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AMINO ACIDS: form proteins; carboxyl group, amino group, H & side group all bonded to chiral cent. only glycine (R=H) is not chiral.

HANNAH'S PREDICTION: primary: cov. peptide

GIBB'S PHASE RULE: $F = C - P + Z$ (comp.) + 1 (gas)

BINARY PHASE DIAGRAM: $F = C - P + 1$

UNARY PHASE DIAGRAM: $F = C - P + 2$

PT TRENDS: $\Delta F^\circ = \text{release heat}$; $\Delta H^\circ = \text{absorb heat}$; $\Delta S^\circ = \text{1st ionization energy}$; $\Delta E^\circ = \text{E to remove outer shell}$; $\Delta E^\circ \text{ AFFINITY} \rightarrow \Delta E^\circ \text{ when e- added to atom}$; $\Delta E^\circ \text{ ELECTRONIC} \rightarrow \Delta E^\circ \text{ in bond (ex: covalent)}$; $\Delta E^\circ \text{ CONDUCTIVITY} \rightarrow K$

COVALENT IONIC: pairwise: ionic-direction; dicovalent: 3D infinitely periodic; unsaturated: e- neutral; strong pairwise interactions

BORN-LANDÉ: $E = \frac{NaMe^2 - e^2}{4\pi\epsilon_0 r_0} (1 - \frac{1}{r})$ [J/mol]

BORN-HABER: $\Delta H_{\text{Born}} = \Delta E_{\text{Vap}} + IP + \frac{1}{2} BE - EA + \Delta U_L$

$Mg^{2+}(g) + 2e^- \rightarrow Cl^{-}(g)$ ΔE_A

$Mg^{2+}(g) + 2e^- + \frac{1}{2}Cl_2(g)$ ΔE_B

$Mg(g) + \frac{1}{2}Cl_2(g)$ ΔE_{Vap}

$Mg(g) + \frac{1}{2}Cl_2(g)$ ΔE_U

$MgCl$

HYPERVERALLENCE \rightarrow atom w/ more than 8 e- in valence shell ex: SF_6 ($\text{F}_1\text{F}_1\text{F}_1\text{F}_1\text{F}_1\text{F}_1$)

RESONANCE \rightarrow more than 1 Lewis structure can be drawn ex: CO_3^{2-} ($\text{[O}_1\text{C=O}]^{2-}$) \leftrightarrow ($\text{[O}_1\text{C=O}]^{2-}$) etc.

ACIDS & BASES:

$HA + B \rightleftharpoons BH^+ + A^-$

ex: $HA(\text{aq}) + H_2O(\text{aq}) \rightleftharpoons H_3O^+(\text{aq}) + A^-(\text{aq})$

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

POLYMER CLASSES: BOTH covalently crosslinked

- THERMOPLASTICS** \rightarrow chains held together by IMFs → reprocessable/recyclable (heat up \rightarrow melts)
- THERMOSETS/ELASTOMERS** \rightarrow intramolecular forces (covalent); not recyclable (heat up \rightarrow degrades); rubber; plastic

RATES: $\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$; $\frac{k_2}{k_1} = \left(\frac{P_2}{P_1}\right)^2$; $\ln k = -\frac{\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R}$

ARRHENIUS LAW: $k = Ae^{-\frac{E_a}{RT}}$; $\ln k = \frac{-E_a}{R}\left(\frac{1}{T}\right) + \ln A$; $\text{rate} = (\text{pre-expo factor})e^{-\frac{E_a}{RT}}$; $r = K \cdot [\text{reactant}]^m [\text{P}]^n$; $\Delta G^\circ = -RT\ln K$; $\Delta G^\circ = \Delta H^\circ + RT\ln Q$

CATALYST \rightarrow accelerates rxns; lowers E_a ; $\Delta E_a \uparrow K$; $A + B \rightarrow C + D$; $D + E \rightarrow F + A$

HETEROGENEOUS: catalyst in diff. phase than product \rightarrow adsorption (chem. bond w/ reactant interacts w/ solid surface; becomes weak then breaks); \rightarrow higher temps, reusable, better for large processes

HOMOGENEOUS: catalyst in same phase as product \rightarrow $A + B + C + D \rightarrow$ catalyst uniformly dispersed in reaction mix; formation of intermediates "sub-rxns" (lower E_a ; easy to go); \rightarrow faster, ambient-temper cond. (inside living being, low temp.)

EQUILIBRIUM: $K_{\text{forward}} = K_{\text{reverse}}$; $K = \frac{[\text{products}]^d}{[\text{reactants}]^a[\text{P}]^b}$

LECHATLIER: system responds to change by establishing new equilibrium left (reverse rxn); right (endo, forward); depends; favors fewer moles (ΔV : goes to more mols); whole system favors side w/ fewer molecules favor reactant (equil. left); (ΔT favor right) favor products (shift right) shift towards products NO EFFECT (catalysts change rate, NOT destination)

EXOTHERMIC: $\Delta H < 0$ the process occurs spontaneously, $\Delta S_{\text{uni}} > 0$, $Q < K$ ($\Delta G < 0$ process @ equilibrium, $\Delta S_{\text{uni}} > 0$, $Q = K$, $\Delta G = 0$) ($\Delta G > 0$ process proceeding other direction (unfavorable))

ENDOTHERMIC: $\Delta H > 0$ ($\Delta G_{\text{rxn}} = \Delta H_{\text{rxn}} - T\Delta S_{\text{rxn}}$ (spontaneous))

HYDROPHILIC \rightarrow polar; **HYDROPHOBIC \rightarrow non-polar**

LAW OF THERMO: $\Delta U = Q - W$ by system; $-E$ is conserved

- $\Delta U = Q - W$ by system
- entropy stays same/increases (spontaneous $\Delta G < 0$)
- entropy $S \neq 0$ approaches constant value as $T \rightarrow 0$ K

GIBBS FREE ENERGY: $\Delta G = \Delta H - T\Delta S^\circ$ @ constant T & P

EXOTHERMIC: $\Delta G < 0$ the process occurs spontaneously, $\Delta S_{\text{uni}} > 0$, $Q < K$ ($\Delta G = 0$ process @ equilibrium, $\Delta S_{\text{uni}} > 0$, $Q = K$, $\Delta G = 0$) ($\Delta G > 0$ process proceeding other direction (unfavorable))

ENDOTHERMIC: $\Delta G > 0$ ($\Delta G_{\text{rxn}} = \Delta H_{\text{rxn}} - T\Delta S_{\text{rxn}}$ (spontaneous))

UNFAVORABLE: $\Delta G > 0$

FAVORABLE: $\Delta G < 0$

INTERNAL ENERGY: $U \rightarrow$ internal energy [J]; $W \rightarrow$ work [J]; $Q \rightarrow$ heat [J]; $H \rightarrow$ enthalpy [J]; $S \rightarrow$ entropy [J/K]

LAWS OF THERMO: internal heat added; work done by system; E is conserved

- $\Delta U = Q - W$ by system
- entropy stays same/increases (spontaneous $\Delta G < 0$)
- entropy $S \neq 0$ approaches constant value as $T \rightarrow 0$ K

AMMONIA: $H\ddot{N}H$; soluble in water (polar); \rightarrow IMFs: H-bonds mainly

AMMONIUM: $H\ddot{N}H$ not gas; nonpolar

gases

PH & pOH scale: pH and pOH scale

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
increasing acidity neutral increasing basicity

DIFFICULT Q's:

Ex: SOLUBILITY PRODUCT
 $Ca_3(PO_4)_2(s) \xrightarrow{H_2O} 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$ \leftarrow ions need to balance out
 $K_{\text{sp}} = [Ca^{2+}]^3[PO_4^{3-}]^2$ \leftarrow solid doesn't matter for K_{sp}
 K_{sp} for $Ca_3(PO_4)_2(s) = 3.091 \times 10^{-12}$, what is concentration of Ca/PO₄ ions?
set $x = [Ca^{2+}] \rightarrow [PO_4^{3-}]^2 = \frac{2}{3}x \rightarrow 3.091 \times 10^{-12} = x^5$ (RICE) $\rightarrow x = 0.0059 M$

Ex: DISSOLVE: COOH acid
 $\xrightarrow{H_2O} COO^- + H^+$
acids release H^+ when dissolved

HALF RXNS: $2N_2 + 6H_2O \rightleftharpoons 4NH_3 + 3O_2$
(any multiple of this is fine)
 $N_2 + 6H^+ + 6e^- \rightleftharpoons 2NH_3$ (reduction)
 $2H_2O \rightleftharpoons O_2 + 2H^+ + 2e^-$ (oxidation)

PRINCIPAL QUANTUM #S:
principal: n, 1, 2, ... dist. from nucleus
angular: l, 0, 1, 2, 3 s p d f shape
magnetic: m_l, [-l, +l] orientation
spin: m_s, ±½ up ↑ / down ↓

RULES:

PAULI'S EXCLUSION: 2 e- can't have the same quantum #

AUFBAU: fill e- from lowest to highest E

HUND'S: fill each subshell singly w/ same spin before filling doubly

POLYMER PROPS:

- CRYSTALLINE**: \rightarrow strong, \rightarrow brittle, \rightarrow opaque, \rightarrow strong IMFs, $\uparrow T_g$, $\uparrow T_m$
- AMORPHOUS**: \rightarrow flexible, \rightarrow transparent, weaker IMFs, $\downarrow T_g$, $\downarrow T_m$
- CHAIN LEN**: \rightarrow strong, $\uparrow T_m$, $\uparrow T_g$
- CROSSLINK**: \rightarrow strong, \rightarrow brittle, \rightarrow stiff, $\uparrow T_g$, $\uparrow T_m$

PV = nRT

Elementary Reaction: A \rightarrow products; molecularity: unimolecular, bimolecular, termolecular; rate law: rate = $k[A]$, $k[A]^2$, $k[A][B]$, $k[A][B][C]$; reaction order: first, second, third

Reaction Order: 0 rate stays the same; 1 rate \propto concentration of A; 2 rate \propto concentration of A squared

Integrated Rate Law: $[A] = [A]_0 e^{-kt}$

Units of k: Mol/s

[Reactants]/[Products] vs. time: concentration vs. time

Linearized Form: $\ln[\text{concent.}]$ vs. time

HENRY'S LAW: $C = kP$ partial pressure constant molarity (g/L)

PH SCALE: $\text{pH} = -\log_{10}[H^+]$; $\text{pH} + \text{pOH} = 14$; $\text{pK}_a = -\log(K_a) \rightarrow K_a = 10^{-\text{pK}_a}$

ACIDS: release H^+ ions when dissolved; ex: HCl, H_2SO_4 , HBr, HNO_3 , $HClO_4$

BASE: accepts H^+ ions/releases OH^- ions when dissolved (neutralizes); ex: $Ca(OH)_2$, $NaOH$

#water can act as base OR acid

TYPES: ELECTROCHEM. CELLS

- GALVANIC**: spontaneous redox
- REDOX**: oxidation: lose e^- (anode) \rightarrow half rxn; reduction: gain e^- (cathode) \rightarrow (combine into cell)
- Ecell = E°cell - E°anode - E°cathode**
- $W = IV = nFE_{\text{cell}}$ (6400 C/mol); Faraday's const. # mols of e-
- $\Delta G = -nFE_{\text{cell}}$
- $E_{\text{cell}} = \frac{RT}{nF} \ln(Q) \leftarrow$ true for equilibrium
- $E_{\text{cell}} = E^\circ - \frac{RT}{nF} \ln(Q) \leftarrow$ true for non-equilibrium
- $E_{\text{cell}} = E^\circ - \frac{RT}{nF} \ln(Q) \leftarrow$ true for non-equilibrium
- $E_{\text{cell}} = E^\circ - \frac{0.0591}{n} \ln(Q) \leftarrow$ @ STP

GENERALIZED EQ: $E_{\text{cell}} = E^\circ - \frac{0.0591}{n} \ln(Q) \leftarrow$ @ STP

ELECTROCHEM: calculate E for non-standard conditions

$2Ce^{4+}(aq) + 2Cl^- (aq) \rightarrow 2Ce^{3+}(aq) + Cl_2(g)$; $E_{\text{cell}} = 0.25V$

$[Ce^{4+}] = 0.013 M$; $[Ce^{3+}] = 0.6 M$; $[Cl^-] = 0.003 M$

$P_{Cl_2} = 1 \text{ atm}$; $T = 25^\circ C$

FIND n: $2Ce^{4+} + 2e^- \rightarrow 2Ce^{3+}$ (reduction); $n = 2$ (# e^- in rxn)

$2Cl^- \rightarrow Cl_2 + 2e^-$ (oxidation)

FIND Q: $Q = \frac{\text{products}}{\text{reactants}} = \frac{[Ce^{3+}]P_{Cl_2}}{[Ce^{4+}][Cl^-]^2} \leftarrow$ Partial P

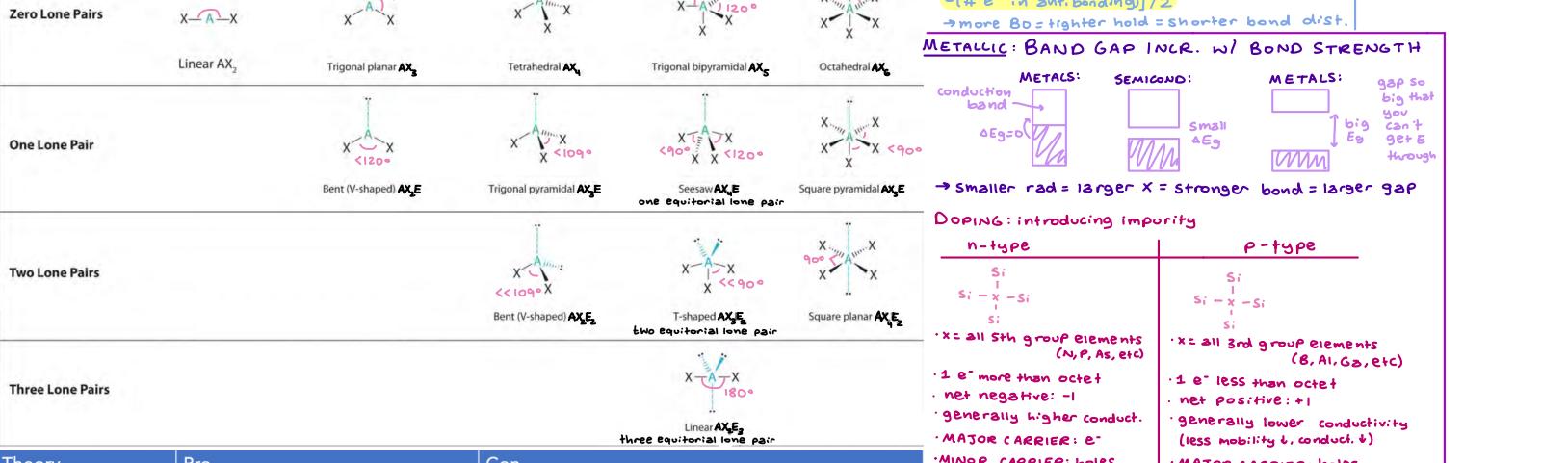
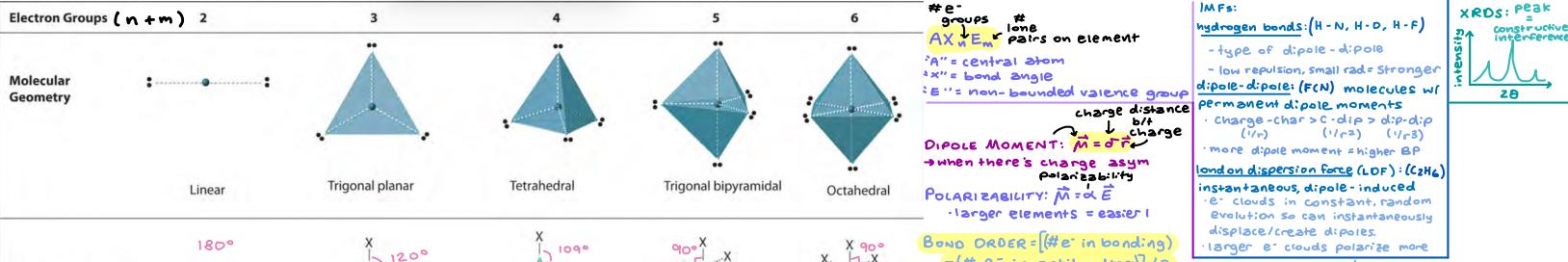
FIND E: $E_{\text{cell}} = E^\circ - \frac{RT}{nF} \ln(Q) = 0.25V - \frac{0.0591}{2} \ln(2.36 \times 10^8) = 0.02V$ @ equilibrium

COMMON ION EFFECT: adding a common ion decreases solubility; shifts left, causing precipitation

ISOTACTIC: $\begin{array}{|c|c|} \hline & F \\ \hline & F \\ \hline \end{array}$

ATACTIC: $\begin{array}{|c|c|} \hline & F \\ \hline & F \\ \hline \end{array}$

SYNDIOTACTIC: $\begin{array}{|c|c|} \hline F & F \\ \hline \end{array}$



Theory	Pro	Con
Lewis structures	<ul style="list-style-type: none"> Explains bonding patterns Simple Only needs simple arithmetic 	<ul style="list-style-type: none"> Weird exceptions to octet rule (hypervalence SF₆, incomplete octet BF₃) Does not explain geometry Does not explain odd-electron molecules (NO) Ignores atomic orbitals
VSEPR	<ul style="list-style-type: none"> Explains geometry Simple rules 	<ul style="list-style-type: none"> Repulsion between lone pairs is a bit hand-wavy Why are double bonds like singles? Ignores atomic orbitals
Valence bond /Hybridization	<ul style="list-style-type: none"> Explains geometry Uses atomic orbitals 	<ul style="list-style-type: none"> Why these combinations and not others? Is there evidence for electron "promotions"
Molecular Orbitals	<ul style="list-style-type: none"> Explains geometry Uses atomic orbitals Explains "exceptions" BeH₂, He⁺, NO 	<ul style="list-style-type: none"> Complex math – needs computers for larger molecules

