

Nuclear and Atomic Chemistry

Avogadro's number: $N_A = 6.02 \times 10^{23}$

N_A amu (u) = 1 gram

$1 \text{ u} = 1.66 \times 10^{-24} \text{ g} = 1.66 \times 10^{-27} \text{ kg}$

$m_p = 1.0073 \text{ u}$, $m_n = 1.0087 \text{ u}$

$Z = \# \text{ protons}$, $N = \# \text{ neutrons}$

mass defect: $\Delta m = (Zm_p + Nm_n) - m_{\text{nucleus}}$

nuclear binding energy: $E_B = (\Delta m) \times \frac{931 \text{ MeV}}{1 \text{ u}}$

$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$, $1 \text{ MeV} = 10^6 \text{ eV}$

$E_{\text{photon}} = hf = hc/\lambda$

electron energy levels: $E_n = \frac{Z^2}{n^2} (-13.6 \text{ eV})$
for any 1-electron (Bohr) atom

Radioactive Decay

$Z = \# \text{ protons} = \text{atomic number}$, $N = \# \text{ neutrons}$,
 $A = Z + N = \text{mass number}$

Decay	Description	ΔZ	ΔN	ΔA
α	eject $\alpha = {}^4_2\text{He}$	-2	-2	-4
β^-	$n \rightarrow p + e^-$	+1	-1	0
β^+	$p \rightarrow n + e^+$	-1	+1	0
EC	$p + e^- \rightarrow n$	-1	+1	0
γ	$X^* \rightarrow X + \gamma$	0	0	0

Periodic Trends & Bonding

Atomic Radius	Electron Affinity
Ionization Energy	Electronegativity
Acidity	Basicity

electronegativity of some common atoms:

$F > O > (N \approx Cl) > Br > (I \approx S \approx C) > H$

intermolecular forces (D = dipole,

I = induced, i = instantaneous):

ion-ion > ion-D > D-D (incl. H-bonds)
> D-ID > iD-ID (London)

Electron Configurations

e^- quantum numbers: n, l, m_l, m_s

$n = 1, 2, \dots$ $l = 0, 1, \dots, n-1$

$[l = 0 \leftrightarrow s, l = 1 \leftrightarrow p,$

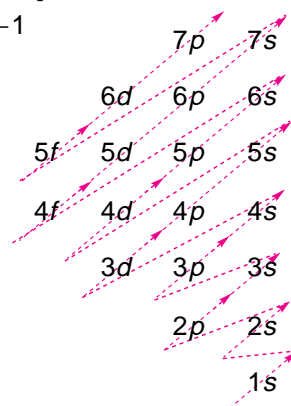
$l = 2 \leftrightarrow d, l = 3 \leftrightarrow f]$

$m_l = -l, -(l-1), \dots, (l-1), l$

$m_s = +\frac{1}{2}$ or $-\frac{1}{2}$

in subshell l ,
max # of electrons = $4l + 2$

in energy level n ,
max # of electrons = $2n^2$



Stoichiometry / Lewis Structures

moles = $\frac{\text{mass in grams}}{\text{MW}}$; molarity: $M = \frac{\text{moles of solute}}{\text{L of solution}}$

% composition by mass of X = $\frac{\text{mass of X}}{\text{mass of molecule}} \times 100\%$

formal charge: $FC = V - (\frac{1}{2}B + L)$

$V = (\# \text{ of valence } e^- \text{'s})$, $B = (\# \text{ of bonding } e^- \text{'s})$,

$L = (\# \text{ of lone-pair } e^- \text{'s})$

Molecular Geometry (VSEPR theory)

# lone pairs on central atom	Geometric Family				
	Linear	Trigonal planar	Tetrahedral	Trigonal bipyramid	Octahedral
0					
shape = geometry					
1					
shape =		Bent	Trigonal pyramidal	See-saw	Square pyramidal
2					
shape =			Bent	T-shaped	Square planar

Constants or equations in a shaded box do not need to be memorized.

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Gases

STP: $T = 0\text{ }^\circ\text{C} = 273\text{ K}$, $P = 1\text{ atm} = 760\text{ torr} = 760\text{ mmHg}$

Avogadro's law: $V \propto n$

$$V_{\text{at STP}} = n(22.4\text{ L})$$

Boyle's law: $V \propto 1/P$ (at constant T)

Charles' law: $V \propto T$ (at constant P)

Combined: $P_1 V_1 / T_1 = P_2 V_2 / T_2$

Ideal-Gas law: $PV = nRT$

Dalton's law of partial pressures: $P = \sum p_i$

Graham's law of effusion:

$$V_{2,\text{rms}} = V_{1,\text{rms}} \sqrt{\frac{m_1}{m_2}} \Rightarrow \frac{\text{rate of effusion of gas 2}}{\text{rate of effusion of gas 1}} = \sqrt{\frac{m_1}{m_2}}$$

Kinetics

concentration rate = $-\frac{\Delta[\text{reactant}]}{\text{time}}$ or $+\frac{\Delta[\text{product}]}{\text{time}}$

reaction rate = $-\frac{1}{\text{coeff}} \frac{\Delta[\text{reactant}]}{\text{time}}$ or $+\frac{1}{\text{coeff}} \frac{\Delta[\text{product}]}{\text{time}}$

rate law for *rate-determining* step: $\text{rate} = k[\text{reactant}_i]^{\text{coeff}_i} \dots$

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

Equilibrium

for generic balanced reaction $aA + bB \rightleftharpoons cC + dD$,

$$\text{equilibrium constant: } K_{\text{eq}} = \frac{[\text{C}]_{\text{at eq}}^c [\text{D}]_{\text{at eq}}^d}{[\text{A}]_{\text{at eq}}^a [\text{B}]_{\text{at eq}}^b} \quad \leftarrow \begin{array}{l} \text{excluding} \\ \text{pure solids} \\ \text{and liquids} \end{array}$$

(gas rxns use partial pressures in K_{eq} expression)

K_{eq} is a constant at a given temperature.

$K_{\text{eq}} < 1 \Leftrightarrow$ equilibrium favors reactants

$K_{\text{eq}} > 1 \Leftrightarrow$ equilibrium favors products

$$\text{reaction quotient: } Q = \frac{[\text{C}]^c [\text{D}]^d}{[\text{A}]^a [\text{B}]^b}$$

Law of Mass Action (Le Châtelier's principle):

$Q < K_{\text{eq}} \Leftrightarrow$ rxn proceeds forward

$Q = K_{\text{eq}} \Leftrightarrow$ rxn at equilibrium

$Q > K_{\text{eq}} \Leftrightarrow$ rxn proceeds in reverse

Acids and Bases

$\text{pH} = -\log [\text{H}^+] = -\log [\text{H}_3\text{O}^+]$

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

$K_w = [\text{H}^+][\text{OH}^-] = 1 \times 10^{-14}$ at $25\text{ }^\circ\text{C}$

$\text{pH} + \text{pOH} = 14$ at $25\text{ }^\circ\text{C}$

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}, \quad \text{p}K_a = -\log K_a$$

$$K_b = \frac{[\text{OH}^-][\text{HB}^+]}{[\text{B}]}, \quad \text{p}K_b = -\log K_b$$

$K_a K_b = K_w =$ ion-product constant for water

Henderson-Hasselbalch equations:

$$\text{pH} = \text{p}K_a + \log \frac{[\text{conjugate base}]}{[\text{weak acid}]} = \text{p}K_a - \log \frac{[\text{weak acid}]}{[\text{conjugate base}]}$$

$$\text{pOH} = \text{p}K_b + \log \frac{[\text{conjugate acid}]}{[\text{weak base}]} = \text{p}K_b - \log \frac{[\text{weak base}]}{[\text{conjugate acid}]}$$

acid-base neutralization: $N_a V_a = N_b V_b$

Colligative Properties

molality: $m = \frac{\text{moles of solute}}{\text{kg of solvent}}$

normality: $N = \frac{\text{equivalents (eq)}}{\text{L of solution}}$

BP elevation: $\Delta T_b = k_b i m$

FP depression: $\Delta T_f = -k_f i m$

mole fraction: $X_S = \frac{\text{moles of S}}{\text{total moles}}$

Raoult's law: $P_A = X_A P_A^\circ$

vapor pressure depression: $\Delta P_A = -(1 - X_A) P_A^\circ$

osmotic pressure: $\Pi = iMRT$

Thermochemistry

T (in K) = $T_{\text{C}} + 273$, $1\text{ cal} \approx 4.2\text{ J}$, $q =$ heat

$q = mc\Delta T = C\Delta T$ (if no phase change)

$q = n\Delta H_{\text{phase change}}$ ($\Delta T = 0$ during phase change)

enthalpy change: $\Delta H =$ heat of rxn at const P

$\Delta H < 0 \Leftrightarrow$ exothermic, $\Delta H > 0 \Leftrightarrow$ endothermic

standard state: one most stable at $25\text{ }^\circ\text{C}$, 1 atm

$$\Delta H_{\text{rxn}}^\circ = \sum n\Delta H_{\text{f,products}}^\circ - \sum n\Delta H_{\text{f,reactants}}^\circ$$

Laws of Thermodynamics ($E =$ energy, $S =$ entropy):

1) E_{universe} is constant. $\Delta E_{\text{system}} = q + W$.

2) Spontaneous rxn $\Rightarrow \Delta S_{\text{universe}} > 0$

3) $S = 0$ for pure crystal at $T = 0\text{ K}$

Gibbs Free Energy: $\Delta G = \Delta H - T\Delta S$ [const. T]

$\Delta G < 0 \Leftrightarrow$ spontaneous

$\Delta G = 0 \Leftrightarrow$ at equilibrium

$\Delta G > 0 \Leftrightarrow$ reverse rxn is spontaneous

$$\Delta G^\circ \approx -RT \ln K \approx -2.3RT \log K \approx (-5.7 \frac{\text{kJ}}{\text{mol}}) \log K$$

Redox and Electrochemistry

Rules for determining oxidation state (OS):*

1) sum of OS's = 0 in neutral molecule;

sum of OS's = charge on ion

2) Group 1 metals: OS = +1;

Group 2 metals: OS = +2

3) OS of F = -1

4) OS of H = +1

5) OS of O = -2

6) OS of halogens = -1; OS of O family = -2

If one rule contradicts another, rule higher in list takes precedence. [*These rules work 99% of the time.]

$F =$ faraday $\approx 96,500\text{ C/mol e}^-$

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

$E_{\text{cell}} > 0 \Leftrightarrow$ spontaneous

$E_{\text{cell}} < 0 \Leftrightarrow$ reverse rxn is spontaneous

$$\text{Nernst equation: } E \approx E^\circ - \frac{0.06}{n} \log Q$$

Faraday's Law of Electrolysis:

The amount of chemical change is proportional to the amount of electricity that flows through the cell.