OH}^-], \quad \text{pH} + \text{pOH} = 14$$

$$\text{Ostwald Dilution Law: } K_a = \frac{C\alpha^2}{1-\alpha} \approx C\alpha^2 \quad (\text{for } \alpha \ll 1)$$

Buffer Solutions (Henderson-Hasselbalch):

$$\text{Acidic Buffer: pH} = pK_a + \log(\frac{[\text{Salt}]}{[\text{Acid}]})$$

$$\text{Basic Buffer: pOH} = pK_b + \log(\frac{[\text{Salt}]}{[\text{Base}]})$$

Solubility Product:

$$A_xB_y leftharpoonsxA^{y+} + yB^{x-} \implies K_{sp} = x^xy^yS^{x+y}$$

3. Chemical Kinetics

Rate Laws & Integrated Equations:

- **Zero Order:** $kt = [A]_0 - [A], \quad t_{1/2} = \frac{[A]_0}{2k}$
- **First Order:** $kt = \ln(\frac{[A]_0}{[A]}), \quad t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$
- **Second Order:** $kt = \frac{1}{[A]} - \frac{1}{[A]_0}, \quad t_{1/2} = \frac{1}{k[A]_0}$

Temperature Dependence:

$$\text{Arrhenius Eq: } k = Ae^{-E_a/RT} \implies \ln k = \ln A - \frac{E_a}{RT}$$

$$\ln(\frac{k_2}{k_1}) = \frac{E_a}{R}(\frac{1}{T_1} - \frac{1}{T_2})$$

4. Electrochemistry

Nernst Equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{nF}\ln Q = E^\circ_{\text{cell}} - \frac{0.0591}{n}\log_{10} Q \quad (\text{at 298 K})$$

$$\Delta G^\circ = -nFE^\circ_{\text{cell}}, \quad E^\circ_{\text{cell}} = \frac{0.0591}{n}\log K_{\text{eq}}$$

Conductance & Kohlrausch's Law:

$$\text{Molar Cond.: } \Lambda_m = \frac{\kappa \times 1000}{M}$$

$$\text{Kohlrausch Law: } \Lambda^0_m(A_xB_y) = x\lambda^0_A + y\lambda^0_B$$

5. Solutions & Colligative Properties

Raoult's Law: $P_A = P_A^0 X_A$
Colligative Properties (with van 't Hoff factor i):

- **RLVP:** $\frac{P^0 - P}{P^0} = iX_{\text{solute}}$
- **Boiling Point Elevation:** $\Delta T_b = i \cdot K_b \cdot m$
- **Freezing Point Depression:** $\Delta T_f = i \cdot K_f \cdot m$
- **Osmotic Pressure:** $\Pi = iCRT$

van 't Hoff Factor: $i = 1 + (n-1)\alpha$ (Dissociation)

6. Atomic Structure & Quantum Chemistry

Bohr Model (Hydrogen-like):

$$r_n = 0.529\frac{n^2}{Z}\ \text{Å}, \quad E_n = -13.6\frac{Z^2}{n^2}\ \text{eV}$$

$$\frac{1}{\lambda} = R_H Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Quantum Mechanics & Wave Nature:

$$\text{de Broglie Wavelength: } \lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\text{Heisenberg Uncertainty: } \Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$\text{Schrödinger Eq: } \hat{H}\psi = E\psi$$

7. Gaseous State & Real Gases

Ideal Gas Law: $PV = nRT$
Velocities:

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}, \quad v_{\text{avg}} = \sqrt{\frac{8RT}{\pi M}}, \quad v_{\text{mp}} = \sqrt{\frac{2RT}{M}}$$

van der Waals Equation (Real Gases):

$$(P + a\frac{n^2}{V^2})(V - nb) = nRT$$

$$\text{Critical Constants: } V_c = 3b, \quad P_c = \frac{a}{27b^2}, \quad T_c = \frac{8a}{27Rb}$$

$$\text{Compressibility Factor: } Z = \frac{PV_m}{RT}$$

8. Surface Chemistry & Catalysis

Freundlich Adsorption Isotherm:

$$\frac{x}{m} = kP^{1/n} \implies \log(\frac{x}{m}) = \log k + \frac{1}{n}\log P$$

Langmuir Isotherm:

$$\theta = \frac{KP}{1+KP} \implies \frac{x}{m} = \frac{aP}{1+bP}$$