

Energy of a Photon

$E_{\text{Photon}} = h\nu = \frac{hc}{\lambda}$

Normal Charge

$\text{Na}(g) \rightarrow \text{Na}^+ + e^- \quad \Delta H = +497 \text{ kJ/mol}$

= # of Valence electrons

- lone pair + Non bonding

S_p^2 2 linear

S_p^2 3 trigonal planar

S_p^2 4 tetrahedral

S_p^3 5 trigonal bipyramidal

S_p^3 6 octahedral

S_p^3 7 linear

S_p^3 8 bent

S_p^3 9 linear

S_p^3 10 linear

S_p^3 11 linear

S_p^3 12 linear

S_p^3 13 linear

S_p^3 14 linear

S_p^3 15 linear

S_p^3 16 linear

S_p^3 17 linear

S_p^3 18 linear

S_p^3 19 linear

S_p^3 20 linear

S_p^3 21 linear

S_p^3 22 linear

S_p^3 23 linear

S_p^3 24 linear

S_p^3 25 linear

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S_p^3 221 linear

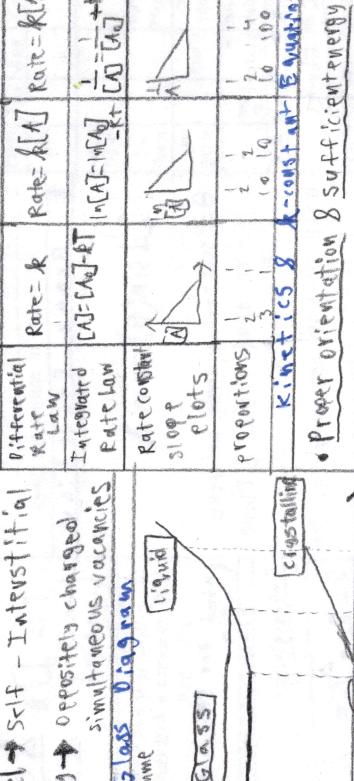
S_p^3 222 linear

S_p^3 223 linear

S_p^3 224 linear

S_p^3 225 linear

REACTIONS IN IONIC SOLIDS



EQUILIBRIUM CONSTANT

$$\Delta H_{\text{soln}} = -\frac{1}{2} w K_A \chi_B$$

$\chi_B < 0$ if salt is acid

$$\Delta H_{\text{soln}} = w K_A \chi_B$$

- Salt ions that generate greater amounts of charging both base/acid
- COMMON ION EFFECT

- Solubility in a solution decreases when the solution contains free flowing ions of some type
- ENTROPY

BUFFERS

- Solutions that generate greater amounts of charging both base/acid
- COMMON ION EFFECT

STRONG ACIDS / BASES

- Solubility in a solution decreases when the solution contains free flowing ions of some type
- ENTROPY

ACID-BASE EQUILIBRIUM

- Solids in Keq expression
- Reaction Quotient

- $K_{\text{sp}} = [A]^a [B]^b$
- Acids are proton donors
- Bases are proton acceptors

- $K_a = \frac{[H_3O^+][A^-]}{[HA]}$
- $K_b = \frac{[OH^-][HA]}{[A^-]}$
- Phase Diagrams

- Paras magnet ic - Responds to magnetic field due to unpaired electrons in MO diagram
- Dia magnetic - Doesn't respond to e' fields

- Metals
- low bp

- Saltwater
- Salt + saltwater
- ice + salt

- Lev Rule: Take relative proportions to liquids
- 8 solidus line

- Other Rule - Go down from their top and top of liquid & solid state

- RATE LIMITING STEP
- RATE LIMITING STEP IS SLOWEST STEP

VITRIFICATIONS

$$A_n B_m \rightleftharpoons a A_{(aq)} + b B_{(aq)}$$

$\chi_B < 0$ if salt is acid

$$A_n B_m \rightleftharpoons a A_{(aq)} + b B_{(aq)}$$

- Solubility in a solution decreases when the solution contains free flowing ions of some type
- ENTROPY

- Solubility in a solution decreases when the solution contains free flowing ions of some type
- ENTROPY

KINETICS & CONSTANT EQUATION

- Proper orientation & sufficient energy needed for a reaction
- T_g Fast melting

$$k = A e^{-E_a/RT}$$

- R=Total gas constant
- E_a =Activation energy
- A=frequency of reaction

Thermodynamics

- Energy = heat + work
- $\Delta H = \Delta E + P\Delta V$

Gibbs Free Energy

- Entropy = # of microsystems that exist

$$\Delta G = -RT \ln(K_{\text{eq}})$$

Le Chatelier's Principle

- If $Q > K_{\text{eq}}$ \Rightarrow Reaction proceeds backwards
- If $Q < K_{\text{eq}}$ \Rightarrow Reaction proceeds forward

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

- A system under stress will act in a way to alleviate that stress

NON-SPOONTANEOUS

- Higher pressure favors side with more gas moles
- Lower pressure favors side with less

ACID-BASE TRENDS

- The stronger the +X bond, the weaker the acid & higher the pKa
- Also addition of more EN atoms (ex. Oxygen) draws electrons away

- Henderson-Hasselbach Given: $HAT + H_2O \rightleftharpoons H_3O^+ + A^-$
- $pH = pK_A + \log \frac{[A^-]}{[H_3O^+]}$

- Cohesive Energy/E nthalpy Crystals
- No net change in product
- Reaction is proceeding in forward & opposite direction
- Forward & same rate at the same rate

- RATE LIMITING STEP
- RATE LIMITING STEP IS SLOWEST STEP

Lecture 1

$$E_{\text{photon}} = h\nu = \frac{hc}{\lambda}$$

Elementary charge (e) = -1.602×10^{-19} coulombs

$$E_{\text{photon}} = E_{\text{binding}} + KE$$

$$1 \text{ Angstrom} = 1 \times 10^{-10} \text{ m}$$

$$1 \text{ electro Volt} = 1.602 \times 10^{-19} \text{ Joules}$$

1 mole = 6.023×10^{23} atoms, particles, electrons, photons, etc.

$$E_{\text{binding}} = -\frac{Z^2}{n^2} k$$

$\hookrightarrow Z = \# \text{ of Protons}$

$\hookrightarrow n = \text{principal quantum \#}$

$$\hookrightarrow k = 2.18 \times 10^{-18} \text{ Joules}$$

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

* notice it now

\hookrightarrow when electron is fully ejected we set $n_f = \infty$

Lecture 2

$$E_{\text{photon}} = h\nu = \frac{hc}{\lambda} = hc\bar{\nu}$$

$$\bar{\nu} = \text{wave number} = \frac{1}{\lambda}$$

$$\text{Energy} = (\bar{\nu})(\text{Voltage}) = \frac{1}{2}mv^2$$

$\hookrightarrow q = \text{elementary charge}$

$\hookrightarrow m = \text{mass of the electron}$ ($9.11 \times 10^{-31} \text{ kg}$)

$$\text{Radius of Energy level} = r_0 n^2$$

$$\hookrightarrow r_0 = 0.529 \text{ Angstroms}$$

$$\bar{\nu} = -R \frac{Z^2}{n^2} \quad R = \text{Rydberg constant}$$

$$E_n = -\frac{kZ^2}{n^2} \quad k = 2.18 \times 10^{-18} \text{ J}$$

$$K = Rhc$$

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

absorption: $\Delta E > 0$

emission: $\Delta E < 0$

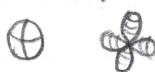
Quantum Numbers:

(n, l, m, s)

n - Principal Quantum #

l - Orbital Quantum Number

$0 \quad 1 \quad 2 \quad 3$
s-orbital p-orbital d-orbital f-orbital



m - Magnetic Quantum Number ($-l \leq m \leq l$)

$s = 0$
 $p = -1, 0, 1$
 $d = -2, -1, 0, 1, 2$
 $f = -3, -2, -1, 0, 1, 2, 3$

s - Spin Quantum # ($\pm \frac{1}{2}$ or $-\frac{1}{2}$)

- orbitals fill with $\pm \frac{1}{2}$ first

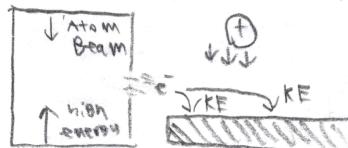
① Pauli exclusion principle (no 2 electrons can have the same quantum #)

② Aufbau Rule (lowest energy levels fill first)

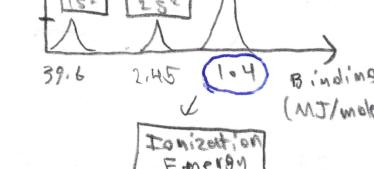
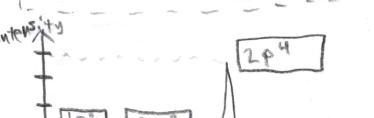
③ Hund's Rule: ($\uparrow \downarrow$ fills singly) First 1 1 1

Lecture 4

Photo-electron Spectroscopy



$$E_{\text{hv}} = E_{\text{KE}} + E_{\text{binding}}$$



Note: Relative height of Seikes indicates # of electrons

As you increase in atomic #, ionization energy will increase for one of 3 reasons

1. change in principal energy level
2. going to a different orbital
3. one e^- is added to a half full orbital (notable in p-orbital)

to find Bond Length

Set $\frac{\partial E}{\partial r} = 0$, then plug in that r value to get bond energy

⑥ Energy of lattice formation

$$\Delta E_{\text{crystal}}$$

$$= -\frac{e^2 Q_1 Q_2 M N_A}{4\pi \epsilon_0 r} \left(1 - \frac{1}{r} \right)$$

$M = \text{Mendeleev Constant}$

$N_A = \text{Avogadro's \#}$

$n = \text{Repulsive exponent}$

Properties of Ionic Solids

• Crystalline • Brittle

• High melting point

• Not conductive

• Translucent

Covalent Bonding

Electronegativity

• The ability of an atom to draw electrons towards itself in a bond

→ this concept is only applied in the context of bonds

$\Delta X = \text{difference in electronegativity}$

if ΔX is ($0 - 0.5$) bond is non-polar covalent

if bond is between $0.5 - 0.7$ bond is Polar Covalent

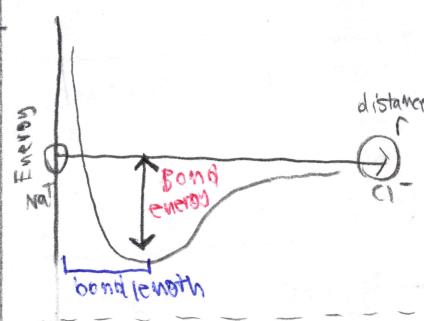
if ΔX is between ($1.7 - 4.0$) bond is Ionic

$$\Delta X = X_A - X_B$$

$$= \sqrt{\frac{E_{d(A-B)} - (E_{AA} - E_{BB})}{2}}$$

$E_{d(A-B)}$ = dissociation of A-B bond

E_{AA} = " AA Bond



$$E_{\text{Coulombic}} = \text{Attract} + \text{Repulse}$$

$$= -\frac{e^2 Q_1 Q_2}{4\pi \epsilon_0 r} + \frac{b}{r^n}$$

$\hookrightarrow e = \text{electron charge}$

$\hookrightarrow Q_1, Q_2 = \text{magnitude of charge of } Q_1 \text{ & } Q_2$

$\hookrightarrow \epsilon_0 = \text{permittivity of free space}$

$\hookrightarrow n = \text{repulsive exponent}$

$\hookrightarrow b = \text{a factor}$

LEWIS DOT STRUCTURE

• single bond weaker & longer

than

double bond weaker & longer than

triple bond

RULES FOR LEWIS DOT STRUCTURES

1. Determine # of valence e's for each atom

2. Determine # of e's needed to fill each octet

3. Put least electro negative atom at the center

4. Add in other atoms & other e's

CHECKS

1. Carbon **ALWAYS** at the center of the molecule

2. Carbon always has **4** bonds

3. Formula helps describe shape of Molecules

• It's possible for a molecule to have a Net charge but must be noted

ex. $\left[\begin{array}{c} + \\ || \\ \text{H}-\text{N}-\text{H} \\ || \\ \text{H} \end{array} \right]^+$

FORMAL CHARGE

= # of Valence e's

$$= (\text{e's in lone pairs}) - \frac{(\text{bonded e's})}{2}$$

* The most stable arrangements of molecules will have

A. No Formal Charge

B. Appropriate charge on atoms based off electronegativity

↳ + charge on least X

↳ - charge on most X

Resonance structures

Under FILLED Octets

- Boron will be satisfied with 6 valence e's

Over FILLED Octets

• Sulfur can make 6 bonds

• Phosphorus can make 5 bonds

Molecular Orbitals

• There must be as many Atomic Orbitals as there are Molecular Orbitals

KNOW sp , sp_2 , sp_3

Hybridizations

ex. C_2H_2 , C_2H_4 , C_2H_6

- Common in carbon

Bond ORDER =

$$\frac{1}{2} (\# \text{ of e's in bonding orbitals} - \# \text{ of e's in anti-bonding orbitals})$$

Diagram for diatomic molecules ($\text{B}, \text{C}, \text{N}$)

$\text{N}=\text{N}$

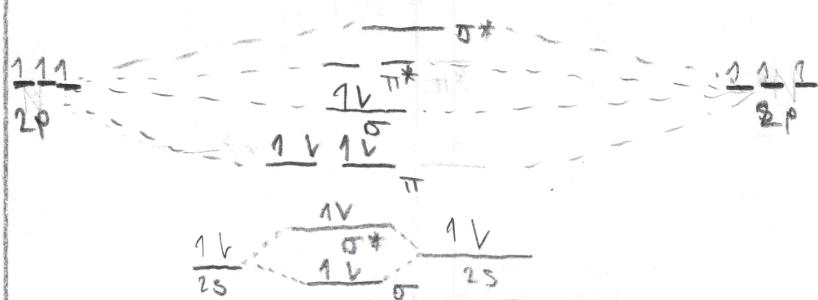


Diagram for Diatomic Molecules (O, F , below these?)

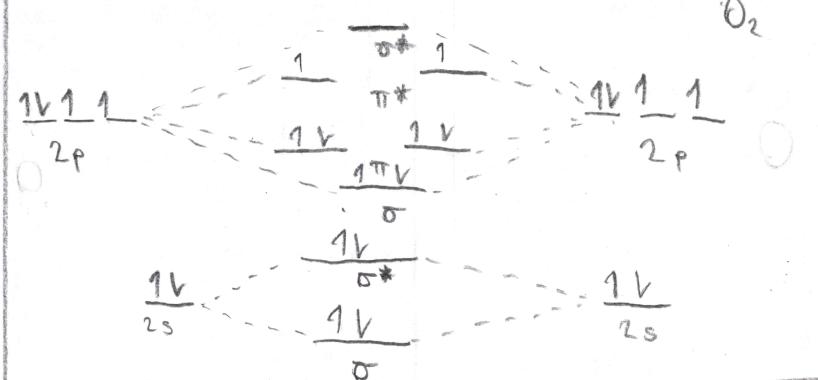
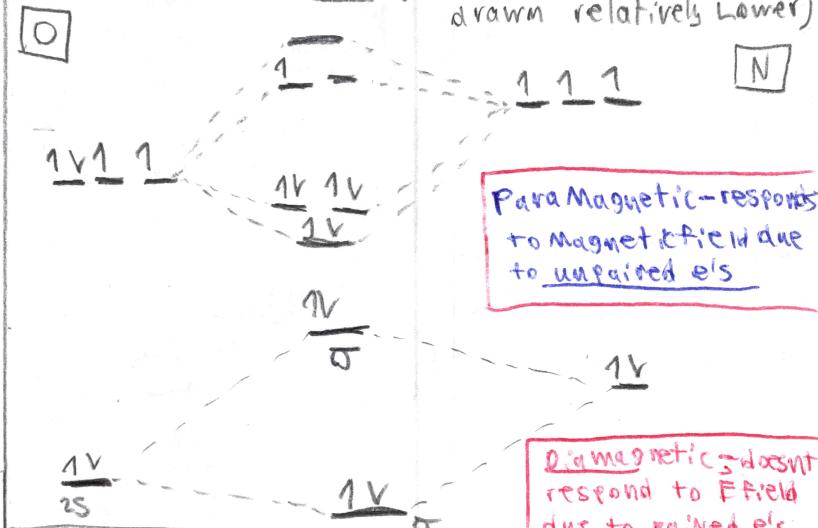


Diagram for covalent molecule of 2 different electronegativities (More electronegative drawn relatively lower)



Para Magnetic - responds to magnetic field due to unpaired e's

Diamagnetic - doesn't respond to E field due to paired e's

* When N, BC is paired with other in diatomic, its weird case doesn't apply

Collision Theory

- Concentration
↑ Concentration, ↑ Rxn Rate
 - Temperature
↑ temp, Greater Rxn Rate
 - Surface Area
↑ Greater Surface Area, ↑ Rxn Rate
 - Solvent Effects
 - Catalyst Effects
↑ Catalysts, ↑ Rxn Rate
- The Rate Law

$$\text{Rate} = k[A]^m[B]^n$$

Half Lives

$$0^{\text{th}} \text{ order: } t_{1/2} = \frac{[A_0]}{2k}$$

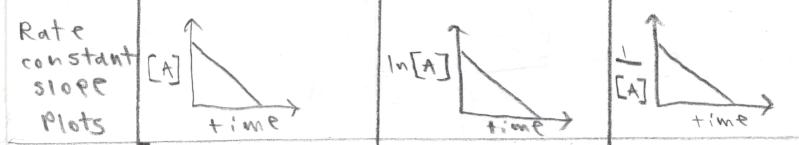
$$1^{\text{st}} \text{ order: } t_{1/2} = \frac{0.693}{k}$$

$$2^{\text{nd}} \text{ order: } t_{1/2} = \frac{1}{k[A_0]}$$

[A]	[B]	[C]	Rate
			"Se how rates differ"

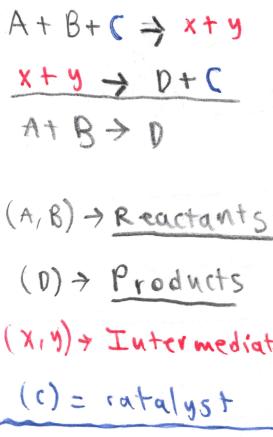
"See how rates differ"

	0 th Order	1 st Order	2 nd Order
Differential Rate Law	Rate = k	Rate = $k[A]$	Rate = $k[A]^2$
Integrated Rate law	$[A] = [A_0] - kt$	$\ln[A] = \ln[A_0] - kt$	$\frac{1}{[A]} = \frac{1}{[A_0]} + kt$



proportions	[A]	Rate	[A]	Rate	[A]	Rate
1	1	1	2	2	2	4
2	1	1	10	10	10	100
10	1	1				

Multi-Step Reaction



*THE RATE LIMITING STEP is the SLOWEST ONE

Kinetics

- Proper Orientation & Sufficient collision energy needed for Rxn to occur

$$k = A e^{-(E_a/RT)}$$

T = Temperature (K)

R = Ideal gas constant

E_a = Activation Energy

A = Frequency of Rxn

Thermo Dynamics

$$\text{Energy} = \text{heat} + \text{work}$$

Enthalpy:

$$\begin{aligned} H &= E + PV \\ \Delta H &= \Delta E + P\Delta V \end{aligned}$$

Entropy: # of microsystems or ways to arrange a system

Laws of Thermo Dynamics:

1st Law: Energy is constant in a closed system

2nd Law: Entropy (S) can only increase

3rd Law: @ absolute zero, S = 0

Gibbs Free Energy

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

if $\Delta G < 0$, Rxn is spontaneous

if $\Delta G > 0$, Rxn is non-spontaneous

$\Delta H < 0$	$\Delta H > 0$
Spontaneous everywhere	only for High temps
Only for Low temps	spontaneous nowhere

when

$$\Delta G = 0$$

Reaction is at Dynamic Equilibrium

- Both Reactions are occurring at equal & opposite Rates
- No net change in Product Produced

Equilibrium Constant

K_{eq} - Equilibrium constant

Given: $aA + bB \rightleftharpoons cC + dD$

$$\text{Fwd Rate} = k_f [A]^a [B]^b$$

$$\text{Reverse Rate} = k_r [C]^c [D]^d$$

$$K_{eq} = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

if $K_{eq} < 1$, Reaction proceeds forward

if $K_{eq} > 1$, Reaction proceeds Backwards

NOTE: Don't put

Liquids or Solids

in K_{eq} expression

Reaction Quotient

$$Q = \frac{[A_o]^a [B_o]^b}{[C_o]^c [D_o]^d}$$

if $Q_{eq} > K_{eq}$

↳ Reaction should Proceed Backwards

if $Q_{eq} < K_{eq}$

↳ Reaction should Proceed Forwards

R_i = Ideal Gas

$$\Delta G = -RT \ln(K_{eq})$$

$K_{eq} = ??$

Common Ion Effect

Le Chatelier's Principle

- A system under stress will act in a way to alleviate that stress

ex.

1) Pressure

- Higher Pressure favors side with less Moles of gas
- Lower Pressure favors side with more Moles of gas

2) Temperature

- Adding heat favors Endothermic Rxn's
- Taking heat favors Exothermic Rxn's

Cohesive Energy/Enthalpy

Crystals:

$$\Delta H_A = \frac{1}{2} Z w_a n_a$$

Z = Co-ordinate #

w_a = Bond Energy

n_a = # of Atoms

Solution:

$$\Delta H_{\text{soln}} = \frac{1}{2} \Delta W \chi_A \chi_B$$

Z = Co-ordinate #

$$\left\{ \begin{array}{l} \Delta W = 2w_{AB} - w_{BB} - w_{AA} \\ \Delta W > 0; \text{ Exothermic} \\ \Delta W < 0; \text{ Endothermic} \end{array} \right.$$

$$\chi_A = \left(\frac{n_a}{n_a + n_b} \right); \chi_B = \left(\frac{n_b}{n_a + n_b} \right)$$

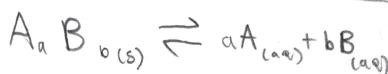
Entropy

$$S = K_b \ln(\phi)$$

K_b = Boltzmann Constant

$$\phi = \frac{(n_a + n_b)!}{n_a! n_b!}$$

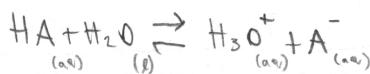
Acid-Base Equilibrium



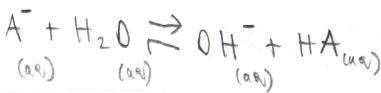
$$K_{sp} = [A]^a [B]^b$$

- Acids are Proton donors

- Bases are Proton Acceptors



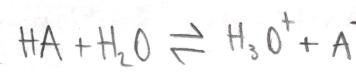
$$K_a = \frac{[H_3O^+] [A^-]}{[HA]}$$



$$K_b = \frac{[OH^-] [HA]}{[A^-]}$$

$K_a > 1$ Strong Acid

$K_a < 1$ Weak Acid



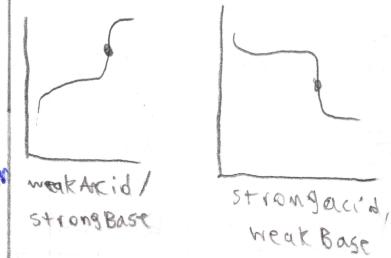
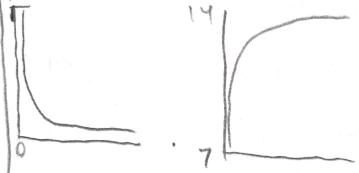
$$K_a = \frac{[H_3O^+] [A^-]}{[HA]}$$

$$pK_a = -\log(K_a)$$

Acid/Base Trends

* The stronger the

H-X Bond, The weaker the acid & higher the K_a



Buffers

* Substances that generate greater amounts of conjugate base/acid

HOX	EN of X	pKa
HOCl	3.0	7.4
HOBr	2.8	8.5
HOI	2.5	10.5

* The EN the attached atoms the stronger the acid

Properties of water

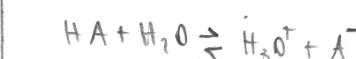
$$K_w = [H_3O^+] [OH^-]$$

$$K_w = 1 * 10^{-14}$$

$$pH = 14 - pOH$$

Henderson-Hasselbach Eqn

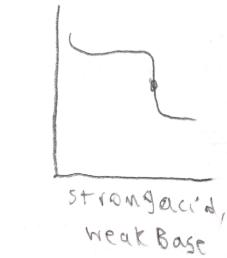
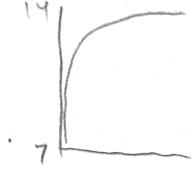
Given:



$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$$* [pH = pK_a] \Rightarrow [A^-] = [HA]$$

* Titrations



Common Ion Effect

* Solubility in a solution decreases when the solution contains free flowing ions of the same type

Strong Acids/Bases

- HCl
- HBr
- HI
- H_2SO_4
- HNO_3
- $HClO_4$
- Group 1/2 metals
- + OH^-

Relevant Equations

Intrinsic Doping

$$N_i = N_s e^{-(-E_g/2k_b T)}$$

N_i = # of carrier electrons
 N_s = # of states per unit volume (# of e's/cm^3)

N_s = # of states that can be occupied

E_g = Band Gap energy (eV or Joules)

K_B = Boltzmann Constant (be careful if J/K or eV/K)

T = temperature (Kelvin)

Extrinsic Doping

$$n_i = (\text{# of dopants in Moles}) * \Delta e^-$$

n_i = # of charge carrying electrons ONLY

$\Delta e'$ = change in the number of electrons the material is made with and the dopant atom

Doping Level

$$\frac{\text{# of moles of carriers}}{\text{Volume of material doped}}$$

$$= n_i \cdot \frac{n_i(\text{intrinsic})}{\text{Volume of material doped}}$$

Bragg Condition

$$2d \sin(\theta) = n\lambda$$

θ = scattering angle between incident light & plane of crystal

d = distance between lattice planes

n = an integer (1 unless otherwise said)

λ = wavelength of the X-ray

Formula for d (in Bragg's Law)

$$d = a \sqrt{\frac{1}{h^2 + k^2 + l^2}}$$

a = length of cubic unit cell

$(h k l)$ = co-ordinates of a miller plane of the system

Fick's 1st Law of diffusivity

$$J = D * \frac{\Delta C}{\Delta X}$$

(Flux or LOSS RATE)

$$D = \text{diffusivity} \left(\frac{\text{cm}^2}{\text{s}} \right)$$

Flux (J) is ($\text{Moles/cm}^2 \cdot \text{s}$)

$$\frac{\Delta C}{\Delta X} \left(\frac{\text{mol/cm}^3}{\text{cm}} \right)$$

↳ How much concentration changes a distance away you get

(ONLY USED FOR STEADY STATE SYSTEMS)

Diffusivity (Interstitial)

$$D_i = \prod d^2$$

or

$$VZ e^{-(-\Delta E_m / k_b T)} d^2$$

or

$$D_0 e^{-(-\Delta E_m / k_b T)}$$

Γ = successful jump frequency
 d = jump length (distance jumped)

V = lattice vibrational frequency

Z = Geometric constant

ΔE_m = Energy of Movement

K_b = Boltzmann constant

T = temperature (Kelvin)

Diffusivity (substitutional)

$$D_s = D_0 e^{-(-(AE_m + E_s)/k_b T)}$$

of Vacancy defects

$$n_v = A N e^{(-\Delta H_v / k_b T)}$$

* You can get Fractional Vacancy by having n_v/N

A = Pre-factor

N = # of lattice sites

ΔH_v = energy required to create vacancy

k_b = Boltzmann constant

T = temperature (Kelvin)

Fick's Second Law

$$\frac{C_s - C(x,t)}{C_s - C_0} = \frac{\text{erf}}{(2\sqrt{Dt})} \left(\frac{x}{\sqrt{Dt}} \right)$$

* used for non-steady state solns

* doesn't have to be specifically concentration to apply

C_s = concentration of substance being diffused at material's surface

$C(x,t)$ = concentration of substance at certain time & depth into material

C_0 = concentration of substance initially present at time zero in solid

x = distance

t = time (secs)

D = diffusivity

erf = erf Function

Energy of Wavelength

* use for conductor band problems

$$E = \frac{hc}{\lambda} \text{ (Joules)}$$

Crystallography info

	SC	BCC	FCC
Lattice Parameter	a	a	a
# of lattice points in cell	1	2	4
# of atoms in unit cell	1	2	4
# of nearest neighbors	6	8	12
Distance to nearest neighbor	a	$\sqrt{3}a/2$	$\sqrt{2}a/2$

Point	(1,1,1)	parentheses, commas
vector	[1 1 1]	Brackets, NO commas
vector Family	<1 1 1>	Pointy , NO
Plane	(1 1 1)	Parathesis, NO
Plane Family	{1 1 1}	curly , NO

Simple	All planes work
BCC	$h+k+l$ must be Even
FCC	h,k,l all odd or all even

given Miller Indices (hkl)
(hkl)

Constructive Interference Spikes

Simple cubic	$X, 1.4X, 1.7X, 2.0X$
FCC	$X, 1.5X, 1.63X, 1.91X$
BCC	$X, 1.41X, 1.7X, 2X$

For

$$SC: a = 2r_m$$

$$BCC: a = 4r_m/\sqrt{3}$$

$$FCC: a = \sqrt{2} r_m$$

r_m = Metallic Radius on table

VSEPR Geometries						
hybridization	steric #	Basic Geometry (0 lone pairs)	1 lone pair	2 lone Pairs	3 lone Pairs	4 lone Pairs
sp	2	linear				180°
sp^2	3	trigonal planar	bent or angular			$120^\circ \times 120^\circ$
sp^3	4	tetrahedral	trigonal pyramidal	bent or angular		$109^\circ \times 109^\circ$
$sp^3 d$	5	trigonal bipyramidal	seesaw shape	linear		$120^\circ, 90^\circ$ $120^\circ, 59^\circ$
$sp^3 d^2$	6	octahedral	square pyramid	seesaw planar	T-Shape	linear

Defects:

Interstitial (Self or Foreign)

Substitutional

(atoms of similar size replace one)

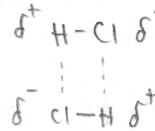
Vacancy

(atom is removed)

InterMolecular Bonds

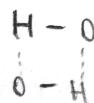
1) Dipole-Dipole Inter Molecular Force

- Force of attraction between 2 dipoles



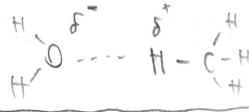
2) Hydrogen Bonding

* when H is bonded to F, N, O

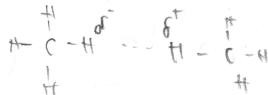


3) Dipole induced Dipole

(one molecule is polar, one isn't)



4) Instantaneous Dipole



* increases with greater surface area or molecular mass

Doping of Semiconductors

* E_F on front

- Intrinsic doping increases with greater temp, lower band gap

1.2 Types of Extrinsic Doping

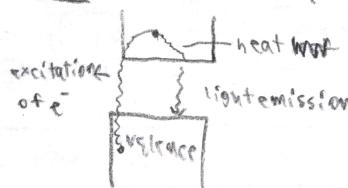
n-type - Doping lattice with atoms with more valence e's

f-type - Doping lattice with atoms with less e's

Insulators - Huge Band Gap

Semiconductors - Small band gap

Metals - NO Band Gap



"Sea of e's"

- The presence of free flowing e's in metals explains:

- 1) Dielectric conductivity
- 2) Thermal conductivity
- 3) Material Properties

How to Form Point Vectors

- 1) Normalize it (No fractions)
- 2) Replace negative with bar
- 3) Use notation $[a \bar{b} c]$

A vector family $\langle a \bar{b} c \rangle$ all has same magnitude

How to Form Miller Planes

Find points $x \bar{y} z$ where planes cross that axis

$$h = \frac{1}{x}, k = \frac{1}{\bar{y}}, l = \frac{1}{z}$$

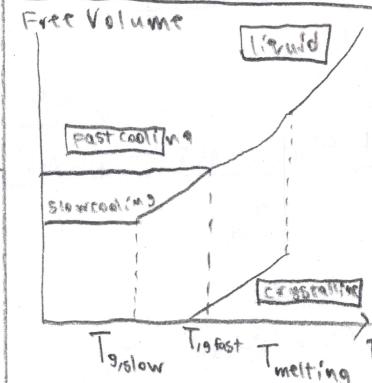
$$\text{Plane} \Rightarrow (h \bar{k} l)$$

Frenkel & Schottky Defects

Frenkel \rightarrow self-interstitial

Schottky - oppositely charged simultaneous Vacancies

Glass Diagram



* The more modifiers in a glass



the less bonding in glass lattice network



lower viscosity



lower T_g of glass

Formation

Fundamental Physical Constants — Frequently used constants

Quantity	Symbol	Value	Unit	Relative std. uncert. u_r
speed of light in vacuum	c, c_0	299 792 458	m s^{-1}	(exact)
magnetic constant	μ_0	$4\pi \times 10^{-7}$ $= 12.566 370 614\dots \times 10^{-7}$	N A^{-2}	
electric constant $1/\mu_0 c^2$	ϵ_0	$8.854 187 817\dots \times 10^{-12}$	F m^{-1}	(exact)
Newtonian constant of gravitation	G	$6.674 28(67) \times 10^{-11}$	$\text{m}^3 \text{kg}^{-1} \text{s}^{-2}$	1.0×10^{-4}
Planck constant	h	$6.626 068 96(33) \times 10^{-34}$	J s	5.0×10^{-8}
$h/2\pi$	\hbar	$1.054 571 628(53) \times 10^{-34}$	J s	5.0×10^{-8}
elementary charge	e	$1.602 176 487(40) \times 10^{-19}$	C	2.5×10^{-8}
magnetic flux quantum $h/2e$	Φ_0	$2.067 833 667(52) \times 10^{-15}$	Wb	2.5×10^{-8}
conductance quantum $2e^2/h$	G_0	$7.748 091 7004(53) \times 10^{-5}$	S	6.8×10^{-10}
electron mass	m_e	$9.109 382 15(45) \times 10^{-31}$	kg	5.0×10^{-8}
proton mass	m_p	$1.672 621 637(83) \times 10^{-27}$	kg	5.0×10^{-8}
proton-electron mass ratio	m_p/m_e	1836.152 672 47(80)		4.3×10^{-10}
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	$7.297 352 5376(50) \times 10^{-3}$		6.8×10^{-10}
inverse fine-structure constant	α^{-1}	137.035 999 679(94)		6.8×10^{-10}
Rydberg constant $\alpha^2 m_e c / 2h$	R_∞	10 973 731.568 527(73)	m^{-1}	6.6×10^{-12}
Avogadro constant	N_A, L	$6.022 141 79(30) \times 10^{23}$	mol^{-1}	5.0×10^{-8}
Faraday constant $N_A e$	F	96 485.3399(24)	C mol^{-1}	2.5×10^{-8}
molar gas constant	R	8.314 472(15)	$\text{J mol}^{-1} \text{K}^{-1}$	1.7×10^{-6}
Boltzmann constant R/N_A	k	$1.380 6504(24) \times 10^{-23}$	J K^{-1}	1.7×10^{-6}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3c^2$	σ	$5.670 400(40) \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	7.0×10^{-6}
Non-SI units accepted for use with the SI				
electron volt: $(e/C) J$	eV	$1.602 176 487(40) \times 10^{-19}$	J	2.5×10^{-8}
(unified) atomic mass unit	u	$1.660 538 782(83) \times 10^{-27}$	kg	5.0×10^{-8}
$1 \text{ u} = m_u = \frac{1}{12} m(^{12}\text{C})$ $= 10^{-3} \text{ kg mol}^{-1}/N_A$				

TABLE 5.1 Tabulation of Error Function Values

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

