Chemistry Key Equations

Flash Card Study Guide

Systematic Review

Contents

Electrochemistry 1

$$E^\circ_{\textbf{cell}} = E^\circ_{\textbf{cathode}} - E^\circ_{\textbf{anode}}$$

Relevance: How you get the standard voltage of a galvanic cell from standard reduction potentials. Use it to predict spontaneity under standard conditions (1 M, 1 atm, 25°C).

Electrochemistry 2

$$E^\circ_{\textbf{cell}} = \frac{RT}{nF} \ln K$$

Relevance: Links electrochemistry to equilibrium: a larger K means a more positive E°_{cell}. Lets you convert between voltage and equilibrium constant.

Electrochemistry 3

$$E^\circ_{\textbf{cell}} = \frac{0.0257}{n} \ln K = \frac{0.0592}{n} \log K \qquad \textbf{(298.15 K)}$$

Relevance: Same as above but "plug-and-chug" at room temperature. Very common on exams.

Electrochemistry 4

$$E_{\textbf{cell}} = E^{\circ}_{\textbf{cell}} - \tfrac{RT}{nF} \ln Q$$

Relevance: Nernst equation: adjusts cell voltage for non-standard concentrations/pressures via Q. Used for concentration cells, pH effects, and "what is E right now?" problems.

Electrochemistry 5

$$E_{\textbf{cell}} = E^{\circ}_{\textbf{cell}} - \frac{0.0592}{n} \log Q \qquad \textbf{(298.15 K)}$$

Relevance: Nernst at 25°C in base-10 log form (fast calculations).

Electrochemistry 6

$$\Delta G = -nFE_{\textbf{cell}}$$

Relevance: Converts cell voltage to Gibbs free energy change under the stated (possibly nonstandard) conditions; tells direction/spontaneity.

Electrochemistry 7

$$\Delta G^\circ = -nFE^\circ_{\mathbf{cell}}$$

Relevance: Same link but for standard conditions; often combined with $\Delta G^\circ = -RT \ln K$ to connect E° and K.

Electrochemistry 8

$$w_{\mathbf{elec}} = w_{\mathrm{max}} = -nFE_{\mathbf{cell}}$$

Relevance: Maximum electrical work a cell can do equals $-\Delta G$. Useful conceptually and sometimes numerically.

Electrochemistry 9

$$Q = It = nF$$

Relevance: Charge bookkeeping in electrolysis/redox: current × time gives charge; charge / F gives moles of electrons. Used to find mass plated, time required, etc.

Thermodynamics 1

$$\Delta S = \frac{q_{\textbf{rev}}}{T}$$

Relevance: Defines entropy change for a reversible process—connects heat flow at temperature T to entropy.

Thermodynamics 2

$$S = k \ln W$$

Relevance: Statistical meaning of entropy: more microstates $W \Rightarrow$ higher disorder/entropy. Explains trends (mixing, phase changes).

Thermodynamics 3

$$\Delta S = k \ln \left(\frac{W_f}{W_i} \right)$$

Relevance: Entropy change from microstate counts; reinforces that entropy depends on how “many arrangements” are possible.

Thermodynamics 4

$$\Delta S^\circ = \sum \nu S^\circ(\textbf{products}) - \sum \nu S^\circ(\textbf{reactants})$$

Relevance: How to compute standard reaction entropy from tabulated molar entropies and stoichiometric coefficients.

Thermodynamics 5

$$\Delta S = \frac{q}{T}$$

Relevance: Same relationship written generically; in many problems it's implicitly q_{rev}. Use with care: strictly valid for reversible heat transfer.

Thermodynamics 6

$$\Delta S_{\textbf{univ}} = \Delta S_{\textbf{sys}} + \Delta S_{\textbf{surr}}$$

Relevance: Core spontaneity test: spontaneous processes have $\Delta S_{\text{univ}} > 0$.

Thermodynamics 7

$$\Delta S_{\textbf{univ}} = \Delta S_{\textbf{sys}} + \frac{q_{\textbf{surr}}}{T}$$

Relevance: Practical way to compute surrounding entropy change (often $q_{\text{surr}} = -q_{\text{sys}}$ at constant pressure).

Thermodynamics 8

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

Relevance: Main spontaneity criterion at constant T, P: $\Delta G < 0$ spontaneous. Also shows the "enthalpy vs entropy" tradeoff.

Thermodynamics 9

$$q = cm\Delta T = cm(T_f - T_i)$$

Relevance: Calorimetry: heat gained/lost for temperature change using specific heat.

Thermodynamics 10

$$\Delta U = q + w$$

Relevance: First Law of Thermodynamics: internal energy change equals heat + work (sign conventions matter).

Thermodynamics 11

$$\Delta H^\circ_{\textbf{rxn}} = \sum n\Delta H^\circ_f(\textbf{products}) - \sum n\Delta H^\circ_f(\textbf{reactants})$$

Relevance: Standard reaction enthalpy from heats of formation—workhorse for combustion and Hess's law style problems.

Equilibrium 1

$$Q_c = \frac{[C]^x[D]^y}{[A]^m[B]^n} \qquad \textbf{for } mA + nB \rightleftharpoons xC + yD$$

Relevance: Reaction quotient from concentrations; compare Q to K to predict shift direction (toward products/reactants).

Equilibrium 2

$$Q_p = \frac{P_C^x P_D^y}{P_A^m P_B^n}$$

Relevance: Same idea but using partial pressures for gases.

Equilibrium 3

$$P = MRT$$

Relevance: Converts between molarity of a gas and its pressure (from $PV = nRT$). Useful for connecting K_c and K_p reasoning.

Equilibrium 4

$K_c = Q_c$ **at equilibrium**

Relevance: Definition of K: the value of Q once equilibrium is reached.

Equilibrium 5

$$K_p = Q_p \quad \textbf{at equilibrium}$$

Relevance: Same definition for pressure-based equilibrium constant.

Equilibrium 6

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

Relevance: Converts between K_c and K_p when gases are involved; Δn is (moles gas products − moles gas reactants).

Equilibrium 7

Dissolution: $M_pX_q(s) \rightleftharpoons pM^{m+} + qX^{n-}$

Relevance: Defines what "solubility equilibrium" is for ionic solids; sets up the K_{sp} expression.

Equilibrium 8

$$K_{\mathbf{sp}} = [M^{m+}]^p[X^{n-}]^q$$

Relevance: Solubility product constant: predicts whether a precipitate forms and helps compute solubility / ion concentrations.

Acid–Base 1

$$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14} \qquad \textbf{(25°C)}$$

Relevance: Water autoionization; links acid and base strength in aqueous solutions.

Acid–Base 2

$$\mathbf{pH} = -\log[H_3O^+]$$

Relevance: Converts hydronium concentration to pH scale (acidity).

Acid–Base 3

$$\mathbf{pOH} = -\log[OH^-]$$

Relevance: Base-side analog of pH.

Acid–Base 4

$$[H_3O^+] = 10^{-\textbf{pH}}$$

Relevance: Inverse of the pH definition; used constantly in calculations.

Acid–Base 5

$$[OH^-] = 10^{-\mathbf{pOH}}$$

Relevance: Inverse of the pOH definition.

Acid–Base 6

$$\textbf{pH} + \textbf{pOH} = \textbf{p}K_w = 14.00 \qquad \textbf{(25°C)}$$

Relevance: Quick conversion between pH and pOH (temperature-dependent, but 14.00 at 25°C).

Acid–Base 7

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

Relevance: Acid dissociation constant: quantifies acid strength and governs weak acid equilibrium problems.

Acid–Base 8

$$K_b = \frac{[HB^+][OH^-]}{[B]}$$

Relevance: Base dissociation constant: quantifies base strength and governs weak base equilibrium problems.

Acid–Base 9

$$K_a K_b = K_w$$

Relevance: Connects conjugate acid/base strengths; lets you find K_b from K_a (or vice versa).

Acid–Base 10

$$\mathbf{p}K_a = -\log K_a$$

Relevance: Log form of acidity constant; easier comparisons and used in buffer equation.

Acid–Base 11

$$\mathbf{p}K_b = -\log K_b$$

Relevance: Log form for base strength; used similarly.

Acid–Base 12

$$\textbf{Henderson–Hasselbalch: } \mathbf{pH} = \mathbf{p}K_a + \log\left(\frac{[A^-]}{[HA]}\right)$$

Relevance: The buffer equation: fast pH of buffer from conjugate base/acid ratio; also explains buffer behavior and titration curve regions.

Acid–Base 13

$$\textbf{Percent ionization} = \frac{[H_3O^+]_{\textbf{eq}}}{[HA]_0} \times 100$$

Relevance: Measures how much a weak acid actually dissociates; shows weak acids ionize more when diluted.

Kinetics 1

For $aA \to bB$**:** $-\frac{1}{a}\frac{\Delta[A]}{\Delta t} = \frac{1}{b}\frac{\Delta[B]}{\Delta t}$

Relevance: Relates consumption/formation rates using stoichiometry; defines reaction rate consistently across species.

Kinetics 2

Zero order: $[A]_t = -kt + [A]_0$

Relevance: Concentration decreases linearly; identifies zero-order by linear $[A]$ vs t plot.

Kinetics 3

Zero-order half-life: $t_{1/2} = \frac{[A]_0}{2k}$

Relevance: Shows half-life depends on initial concentration for zero order.

Kinetics 4

First order: $\ln[A]_t = -kt + \ln[A]_0$

Relevance: Exponential decay; linear $\ln[A]$ vs t plot; common for decomposition/radioactivity analogs.

Kinetics 5

First-order half-life: $t_{1/2} = \frac{0.693}{k}$

Relevance: Key feature: half-life is constant (independent of $[A]_0$) for first order.

Kinetics 6

Second order: $\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$

Relevance: Linear $1/[A]$ vs t plot; typical for bimolecular steps.

Kinetics 7

Second-order half-life: $t_{1/2} = \frac{1}{k[A]_0}$

Relevance: Half-life depends inversely on initial concentration for second order.

Kinetics 8

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

Relevance: Explains why rate increases with temperature; connects k to activation energy.

Kinetics 9

$$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

Relevance: Linear form: slope of $\ln k$ vs $1/T$ gives $-E_a/R$. Used to find E_a from data.

Kinetics 10

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

Relevance: Two-temperature shortcut to compute k change or E_a without making a full plot.

Gas Laws 1

$$PV = nRT$$

Relevance: The ideal gas law; core relationship among P, V, n, T.

Gas Laws 2

$$P = \frac{F}{A}$$

Relevance: Mechanical definition of pressure; shows pressure is force distributed over area.

Gas Laws 3

$$P = h\rho g$$

Relevance: Hydrostatic pressure (fluids/manometers/barometers); converts height of liquid column to pressure.

Gas Laws 4

$$P_{\textbf{total}} = \sum P_i$$

Relevance: Dalton's law: total pressure is sum of partial pressures in a gas mixture.

Gas Laws 5

$$P_A = X_A P_{\textbf{total}}$$

Relevance: Partial pressure from mole fraction; very common for collection over water and mixture problems.

Gas Laws 6

$$X_A = \frac{n_A}{n_{\textbf{total}}}$$

Relevance: Defines mole fraction; connects composition to partial pressure.

Gas Laws 7

$$\textbf{Rate of diffusion} = \textbf{(amount through area)/(time)}$$

Relevance: Basic definition; used conceptually in transport/diffusion contexts.

Gas Laws 8

Graham's law: $\frac{\textbf{rate}_A}{\textbf{rate}_B} = \sqrt{\frac{m_B}{m_A}} = \sqrt{\frac{M_B}{M_A}}$

Relevance: Lighter gases effuse/diffuse faster; lets you compare rates or identify molar masses.

Gas Laws 9

$$u_{\mathbf{rms}} = \sqrt{\overline{u^2}} = \sqrt{\frac{u_1^2+u_2^2+\cdots}{n}}$$

Relevance: Statistical definition of root-mean-square speed (connects molecular speed distribution to a single representative value).

Gas Laws 10

$$\mathbf{KE_{avg}} = \frac{3}{2}RT$$

Relevance: Average kinetic energy depends only on temperature; explains why hotter gases move faster.

Gas Laws 11

$$u_{\mathbf{rms}} = \sqrt{\frac{3RT}{M}}$$

Relevance: Computes rms speed; shows lighter molar mass ⇒ higher speed at same T.

Gas Laws 12

$$Z = \frac{\textbf{real molar volume}}{\textbf{ideal molar volume}} = \left(\frac{PV_m}{RT}\right)_{\textbf{measured}}$$

Relevance: Compressibility factor measures non-ideality: $Z = 1$ ideal; deviations indicate attractions/repulsions.

Gas Laws 13

van der Waals: $\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$

Relevance: Corrects ideal gas law for real gases: *a* accounts for attractions, *b* for finite particle volume.

Colligative 1

Henry's law: $C_i = kP_i$

Relevance: Gas solubility in a liquid increases with partial pressure (soda carbonation, decompression sickness).

Colligative 2

Raoult's law: $P_A = X_A P_A^*$

Relevance: Vapor pressure lowering in ideal solutions; foundation for colligative properties and phase diagrams.

Colligative 3

$$P_{\textbf{solution}} = \sum P_i = \sum X_i P_i^*$$

Relevance: Total vapor pressure over a multi-component ideal solution.

Colligative 4

$$P_{\textbf{solution}} = X_{\textbf{solvent}} P^{*}_{\textbf{solvent}}$$

Relevance: Common special case when the solute is nonvolatile (only solvent contributes to vapor pressure).

Colligative 5

$$\Delta T_b = K_b m$$

Relevance: Boiling point elevation: depends on molality (and number of solute particles if using van't Hoff factor).

Colligative 6

$$\Delta T_f = K_f m$$

Relevance: Freezing point depression: same idea; used for antifreeze-type calculations.

Colligative 7

Osmotic pressure: $\Pi = MRT$

Relevance: Pressure needed to stop osmosis; useful for molar mass of solutes (polymers/biomolecules) and osmolarity.

Phase Changes 1

Capillary rise: $h = \frac{2T\cos\theta}{r\rho g}$

Relevance: Explains capillary action: smaller radius $r \Rightarrow$ higher rise; depends on surface tension and wetting angle.

Phase Changes 2

Clausius–Clapeyron: $P = Ae^{-\Delta H_{\textbf{vap}}/RT}$

Relevance: How vapor pressure depends exponentially on temperature; connects to enthalpy of vaporization.

Phase Changes 3

$$\ln P = -\frac{\Delta H_{\mathbf{vap}}}{RT} + \ln A$$

Relevance: Linearized form; useful for plotting $\ln P$ vs $1/T$.

Phase Changes 4

$$\ln\left(\frac{P_1}{P_2}\right) = \frac{\Delta H_{\mathbf{vap}}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Relevance: Two-temperature shortcut to find vapor pressure at a new temperature or estimate ΔH_{vap}.

Phase Changes 5

Bragg's law: $n\lambda = 2d \sin\theta$

Relevance: X-ray diffraction: relates wavelength and diffraction angle to lattice spacing d; used to determine crystal structures.

Atomic Structure 1

$$c = \lambda\nu$$

Relevance: Wave relationship: links wavelength and frequency; used constantly in photon/EM spectrum problems.

Atomic Structure 2

$$E = h\nu = \frac{hc}{\lambda}$$

Relevance: Photon energy; connects light properties to quantized energy changes (spectroscopy, photoelectric-type reasoning).

Atomic Structure 3

Rydberg: $\frac{1}{\lambda} = R_\infty \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$

Relevance: Predicts wavelengths of hydrogen spectral lines (Lyman/Balmer series).

Atomic Structure 4

$$E_n = -k\frac{Z^2}{n^2}$$

Relevance: Energy levels for hydrogen-like ions; shows levels get more negative with higher Z and lower n.

Atomic Structure 5

$$\Delta E = kZ^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Relevance: Energy change for an electron transition; magnitude equals photon energy absorbed/emitted.

Atomic Structure 6

$$r = \frac{n^2}{Z} a_0$$

Relevance: Bohr-model radius for hydrogen-like atoms/ions; shows radius increases with n^2 and decreases with Z.

Bonding 1

$$\textbf{Bond order} = \frac{\#\textbf{bonding } e^- - \#\textbf{antibonding } e^-}{2}$$

Relevance: From MO theory: predicts bond strength/length and whether a species is stable (bond order > 0).

Bonding 2

$$\textbf{Formal charge} = \textbf{valence } e^- - \textbf{lone pair } e^- - \frac{1}{2}(\textbf{bonding } e^-)$$

Relevance: Picks the best Lewis structure/resonance form (minimize formal charges; put negative on more electronegative atoms).

Bonding 3

$$XY(g) \rightarrow X(g) + Y(g), \qquad D_{X-Y} = \Delta H^\circ$$

Relevance: Definition of bond dissociation energy: enthalpy required to break one mole of a specific bond in gas phase.

Bonding 4

$$\Delta H = \sum D_{\textbf{broken}} - \sum D_{\textbf{formed}}$$

Relevance: Estimates reaction enthalpy from bond energies (approximate, best for gas-phase).

Bonding 5

$$MX(s) \to M^{n+}(g) + X^{n-}(g), \qquad \Delta H_{\textbf{lattice}}$$

Relevance: Defines lattice energy conceptually: energy to separate an ionic solid into gaseous ions (ties to ionic stability/solubility).

Bonding 6

$$\Delta H_{\textbf{lattice}} = \frac{C(Z^{+})(Z^{-})}{R_0}$$

Relevance: Shows lattice energy trends: larger charges and smaller ion separation give stronger ionic solids.

Stoichiometry 1

$$\%X = \frac{\textbf{mass of } X}{\textbf{mass of compound}} \times 100\%$$

Relevance: Percent composition; used for empirical formulas and composition analysis.

Stoichiometry 2

$$\frac{\textbf{molar mass}}{\textbf{empirical formula mass}} = n$$

Relevance: Finds molecular formula multiplier n from empirical formula.

Stoichiometry 3

$$(A_x B_y)_n = A_{nx} B_{ny}$$

Relevance: Applies that multiplier to every subscript to get the molecular formula.

Stoichiometry 4

$$M = \frac{\textbf{mol solute}}{\textbf{L solution}}$$

Relevance: Molarity; primary concentration unit for solution stoichiometry.

Stoichiometry 5

$$C_1 V_1 = C_2 V_2$$

Relevance: Dilution (moles conserved): quick way to compute new concentration or volume after adding solvent.

Stoichiometry 6

$$\textbf{Percent by mass} = \frac{\textbf{mass solute}}{\textbf{mass solution}} \times 100$$

Relevance: Concentration for mixtures/solutions when masses are known (common in lab prep).

Stoichiometry 7

$$\textbf{ppm} = \frac{\textbf{mass solute}}{\textbf{mass solution}} \times 10^6$$

Relevance: Trace concentrations (environmental, water quality).

Stoichiometry 8

$$\textbf{ppb} = \frac{\textbf{mass solute}}{\textbf{mass solution}} \times 10^9$$

Relevance: Even more dilute trace concentrations.

Stoichiometry 9

$$\textbf{Percent yield} = \frac{\textbf{actual}}{\textbf{theoretical}} \times 100$$

Relevance: Reaction efficiency; compares real lab outcome to stoichiometric maximum.

Measurements 1

$$\textbf{Average atomic mass} = \sum(\textbf{fractional abundance} \times \textbf{isotopic mass})$$

Relevance: Explains periodic table atomic weights; used in isotope problems.

Measurements 2

$$\textbf{Density} = \frac{\textbf{mass}}{\textbf{volume}}$$

Relevance: Material identification and conversions between mass and volume (lab fundamentals).

Measurements 3

$$T_{\circ C} = \frac{5}{9}(T_{\circ F} - 32)$$

Relevance: Fahrenheit → Celsius conversion (for temperature-based chemistry contexts).

Measurements 4

$$T_{\circ F} = \frac{9}{5} T_{\circ C} + 32$$

Relevance: Celsius → Fahrenheit conversion.

Measurements 5

$$T_K = {}^\circ C + 273.15$$

Relevance: Converts to Kelvin, required for gas laws, kinetics, thermodynamics.

Measurements 6

$$T_{^\circ C} = K - 273.15$$

Relevance: Kelvin → Celsius conversion.

End of Flash Cards

Review these equations systematically for exam preparation!