

# AP Chemistry Notes

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Special Thanks to Stephen Bosley (Boser)

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## 1 FOREWORD/DISCLAIMER

First and foremost, I am going to say what everyone has on their minds. **No** you really should not just forget about taking notes anymore in AP Chemistry class because of this packet. This packet is meant to be a **review** and should be used as such. However that does not mean you can use this packet as your main notes and write notes in the margins to supplement your learning. *Please take into account that this entire thing was written over the course of 4 days. As such it is inevitable that I made mistakes in spelling and/or formulas.*

If you have any questions/comments/fixes to the text you can email me at [theangrybaby@gmail.com](mailto:theangrybaby@gmail.com)  
 Good Luck

## 2 Solubility Rules

### 2.1 Soluble

- Nitrates  $NO_3^{-1}$  - All nitrates are soluble
- Chlorates  $ClO_3^{-1}$  - All chlorates are soluble
- Alkali metal Cations and Ammonium cation compounds  $NH_4^{+1}$  are all soluble
- Chlorides, Bromides, and Iodides are all soluble EXCEPT  $Ag^{+1}$ ,  $Pb^{+2}$ , and  $Hg^{+2}$
- Acetates - All are soluble except  $Ag^{+}$
- Sulfates - All are soluble except  $Ba^{+2}$ ,  $Pb^{+2}$ ,  $Hg^{+2}$ ,  $Ca^{+2}$ ,  $Ag^{+1}$ , and  $Sr^{+2}$

### 2.2 Insoluble

- Carbonates  $CO_3^{-2}$  - all carbonates are insoluble except alkali metals and ammonium compounds
- Chromates  $CrO_4^{-2}$  - all chromates are insoluble except alkali metals, ammonium,  $Ca^{+2}$ , and  $Sr^{+2}$
- Hydroxides  $OH^{-1}$  - all hydroxides are insoluble except alkali metals, ammonium,  $Ba^{+2}$ ,  $Sr^{+2}$ , and  $Ca^{+2}$  although the last two ( $Sr^{+2}$  and  $Ca^{+2}$ ) are only slightly soluble so a precipitate can form.
- Phosphates  $PO_4^{-3}$  all are insoluble except alkali metals and ammonium
- Sulfites  $SO_3^{-2}$  all are insoluble except alkali metals and ammonium
- Sulfides  $S^{-2}$  all are insoluble except Alkali metals, alkali earth metals and ammonium

### 2.3 Naming Rules

- All strong acids and bases are soluble and should be written as the ions when completing net ionic reactions
  - ▷ Sulfuric acid ( $H_2SO_4$ ) should be written as  $H^+ + HSO_4^{-1}$
- The strong acids are:  $HCL$ ,  $HBR$ ,  $HI$ ,  $HNO_3$ ,  $HClO_4$ , and  $H_2SO_4$
- Strong bases are any alkali metal hydroxides ( $LiOH$ ,  $NaOH$ , etc) and  $Ca(OH)_2$ ,  $Sr(OH)_2$ ,  $Ba(OH)_2$
- All acids and bases should be left in their molecular form:
  - ▷ Acetic acid  $\rightarrow HC_2H_3O_2$

## 3 Periodic Table of Elements

Periodic Table of the Elements																		
1 H 1.0079																	2 He 4.0026	
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180	
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948	
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80	
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98	44 Ru 101.07	45 Rh 101.07	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29	
55 Cs 132.91	56 Ba 137.33	57-70 * Lanthanide series	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po 209	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226	89-102 ** Actinide series	103 Lr 260	104 Rf 261	105 Db 262	106 Sg 263	107 Bh 264	108 Hs 265	109 Mt 266	110 Uun 267	111 Uuu 268	112 Uub 269	114 Uuq 269					

\* Lanthanide series

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 144.91	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
89 Ac 227	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259

\*\* Actinide series

## 4 Poly Atomic Naming

- Zinc  $Zn^{+2}$
- Silver  $Ag^{+1}$
- Ammonium  $NH_4^{+1}$
- Hydroxide  $OH^{-1}$
- Cyanide  $CN^{-1}$
- Nitrate  $NO_3^{-1}$
- Acetate  $C_2H_3O_2^{-1}$
- Chlorate  $ClO_3^{-1}$
- Bromate  $BrO_3^{-1}$
- Iodate  $IO_3^{-1}$
- Manganate  $MnO_3^{-1}$
- Sulfate  $SO_4^{-2}$
- Bisulfate (Hydrogen Sulfate)  $HSO_4^{-1}$
- Carbonate  $CO_3^{-2}$
- Bicarbonate (Hydrogen Carbonate)  $HCO_3^{-1}$
- Selenate  $SeO_4^{-2}$
- Biselenate (Hydrogen Selenate)  $HSeO_4^{-1}$
- Oxalate  $C_2O_4^{-2}$
- Phosphate  $PO_4^{-3}$
- Hydrogen Phosphate  $HPO_4^{-2}$
- Dihydrogen Phosphate  $H_2PO_4^{-1}$
- Chromate  $CrO_4^{-2}$

Per _ Ate	Ate	Ite	Hypo _ Ite
Per _ Ic	Ic	Ous	Hypo _ Ous
<b>+1 Oxygen</b>	<b>Most Common Ion</b>	<b>-1 Oxygen</b>	<b>-2 Oxygen</b>

## 5 Common Units, Constants and Charges

### 5.1 Fundamental Constants

- Avogadro's Number ( $N$ )  
▷  $6.02214199 * 10^{23} mol^{-1}$
- Planck's Constant ( $h$ )  
▷  $6.62606876 * 10^{-34} J * s$
- Speed of Light ( $c$ )  
▷  $2.99792458 * 10^8 m/s$

## 5.2 Charge

- $e^-$  charge =  $-1.602 * 10^{-19}$  coulombs
- $p^+$  charge =  $1.602 * 10^{-19}$  coulombs
- Atomic Mass Unit (amu) =  $1.66054 * 10^{-24}$ 
  - ▷  $p^+$  = 1.0073 amu
  - ▷  $n^0$  = 1.0087 amu
  - ▷  $e^-$  =  $5.486 * 10^{-4}$  amu

## 5.3 Radius

Angstroms ( $\overset{\circ}{A}$ ) =  $10^{-10}$  meters

# 6 Atomic Theory

## 6.1 J.J. Thompson

- Discovered  $e^-$  and  $\frac{charge}{mass}$  ratio
  - ▷ Charge to Mass ratio:  $1.76 * 10^8$  Coulombs/Gram (Charge of  $e^-$ /mass)
- **Plum Pudding** Model of atom

## 6.2 Robert Millikan

- Found charge and mass of  $e^-$
- Millikan Oil Drop:
  - ▷ Charge oil drops in a field and adjust field until drops levitate

## 6.3 Ernest Rutherford

- Discovered 3 types of radiation (Decay Particles)
  - ▷ Alpha particles:  $He^{2+}$  size, very damaging, stoppable -  $\alpha$
  - ▷ Beta particles -  $e^-$  size, damaging, hard to stop -  $\beta$
  - ▷ Gamma particles - tiny, not so damaging, unstoppable -  $\gamma$
- Also discovered proton and new **dense nucleus model**
  - ▷ Rutherford worked with  $\alpha$  particles most and discredited Thompsons model of the nucleus

## 6.4 Chadwick

- Discovers neutron by shooting radiation at light elements and it watching it kick out a neutral particle

## 6.5 John Dalton

- **Four Postulates**
  - ▷ Everything made of atoms
  - ▷ Atoms of one element differ from those of a different element
  - ▷ Atoms will combine in whole number ratios
  - ▷ Atoms can not be created or destroyed
- Law of Constant Composition
  - ▷ In a compound, atom ratios are constant

## 7 Naming

### 7.1 Binary

- Smallest atomic number comes first
- Second element ends with -ide

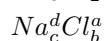
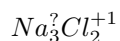
#### 7.1.1 Greek Prefixes

- 1-Mono
- 2-Di
- 3-Tri
- 4-Tetra
- 5-Penta
- 6-Hexa
- 7-Hepta
- 8-Octa
- 9-Nona
- 10-Deca

<b>Example</b>
$Cl_2O$
Dichlorine Monoxide

### 7.2 Ionic

- Finding Charge:



$$\frac{(a*b)}{c} = d$$

### 7.3 Acids

#### 7.3.1 Polyatomic

- Per...ate → Per...ic acid  
▷  $HNO_4$  → pernitric acid
- ---ate → ...ic acid  
▷  $H + NO_3$  →  $HNO_3$  (Nitric Acid)
- ---ite → ...ous acid  
▷  $HNO_2$  → nitrous acid
- Hypo...ite → hypo...ous acid  
▷  $HNO$  → hyponitrous acid

#### 7.3.2 Binary

- Hydro + (stem)ic  
▷  $H + Br$  → Hydrobromic acid  
▷  $H + N$  → Hydronitric acid  
▷ Hydrocarbonic acid →  $HC$   
▷ Carbonic Acid →  $HCO_3$

## 8 Cations

- Which cation forms a white precipitate with  $HCl$ ?
  - ▷  $Ag^+$  (reversed proves  $Cl^-$ ).
- What color is a typical Manganese solution?
  - ▷ Pink/light purple. The precipitate is dark black.
- How would you test for  $Al^{3+}$  and what would it look like?
  - ▷ Add Aluminum, it will make a precipitate red and leave the solution clear.
- Which cation forms a gel like precipitate?
  - ▷ Aluminum.
- Which cation turns deep red with  $KSCN$ ?
  - ▷ Iron.
- How do you confirm the presence of zinc and what color is it?
  - ▷ Add acid, then ammonia, which results in a white/bluish precipitate.
- What cation turns a deep blue with ammonia?
  - ▷ Copper.

## 9 Reaction Type

### 9.1 Combination (Synthesis)

When two or more chemicals react to form one product

Example
$2Mg + O_2 \rightarrow 2MgO$
$2Na + S \rightarrow Na_2S$

- Metal + Non-Metal  $\rightarrow$  Metal Nonmetal (Binary Salt)
- Metal Oxide + Water  $\rightarrow$  Metal Hydroxide
  - ▷  $CaO + H_2O \rightarrow Ca(OH)_2$
  - ▷  $K_2O + H_2O \rightarrow 2KOH$
- Metal Oxide +  $CO_2 \rightarrow$  Metal Carbonate
  - ▷  $Na_2O + CO_2 \rightarrow Na_2CO_3$
- Nonmetallic Oxides + water  $\rightarrow$  Acids (nonmetal oxides retains its oxide number)
  - ▷  $Na_2O + SO_3 \rightarrow Na_2SO_4$

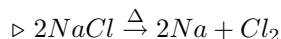
### 9.2 Decomposition

When one chemical decomposes into 2 or more

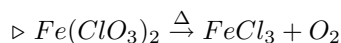
Example
$2Ag_2O \xrightarrow{\Delta} 4Ag + O_2$
$\Delta = \text{Heat}$

- Metal Carbonate  $\xrightarrow{\Delta}$  Metal Oxide +  $CO_2$ 
  - ▷  $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$
- Metal Hydroxide  $\xrightarrow{\Delta}$  Metal Oxide +  $H_2O$ 
  - ▷  $Mg(OH)_2 \xrightarrow{\Delta} MgO + H_2O$

- Metal Nonmetal  $\xrightarrow{\Delta}$  Metal + Nonmetal (diatomic in nature)

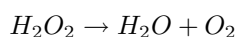
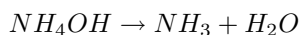
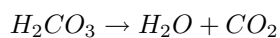
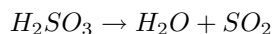


- Metal Chlorates  $\xrightarrow{\Delta}$  Metal Chlorides +  $O_2$

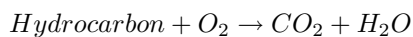


### 9.2.1 Special Binary Salt Splits

These binary salts split into different elements



## 9.3 Combustion



.... $\downarrow$ ....

$C_xH_y \rightarrow$  double x (multiply by 2) then add 2

- $C_1$ : meth
- $C_2$ : eth
- $C_3$ : pro
- $C_4$ : bu
- $C_5$ : pent
- $C_6$ : hex
- $C_7$ : hept
- $C_8$ : oct
- $C_9$ : non
- $C_{10}$ : dec

## 10 Blackbody Radiation

When an object is heated it will emit radiant energy

$$E = h\nu$$

- E = Energy
- h = Max Planck's constant ( $6.626 \times 10^{-34} J \cdot s$ )
- $\nu$  = frequency

**Photoelectric effect:** Metal will give off  $e^-$ s if light shines on it. Light shining on a clean sheet of metals will release  $e^-$ s if  $\nu$  is strong enough.

# 11 Bohr Model

Neils Bohr:

1. Only orbits of certain radii, corresponding to certain definite energies are permitted for the electron in a hydrogen atom.
2. An electron in a permitted orbit has a specific energy and is in an allowed energy state. An electron in an allowed state will not radiate energy and therefore will not spiral into the nucleus.
3. Energy is emitted or absorbed by the  $e^-$  only as the  $e^-$  changes from one allowed energy state to another.
4. **Flawed theory because it only works for hydrogen**

## 11.1 Energy Level Formula

$$E_n = (-2.18 * 10^{-18} J) \left(\frac{1}{n^2}\right)$$

- $E_1: -2.18 * 10^{-18} J$
- $E_2: -5.45 * 10^{-19} J$
- $E_3: -2.42 * 10^{-19} J$
- $E_4: -1.36 * 10^{-19} J$
- $E_5: -8.72 * 10^{-20} J$
- $E_6: -6.056 * 10^{-20} J$
- $E_\infty: 0$

### 11.1.1 Energy Change during Level Jumps

$$\Delta E = E_F - E_0$$

- $n = 3 \rightarrow 2 \mid -3.03 * 10^{-19} J$
- $n = 4 \rightarrow 2 \mid -4.09 * 10^{-19} J$
- $n = 5 \rightarrow 2 \mid -4.578 * 10^{-19} J$
- $n = 6 \rightarrow 2 \mid -4.844 * 10^{-19} J$

# 12 Wavelength

## 12.1 De Broglie Formulas

$$\lambda = \frac{h}{mv}$$

or

$$\lambda = \frac{h}{p}$$

- $\lambda =$  Wavelength
- $h =$  Plancks Constant ( $6.626 * 10^{-34} J * s$ )
- $m =$  Mass of particle in **Kg**
- $v =$  Velocity of particle ( $\frac{meters}{second}$ )
- $p =$  Momentum

Example
$m = 9.11 * 10^{-28} g$
$v = 5.97 * 10^6 m/s$
$\lambda = \frac{6.626 * 10^{-34} J * s}{(9.11 * 10^{-31} Kg)(5.97 * 10^6 m/s)} = 1.22 * 10^{-10} m$

## 13 Quantum Values

### 1. Principle Quantum number - ( $n$ )

$$n = 1 \text{ (lowest)}$$

$$n = \infty \text{ (at 8 or 9)}$$

$$\text{Follows Bohrs } E_n = (-2.18 * 10^{-18} J) \left(\frac{1}{n^2}\right)$$

### 2. Azimuthal Quantum number - ( $l$ )

$$l = n - 1$$

if...

- $l = 0 \rightarrow$  S shape
- $l = 1 \rightarrow$  P shape
- $l = 2 \rightarrow$  D shape
- $l = 3 \rightarrow$  F shape

Example
$n = 3$
$l = 2$
$\downarrow$
3d

### 3. Magnetic Quantum number (orbital) - ( $ml$ )

$-l$  and  $l$  including zero

$$m_0 = 0$$

$$m_1 = -1, 0, 1$$

$$m_2 = -2, -1, 0, 1, 2$$

### 4. Spin magnetic quantum number - ( $ms$ )

$$+\frac{1}{2} \text{ or } -\frac{1}{2}$$

## 13.1 Quantum Value Table

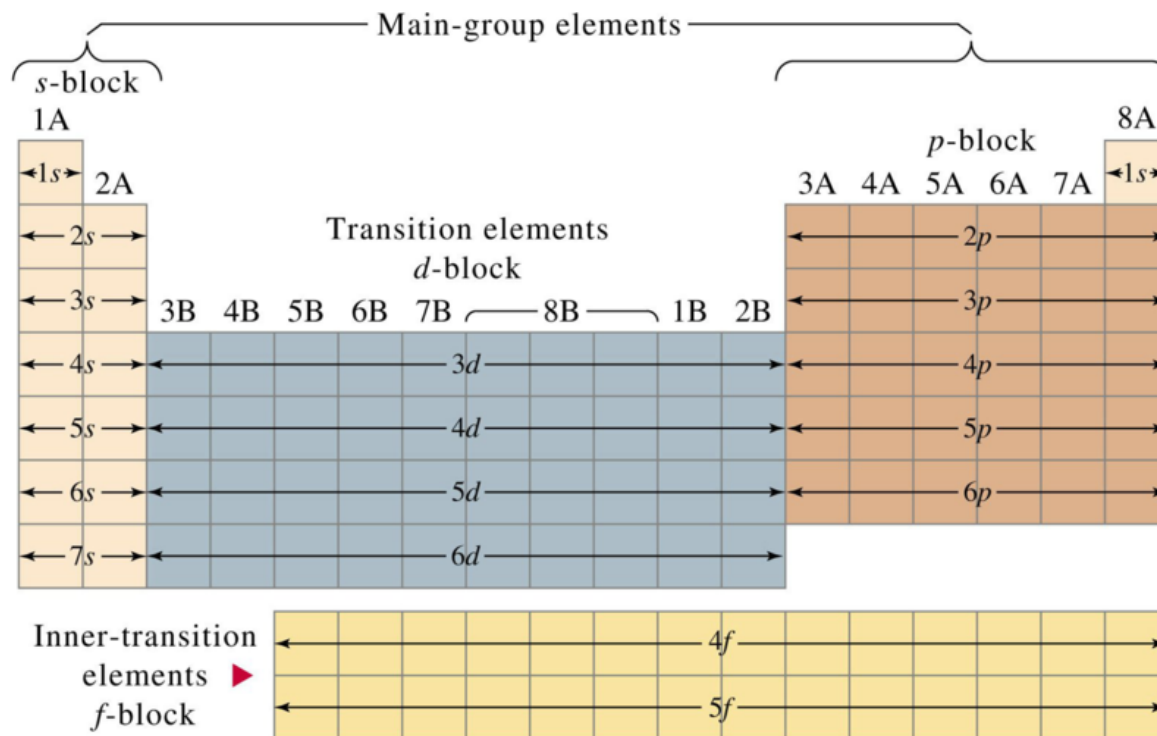
n	Possible $l$ values	Subshell	$ml$ values	# of orbitals in subshell	total # of orbitals in shell	$e^-$ in shell
1	0	1s	0	1	1	2
2	0	2s	0	1	4	8
	1	2p	-1,0,1	3	-	-
3	0	3s	0	1	9	18
	1	3p	-1,0,1	3	-	-
	2	3d	-2,-1,0,1,2	5	-	-
4	0	4s	0	1	16	32
	1	4p	-1,0,1	3	-	-
	2	4d	-2,-1,0,1,2	5	-	-
	3	4f	-3,-2,-1,0,1,2,3	7	-	-

## 13.2 Special cases

- Chromium has 6 half-filled orbitals
- Copper has one half-filled orbital and 5 filled orbitals

# 14 Periodicity

## 14.1 Electron Configuration



## 14.2 Isoelectricity

Two atoms are considered isoelectric when they gain or lose electrons to become ions and have the same electron configuration as each other.

Example
$Na^{+1}: 1S_2, 2S_2, 2P_6$
$Ne: 1S_2, 2S_2, 2P_6$

# 15 Nuclear Chemistry

Nuclear Chemistry involves changes in the nucleus of an atom.

Normal	Nuclear
Reactions involve electron transfer	Reactions involve decay of nucleus i.e. transforming one element into another
Reaction affected by factors such as pH, temp, pressure, [], etc.	Affected by the type of decay and the half-life of what is decaying
Reactions involve relatively small energy: 400 kJ-1500kJ	Reactions deal with <b>huge</b> amounts of energy

## 15.1 Isotopes

**Isotopes:** Atoms of the same element that have a different number of neutrons

$$X - A$$

$$\frac{A}{Z}X$$

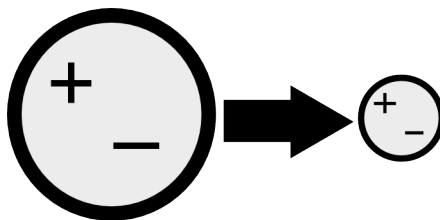
$${}^A X$$

- X = Element Symbol
- A = Atomic Mass
- Z = Atomic Number

## 15.2 Radiation

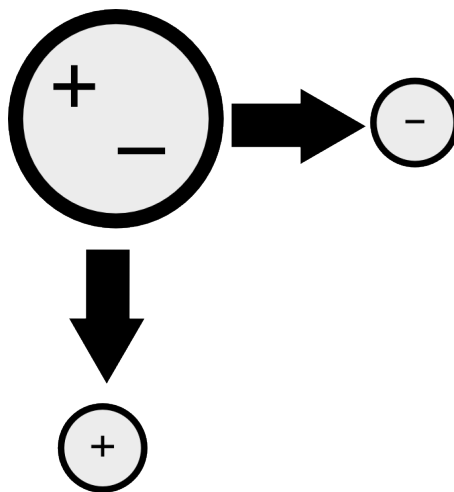
### 15.2.1 Alpha Radiation

When a big nucleus ejects a  $He^{+2}$  size chunk of itself.



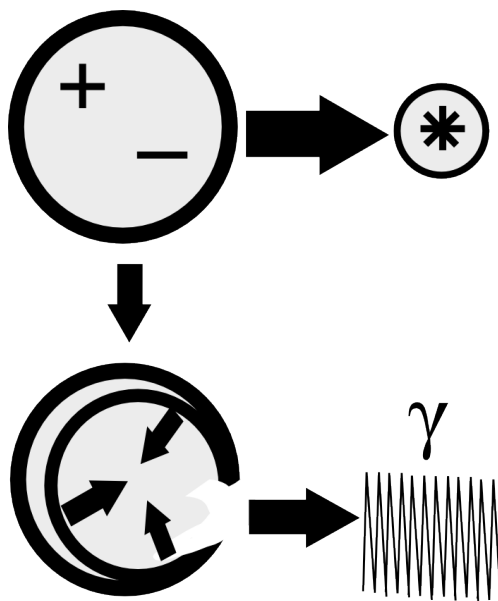
### 15.2.2 Beta Radiation

When a neutrally charged particle (equal amount of  $p^+$ s and  $e^-$ s) ejects its  $e^-$ s leaving only the  $p^+$ s.



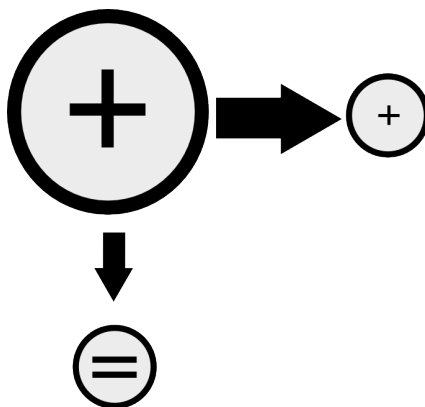
### 15.2.3 Gamma Radiation

When a particle experiences some type of radiation (called \* here) that causes the remaining nucleus to collapse. This causes gamma ( $\gamma$ ) rays to be emitted. Gamma radiation is also caused when a positron and an electron smash into each other.



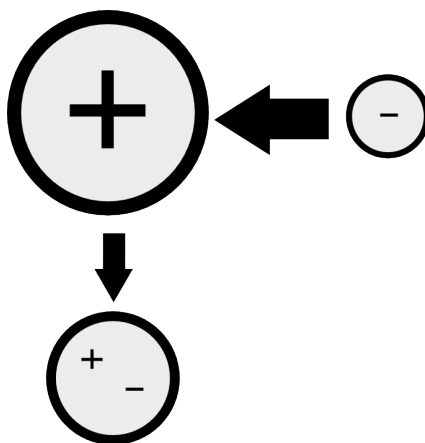
### 15.2.4 Positron Radiation

When a positively charged nucleus emits its  $p^+$  leaving only the  $n^0$ .



### 15.2.5 Electron Capture

When an electron in orbit falls into the nucleus (positively charged) and makes it neutrally charged.



## 15.3 Nuclear Equations

### 15.3.1 Radiation Table

Neutron:	${}^1_0n$
Proton:	${}^1_1p^+$
Electron:	${}^0_{-1}e^-$
Positron:	${}^0_1e^-$
Alpha Particle:	${}^4_2He$ or ${}^4_2\alpha$
Beta Particle:	${}^0_{-1}e^-$ or ${}^0_{-1}\beta$

Example
<b>Alpha</b> ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^4_2He$
<b>Beta</b> ${}^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^0_{-1}e^-$ ${}^1_0n \rightarrow {}^1_1p + {}^0_{-1}e^-$
<b>Positron</b> ${}^{11}_6C \rightarrow {}^{11}_5B + {}^0_1e^-$ ${}^1_1p \rightarrow {}^1_0n + {}^0_1e^-$
<b>Electron Capture</b> ${}^{81}_{37}Rb + {}^0_{-1}e^- \rightarrow {}^{81}_{36}Kr$ ${}^1_1p + {}^0_{-1}e^- \rightarrow {}^1_0n$
<b>Positron-Electron Collision (Gamma)</b> ${}^0_1e^+ + {}^0_{-1}e^- \rightarrow {}^0_0\gamma$

## 15.4 Nuclear Stability

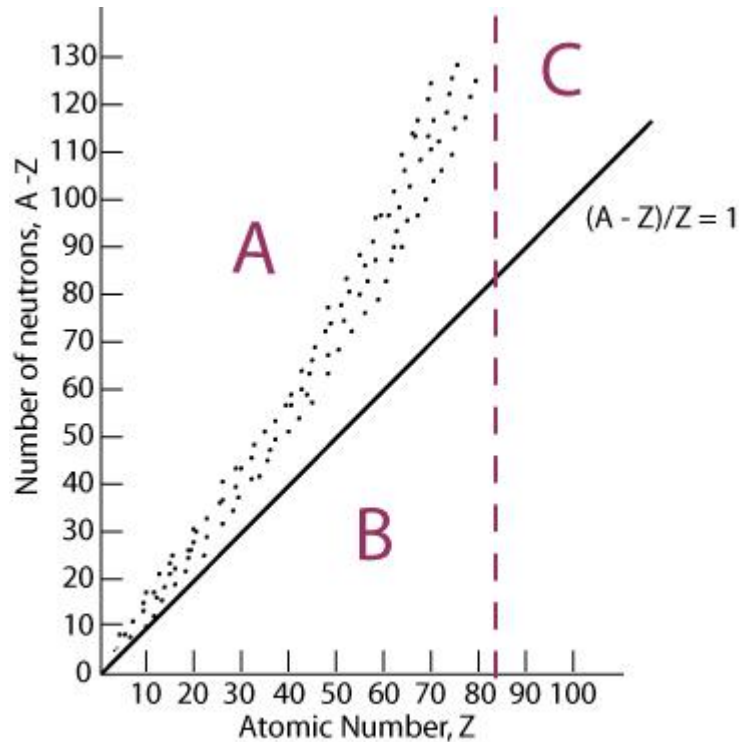
Understanding why are some nuclides are radioactive while others are not.

### 15.4.1 Forces Involved

- Electrostatic
  - ▷ Try to rip apart the nucleus because of like charges
- Strong Nuclear
  - ▷ Try to pull together the nucleus because subatomic particles naturally stick together
- The Glue
  - ▷ Neutrons act as the glue and more of it is required when the electrostatic force gets really strong

### 15.4.2 Belt of Stability

- Area A
  - ▷ More neutrons than protons - **Beta decay** → creates protons
- Area B
  - ▷ Less neutrons than protons - **Positron emission** (Smaller B) or **Electron Capture** (Larger B)
- Area C
  - ▷ Every element above 83  $p^+$  is radioactive and no glue can hold it together - **Alpha decay**



### 15.4.3 Magic Numbers

The Magic Numbers tend to be stable if you have either a proton or neutron in those numbers. If you have both, they are very stable.

$(p^+)$	2	8	20	28	50	82	-
$(n^\circ)$	2	8	20	28	50	82	126

- If  $(p^+)$  and  $(n^\circ)$  even → likely stable
- If either is odd → could go either way
- If  $(p^+)$  and  $(n^\circ)$  odd → likely unstable

### 15.4.4 Half-Life

The time it takes  $\frac{1}{2}$  the amount of a substance to decay.

Example	
5g of nuclide	
$\frac{1}{2}$ life of 15 years	
How much of the original nuclide remains after 45 years?	
5	
↓	(15 years)
2.5	
↓	(30 years)
1.25	
↓	(45 years)
<b>0.625g</b>	

## 16 Ionization and Affinity

### 16.1 Ionization Energy

The energy needed to remove an  $e^-$  (how easy it is to lose an  $e^-$ ). **Needs** energy (+).

### 16.2 Electron Affinity

How much a gaseous atom will be attracted to a free  $e^-$  (how easy it is to gain an  $e^-$ ). **Releases** energy (-).

## 17 Reactions of Metals

### Metal Oxides = Basic

- Metal + Water  $\rightarrow$  Metal Hydroxide +  $H_2$
- Metal +  $O_2$  (Li or any non-Alkali metal)  $\rightarrow$  Metal Oxide
- K +  $O_2$  (Any other Alkali metal)  $\rightarrow$  Metal Peroxide ( $O_2^{-1}$ )  
▷  $K + O_2 \rightarrow KO_2$
- Metal Oxide +  $H_2O$   $\rightarrow$  Metal Hydroxide  
▷  $Na_2O + H_2O \rightarrow NaOH$
- Metal Oxide + Acid  $\rightarrow$  Salt +  $H_2O$   
▷  $Na_2O + HCl \rightarrow NaCl + H_2O$

### Nonmetal Oxides = Acidic

- Nonmetal Oxide +  $H_2O$   $\rightarrow$  Acid  
▷  $CO_2 + H_2O \rightarrow H_2CO_3$   
▷  $SO_2 + H_2O \rightarrow H_2SO_3$   
▷  $P_4O_{10} + H_2O \rightarrow H_3PO_4$
- Nonmetal Oxide + Base  $\rightarrow$  Salt +  $H_2O$   
▷  $CO_2 + NaOH \rightarrow Na_2CO_3 + H_2O$

## 18 Chemical Bonds

When 2 or more atoms are strongly attached (attracted) to each other.

### 18.1 Intramolecular

These forces act inside an atom or molecule:

### 18.1.1 Ionic Bonding

Gain/lose  $e^-$ s (strong metal + strong nonmetal)

### 18.1.2 Covalent Bonding

Share  $e^-$ s (weak metal or nonmetal + nonmetal)

### 18.1.3 Metallic Bonding

There are two models that explain metallic bonding:

- **Electron Sea Model** <sup>1</sup>

▷ Metal atoms are floating in a sea of  $e^-$ s. No one  $e^-$  belongs to any particular atom.

- **Orbital Bonding Model**

▷ The valence  $e^-$ s are overlapped and shared so much you have bonds of delocalized  $e^-$ s that are free to move but are still holding the atoms together.

Properties that result from metallic bonding include:

- Conductivity of electricity and heat
- Malleability and ductility
- Ability to form alloys

## 18.2 Intermolecular

These forces act between molecules:

### 18.2.1 Ion-Dipole

Ions bonding to molecules with a dipole (polar solvent). **The strongest intermolecular force.**

### 18.2.2 Dipole-Dipole

Polar near another polar. **Weaker than Ion-Dipole but still strong, based on how strong the polarity is.**

### 18.2.3 Hydrogen Bond

Either ( $H - N$ ), ( $H - O$ ), or ( $H - F$ ). No shielding  $e^-$ s on Hydrogen so central atoms  $e^-$  pair gets full pull of Hydrogen nucleus.

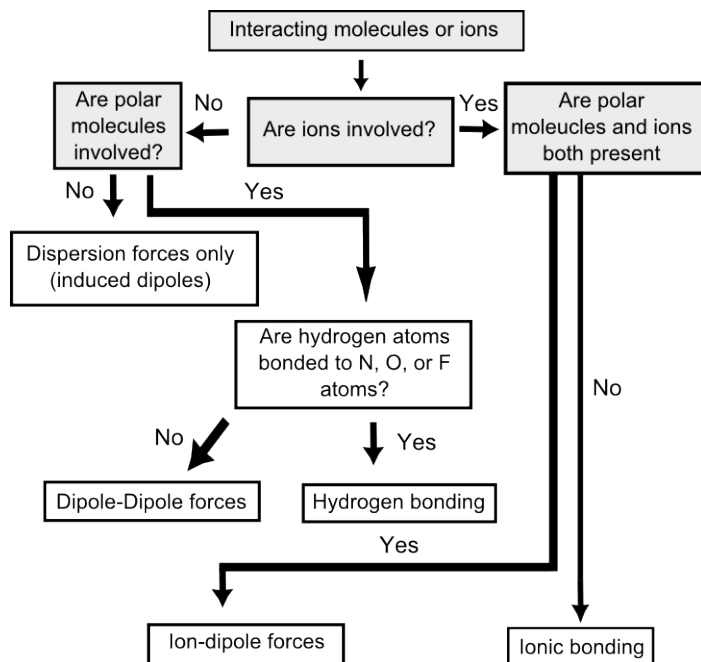
### 18.2.4 London Dispersion/Van der Waals

An induced dipole between 2 polar molecules. An increase in pressure or decrease in temperature will cause one side to have a more positive force as the majority of  $e^-$ s move to other side.

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<sup>1</sup>Of the two theories, this is generally the more accepted one

### 18.2.5 Intermolecular Flowchart

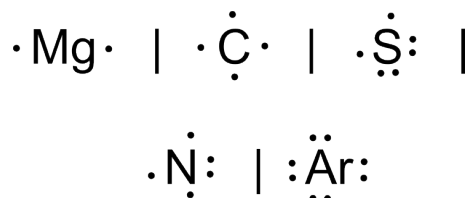


### 18.3 Rule of Octet

Atoms tend to bond in such a way as to gain, lose, or share  $e^-$ s in order to gain a complete valence (outer s and p).

## 19 Lewis Structures

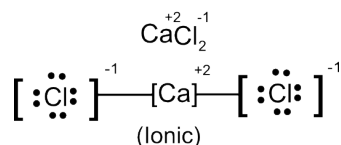
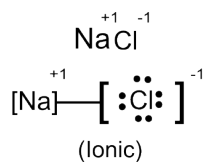
### 19.1 Structures for Atoms



### 19.2 Structures for Ions

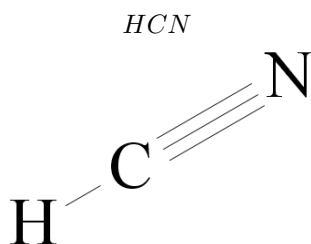
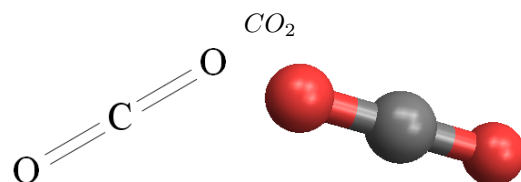
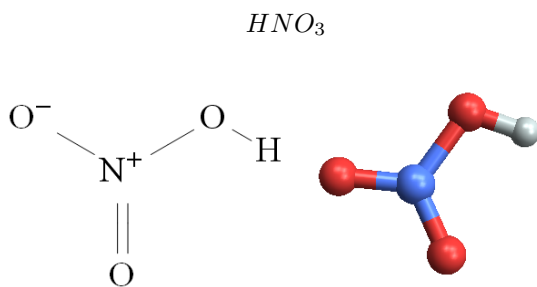
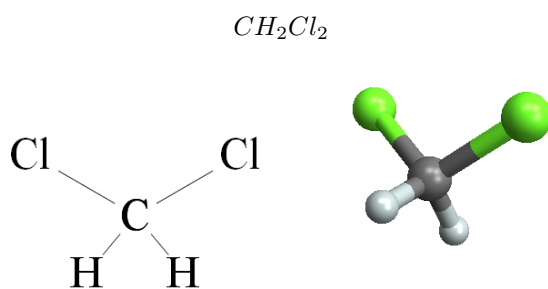
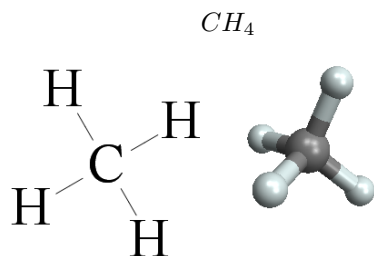


### 19.3 Structure for Ions of Molecules

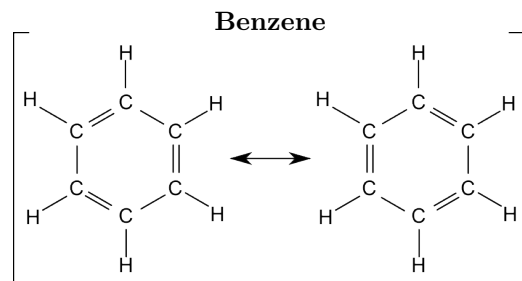


## 19.4 Lewis Structures for Molecular Structures (Covalent)

1. Add valence  $e^-$ s from all the atoms.
2. Write the symbols for the atoms. If there are more than 2 atoms, identify the central atom. Connect them with a single line which represents 2 shared  $e^-$ s. Subtract the number of  $e^-$ s from total found in step 1.
  - ▷ Central atom will be closest to Si, P or Metalloid staircase.
3. Complete octets around the atoms bonded to the central atom (Hydrogen does not get more than 2).
4. Place the remaining pairs around the central atom even if doing so gives more than an octet to the central atom.
5. If there are not enough pairs to complete an octet in the central atom, then you need to try using double or triple bonds.

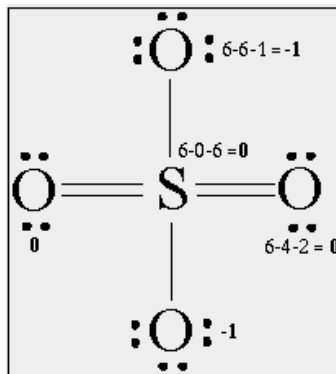


## 19.5 Resonance Structures



### 19.5.1 Formal Charge

Valence  $e^-$ s of an atom - (total unbonded  $e^-$ s +  $\frac{1}{2}$  total bonded  $e^-$ s)



Molecular structures that tend to be the common one have a formal charge is closest to zero and any negative charge is on the most electronegative element.

## 20 Lattice Energies of Ionic Solids

Coulombs Law

$$E = \frac{KQ_1Q_2}{d}$$

- $Q_1/Q_2$  = ion charges
- $d$  = Distance between ions of the final crystalized lattice form.
- † **The greater the charge, the higher the energy.**
- † **The closer the ions, the higher the energy.**

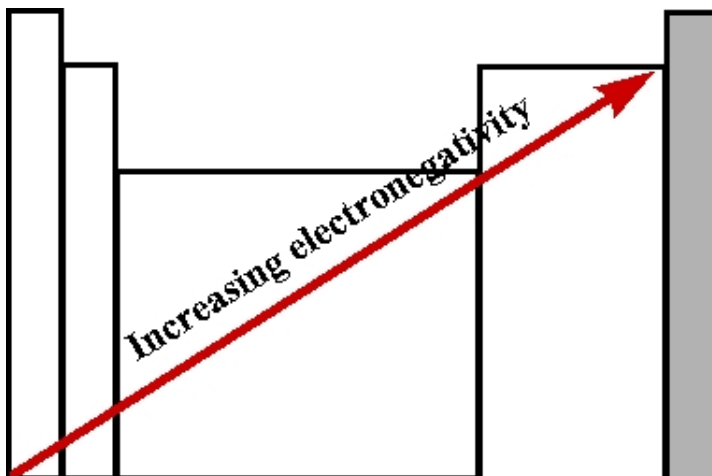
Example
Which has a greater lattice energy?
$\begin{matrix} +1 & -1 & & +2 & -1 \\ NaCl & vs & MgCl_2 \end{matrix}$
$\begin{matrix} +2 & -1 \\ MgCl_2 \end{matrix}$ has greater charges thus a higher lattice energy.
$\begin{matrix} +1 & -1 & & +1 & -1 \\ LiCl & vs & NaCl \end{matrix}$
$\begin{matrix} +1 & & +1 & +1 \\ Li & \text{is smaller than } Na & \text{so } Li & \text{will be closer} \\ \text{to } Cl & \text{than } Na & \text{will so } LiCl & \text{will have a higher} \\ & & & \text{lattice energy.} \end{matrix}$

## 21 Bond Lengths of Covalent Bonds

- Single - Longest
- Double - Medium
- Triple - Shortest

Length		
Single	$CO_4^{-4}$	$1.42 \text{ \AA}$
Double	$CO_2$	$1.24 \text{ \AA}$
Triple	$CO$	$1.13 \text{ \AA}$

## 22 Electronegativity



Difference in electronegativity determines the character of the bond.

- Large difference  $\rightarrow$  Ionic Bond
  - $\triangleright$  Biggest difference is 3.3
- Medium difference  $\rightarrow$  Polar Covalent
  - $\triangleright$  HF - 1.8
- Small/No difference  $\rightarrow$  Non-Polar Covalent
  - $\triangleright$   $H_2$  - 0

### 22.1 Dipole



Arrow points towards more electronegative atom.

#### 22.1.1 Dipole Moment

Numeric value that represents how strong the dipole is

Example
Which has the greater dipole moment?
<i>OR</i>
Which has greater electronegative difference?
<i>HI or HF</i>
<b>Answer: <i>HF</i></b>

## 23 Bond Enthalpy

$\Delta H$ : Energy given off or taken in during a reaction.

- $\Delta H = -$ 
    - ▷ Exothermic
  - $\Delta H = +$ 
    - ▷ Endothermic
- ‡ **Breaking bonds requires energy**
- ‡ **Forming bonds releases energy**

Example	
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	
<b>Breaking</b>	<b>Forming</b>
$4 * (C - H) = (4 * 413)$	$2 * (C=O) = (2 * 799)$
$2 * (O_2) = (2 * 495)$	$4 * (H - O) = (4 * 463)$
<hr/> 2642	<hr/> 3450
$\Delta H = \text{Broken} - \text{Formed}$	
$\Delta H = 2642 - 3450 = -808 \text{ KJ}$	

## 24 VSEPR

VSEPR stands for Valence Shell Electron Pair Repulsion. Make sure when counting bonds to treat double and triple bonds like a single bond. Also keep in mind that bonded pairs and lone pairs repel.

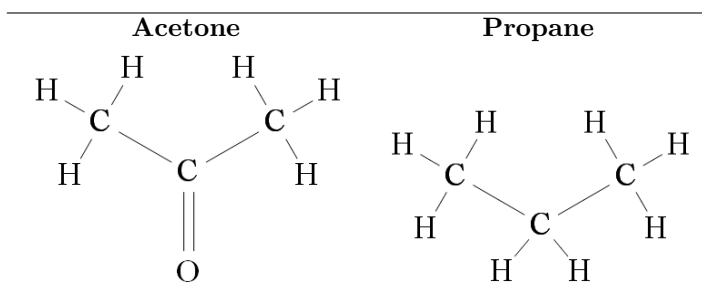
### 24.1 Bond Shape Table

Shape	Example	Total $e^-$	Bonded Pairs	Lone $e^-$ Pairs	Hybrid Orbital
Linear	$BeH_2$	2	2	0	$sp$
Trigonal Planar	$BCl_3$	3	3	0	$sp_2$
Bent	$NO_2^-$	3	2	1	$sp_2$
Tetrahedral	$CH_4$	4	4	0	$sp_3$
Trigonal Pyramidal	$NH_3$	4	3	1	$sp_3$
Bent	$H_2O$	4	2	2	$sp_3$
Trigonal Bipyramidal	$PCl_5$	5	5	0	$sp_3d$
See-Saw	$SF_4$	5	4	1	$sp_3d$
T-Shape	$BrF_3$	5	3	2	$sp_3d$
Linear	$ICl_2$	5	2	3	$sp_3d$
Octahedral	$SF_6$	6	6	0	$sp_3d_2$
Square Pyramidal	$BrF_5$	6	5	1	$sp_3d_2$
Square Planer	$ICl_4^-$	6	4	2	$sp_3d_2$

## 25 Organic Chemistry

### 25.1 Polarity

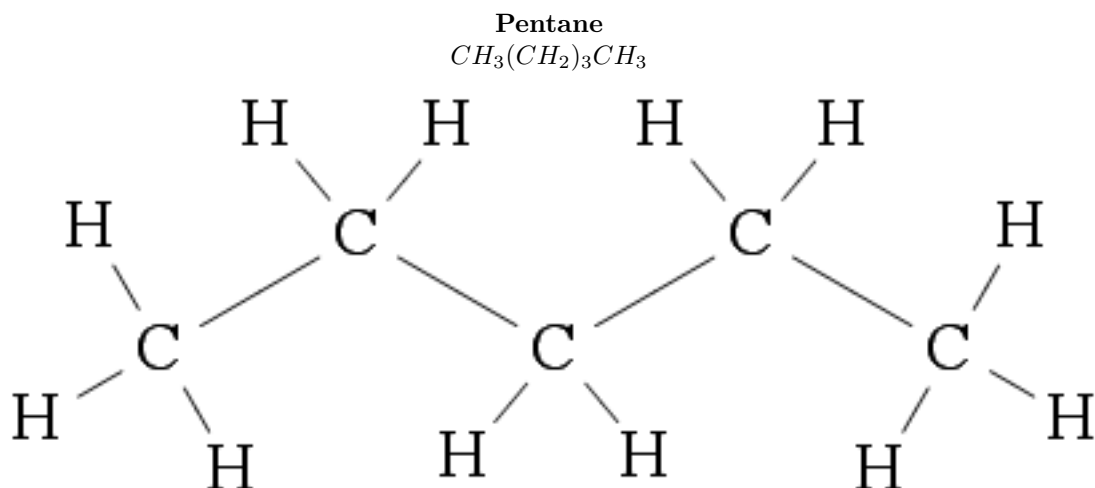
Polarity in regards to organic chemistry relies on an element disrupting the symmetry of a molecule. For example the double bonded oxygen in Acetone allows it to be more polar than Propane.



## 25.2 Alkanes

† Spotted by seeing a single bond

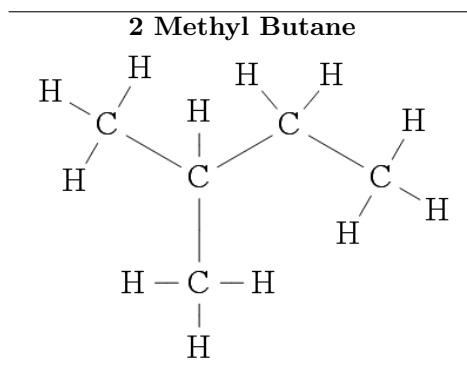
- $CH_4 \rightarrow$  Methane
- $C_2H_6 \rightarrow$  Ethane
- $C_3H_8 \rightarrow$  Propane
- $C_4H_{10} \rightarrow$  Butane
- $C_5H_{12} \rightarrow$  Pentane
- $C_6H_{14} \rightarrow$  Hexane
- $C_7H_{16} \rightarrow$  Heptane
- $C_8H_{18} \rightarrow$  Octane
- $C_9H_{20} \rightarrow$  Nonane
- $C_{10}H_{22} \rightarrow$  Decane



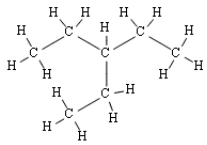
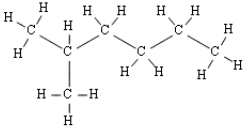
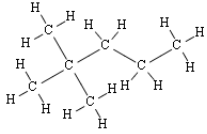
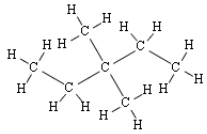
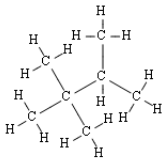
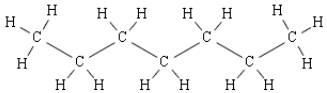
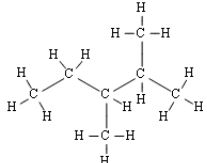
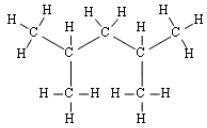
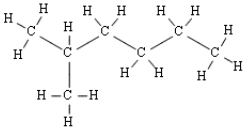
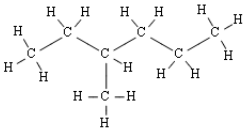
## 25.3 Alkane Branch Structure Naming

To name all single-bonded Carbon chains, see subsection on Alkanes above.

To name a branch structure first look for the longest unbroken Carbon chain, this is the root name. Then take the root prefix of the alkyl (the branch of the root chain) and add -yl (for instance Methane becomes methyl). Number the Carbon chain giving the side with an alkyl the lowest number. The end result should be something such as *2 Methyl Butane*.



### 25.3.1 Branch Structure Naming Table

	$C_7H_{16}$	3-ethylpentane
	$C_7H_{16}$	isoheptane
	$CH_3CH_2CH_2C(CH_3)_3$	2,2-dimethylpentane
	$CH_3CH_2C(CH_3)_2CH_2CH_3$	3,3-dimethylpentane
	$(CH_3)_2CHC(CH_3)_3$	2,2,3-trimethylbutane
	$CH_3(CH_2)_5CH_3$	<i>n</i> -heptane
	$C_2H_5CH(CH_3)CH(CH_3)_2$	2,3-dimethylpentane
	$(CH_3)_2CHCH_2CH(CH_3)_2$	2,4-dimethylpentane
	$CH_3(CH_2)_3CH(CH_3)_2$	2-methylhexane
	$CH_3CH_2CH_2CH(CH_3)CH_2CH_3$	3-methylhexane

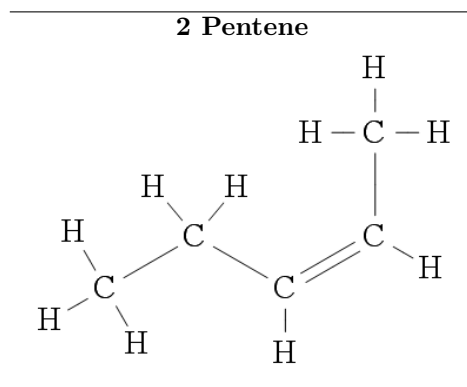
## 25.4 Alkenes

† Spotted by seeing a double bond

- $CH_2 \rightarrow$  Methene
- $C_2H_4 \rightarrow$  Ethene
- $C_3H_6 \rightarrow$  Propene
- $C_4H_8 \rightarrow$  Butene
- $C_5H_{10} \rightarrow$  Pentene
- $C_6H_{12} \rightarrow$  Hexene
- $C_7H_{14} \rightarrow$  Heptene
- $C_8H_{16} \rightarrow$  Octene
- $C_9H_{18} \rightarrow$  Nonene
- $C_{10}H_{20} \rightarrow$  Decene

### 25.4.1 Alkene Naming

Naming Alkenes is similar to naming Alkanes save for the naming of the root chain. To name the root chain you must give side where the double bond is the lowest number and name all branches after using this number scheme. You should end up with something like *2 Pentene*



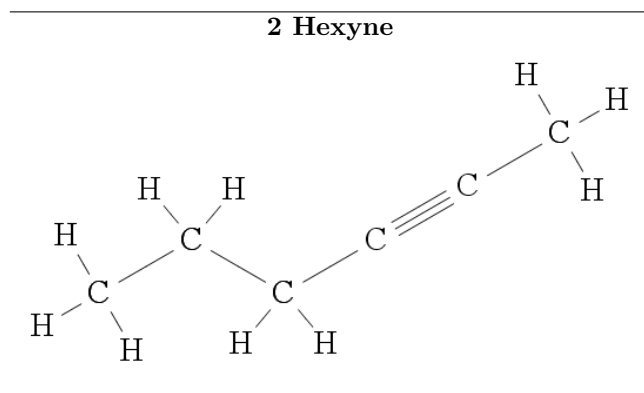
## 25.5 Alkynes

† Spotted by seeing a triple bond

- $CH \rightarrow$  Methyne
- $C_2H_2 \rightarrow$  Ethyne
- $C_3H_4 \rightarrow$  Propyne
- $C_4H_6 \rightarrow$  Butyne
- $C_5H_8 \rightarrow$  Pentyne
- $C_6H_{10} \rightarrow$  Hexyne
- $C_7H_{12} \rightarrow$  Heptyne
- $C_8H_{14} \rightarrow$  Octyne
- $C_9H_{16} \rightarrow$  Nonyne
- $C_{10}H_{18} \rightarrow$  Decyne

### 25.5.1 Alkyne Naming

Naming Alkynes is similar to naming Alkenes. Identify the root chain as you would using Alkenes except now you identify the triple bond instead of the double bond.

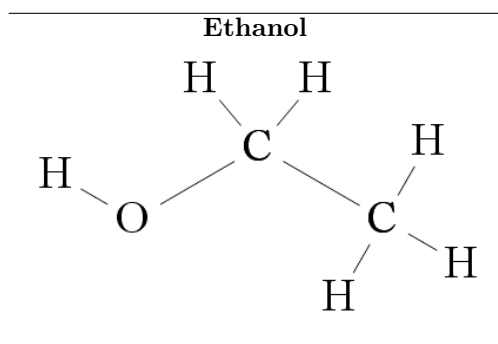


## 26 Functional Groups

» When discussing functional groups, the letter **R** is used to signify any hydrocarbon or hydrocarbon chain.

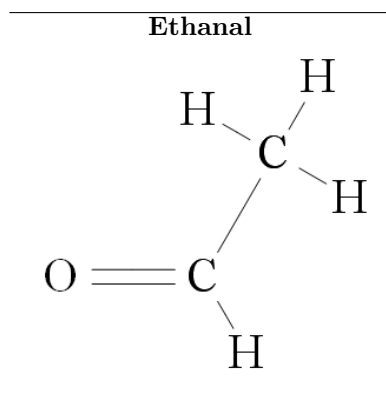
### 26.1 Alcohol

- **Root Name:** -ol
- **Identification:** R-OH



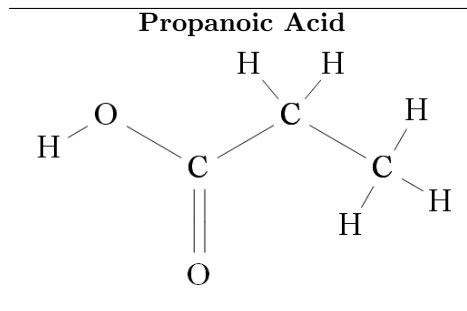
### 26.2 Aldehyde

- **Root Name:** -al
- **Identification:** R-CHO



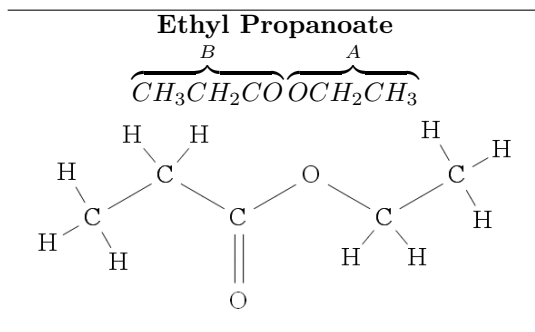
## 26.3 Carboxylic Acid

- Root Name: -oic
- Identification: R-COOH



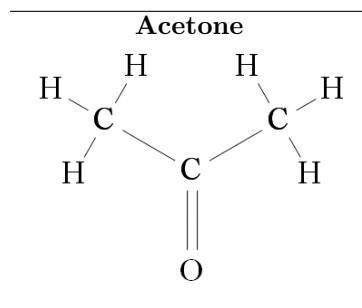
## 26.4 Ester

- Root Name: A-yl B-oate
- Identification: R-COO-R



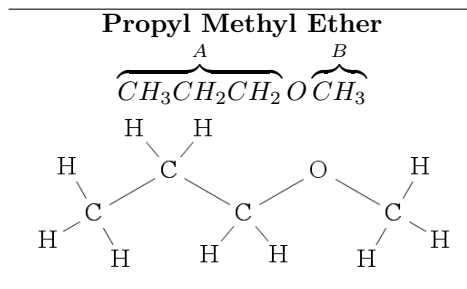
## 26.5 Ketone

- Root Name: -one
- Identification: R-CO-R



## 26.6 Ether

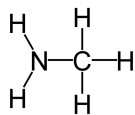
- Root Name: A-yl B-yl Ether
- Identification: R-O-R



## 26.7 Amine

- **Root name:** -amine
- **Identification:** R-NH<sub>2</sub>

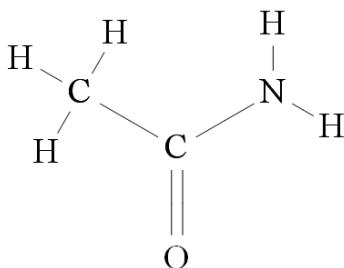
Methylamine



## 26.8 Amide

- **Root Name:** -amide
- **Identification:** R-CONH<sub>2</sub>

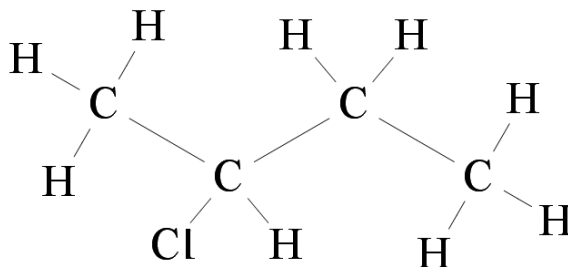
Ethanamide



## 26.9 Haloalkane

- **Root Name:** None, use standard naming of root chain
- **Identification:** Some Hydrogens in a hydrocarbon are replaced with a halogen (F, Cl, Br, I)

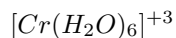
2 Chloro Butane



## 27 Complex Ions

Complex Ions are usually metal ions with attached ligands (Lewis Bases).

### 27.1 Cations



→ The charge of a cation is the charge of the transition metal (Cr in this case).

## 27.2 Anions



⊖ The charge of an anion is determined by the individual charges of the elements.

$$\triangleright Al^{+3} + 4(OH)^{-1}$$

$$\triangleright 3 - 4$$

$$\triangleright -1$$

## 27.3 Coordination Number

Generally (especially with cations) the coordination number is twice the charge of the transition metal.

Example
$[Cr(H_2O)_6]^{+3}$
$Cr^{+3} \rightarrow 3 * 2 = 6$

## 27.4 Naming

### 27.4.1 Cations

- Give the prefix associated with the coordination number
- Give appropriate name for ligand
- Name the transition metal
- Give roman numeral of transition metal

Example
$\left[ \overset{\text{Chromium}}{\underbrace{Cr}} \left( \overset{\text{Hexa}}{\underbrace{(H_2O)}_6} \right) \right]^{+3}$
<b>Hexa Aqua Chromium (III)</b>

### 27.4.2 Anions

- Give prefix associated with the coordination number
- Give appropriate Ligand name
- Name transition metal with -ate ending
- Give roman numeral

Example
$[Al(OH)_4]^{-1}$
Tetra Hydroxo Aluminate
<i>No roman numeral because Al is always +3</i>

## 28 Acidic and Basic Redox

### 28.1 Acidic

- Find oxidation number
- Write  $\frac{1}{2}$  reaction with  $e^-$ s
- Add  $H_2O$ , then  $H^+$  and balance accordingly
- Balance for  $e^-$ s and everything else
- Add together both balanced  $\frac{1}{2}$  reactions and cancel out where possible to simplify

## 28.2 Basic

- Find oxidation number
- Write  $\frac{1}{2}$  reaction with  $e^-$ s
- Add  $H_2O$ , then  $H^+$  and balance accordingly
- Add  $OH$  amounts to both sides equal to the number of  $H^+$
- Cancel out the  $H^+$  with the  $OH$  to form  $H_2O$
- Move all  $H_2O$  to one side
- Balance for  $e^-$ s and everything else
- Add together both balanced  $\frac{1}{2}$  reactions and cancel out where possibly to simplify

Example
$\overset{+7}{Mn} \overset{-2}{O}_4 + \overset{+3}{C} \overset{-2}{O}_4 \rightarrow \overset{+1}{Mn} \overset{-2}{O}_2 + \overset{+4}{C} \overset{-2}{O}_3$
$(4OH + C_2O_4 \rightarrow 2CO_3 + 2e^- + 2H_2O) * 3$
$(2H_2O + MnO_4 + 3e^- \rightarrow MnO_2 + 4OH) * 2$
$12OH + 3C_2O_4 \rightarrow 6CO_3 + 6e^- + 6H_2O$
$4H_2O + 2MnO_4 + 6e^- \rightarrow 2MnO_2 + 8OH$
$4OH + 3C_2O_4 + 2MnO_4 \rightarrow 2MnO_2 + 6CO_3^{-2}$

## 29 Thermodynamics

The study of energy and its transformations

Units of Energy:

- Joules and Calories
  - ▷ 1 cal = 4.184 J

The two main driving forces of thermodynamics is **Enthalpy** and **Entropy**:

### 29.1 Enthalpy

Enthalpy stands for the **Heat of the reaction** and is denoted by  $\Delta H$ .

If:

- $\Delta H < 0$ 
  - ▷ Reaction is exothermic
- $\Delta H > 0$ 
  - ▷ Reaction is endothermic

There are 4 ways to find  $\Delta H$ .

#### 29.1.1 Stoichiometry Problems

Example
How much heat is released when 3.2 grams of Hydrogen is reacted with excess Oxygen?
$2H_2 + O_2 \rightarrow 2H_2O$
$\Delta H^\circ = -572 \text{ KJ}$
$\frac{3.2 \text{ g } H_2}{1} * \frac{1 \text{ mole } H_2}{2.02 \text{ g } H_2} * \frac{-572 \text{ KJ}}{2 \text{ mole } H_2} = -453.069 \text{ KJ}$
$Ratio = \frac{\text{Energy Released}}{\text{Coefficient of Hydrogen in formula}}$

### 29.1.2 Calorimetry

Find the  $\Delta H$  by running a reaction and heating or cooling a substance.

$$q = m * c * \Delta T$$

- $q$  = Heat released or absorbed
- $m$  = Mass of what is being heated (grams)
- $c$  = Specific heat. Unique to every substance ( $\frac{J}{g \cdot C}$ )
  - ▷ Specific heat of water is 4.184
- $\Delta T$  = Change in temperature

Example	
Burn 0.1 grams of $CH_4$ and it heats 100 grams $H_2O$ from $20^\circ C$ to $33.29^\circ C$ .	
$q = 100 * 4.184 * 13.29 = 5560 J = 5.560 KJ$	
$\frac{0.1 \text{ grams } CH_4}{1}$	$* \frac{1 \text{ mole } CH_4}{16 \text{ g } CH_4} = 0.00625 \text{ moles } CH_4$
	$\frac{5.560}{0.00625} = 889.6 \frac{KJ}{Mole}$

### 29.1.3 Hess Law

Multiple reactions can be added together then  $\Delta H$ s can be added together.

Example	
$Si + 2H_2 \rightarrow SiH_4$	$\Delta H = +34 \frac{KJ}{Mole}$
$Si + O_2 \rightarrow SiO_2$	$\Delta H = -911 \frac{KJ}{Mole}$
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$\Delta H = -242 \frac{KJ}{Mole}$
Find $\Delta H$ for:	
$SiH_4 + 2O_2 \rightarrow SiO_2 + 2H_2O$	
$SiH_4 \rightarrow Si + 2H_2$	$\Delta H = -34 \frac{KJ}{Mole}$
$Si + O_2 \rightarrow SiO_2$	$\Delta H = -911 \frac{KJ}{Mole}$
$2H_2 + 2O_2 \rightarrow 2H_2O$	$\Delta H = -484 \frac{KJ}{Mole}$
$SiH_4 + 2O_2 \rightarrow SiO_2 + 2H_2O$	$\Delta H = -1429 \frac{KJ}{Mole}$

### 29.1.4 Standard Heat of Formation

Standard heat (enthalpy) of formation ( $\Delta H_f^\circ$ )<sup>2</sup> is the energy involved in forming **one** mole of a chemical from its elements under standard conditions.

† Elemental substances ( $O_2, H_2$ , etc.) always have a  $\Delta H$  of **zero**.

Example	
Find the $\Delta H$ for:	
$2H_2O_2 \rightarrow 2H_2O + O_2$	
$\Delta H_f H_2O_2 = -187$	
$\Delta H_f H_2O = -285$	
$\underbrace{2 * (-187)}_{-374}$	$\underbrace{2 * (-285)}_{-570}$
$2H_2O_2 \rightarrow 2H_2O + O_2$	
$\Delta H = \sum \text{product} - \sum \text{reactant}$	
$\Delta H = -570 - (-374) = -196 \frac{KJ}{Mole}$	

<sup>2</sup>This symbol may be shortened to  $\Delta H$  or  $\Delta H_f$  in this subsection.

## 29.2 Entropy

Entropy stands for the **Disorder of the reaction** and is denoted by  $\Delta S$ .

If:

- $\Delta S < 0$ 
  - ▷ Order is increasing
- $\Delta S > 0$ 
  - ▷ Disorder is increasing

### 29.2.1 State of Matter

If:

- Solid  $\rightarrow$  Liquid
  - ▷  $\Delta S = +$
- Gas  $\rightarrow$  Solid
  - ▷  $\Delta S = -$

Solid	Liquid	Gas
Lowest $\Delta S$	-	Highest $\Delta S$

### 29.2.2 Number of Moles of Gasses

‡ Solids and liquids do not apply

Example	
$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$	
4 moles gas $\rightarrow$ 2 moles gas	$\Delta S = -$
2 moles gas $\rightarrow$ 4 moles gas	$\Delta S = +$

### 29.2.3 Pressure of Gas

- When pressure **increases**, disorder **decreases**.
- When pressure **decreases**, disorder **increases**.

Example
What has more disorder?
$N_2$ at 1 atm
$N_2$ at 0.001 atm
<b>Answer:</b> $N_2$ at 0.001 atm

## 29.3 Gibbs Law of Free Energy

Gibbs Law determines  $\Delta G$  which signifies whether a reaction is spontaneous or not.

$$\Delta G = \Delta H - (T * \Delta S)$$

- $\Delta G$  = Free Energy in a system
- $\Delta H$  = Enthalpy (KJ)
- $\Delta S$  = Entropy ( $\frac{KJ}{K}$ )
  - ▷  $\Delta S$  **MUST** be converted from  $\frac{J}{K}$  to  $\frac{KJ}{K}$ .
- $T$  = Temperature in Kelvin
  - ▷ To convert  $C^\circ \rightarrow K$  add 273

If:

- $\Delta G < 0$   
▷ Spontaneous
- $\Delta G > 0$   
▷ Not spontaneous

### 29.3.1 $\Delta H$ , $\Delta S$ , $\Delta G$ , Relationship Table

$\Delta H = -$	$\Delta S = +$	$\Delta G = -$	Always spontaneous
$\Delta H = -$	$\Delta S = -$	$\Delta G = -$	Spontaneous at low temperatures
$\Delta H = +$	$\Delta S = +$	$\Delta G = +$	Spontaneous at high temperatures
$\Delta H = +$	$\Delta S = -$	$\Delta G = +$	Never spontaneous

Example
$POCl_3 \rightarrow 2PCl_3 + O_2$
$\Delta H = 542 \text{ KJ}$
$\Delta S = 179 \frac{\text{J}}{\text{K}}$
What temperature is it spontaneous at?
$0 = 542 \text{ KJ} - (T * 0.179 \frac{\text{KJ}}{\text{K}})$
$-542 = -0.179T$
$T = 3027.93 \text{ K}$

## 30 Chemical Kinetics and Rate Laws

Factors that affect reaction rates

### 30.1 Physical State

- Solid  
▷ An **increase** in surface area means in an **increase** in the rate.
- Gas - Gas
- Liquid - Gas
- Liquid - Liquid

### 30.2 Concentration

$$^3\text{Molarity} = \frac{\text{moles}}{\text{liter}}$$

$$[HCL] = 3M$$

An **increase** in concentration is generally an **increase** in rate.

### 30.3 Temperature

An **increase** in temperature is an **increase** in rate.

### 30.4 Pressure of Gas

An **increase** in pressure is an *bincrease* in rate.

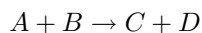
### 30.5 Catalysts and Inhibitors

A catalyst lowers the activation energy while an inhibitor increases the activation energy.

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<sup>3</sup>Molarity is signified by []s

## 30.6 Rate Laws



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

- k = Constant
  - m = Order of A
  - n = Order of B
- † Order of 0 → No effect  
 † Order of 1 → Linear - Double the concentration and you double the rate  
 † Order of 2 → Squared - Double the concentration and you quadruple the rate

### Example:

Trial	[A]	[B]	Rate
1	0.1 M	0.1 M	0.04 M/s
2	0.2 M	0.1 M	0.08 M/s
3	0.1 M	0.2 M	0.04 M/s

### Solve for m:

$$\frac{\text{trial 2}}{\text{trial 1}} = \left(\frac{[A]}{[A]}\right)^m = \frac{\text{rate}}{\text{rate}} = \left(\frac{0.2}{0.1}\right)^m = \frac{0.08}{0.04}$$

$$2^m = 2$$

$$m = 1$$

### Solve for n:

$$\left(\frac{0.2}{0.1}\right)^n = \frac{0.04}{0.04}$$

$$1^n = 1$$

$$n = 0$$

$$\text{rate} = k[A]^1[B]^0$$

### Solve for k:

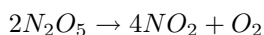
$$0.04 = k[0.1]^1[0.1]^0$$

$$k = 0.4$$

### 30.6.1 Order Table

Comments	Zero Order	First Order	Second Order
Rate Law	$\text{rate} = k$	$\text{rate} = k[A]^1$	$\text{rate} = k[A]^2$
Integrated Rate law	$[A] - [A]_0 = -kt$ $[A] = -kt + [A]_0$	$\ln[A] - \ln[A]_0 = -kt$ $\ln[A] = -kt + \ln[A]_0$	$\frac{1}{[A]} - \frac{1}{[A]_0} = kt$ $\frac{1}{[A]} = kt + \frac{1}{[A]_0}$
Graph	[A] vs Time	ln[A] vs time	$\frac{1}{[A]}$ vs time
K = Slope	Slope = $-k$	Slope = $-k$	Slope = $k$
Half-Life ( $t_{\frac{1}{2}}$ )	$t_{\frac{1}{2}} = \frac{[A]_0}{2k}$	$t_{\frac{1}{2}} = \frac{0.693}{k}$	$t_{\frac{1}{2}} = \frac{1}{k[A]_0}$

### Example:



$[N_2O_5]$	Time (s)
0.1	0
0.0707	50
0.05	100
0.025	200
0.0125	300
0.00625	400

1. What is the order of the reaction?

$$[A] \neq \text{straight}$$

$$\frac{1}{[A]} \neq \text{straight}$$

$$\ln[A] = \text{straight}$$

**Order of 1**

2. What is the k constant value?

$$\frac{\ln(0.0707) - \ln(0.1)}{50 - 0} = \frac{-0.347}{50} = 0.00693$$

$$k = \mathbf{0.00693}$$

3. What is the concentration of  $N_2O_5$  at  $t = 150$ ?

$$\ln[A] = -(0.00693)(150) + \ln(0.1)$$

$$\ln[A] = -3.34$$

$$[A] = 0.0354 \text{ M}$$

4. What is the rate at 150 seconds?

$$\text{rate} = k[A]$$

$$\text{rate} = 0.00693 * [0.0354]$$

$$\text{rate} = 2.45 * 10^{-4} \text{ M/s}$$

5. What is the half life?

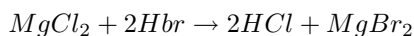
$$t_{\frac{1}{2}} = \frac{0.693}{k}$$

$$t_{\frac{1}{2}} = \frac{0.693}{0.00693}$$

$$t_{\frac{1}{2}} = 100 \text{ s}$$

## 31 Reaction Mechanisms

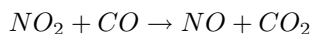
Many/most reactions do not take place in one step. If a reaction were to react in one step, then you could use the balanced reaction to determine the rate law. For example, assume the following occurred in one step.



$$\text{rate} = k[MgCl_2]^1[HBr]^2$$

In reality though, things are not always as easy.

Through experimentation we figure out that the rate law for:



is

$$\text{rate} = k[NO_2]^2$$

Because the rate law does not link up with the equation, it is not a single step reaction.

## 31.1 Elementary Steps

- Unimolecular - 1 reactant
- Bimolecular - 2 reactants
- Termolecular - 3 reactants

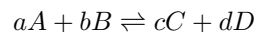
## 32 Equilibrium

The state where the concentration or partial pressures (if it is a gas) of all the reactants and products remain constant with time. For equilibrium to occur, the forward reaction rate must equal the reverse rate. In other words, the amounts do not have to be equal, but the rates must be.

### 32.1 Types of Equilibrium

- Static → No movement
- Dynamic → Movement such as a sealed container of water

### 32.2 Equilibrium Constant Expressions



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

$$K_p = \frac{(PC^c)(PD^d)}{(PA^a)(PB^b)}$$

- $K_c$  = Concentration constant
- $K_p$  = Partial Pressure constant

#### 32.2.1 Converting Constants

To convert between the two constants  $K_c$  and  $K_p$  use the formula:

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

- $\Delta n = \sum \text{Product Coefficients} - \sum \text{Reactant Coefficients}$

## 33 Gas Laws

### 33.1 Gas Units and Conversions

$$1 \text{ Atm} = 760 \text{ Torr (mmHg)} = 101.3 \text{ kPa} = 14.7 \text{ PSI}$$

### 33.2 Ideal Gas Law

$$Pv = nRT$$

- P = Pressure (Atm)
- v = Volume (L)
- n = Number of moles
- R = 0.0821 (constant)
- T = Temperature (Kelvin)

Example
3 grams of $HCl$ at $26^\circ C$ in a 3 Liter container. What is the pressure?
$\frac{P(3)}{3} = \frac{(\frac{3 \text{ grams}}{36.5 \text{ g/mole}})(0.081)(26+273)}{3}$ $P = 0.0664 \text{ Atm}$

### 33.3 Real Gas Law

For use when the ideal gas law fails. The ideal gas law fails when these two postulates fail:

- Molecules do have volume
- Molecules are attracted

This law is also used when there are conditions with **high pressure** and **low temperature**.

$$Pv = nRT$$

↓

$$\left(P + \frac{n^2 a}{v^2}\right) * (v - nb) = nRT$$

- a = constant that fixes the **intermolecular force issue**
  - b = constant that fixes the **volume issue**
- ⊢ a and b are unique to each type of gas
- ⊢ All other variables are the same as the ideal gas law

### 33.4 Combined Gas Law

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

### 33.5 Daltons Law of Partial Pressures

For a mixture of gases in a container, the total pressure ( $P_{tot}$ ) is equal to the sum of the pressures each gas exerts as if it were alone.

$$P_{tot} = P_1 + P_2 + P_3 + \dots + P_n$$

**Example:**

A mixture of 1g H and 1g He in a 1 L container is at 27°C. Calculate the mole fraction of each gas, partial pressures of each and total pressure.

$$H_2 \ 1 \ g * \frac{1}{2} = 0.5 \ moles$$

↓

$$x = \frac{(H \ mole)}{(H + He \ moles)} = \frac{0.5}{0.75} = 0.667$$

$$He \ 1 \ g * \frac{1}{4} = 0.25 \ moles$$

↓

$$x = \frac{0.25}{0.75} = 0.333$$

$H_2$	$He$
$Pv = nRT$	$Pv = nRT$
$P(1) = (0.5)(0.0821)(300)$	$P(1) = (0.25)(0.0821)(300)$
$P = 12.3 \text{ Atm}$	$P = 6.15 \text{ Atm}$

$$P_{tot} = 12.3 + 6.15 = 18.45 \text{ Atm}$$

## 33.6 Gas Collection over a Water Solution

### Example:

A 0.986 g sample has Zinc and some impurities. Excess HCl is added and reacts with the Zinc but not the impurities. Find the percent Zinc in the sample if 240 mL of  $H_2$  are collected over  $H_2O$  at  $30^\circ C$  and 1.032 Atm (HINT: This is the  $P_{tot}$ ).

$$\begin{aligned}P_{tot} &= P_1 + P_{H_2O} \\1.032 &= P_1 + 0.042 \\P_1 &= 0.99 \text{ Atm } H_2 \\&\downarrow \\Pv &= nRT \\(0.99)(0.240) &= n(0.0821)(303) \\n &= 0.0096 \text{ mole } H_2 \\&\downarrow \\0.0096 \text{ mole } H_2 &= 0.0096 \text{ mole Zn} \\ \frac{0.0096 \text{ mole Zn}}{1} * \frac{65.4 \text{ g Zn}}{\text{Mole}} &= 0.628 \text{ g Zn} \\ \frac{0.628 \text{ g Zn}}{0.986 \text{ g total}} * 100 &= 63.7\% \text{ Zn}\end{aligned}$$

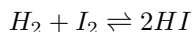
## 34 ICE ICE (Baby)

Given initial values for a system at equilibrium and one of the equilibrium values, you should find:

- a - The other equilibrium values
- b - The equilibrium constant

### Example:

A closed system initially containing  $1 * 10^{-3} M H_2$  and  $2 * 10^{-3} M I_2$  at  $448^\circ C$  is allowed to reach equilibrium. Analysis of the equilibrium mixture shows the  $[HI] = 1.7 * 10^{-3} M$ . Find the equilibrium concentration for  $H_2$  and  $I_2$  as well as the  $K_c$  value.



Initial	$1 * 10^{-3} M$	$2 * 10^{-3} M$	$0 M$
Change	$-0.935 * 10^{-3}$	$0.935 * 10^{-3}$	$1.87 * 10^{-3}$
Equilibrium	$0.065 * 10^{-3}$	$1.065 * 10^{-3}$	$1.87 * 10^{-3}$

$$[H_2] = 0.065 M$$

$$[I_2] = 1.065 * 10^{-3} M$$

$$K_c = \frac{[1.87 * 10^{-3}]^2}{[1.065 * 10^{-3}][0.065 * 10^{-3}]}$$

## 35 Acids and Bases

### 35.1 Definitions of Acids and Bases

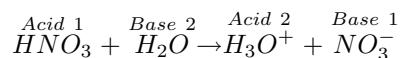
#### 1. Arrhenius

▷ An acid dissociates in water to form  $H^+$  ions and a base dissociates to form  $OH^-$  ions.

#### 2. Bronsted-Lowry

▷ Acids are proton donors ( $H^+$ ) and a base is a proton acceptor.

▷ Conjugate acid base pair



#### 3. Lewis Acid

▷ Acid is an  $e^-$  pair acceptor while a base is an  $e^-$  pair donor.

## 35.2 pH and pOH

pH and pOH are measures of the amount of ions in a solution that either cause the solution to be acidic or basic.

<b>pH Scale</b>
Basic $\Rightarrow$ 0 $\leftrightarrow$ 14 $\Leftarrow$ Acidic
<b>Important Formulas</b>
$pH = -\log[H^+]$
$pOH = -\log[OH^-]$
$pH + pOH = 14$
$[H^+] = 1 * 10^{-pH}$
$[OH^-] = 1 * 10^{-pOH}$
<b>Example</b>
What is the concentration of HCl with a pH of 3?
$[HCl] = 0.001 M$

### 35.2.1 Changing Concentrations

$$M_1V_1 = M_2V_2$$

$$(0.25 M)(5 mL) = M_2(50 mL)$$

$$M_2 = 0.025 M$$

## 35.3 Strong Acids and Bases

Strong acids and bases completely dissociate in water.

### 35.3.1 Strong Acids

- $HCl$
- $H_2SO_4$
- $HBr$
- $HI$
- $HNO_3$
- $HClO_4$

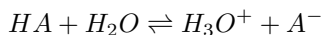
### 35.3.2 Strong Bases

- Group 1 - Hydroxides
  - ▷  $NaOH$
  - ▷  $KOH$
- Group 2 - Heavier Hydroxides
  - ▷  $Ca(OH)_2$
  - ▷  $Sr(OH)_2$
  - ▷  $Ra(OH)_2$

## 35.4 Weak Acids and Bases

Weak acids and bases do not completely dissociate in water.

### 35.4.1 $K_a$ Constant



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

Example
Benzoic acid dissociates as follows:
$HC_7H_5O_2 \rightleftharpoons \underbrace{H^+ + C_7H_5O_2^-}_{x^2}$
$[HC_7H_5O_2] = 0.4 \text{ M}$ $K_a = 6.3 * 10^{-5}$
What is the pH?
$K_a = \frac{[H^+][C_7H_5O_2^-]}{[HC_7H_5O_2]}$ $6.3 * 10^{-5} = \frac{x^2}{0.4}$

### 35.4.2 $K_b$ Constant

The  $K_b$  constant is used when bases are involved in a reaction (as opposed to  $K_a$  which is used in reactions with acids). To convert between  $K_b$  and  $K_a$  use the following formula:

$$K_a * K_b = K_w$$

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

Example
$F^- + H_2O \rightleftharpoons HF + OH^-$
$K_a = 7.2 * 10^{-4}$
What is the $K_b$ constant?
$K_b = \frac{1 * 10^{-14}}{7.2 * 10^{-4}} = 1.39 * 10^{-11}$
Find the pH and pOH.
$K_b = \frac{[HF][OH^-]}{[F^-]}$ $1.39 * 10^{-11} = \frac{x^2}{(\frac{0.002}{20+13.3})}$ $x = 9.13 * 10^{-7}$ $pOH = 6.04$ $pH = 7.96$

### 35.5 Common Ion Effect

The effect of ionization of a weak electrolyte (acid/base) is **decreased** by adding a strong electrolyte that has an ion in common with the weak electrolyte.

### 35.6 Buffer

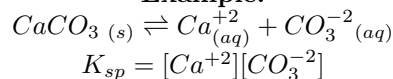
Made of 2 components:

1. Weak acid
2. The salt of that acid

## 36 Equilibrium of Saturated, Soluble Salts

Solubility is how well a solute dissolves in a solvent<sup>4</sup>.

**Example:**



- $K_{sp}$  is the solubility product
  - ▷ A large  $K_{sp}$  means the solution is very soluble (meaning lots of products)
  - ▷ A small  $K_{sp}$  means the solution is not very soluble.

1. Given  $K_{sp}$ , find the ion concentration.

$$K_{sp} = [\text{Ca}^{+2}][\text{CO}_3^{-2}] = 4.5 * 10^{-9}$$
$$[\text{Ca}^{+2}] = [\text{CO}_3^{-2}] = \sqrt{4.5 * 10^{-9}} = 6.7 * 10^{-5} \text{ M}$$

2. Given  $K_{sp}$ , find the solubility (g/L).

$$6.7 * 10^{-5} \text{ M} = \frac{6.7 * 10^{-5}}{1} * \frac{100.1}{1 \text{ mole}} = 6.37 * 10^{-3} \text{ g/L}$$

3. Given solubility, find ion concentration.

*Solubility of Silver Chloride at 25°C is  $1.3 * 10^{-7} \frac{\text{g}}{100 \text{ mL}}$*

$$1.3 * 10^{-7} \frac{\text{g}}{100 \text{ mL}} \rightarrow \frac{\text{g}}{\text{L}} * \frac{10}{10} = 1.3 * 10^{-6} \frac{\text{g}}{\text{L}}$$
$$\frac{1.3 * 10^{-6}}{\text{L}} * \frac{1 \text{ mole}}{143.35 \text{ g}} = 9.11 * 10^{-9} \frac{\text{m}}{\text{L}}$$

4. Given solubility, find  $K_{sp}$

$$K_{sp} = [\text{Ag}^{+}][\text{Cl}^{-}] = (9.11 * 10^{-9})^2 = 8.3 * 10^{-17}$$

## 37 Kinetic Molecular Theory

### 37.1 Postulates:

- The volume of the individual particles of a gas can be assumed to be negligible.
  - ▷ So volume is determined by the space between molecules
- The gas particles are in constant motion. The pressure exerted by a gas is due to collisions of the gas with the walls of the container.
- Gas particles are not attracted to one another.
- The average kinetic energy of a gas is directly proportional to the Kelvin temperature.

$$\overline{K_{energy}} = \frac{3}{2}(0.0821)T$$

**OR**

$$\overline{K_{energy}} = \frac{1}{2}(Molar \ Mass)(Velocity)^2$$

A) CO at 760 torr and 0°C

B) N<sub>2</sub> at 760 torr and 0°C

C) H<sub>2</sub> at 760 torr and 0°C

Q. Which will have the highest kinetic energy?

A. All will have the same kinetic energy

Q. Which will have a higher velocity?

A. H<sub>2</sub> will because if all kinetic energies are constant according to the formula  $k = \frac{1}{2}mv^2$  the smallest mass will yield the highest velocity to keep k constant.

---

<sup>4</sup>Virtually every salt is soluble to some degree.

## 37.2 Root Mean Square Velocity

$$U_{rms} = \sqrt{\frac{3RT}{M}}$$

- $R = 8.314 \frac{J}{K \cdot Mole}$
- $M =$  molar mass (Kg/mole)  
▷ **NOT** g/mole

## 37.3 Effusion and Diffusion

### 37.3.1 Effusion

When you pass a gas through a small opening into an evacuated chamber.

### 37.3.2 Diffusion

When you mix gases

### 37.3.3 Finding the rate

The formula for finding the rate is as follows:

$$\frac{\text{Rate of Effusion of Gas 1}}{\text{Rate of Effusion of Gas 2}} = \frac{\sqrt{(\text{Molar Mass 2})}}{\sqrt{(\text{Molar Mass 1})}}$$

- Which effuses faster,  $He$  or  $NO_2$ ?  
▷  $He$  - it moves faster because it is smaller
- For the reaction:  $H_2 + N_2$  at  $20^\circ C$  and having a rate of effusion for  $H_2$  being 10 mL/min what is the rate for  $N_2$ ?  
▷  $\frac{10}{x} = \frac{\sqrt{28}}{\sqrt{2}}$   
 $x = \frac{10\sqrt{2}}{\sqrt{28}} = 2.67 \text{ ml/min}$
- The rate for the gas is 24 mL/min, at the same temperature methane has a rate of 47.8 mL/min. What is the molar mass of the unknown gas?  
▷  $\frac{24}{47.8} = \frac{\sqrt{16}}{\sqrt{x}}$   
 $x = 63.7 \text{ g/mole}$

## 38 Electro Chemistry

### 38.1 Identifying Oxidation Numbers

$H_2O$	$H_2SO_4$	$Cl_2$
H +1	H +1	Cl 0
O -2	S +6	
	O -2	

The chemical that has been **oxidized** is the **reducing agent**. The chemical that has been **reduced** is the **oxidizing agent**.

### 38.2 Galvanic/Voltaic Cells

There are two beakers with salt and  $e^-$ s in each solution. A salt bridge between the two solutions allows passage of ions. One side is identified as the cathode and the other the anode. The cations go to the cathode and the anions go to the anode. The  $e^-$ s go to the cathode.

## 38.3 Calculating Cell Potential

$$E^\circ_{cell} = E^\circ_{reduction} + E^\circ_{Oxidation}$$

<b>Example</b>
$Cu^{+2} + Zn \rightarrow Zn^{+2} + Cu$
<b>Oxidation</b> $Zn \rightarrow Zn^{+2} + 2e^-$ $e^\circ = 0.76$
<b>Reduction</b> $Cu^{+2} + 2e^- \rightarrow Cu$ $e^\circ = 0.34$
$E^\circ_{cell} = 0.34 + 0.76 = 1.1 \text{ volts}$

### 38.3.1 Nernst Equation to Find $E^\circ_{cell}$

The Nernst equation to be used under standard conditions is:

$$E^\circ_{cell} = E^\circ - \frac{0.0592}{n} \log(Q)$$

- $E^\circ$  = Normal standard potential
- n = Number of moles of  $e^-$ s changing
- Q = Reaction Quotient =  $\frac{[Product]}{[Reactant]}$

<b>Example</b>
$Cu_{(s)} + \underbrace{Cu^{+2}}_{1 \text{ M}} \rightarrow \underbrace{Cu^{+2}}_{0.1 \text{ M}} + Cu_{(s)}$
$Q = \frac{0.1}{1} = 0.1$
n = 2 (2 $e^-$ being transferred)
$E^\circ = 0(1M - 1M = \text{Novoltage})$
$E^\circ_{cell} = 0 - \frac{0.0592}{2} \log(0.1)$

This Nernst equation is to be used when **the temperature is not standard** and **the concentrations are not equal**.

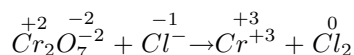
$$E^\circ_{cell} = E^\circ - \frac{RT}{nF} \ln(Q)$$

- R =  $9.31 \frac{\text{volt coulomb}}{\text{mole Kelvin}}$
- F = 96,500 per mole  $e^-$
- T = Temperature in Kelvin

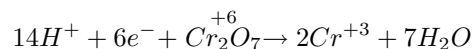
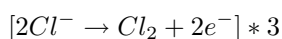
<b>Example</b>
$Zn + \underbrace{Cu^{+2}}_{2 \text{ M}} \rightarrow Cu + \underbrace{Zn^{+2}}_{0.5 \text{ M}}$
$E^\circ_{cell} = 1.1 - \frac{0.0592}{2} \log\left(\frac{0.5}{2}\right)$
$E^\circ_{cell} = 1.1178 \text{ volts}$

## 39 Balancing Redox Reactions

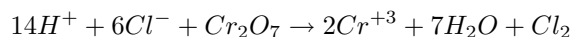
### 39.1 Acidic



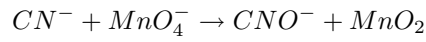
#### Half-Reactions



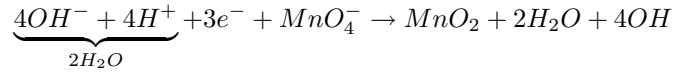
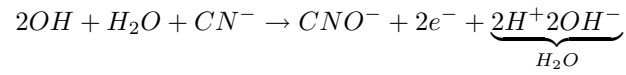
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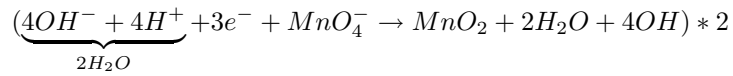
## 39.2 Basic



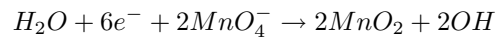
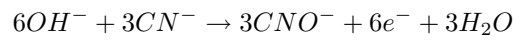
### Half-Reactions



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