Video Instructions if Interested

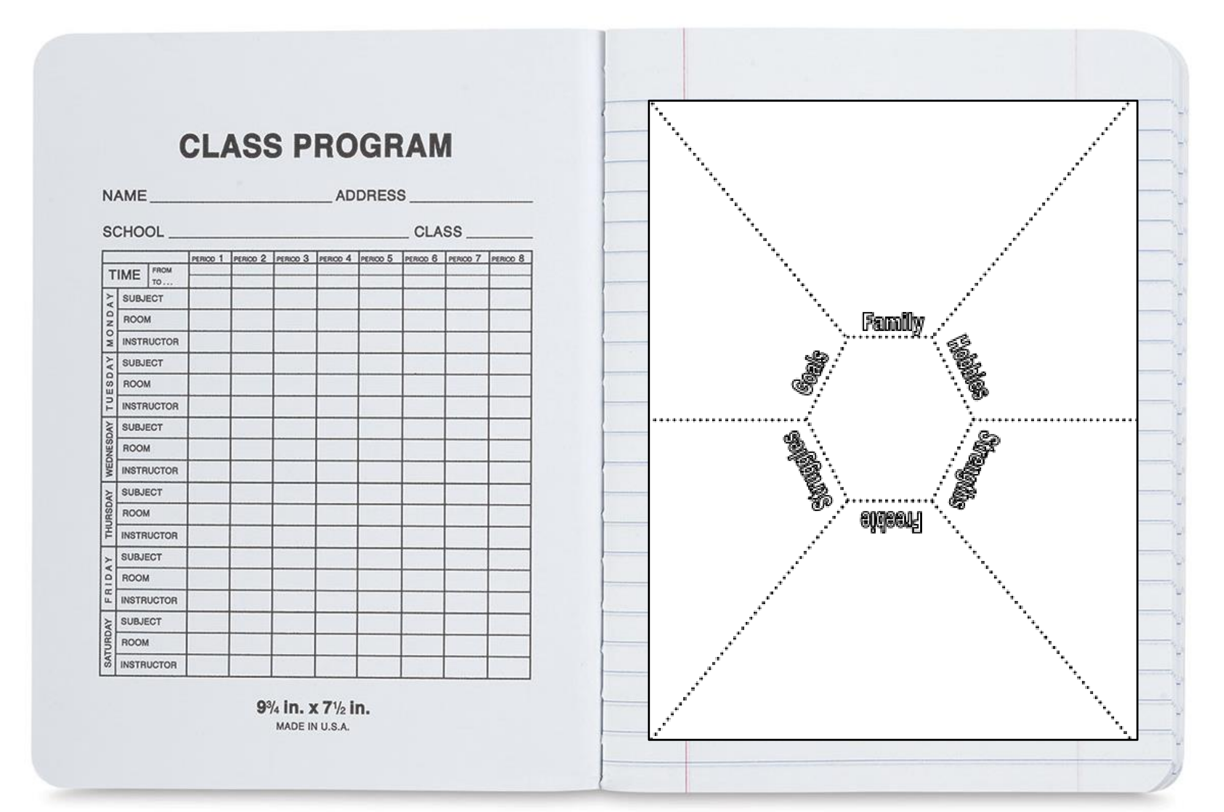
- https://youtu.be/FkEX56_sZOk

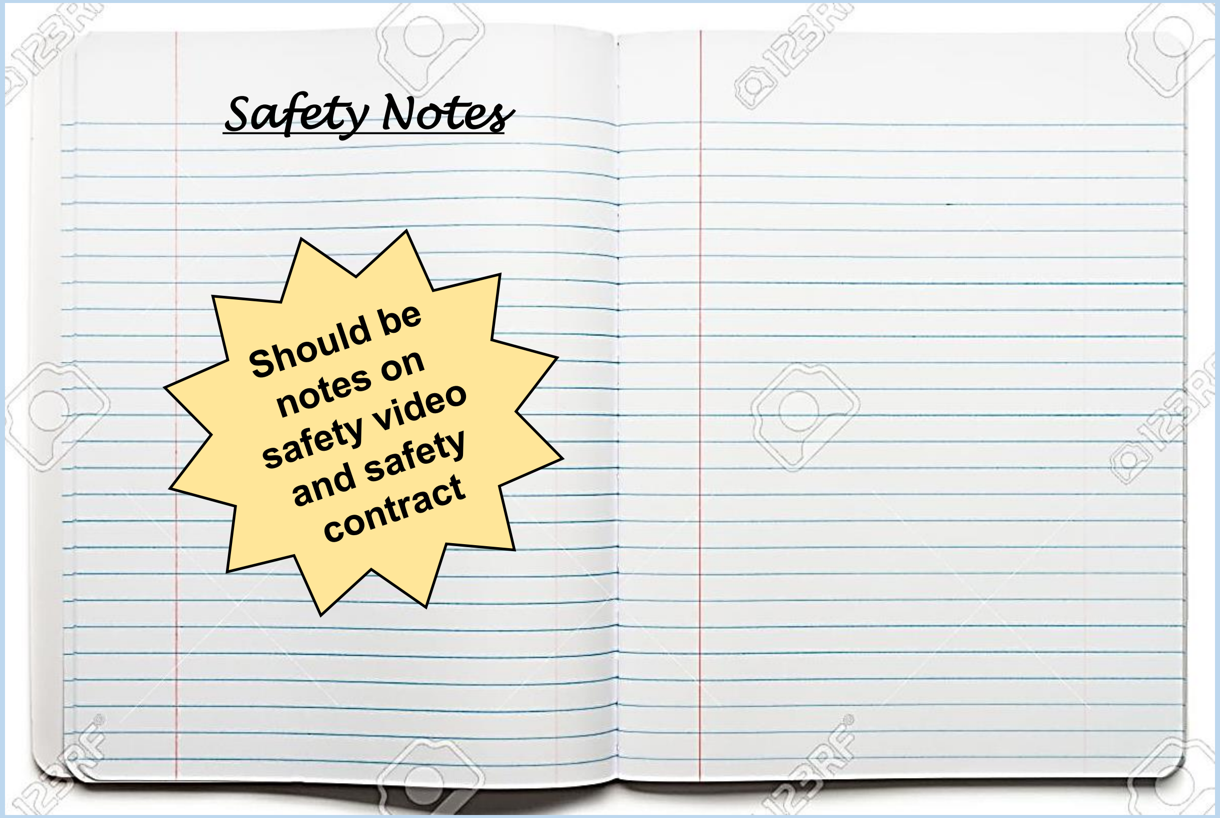
Crash Course:

N1 - Honors Chem Review

How to set up your composition notebook

- Your notebook should look like this so far…

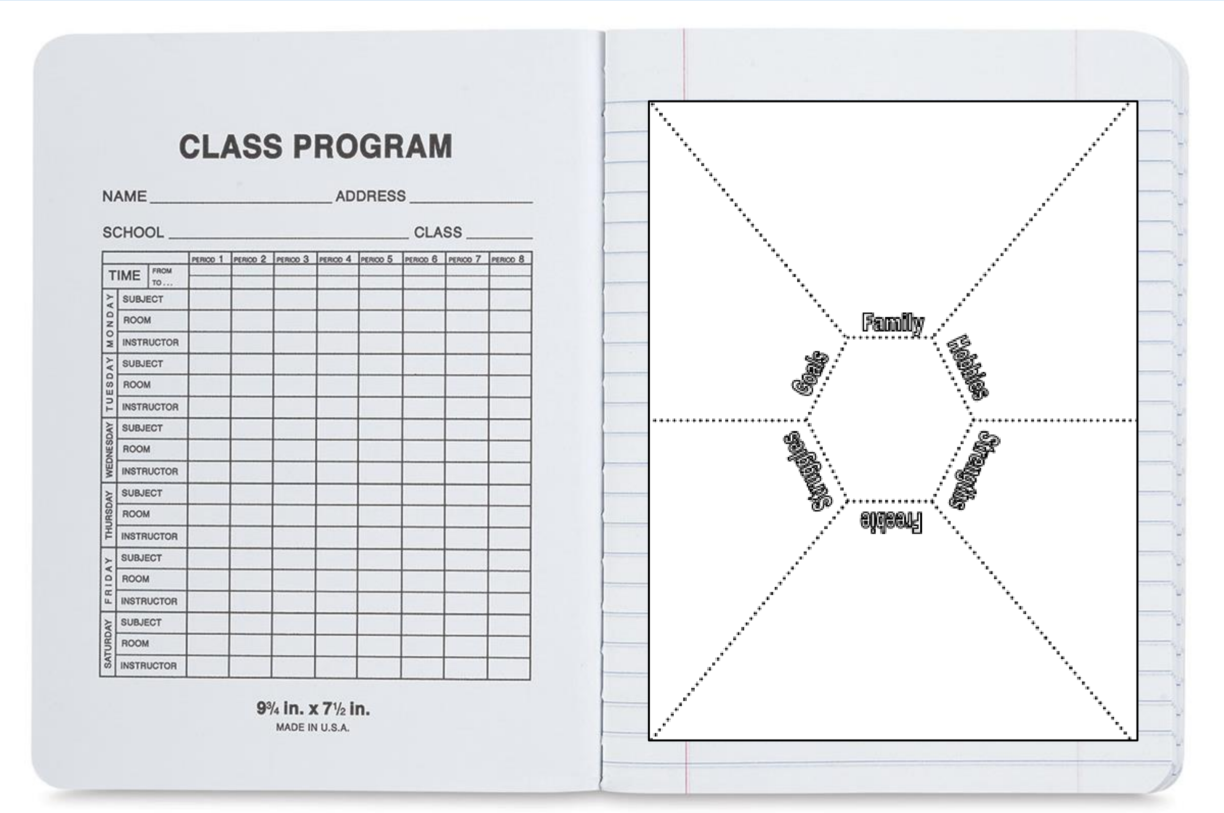


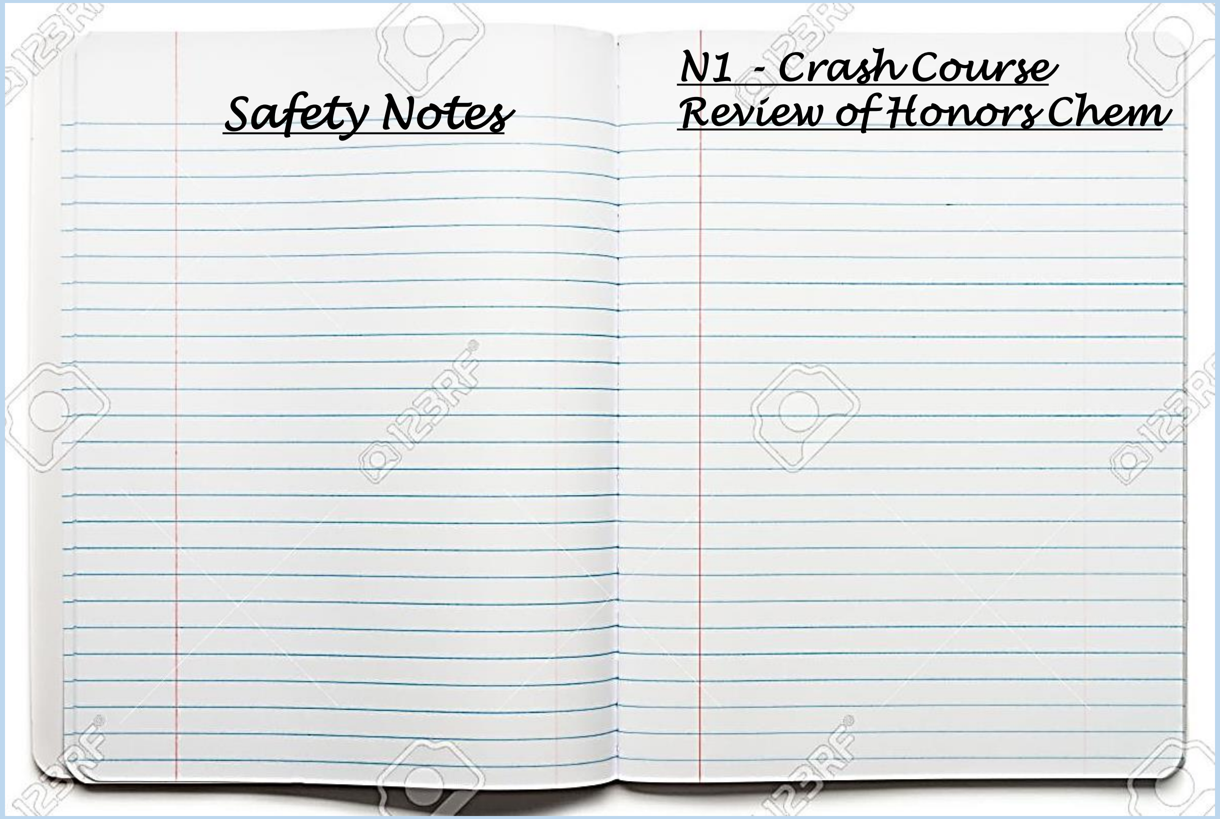


Page 1 **Page 2** **Page 3**

<u>How to set up your composition notebook</u>

- Add a bold, obvious, underlined title to the top of your page 3. *<u>"N1 – Crash Course Review of Honors Chem"</u>*



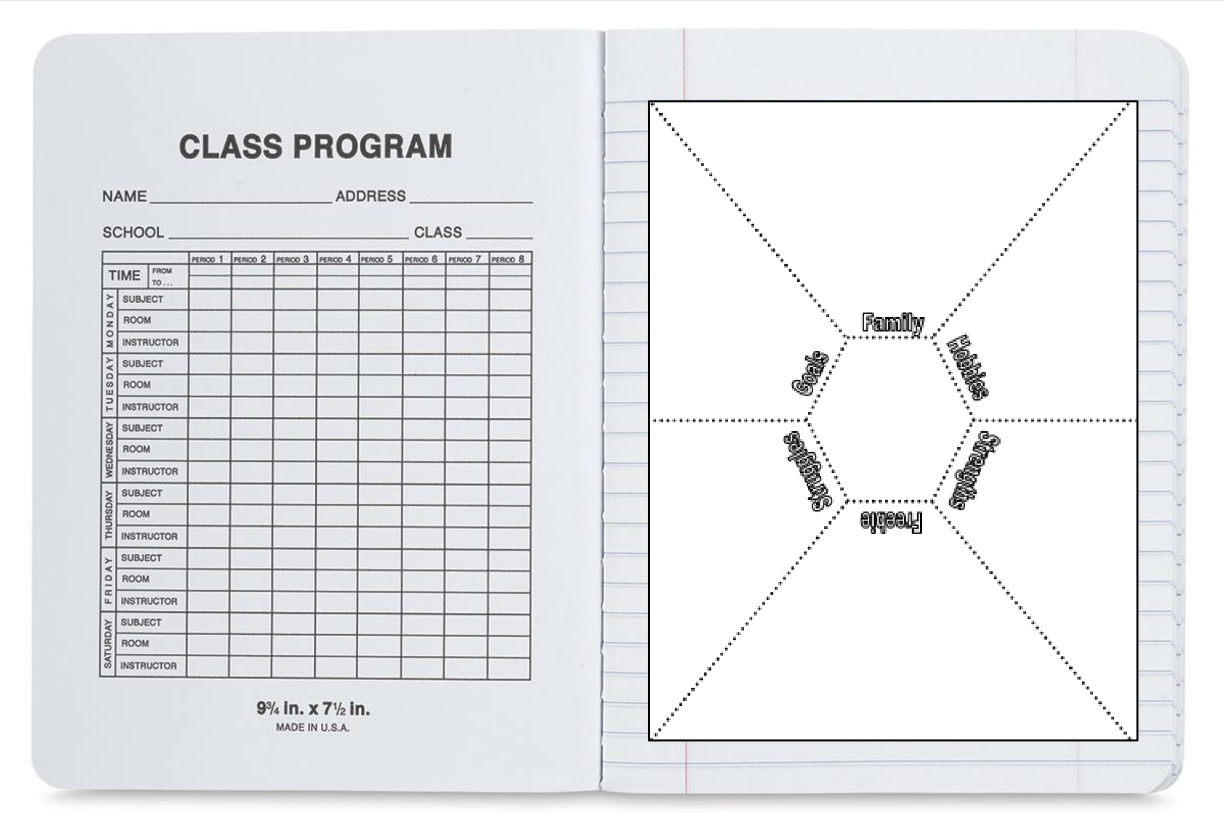


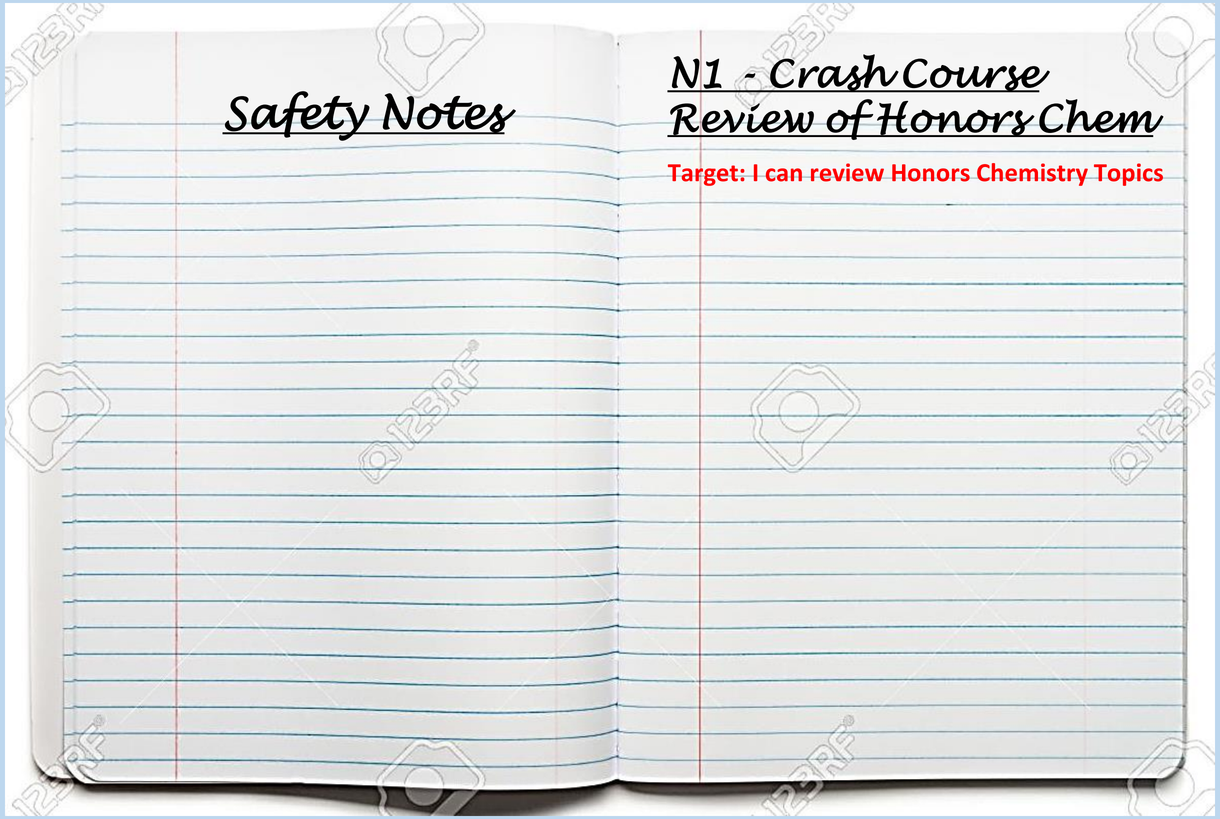
Page 1 **Page 2** **Page 3**

How to set up your composition notebook

- In RED pen, add the “Target” under the title

“Target: I can review Honors Chemistry Topics

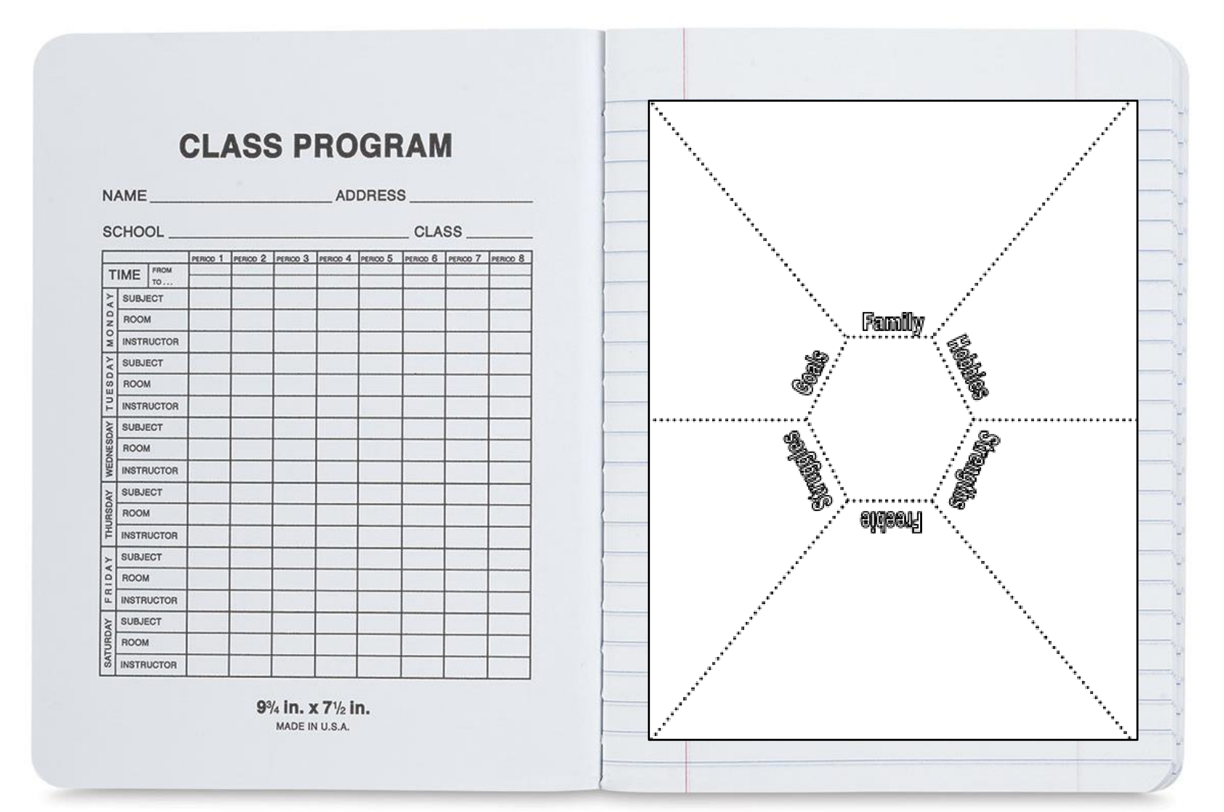


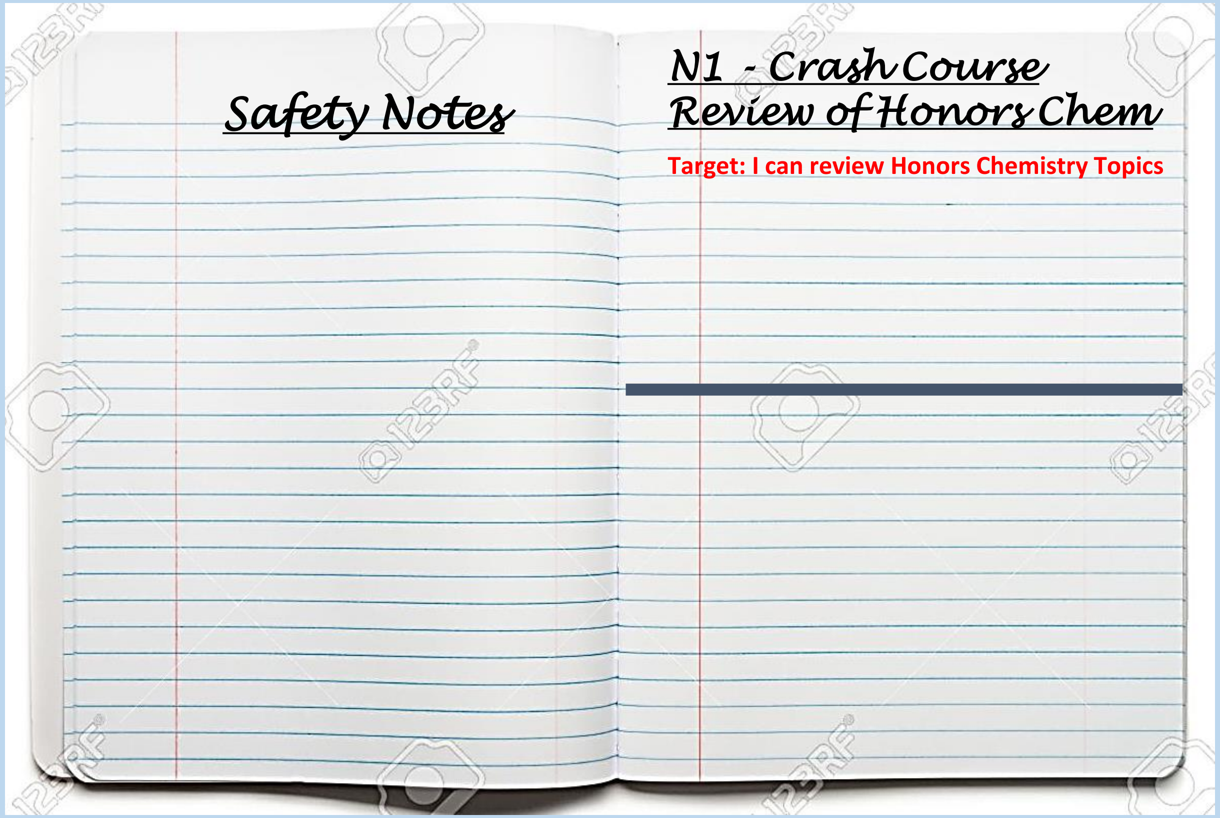


Page 1 **Page 2** **Page 3**

You will divide Pages 3 – 9 in half

- You can use the top and side margin space!

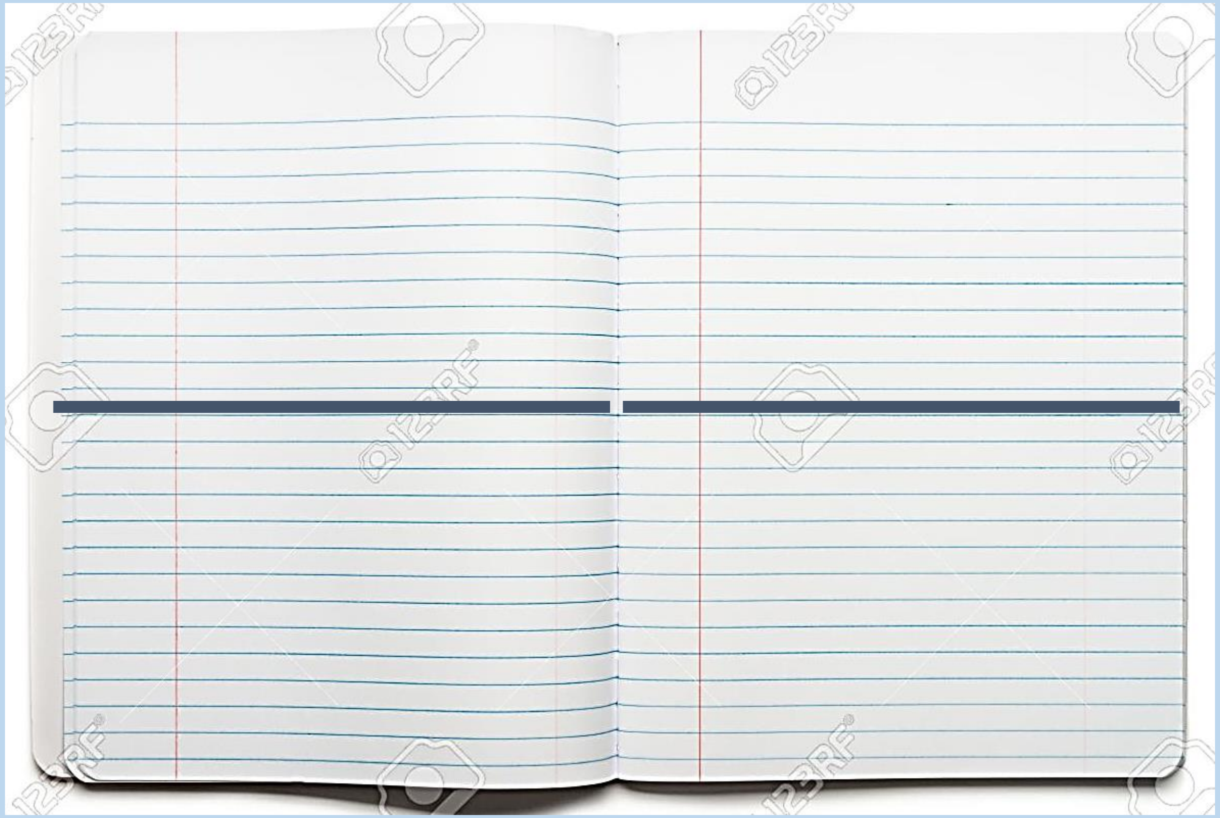




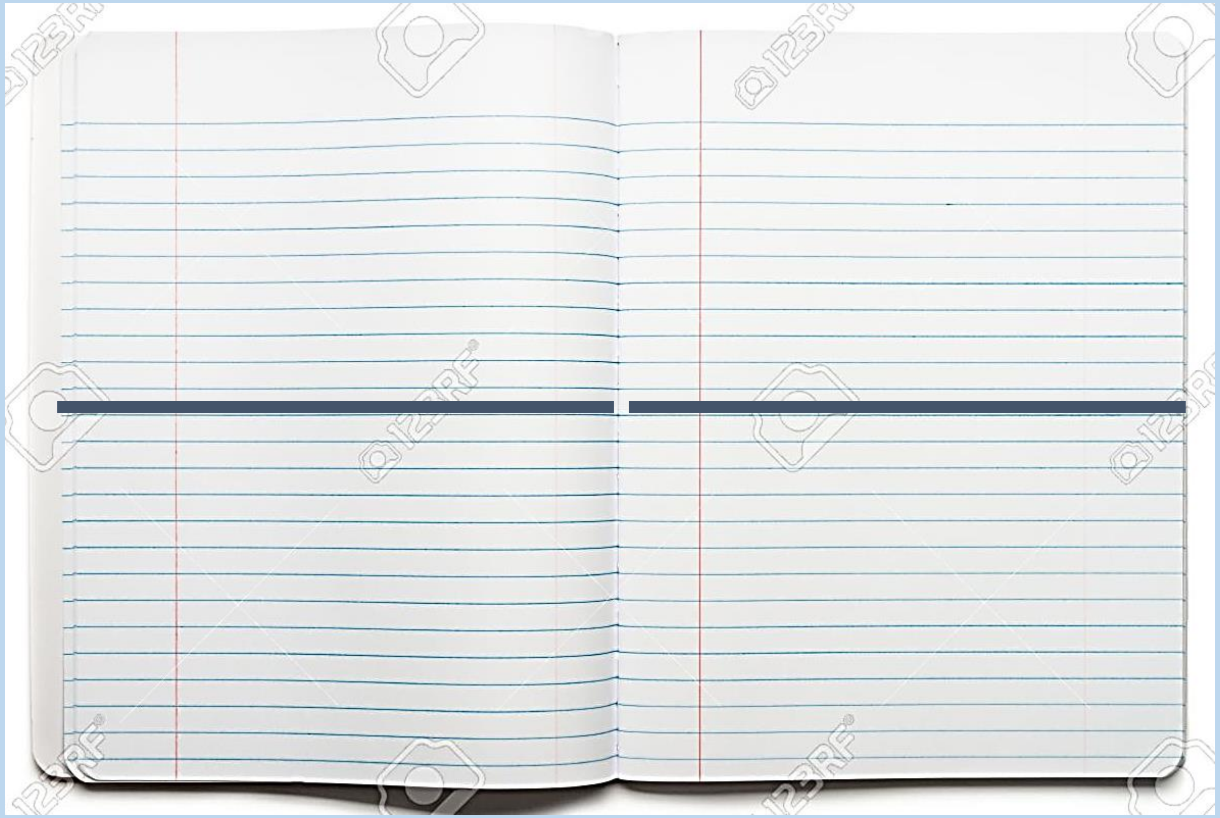
Page 1 Page 2 Page 3

You will divide Pages 3 – 9 in half

- You can use the top and side margin space!



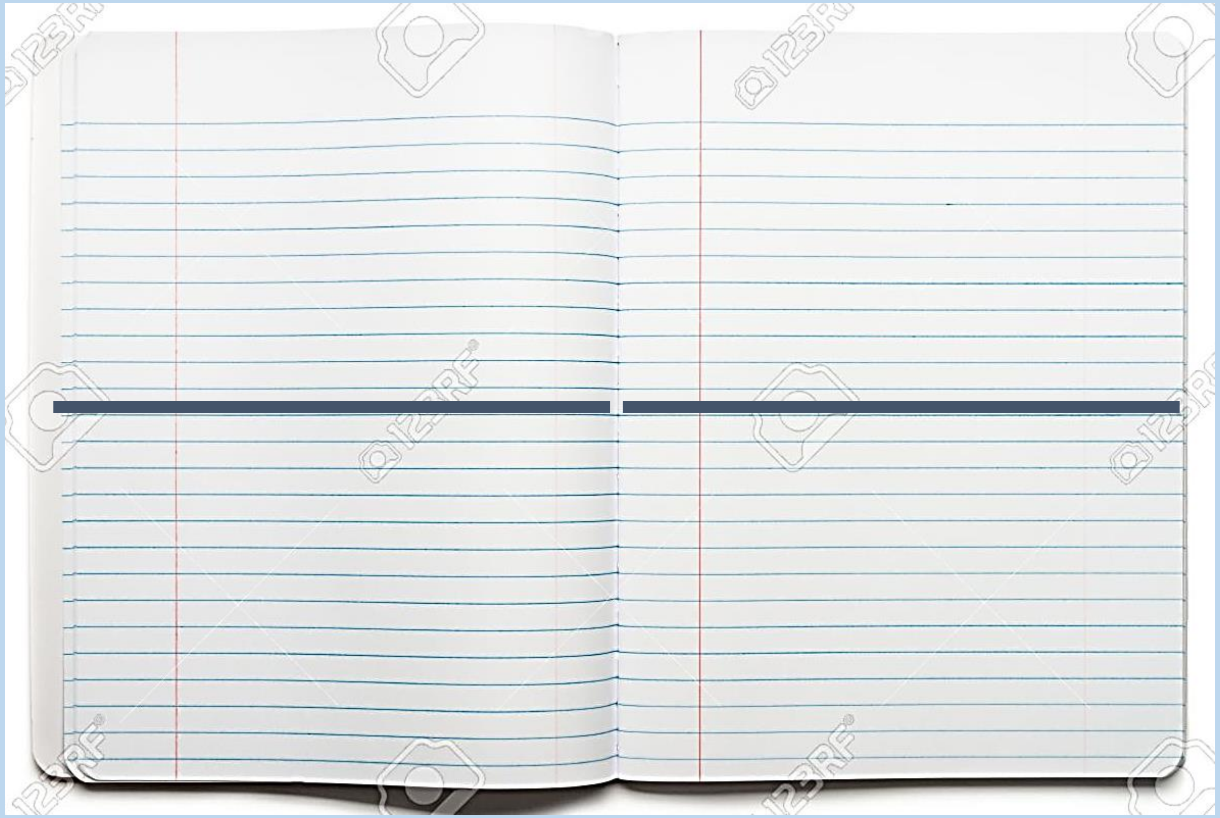
Page 4 Page 5



Page 6 Page 7

You will divide Pages 3 – 9 in half

- Title Page 10 “#15 - Summer Assignment Topics”



Page 8 Page 9 Page 10 Page 11

Now you will label the boxes so you have one box per chapter taught in Honors Chemistry

#1 – Basics and Atomic Structure	#8 – Advanced Chemical Ratios
#2 – Nuclear Chemistry	#9 – Gas Laws
#3 – Electrons	#10 – Thermochemistry
#4 – Periodic Table	#11 – Solutions
#5 – Bonding and Structure	#12 – Kinetics
#6 – Reactions	#13 – Equilibrium
#7 – Stoichiometry	#14 – Acids and Bases
	#15 – Summer Assignment Topics

Now you will label the boxes so you have one box per chapter taught in Honors Chemistry

- Example shown →
- Chapter #'s and Titles on the next slide for you to finish.
- All boxes pages 3-10 should end up with Chapter #'s and Titles

Page 2 Page 3

Time for some self guided review notes!

- The rest of this PowerPoint has screen shots of key pieces of information from the Honors Chem Lectures.
- Please scroll through and jot down notes into your composition book, in the boxes that match the chapter.
- You do NOT need to take super detailed notes on every little thing. This is just a place to jog your memory, write down key equations you might want to remember, etc. Do NOT panic that this PowerPoint is almost 300 slides long! ☺
- If you find that you need MORE info on a topic, then use the class website to pull up the full lecture, or even rewatch lectures on my YouTube Channel. www.mychemistryclass.net
- You will have until the end of the 3rd week of school to complete this assignment. Chip away at it here and there.

*Note about remote learning impacts on topics covered

- In March 2020 school transitioned to "Remote Learning"
- Due to the school closing in March 2020 some topics were not covered in as much detail as a normal year, or not covered at all.
- Therefore two years of Honors Chem students did not cover the topics needed to start AP Chem like normal.
- All required topics are talked about on the Summer Assignment so you should be caught up.
- Items marked with a (*) were not covered in class during the 2019-2020 school year due to school closing in March 2020.
- Items marked with a (**) were not covered in the 2020-2021 school year due to "remote teaching" limiting what we could cover because of reduced instructional minutes.

Unit #1
Chemistry Basics and Atomic Structure

- Scientific notation
- Metric system
- Dimensional analysis
- Significant figures
- Chemical/Physical properties/changes
- Types of matter
- Atomic numbers and Isotopes
- Models of the atom
- Average Atomic Mass Calculations

Scientific Notation

Jump back to title slide

Tired of really big or really small numbers???

- Use scientific notation!
- Move your decimal and rewrite it in "scientific notation format"

$3 . 54 \times 10^{2}$

"x 10 $^{\text{EXPONENT}}$" is the same a

E

$3.54E^{2}$

One # | • | Rest of the #s | x | 10 | Exponent

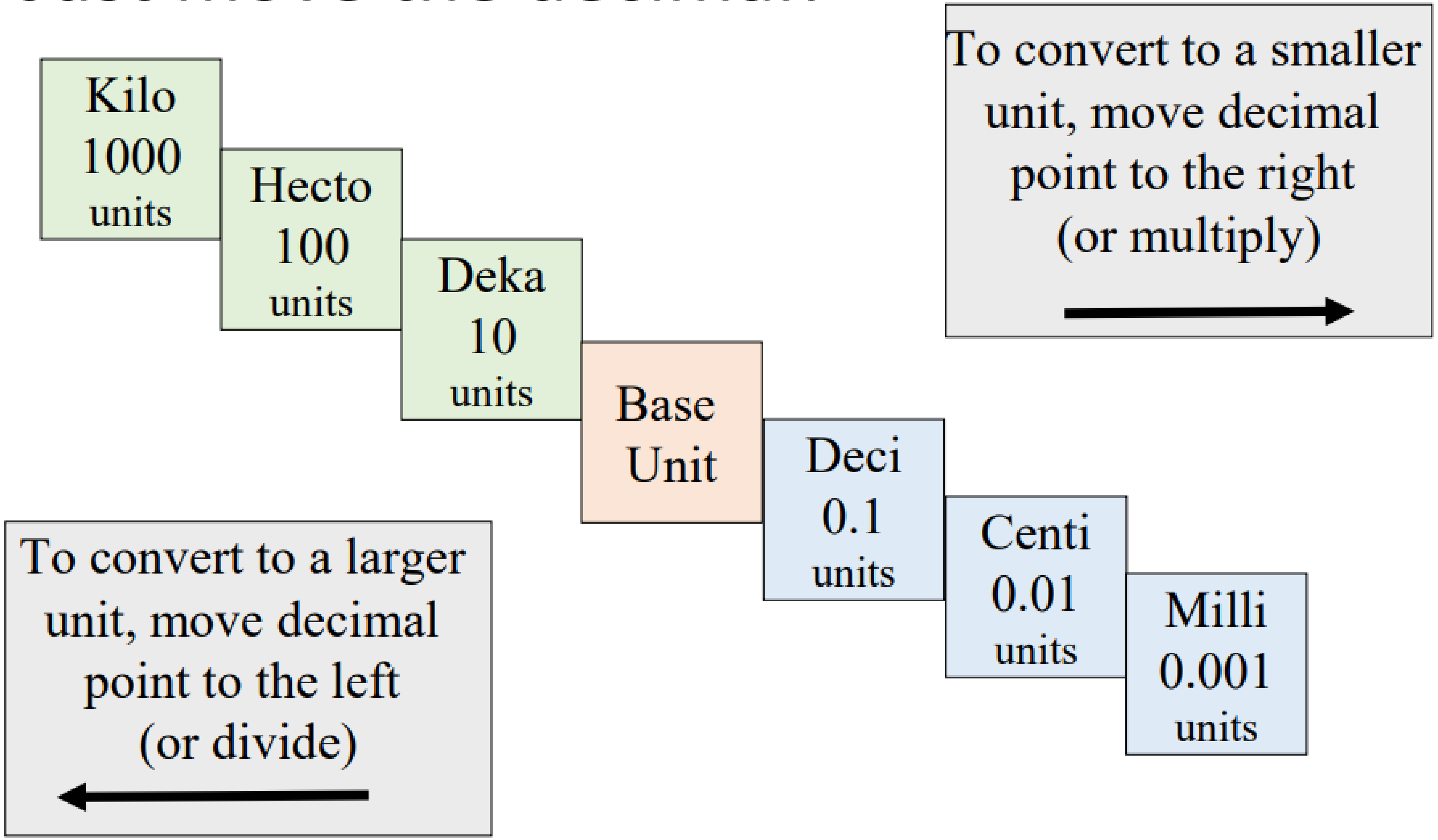
(telling how many times to move the decimal, and which way to move it!)

Metric System

[Jump back to title slide]

Converting Metric System

- Just move the decimal!



Metric System

Jump back to title slide

How do I remember the prefixes?

King Henry Died By Drinking Chocolate Milk

K	H	D	B	D	C	M
I	E	E	a	E	E	I
L	C	K	s	C	N	L
O	T	A	e	I	T	L
	O				I	I

Derived Units

Jump back to title slide

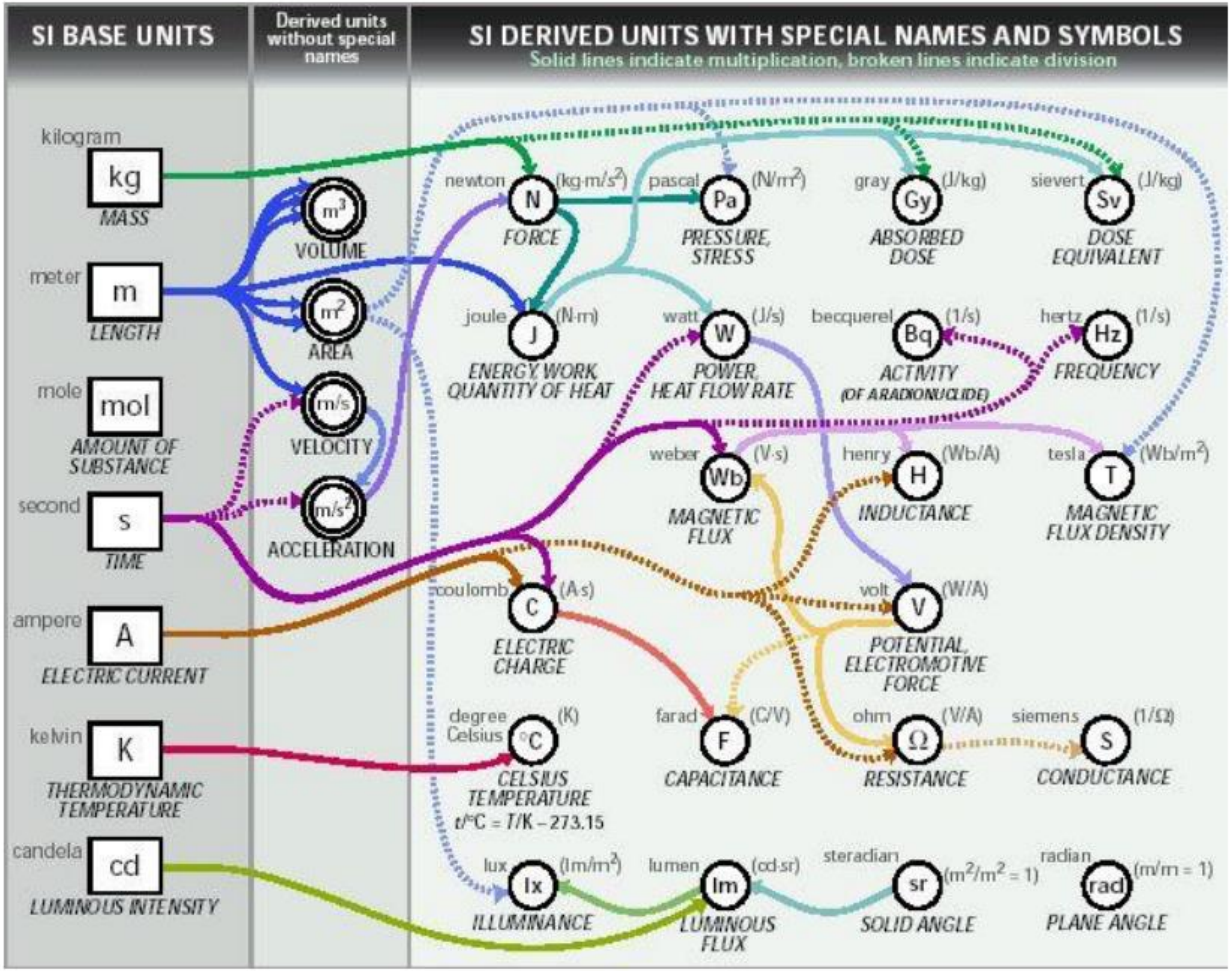
Derived Units

- Made by combining multiple units together
- Examples:

miles/hour	=	speed in our cars in US
cm^3	=	volume
m/s^2	=	acceleration
$kg \cdot m/s^2$	=	newton (measures force)

Derived Units

[Jump back to title slide]



Dimensional Analysis

Jump back to title slide

Remember - Canceling Units

One on top cancels with one on the bottom

$$\frac{\cancel{x}y}{\cancel{x}} = y$$

$$\frac{15\ c\cancel{m}^3}{5\ \ c\cancel{m}} = 3\ cm^2$$

Dimensional Analysis

Jump back to title slide

Conversion Factors

You can flip conversion factors too

12in = 1ft   24hrs = 1,440min

Just depends on what you are doing

$$\frac{12\text{in}}{1\text{ft}} = 1 \qquad \frac{1\text{ft}}{12\text{in}} = 1$$

$$\frac{24\text{hr}}{1{,}440\text{min}} = 1 \qquad \frac{1{,}440\text{min}}{24\text{hr}} = 1$$

Dimensional Analysis

Jump back to title slide

Line Method

Keeps work neat, tidy, takes less space, easier to grade, a very typical way to show conversions in chemistry. I will always use the line method!

Convert 15years into minutes

$$15yrs\ x\frac{365days}{1\ yr}x\frac{24hrs}{1\ day}\ x\frac{60min}{1hr}=7.9x106min$$

15 yrs	365 days	24 hr	60 min	= 7.9 x 10^6 min
	1yr	1 day	1 hr	

Dimensional Analysis

[Jump back to title slide]

Dimensional Analysis with "Derived/Double Units"

Some units are combinations of two or more other units. Like miles per hour (mi/hr). Fix the top unit, then go back and fix the bottom unit

Convert 20mi/hr into in/sec.

20mi	5280ft	12in	1hr	1min
1hr	1mi	1ft	60min	60sec

$$= 352\ \frac{in}{sec}$$

Significant Figures

Jump back to title slide

Nonzero Integers	ALWAYS COUNT as SIGNIFICANT	3456 has 4 sig figs
Leading Zeros	NEVER COUNT as SIGNIFICANT	0.0486 has 3 sig figs
Captive Zeros	ALWAYS COUNT as SIGNIFICANT	16.07 has 4 sig figs.

Significant Figures

Jump back to title slide

Trailing Zeros	AFTER A DECIMAL ALWAYS COUNT as SIGNIFICANT	9.300 has 4 sig figs.
SOMETIMES COUNT as SIGNIFICANT	NO DECIMAL NEVER COUNT as SIGNIFICANT	9300 has 2 sig figs.

Exact Numbers	INFINITE NUMBER of sig figs	1in = 2.54cm 12in = 1ft

Significant Figures

Jump back to title slide

Multiplication & Division	Answer based on LEAST number of SIG FIGS in the problem	6.38 x 2.0 = *3 SF* *2SF* 12.76 → 13 *(2 sig figs)*
Addition & Subtraction	Answer based on LEAST number of DECIMAL PLACES in the problem	6.8 + 11.934 = *1DP* *3DP* 18.734 → 18.7 *(3 sig figs)*

Properties and Changes

Jump back to title slide

Physical and Chemical Properties

• **PHYSICAL PROPERTY** a property that a substance displays without changing its composition. – *Odor, taste, color, appearance, melting point, boiling point, and density*	• **CHEMICAL PROPERTY** a property that a substance displays only by changing its composition via a chemical change/rxn – *Corrosiveness, acidity, and toxicity.*

Properties and Changes

Jump back to title slide

Physical Change

- Alter only the **state or appearance**, but not composition
- The atoms or molecules that compose a substance **do not change their identity** during a physical change.

Chemical Change

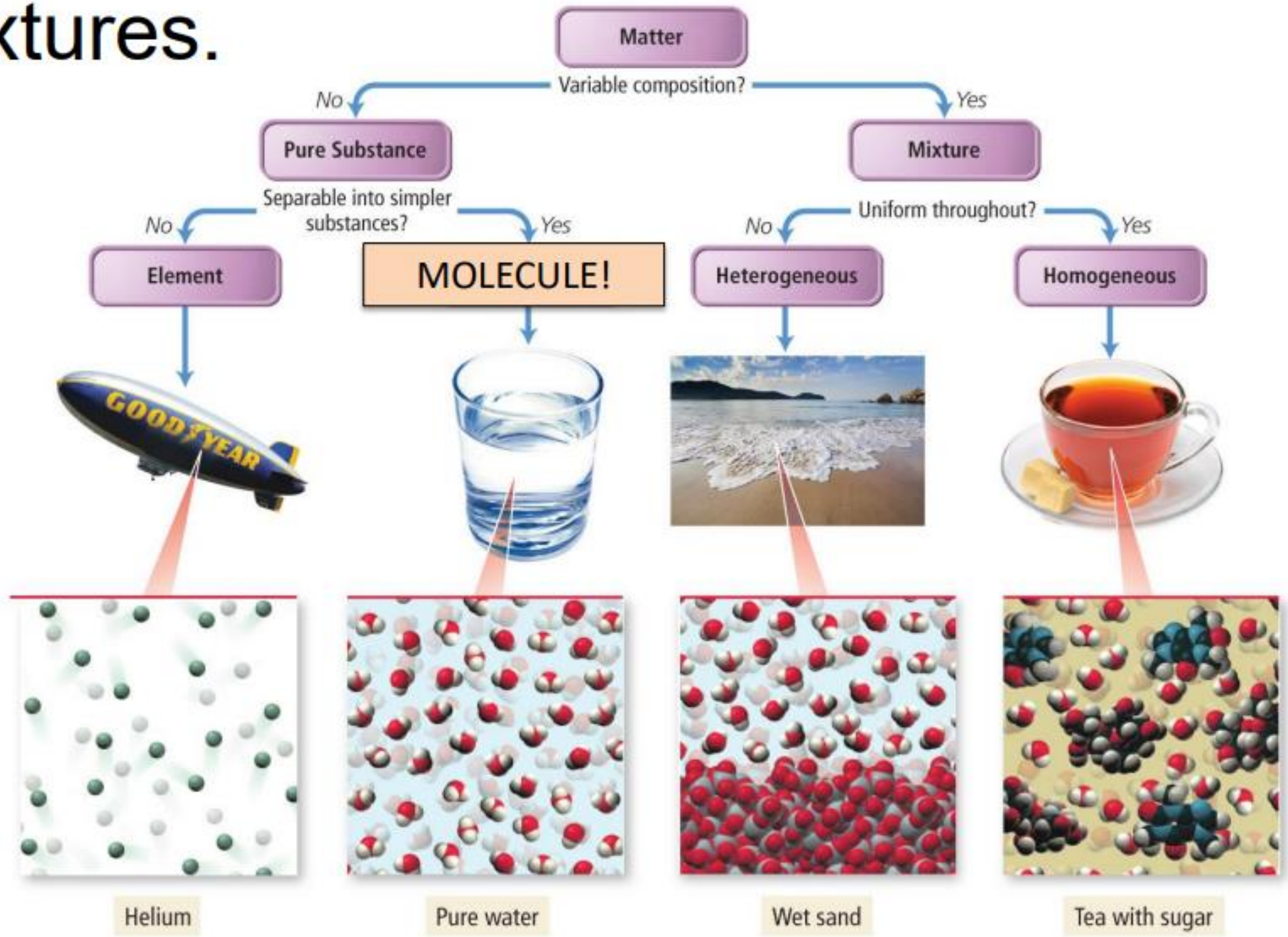
- Alters the **composition/identity** of the substance
- Atoms rearrange, transforming the original substances into **different substances**.

Types of Matter

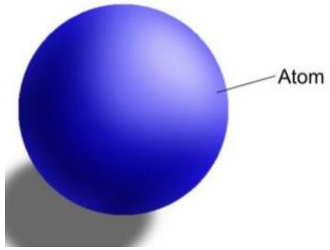
Jump back to title slide

The Classification of Matter by Components

- Elements, compounds, and types of mixtures.



Atomic Models

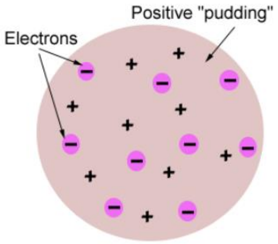


[Jump back to title slide]

DALTON'S BILLIARD BALL MODEL

John Dalton

THOMSON'S ATOMIC MODEL

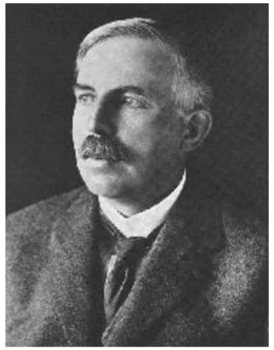


Thomson believed that the electrons were like plums embedded in a positively charged "pudding," thus it was called the "plum pudding" model. We don't usually eat plum pudding in this country, so I like to call it the chocolate chip cookie model.

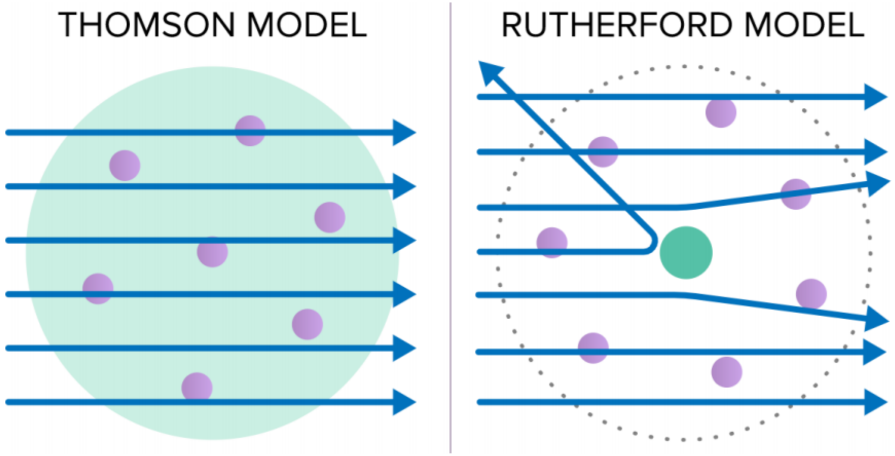
RUTHERFORD'S FINDINGS

1) Most of the particles passed right through
2) A few particles were deflected
3) A FEW were *greatly* deflected

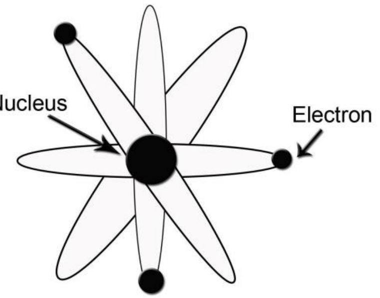
CONCLUSIONS:



- The nucleus is small
- The nucleus is dense
- The nucleus is positively charged
- The atom is mostly empty space

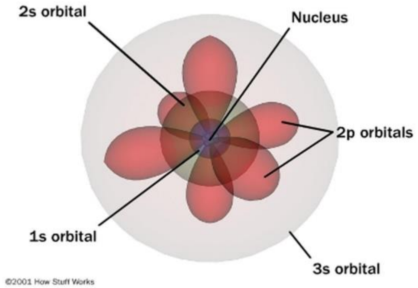


THE BOHR MODEL



The "planet" model because it looks like the planets revolving around the sun. These Electrons have "paths" that they follow around the Nucleus in the center. Usually we DRAW atoms like this but its not accurate!

The Quantum Model



This is a hard model to understand.
The Electrons don't follow paths, they are not objects at all! Instead they are pure charge that has a probability of being somewhere in those orbitals.

Atomic Numbers

Jump back to title slide

ATOMIC NUMBERS

<u>We know:</u> Nucleus has protons (p^+), neutrons (n^0), and electrons(e^-) are on the outside of nucleus

But how many of each???

Atomic Number

\# of protons

\# of electrons = # of protons

3
Li
6.94

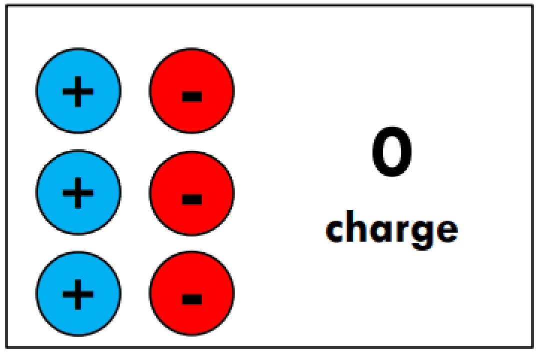
Atomic Mass Number
(round to the nearest whole #)
\# of protons + # of neutrons

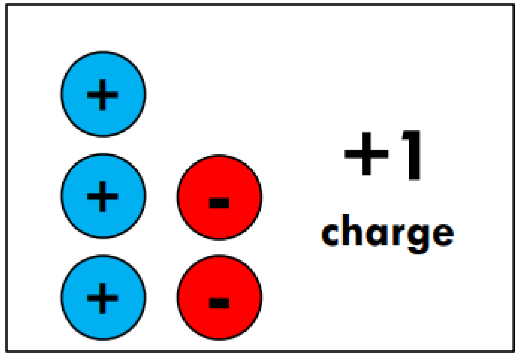
Atomic Numbers

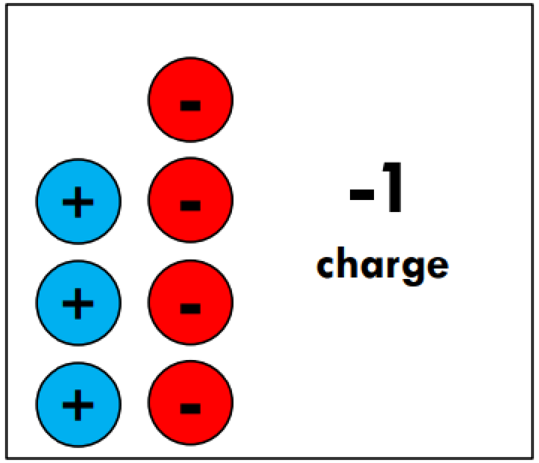
Jump back to title slide

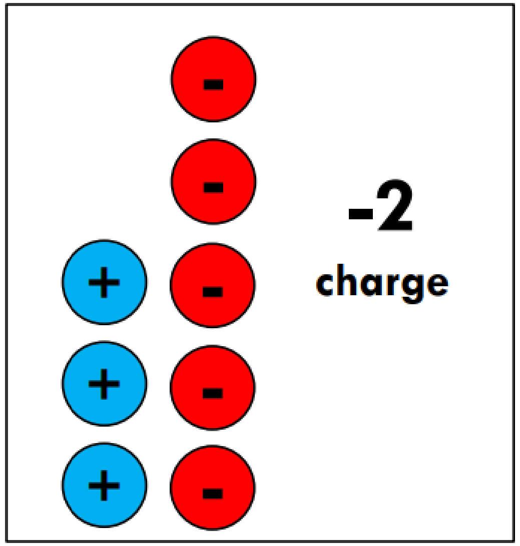
IONS!

Oxygen	Sodium
O^{-2}	Na^{+1}
Negative	Positive
Anion	Cation
Gained electrons	Took away electrons









Average Mass Calcs.

Jump back to title slide

CALCULATING AVERAGE MASS

$$\text{Avg. Mass} = \left(\begin{array}{l} (\text{Mass}_{\text{Isotope1}} \times \%_{\text{abundance1}}) \\ + (\text{Mass}_{\text{Isotope2}} \times \%_{\text{abundance2}}) \\ + (\text{Mass}_{\text{Isotope3}} \times \%_{\text{abundance3}}) \\ \text{etc...} \end{array} \right)$$

Average Mass Calcs.

Jump back to title slide

FINDING % ABUNDANCE

Same equation, just solving for a different variable!

We can use (x) to represent the $\%_{abundance1}$

We can use (1- x) to represent the $\%_{abundance2}$

BECAUSE:

The total has to add up to 100% right?!

100% is the same as 1 to make the math faster

<u>Unit #2</u>
Nuclear Chemistry **

- Why things are radioactive
- Types of radioactive particles
- Writing and balancing nuclear equations
- Decay series
- Half Life

Nuclear Chemistry

Jump back to title slide

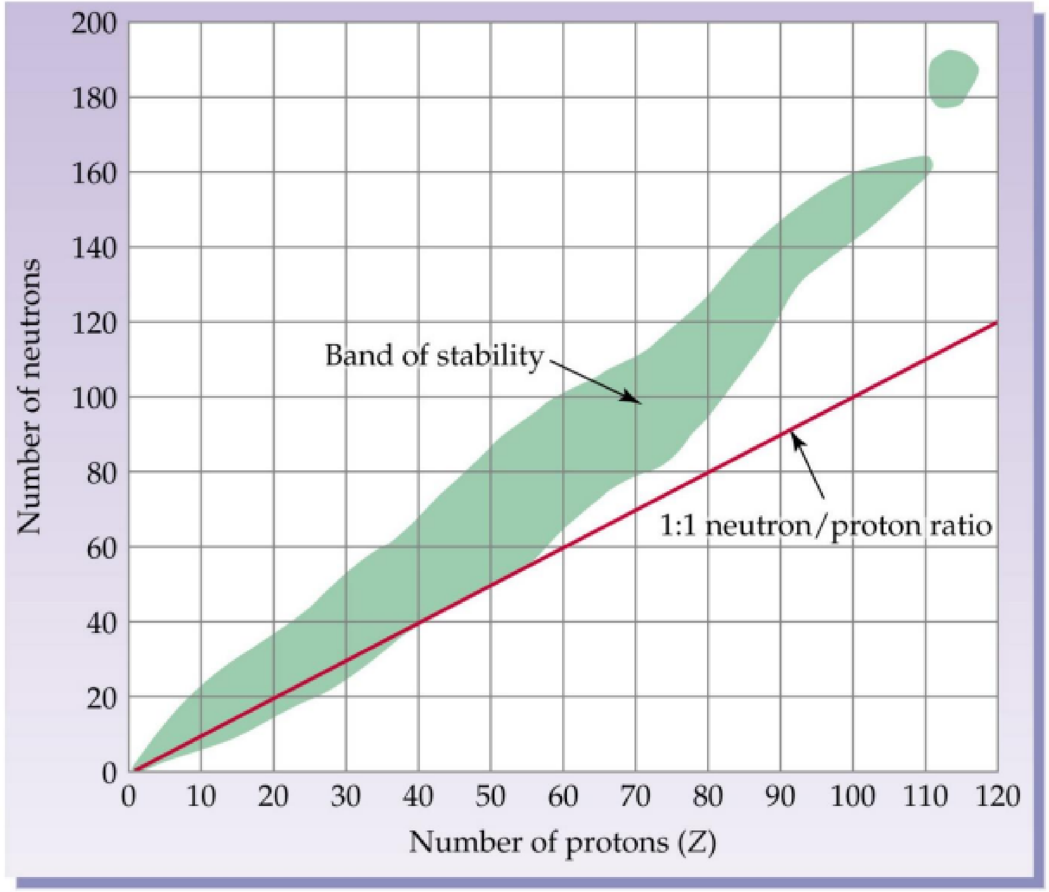
What keeps nuclei together?
Why do they fall apart?

- **STRONG FORCE! –** Holds the nucleus together, even though the protons want to repel each other.
- **Too many neutrons? –** Strong force wont be strong enough, like a rubber band that is stretched too far…it will break!
  - **When it breaks, particles come flying out of the nucleus!**
- **Too many neutrons = radioactive!**

Nuclear Chemistry

Jump back to title slide

Band of Stability and Island of Stability



Radioactive particles

Jump back to title slide

Alpha

Composition	Symbol	Charge	Mass
helium nuclei	$^{4}_{2}He$, α	+2	4amu
Shielding	**Approx. Energy**	**Penetrating power**	
Paper, clothing	5 MeV	Low 0.05mm body tissue	

Beta

Composition	Symbol	Charge	Mass
Same as an electron	e^-, β	-1	1/1837th (basically 0)
Shielding	**Approx. Energy**	**Penetrating power**	
Aluminum foil	0.05-1MeV	Moderate 4mm body tissue	

Gamma

Composition	Symbol	Charge	Mass
High energy electromagnetic radiation	γ	0	0
Shielding	**Approx. Energy**	**Penetrating power**	
Lead, Concrete	1MeV	High Penetrates easily	

Writing Nuclear Equations

Jump back to title slide

Alpha

Mass #

$$^{226}_{88}Ra \rightarrow ^{4}_{2}He + ^{222}_{86}Rn$$

Atomic #

Beta

Mass #

$$^{97}_{40}Zr \rightarrow ^{0}_{-1}e + ^{97}_{41}Nb$$

Atomic #

Jump back to title slide

Sometimes lots of parts! Still just adding/subtracting!

(2 x 1) + 235 = **237**

(3 x 0) + 237 = **237**

$$2\,{}^{1}_{0}n + {}^{235}_{92}U \rightarrow 3\,{}^{0}_{-1}e + {}^{237}_{95}Am$$

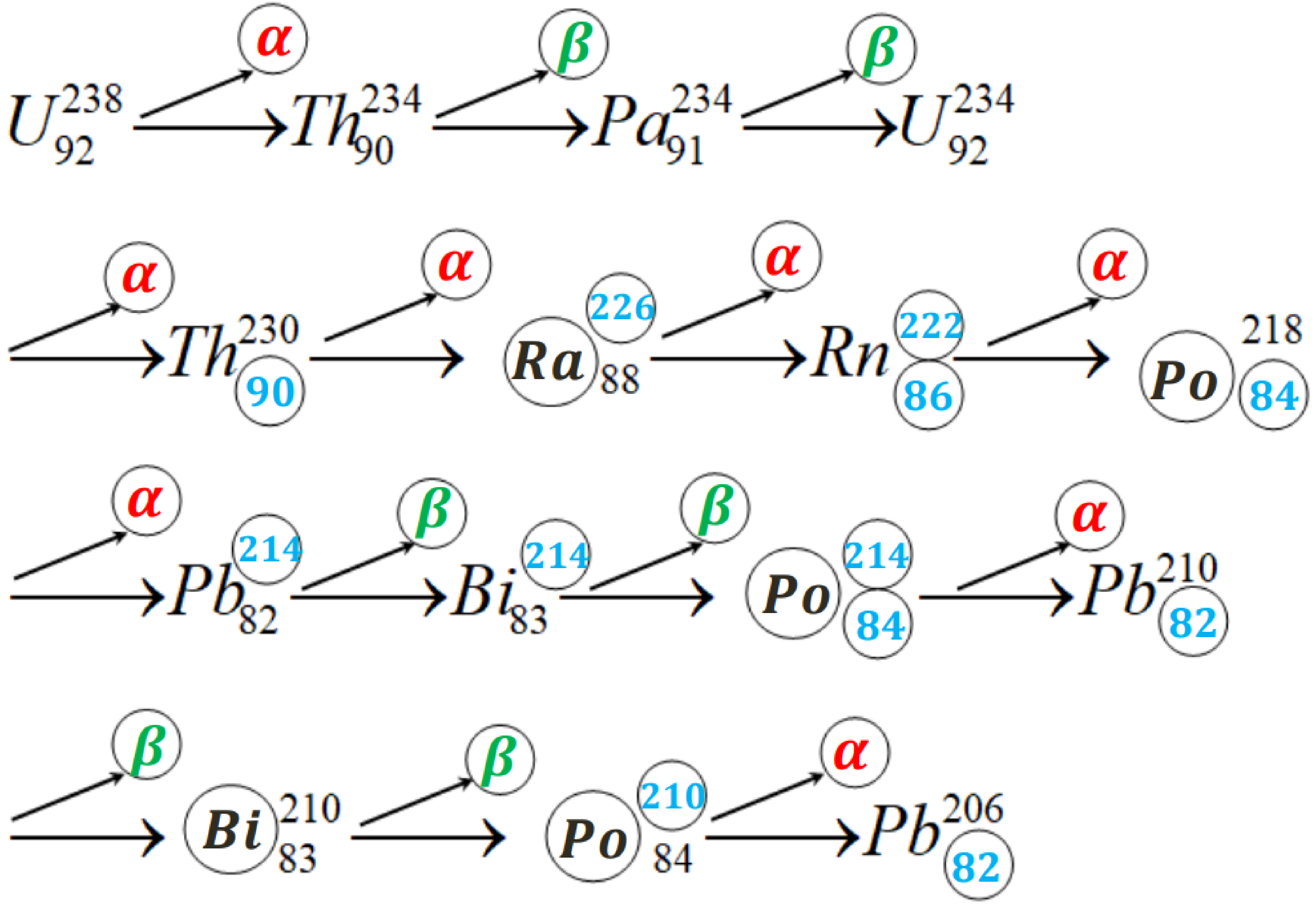
(2 x 0) + 92= **92**

(3 x -1) + 95 = **92**

By the way…This is called "neutron bombardment"

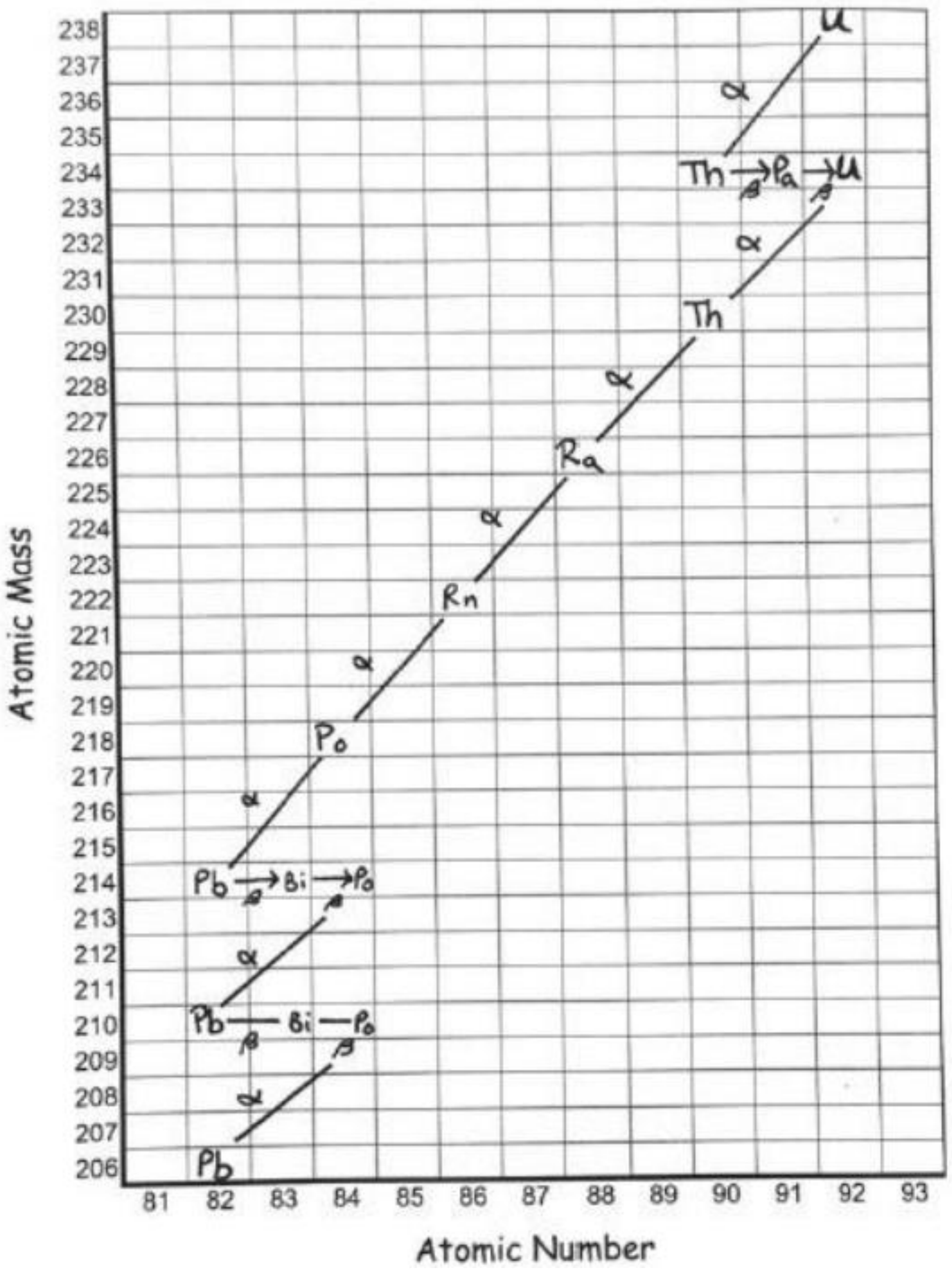
Decay Series

[Jump back to title slide]



Decay Series

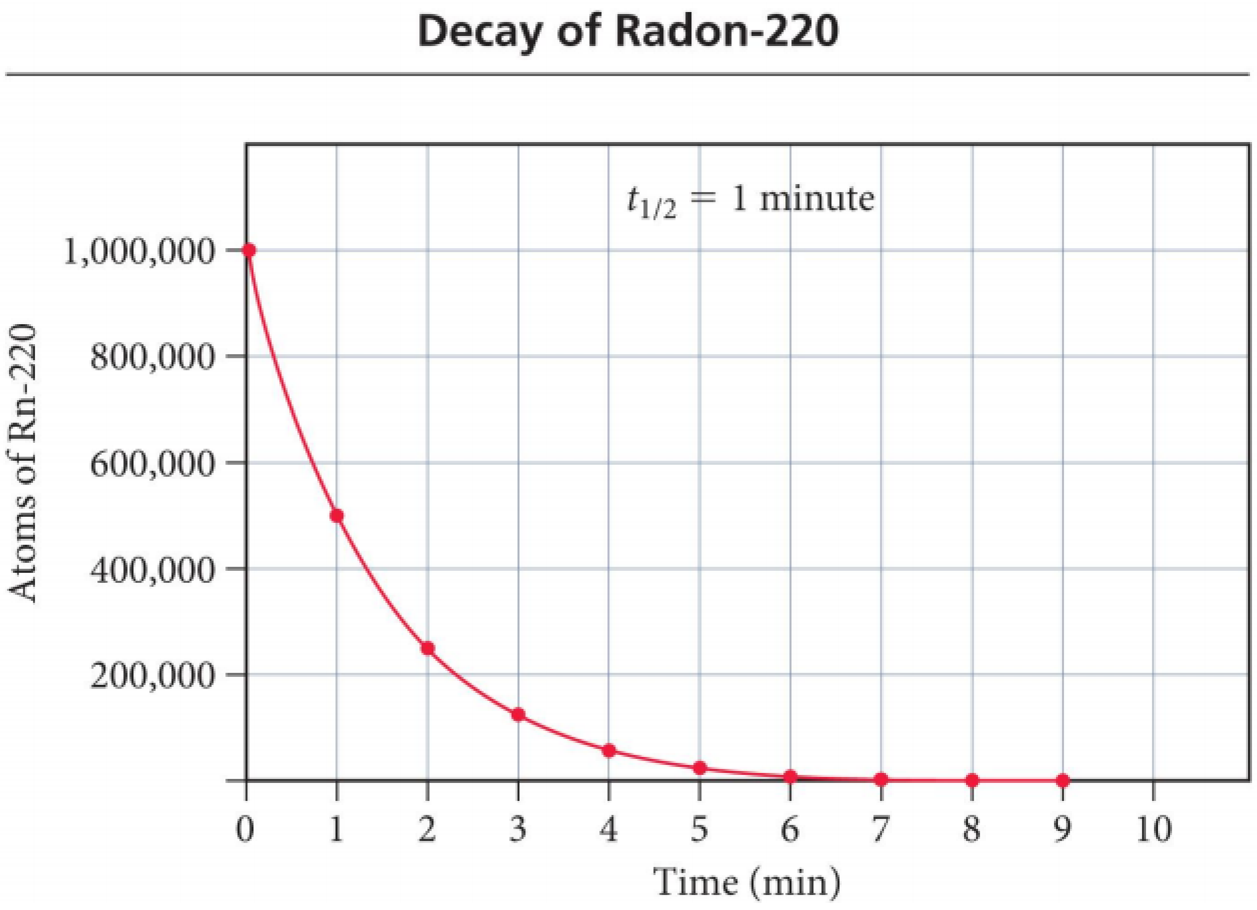
Jump back to title slide



Half Life

[Jump back to title slide]

Half of the radioactive atoms decay each half-life.



Half Life

Jump back to title slide

Half-Life Equation

- Use a handy dandy equation!

Amount Starting

$$A_E = A_S \times (0.5)^n$$

← # of half-lives

Amount Ending

$$n = \frac{t}{h}$$

t = time passed
h = length of one half-life

Half Life

Jump back to title slide

Solving for % remaining

$$A_E = A_S \times (0.5)^n$$

$$\% \text{ remaining} = \frac{A_E}{A_S} \times 100$$

$$\frac{A_E}{A_S} = (0.5)^n$$

Then multiply your answer by 100 to put it in % format!

Half Life

Jump back to title slide

Solve for Time/Half-life

$$A_E = A_s \times (0.5)^{t/h}$$

Isolate $(0.5)^{t/h}$

$$\frac{A_E}{A_s} = (0.5)^{t/h}$$

Bring down exponent using logs

$$\text{Log}\left(\frac{A_E}{A_s}\right) = \frac{t}{h}\ \text{Log}\ (0.5)$$

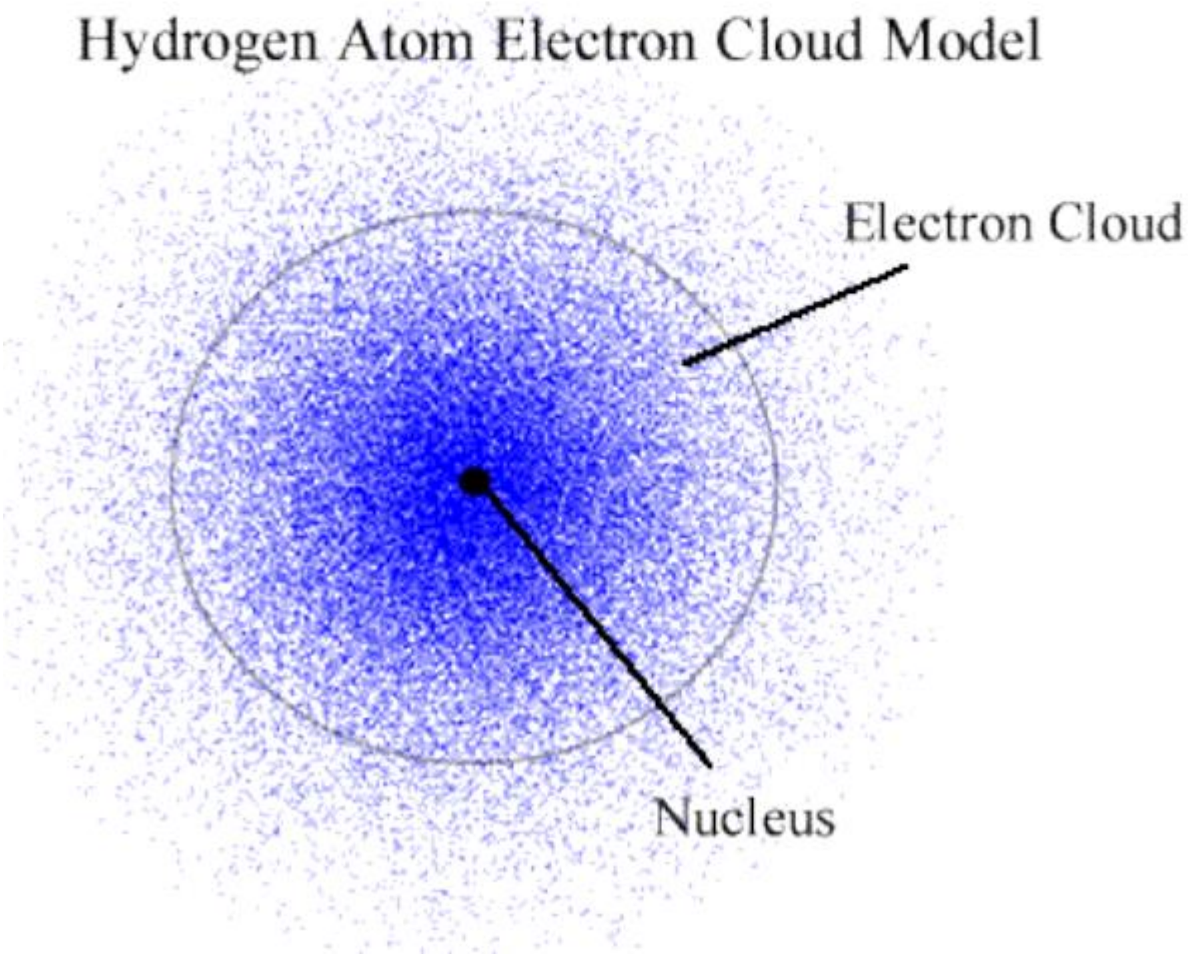
Plug in your #'s then rearrange for t or h depending on what you want to solve for!

Unit #3
Electrons

- Quantum mechanical theory
- Orbital diagrams
- Writing electron configurations
- Noble Gas configuration
- Configuration of ions
- Absorption and emission

Quantum Mechanical Model

Jump back to title slide

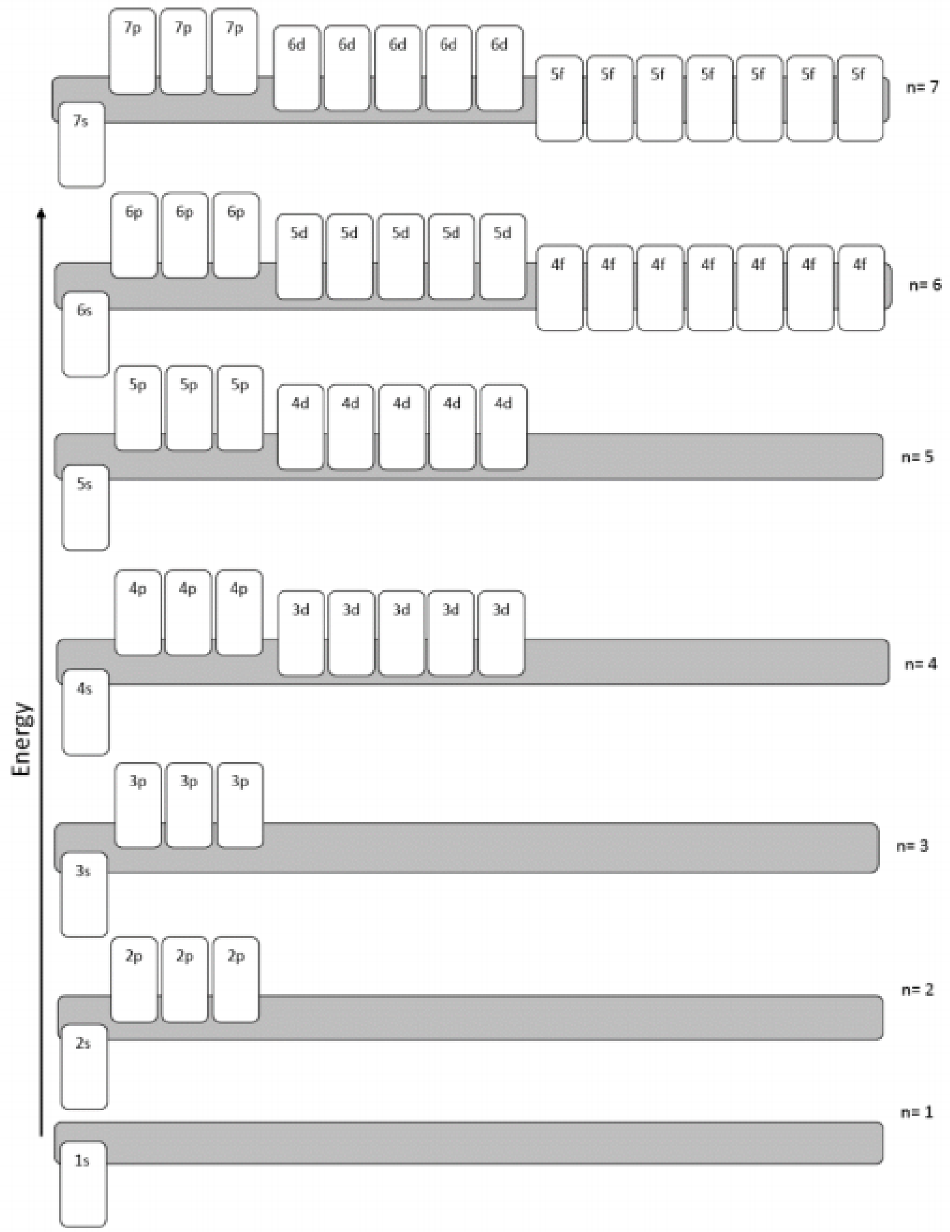


Orbital Diagrams

[Jump back to title slide]

Orbital Diagram

A chart that shows you the order that the orbitals go in.



Orbital Diagrams

Jump back to title slide

Aufbau Principle

An electron occupies the lowest energy orbital that it can.

Pauli Exclusion Principle

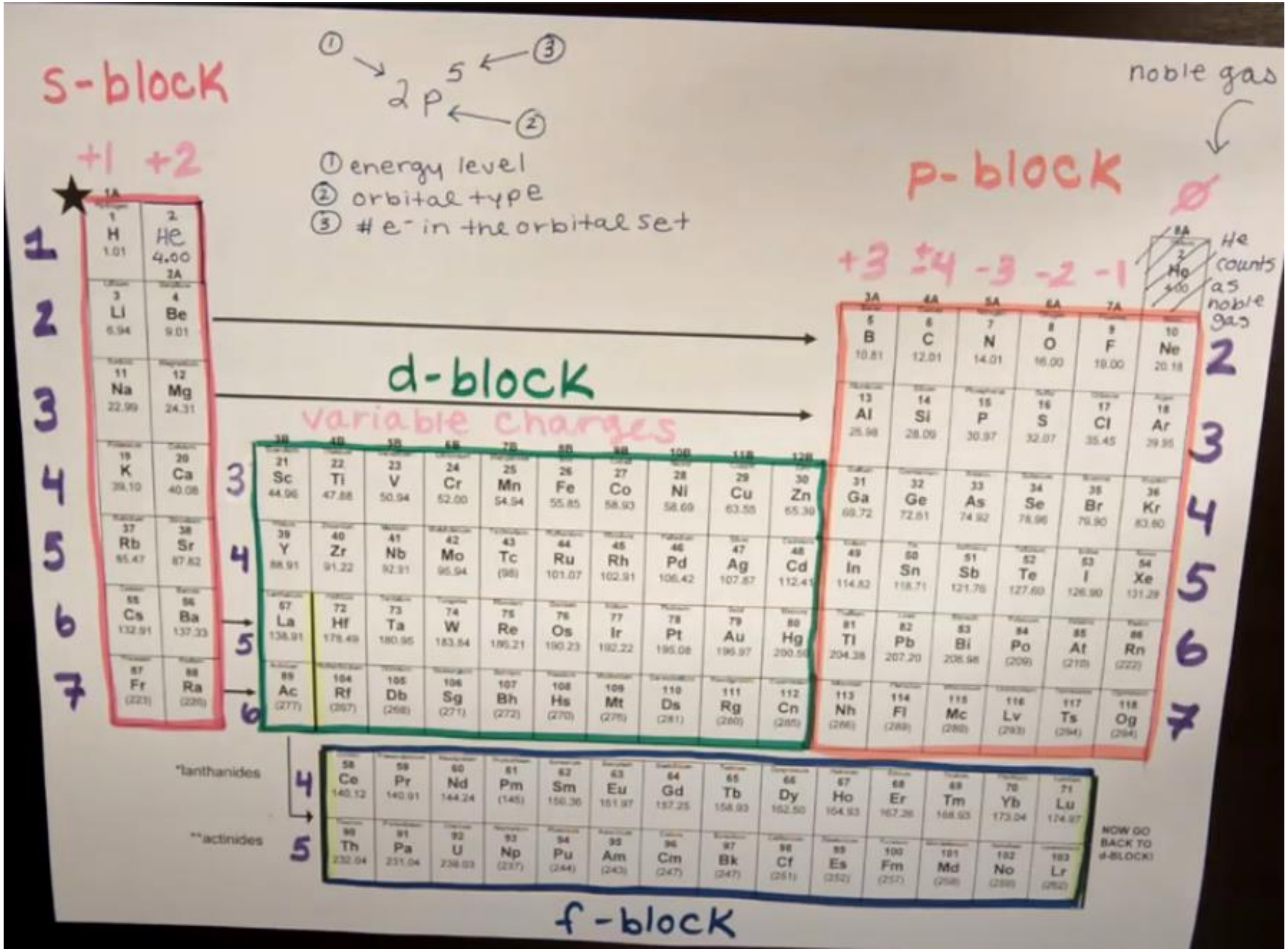
No two electrons in the same atom can have the same set of 4 quantum numbers

Hund's Rule

Orbitals of equal energy are each occupied by one electron before any orbital is occupied by a second electron.

Writing Electron Config.

Jump back to title slide



Noble Gas Config.

Jump back to title slide

He: $1s^2$

Lithium

$1s^2$ $2s^1$

Helium + extra!

[He] $2s^1$

He: $1s^2$

Nitrogen

$1s^2$ $2s^2 2p^3$

Helium + extra!

[He] $2s^2 2p^3$

Ne: $1s^2 2s^2 2p^6$

Sodium

$1s^2 2s^2 2p^6$ $3s^1$

Neon + extra!

[Ne] $3s^1$

Noble Gas Configurations!

Config. of Ions

Jump back to title slide

Configuration of Ions

Ga: $1s^2 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10} 4p^1$

Ga^+: $1s^2 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$ — Take 4p first

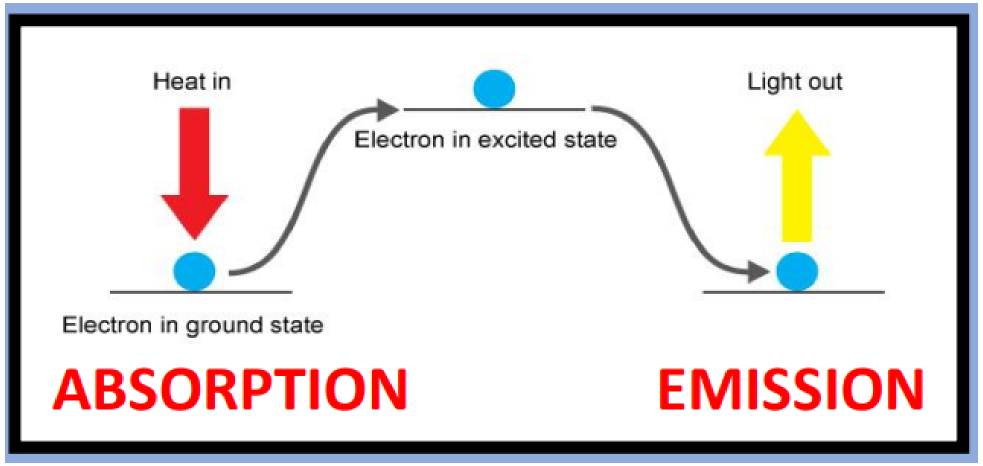
Ga^{2+}: $1s^2 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$ — Take 4s next

Ga^{3+}: $1s^2 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ — Take last 4s

Ga^{4+}: $1s^2 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^9$ — THEN you can take 3d !

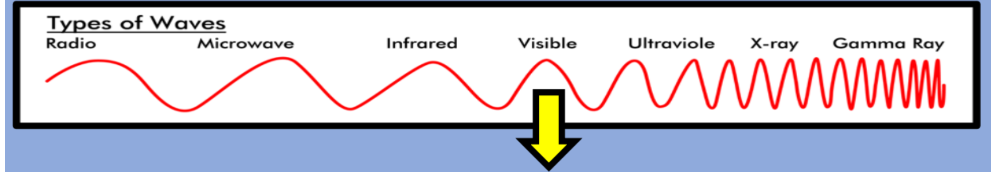
Absorption and Emission

[Jump back to title slide]



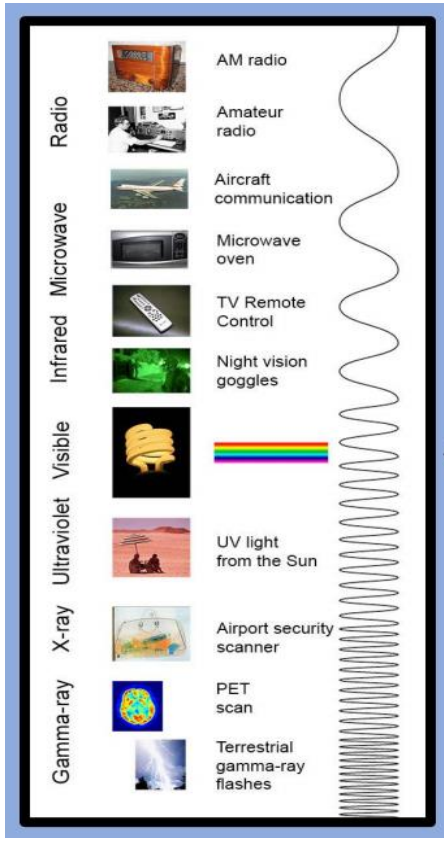
ENERGY SPECTRUM

You can measure the exact wavelength and it can tell you how big the energy gap was that the e- fell from

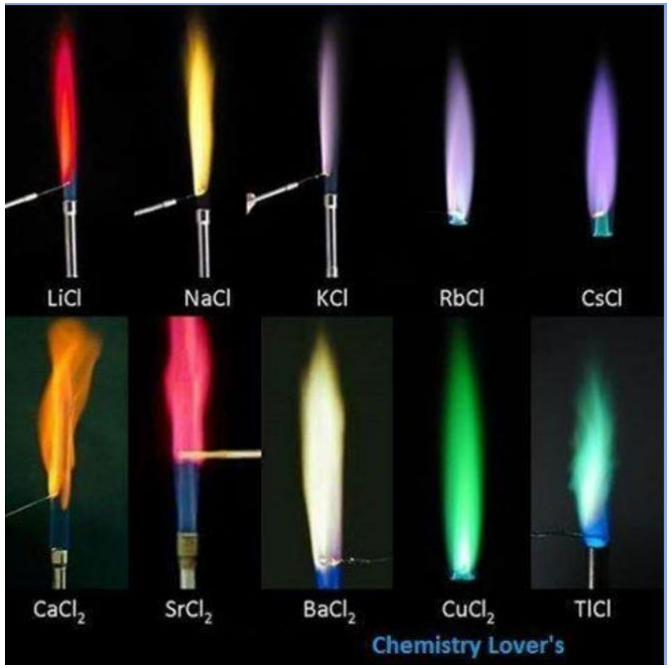


Red Orange Yellow Green Blue Purple

LOW energy — HIGH energy



We can only see this little range here



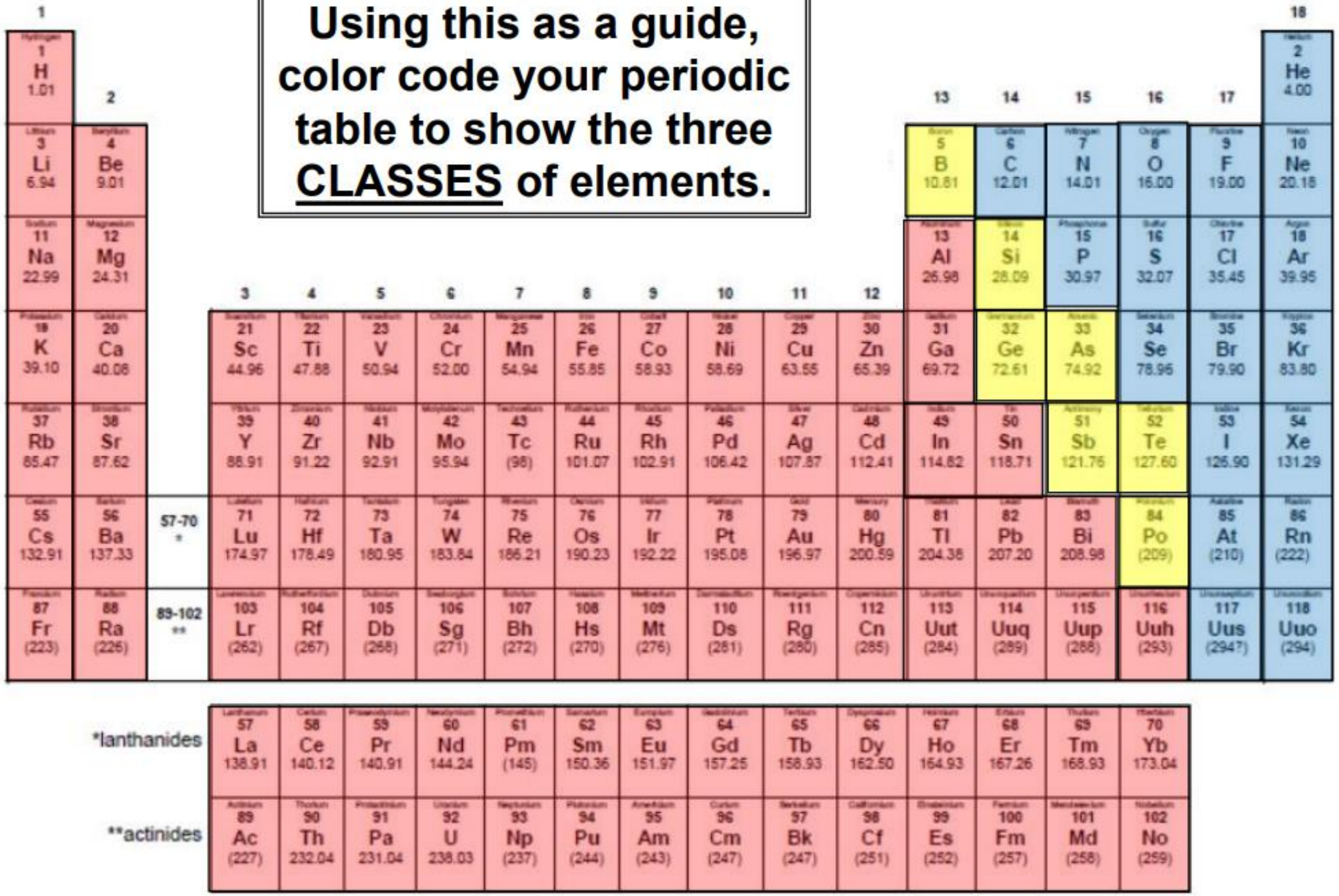
Unit #4
Periodic Table

- Structure of the periodic table
- Periodic trends

Periodic Table Structure

[Jump back to title slide]

Using this as a guide, color code your periodic table to show the three CLASSES of elements.



Metals

Non-metals

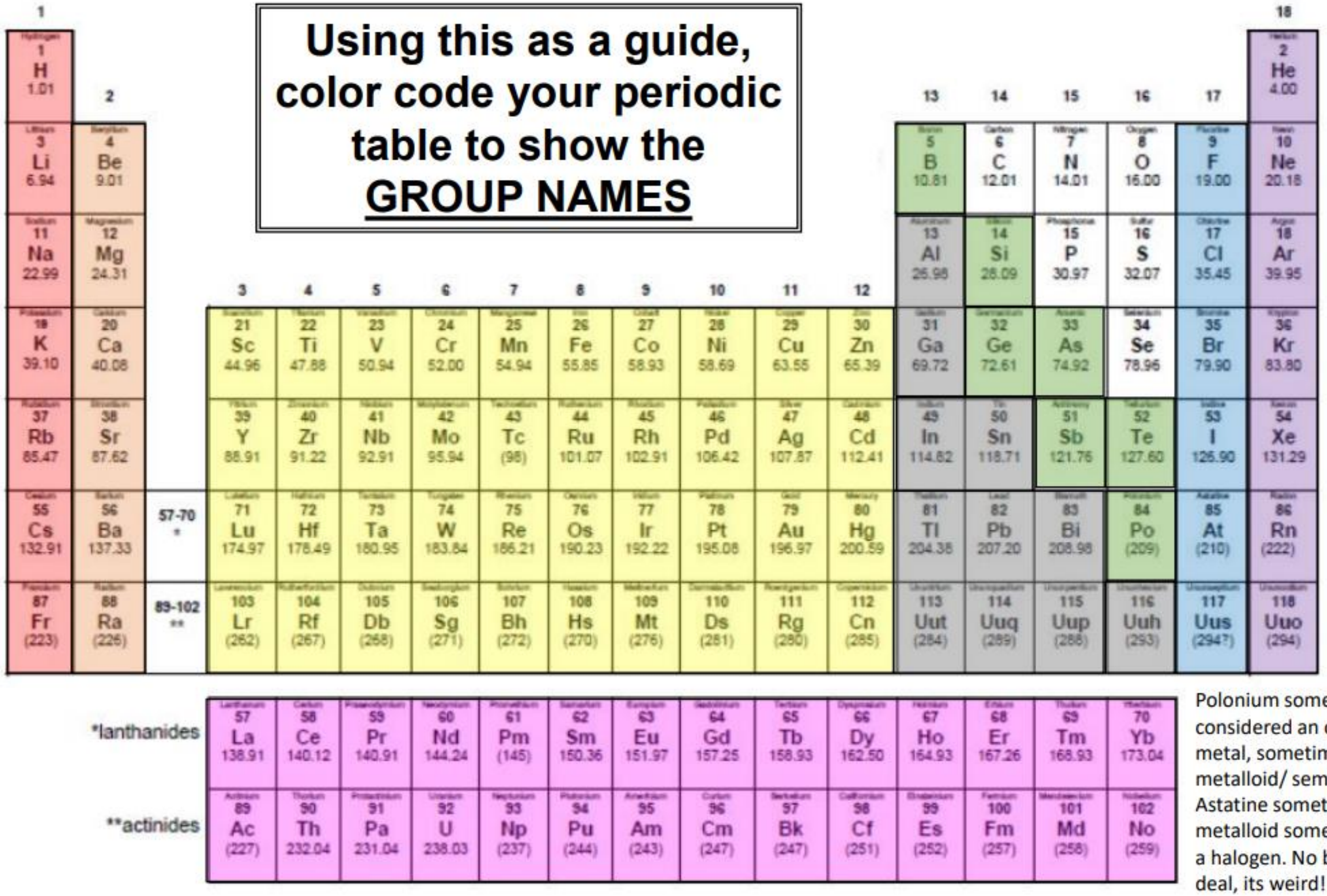
Metalloids

Polonium is sometimes considered a metal, metalloid, or a non-metal depending on which table you are looking at. Astatine is sometimes considered a nonmetal, sometimes a metalloid. No big deal, it is weird!

Periodic Table Structure

[Jump back to title slide]

Using this as a guide, color code your periodic table to show the GROUP NAMES



Polonium sometimes considered an other metal, sometimes a metalloid/ semimetal. Astatine sometimes a metalloid sometimes a halogen. No big deal, its weird!

- Alkali Metals
- Alkaline Earth Metals
- Transition Metals
- Other Metals
- Rare Earth Metals
- Metalloids/ Semimetals
- Other Non-metals
- Halogens
- Noble Gases

Periodic Table Structure

Jump back to title slide

Things in the same period have:

Increasing atomic # and mass L→R

Same number of energy levels

Period 1 has 1 level

Period 2 has 2 levels etc…

Things in the same group have:

Increasing atomic # and mass ↓

Same number of valence electrons

Exceptions: d and f block

Similar physical and chemical properties

b/c they have same # of valence e^-s

Valence Electrons:

Outer electrons

Matches the "A" column number

1A has 1 v.e^-, 2A has 2v.e^-, etc.

d and f blocks don't follow rules

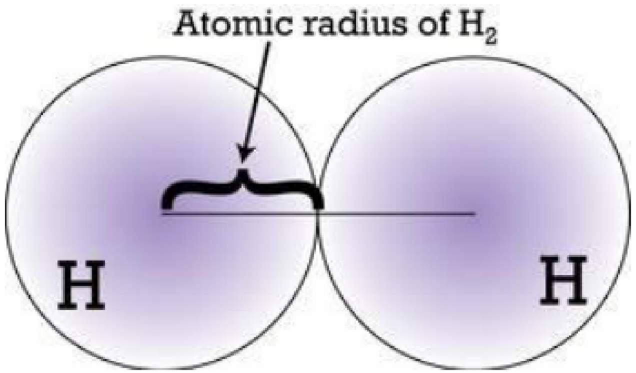
Periodic Trends

Jump back to title slide

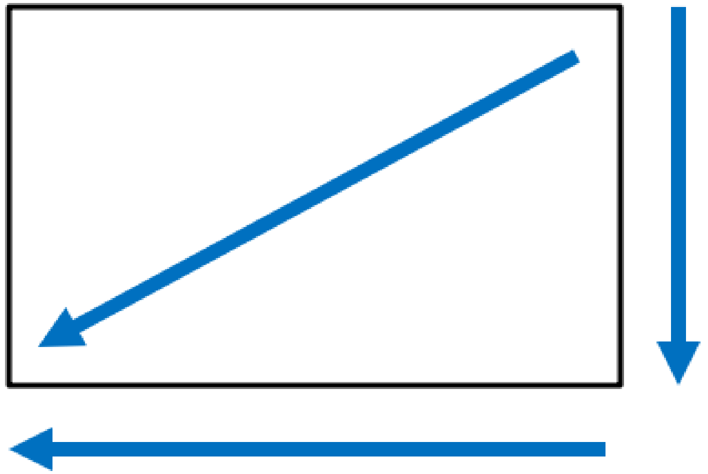
ATOMIC RADIUS

What

- ½ the distance between two bonded nuclei
- Cant measure to the edge b/c orbitals aren't tangible!



How

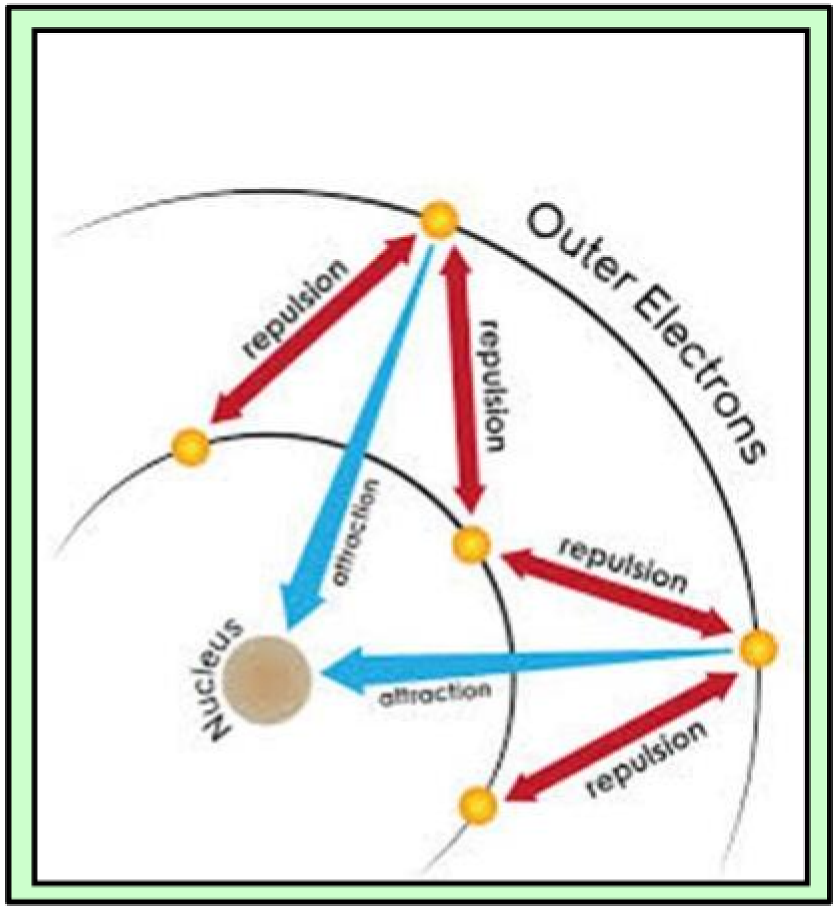


Periodic Trends

Jump back to title slide

Effective Nuclear Charge (Z_{eff})

The relative attraction the valence electrons have for the protons in the nucleus



Shielding Effect

The inner shell electrons repel the outer valence electrons – keeps the valence e- from "feeling" the nucleus. More repulsion results in less attraction between nucleus and valence e-.

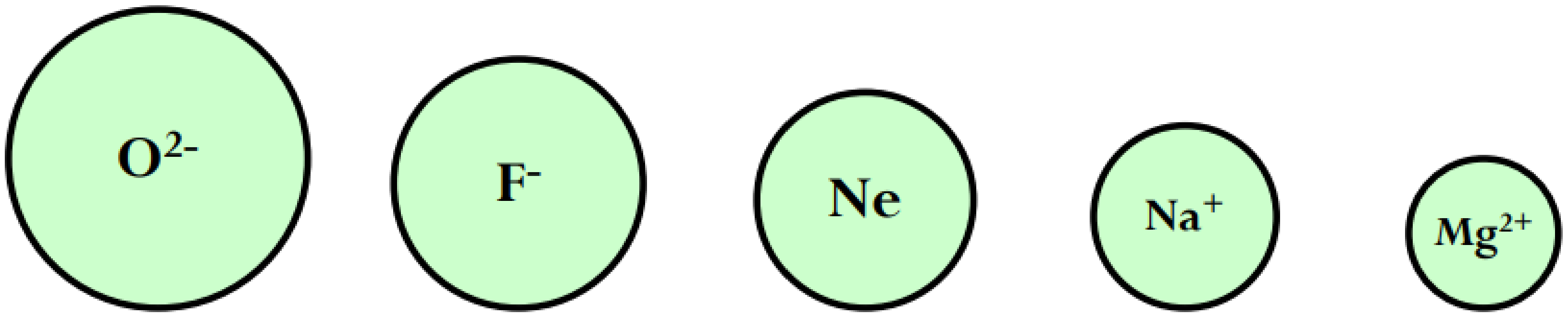
Periodic Trends

Jump back to title slide

Isoelectric Species

Atoms/Ions that have the same number of e-

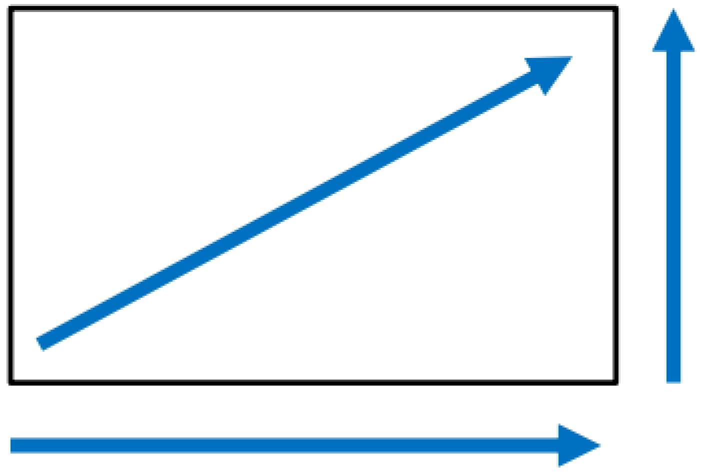
All these examples are $1s^2 2s^2 2p^6$



Increased protons can pull harder on the valence electrons – greater effective nuclear charge – so the radius is smaller even though they have the same number of electrons and energy levels

Jump back to title slide

IONIZATION ENERGY

What	How
The energy required to remove on electron from a neutral atom of an element	 Noble Gases are HIGHEST! They REALLY don't want to let go of an e-

Periodic Trends

Jump back to title slide

Subsequent Ionizations

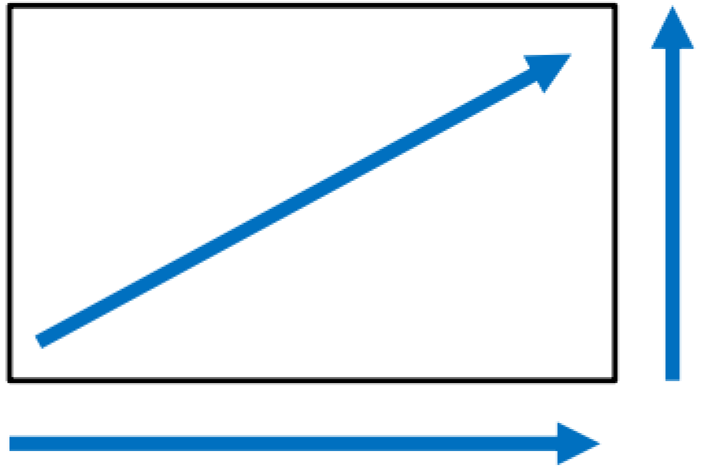
Every time you take an e- away it gets harder to take the next one. Radius is getting smaller, so nucleus can pull harder on the valence - harder to remove the next one. HUGE LEAP in I.E. once it's achieved noble gas configuration – why would it want to lose another one?!

Element	IE_1	IE_2	IE_3	IE_4
Na	496	4560		
Mg	738	1450	7730	
Al	578	1820	2750	11,600

Periodic Trends

[Jump back to title slide]

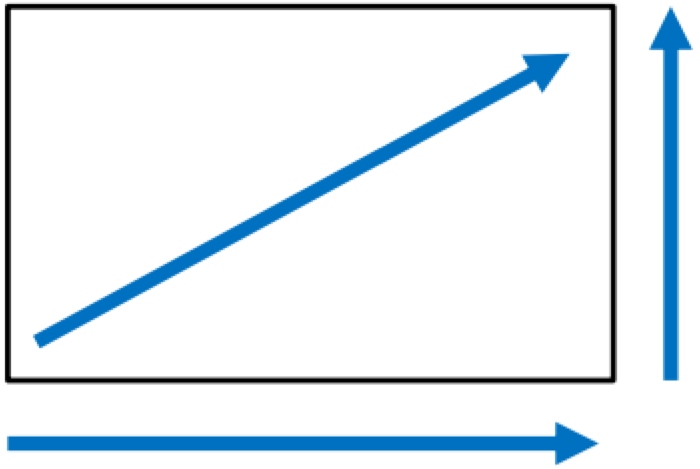
ELECTRONEGATIVITY

What	How
A measure of the ability of an atom in a chemical compound to attract electrons from another atom in the compound *How strongly can one atom pull on the electrons being shared in a bond.*	 Noble Gases are LOWEST! They DON'T CARE about attracting electrons!

Periodic Trends

Jump back to title slide

ELECTRON AFFINITY

What	How
How much energy is released when the atom gains an electron to make a negative ion. *How much stability does it gain once it is an anion. More energy released – more stable.*	 Noble Gases are LOWEST! They DON'T CARE about attracting electrons!

Periodic Trends

Jump back to title slide

REACTIVITY

What	How
Elements in the same group have similar types of behaviors <u>because they have the same number of valence e-</u> BUT The MAGNITUDE of their reactions changes!	 Metals and Non-metals are opposite trends! Noble gases are “INERT” or non-reactive

Periodic Trends

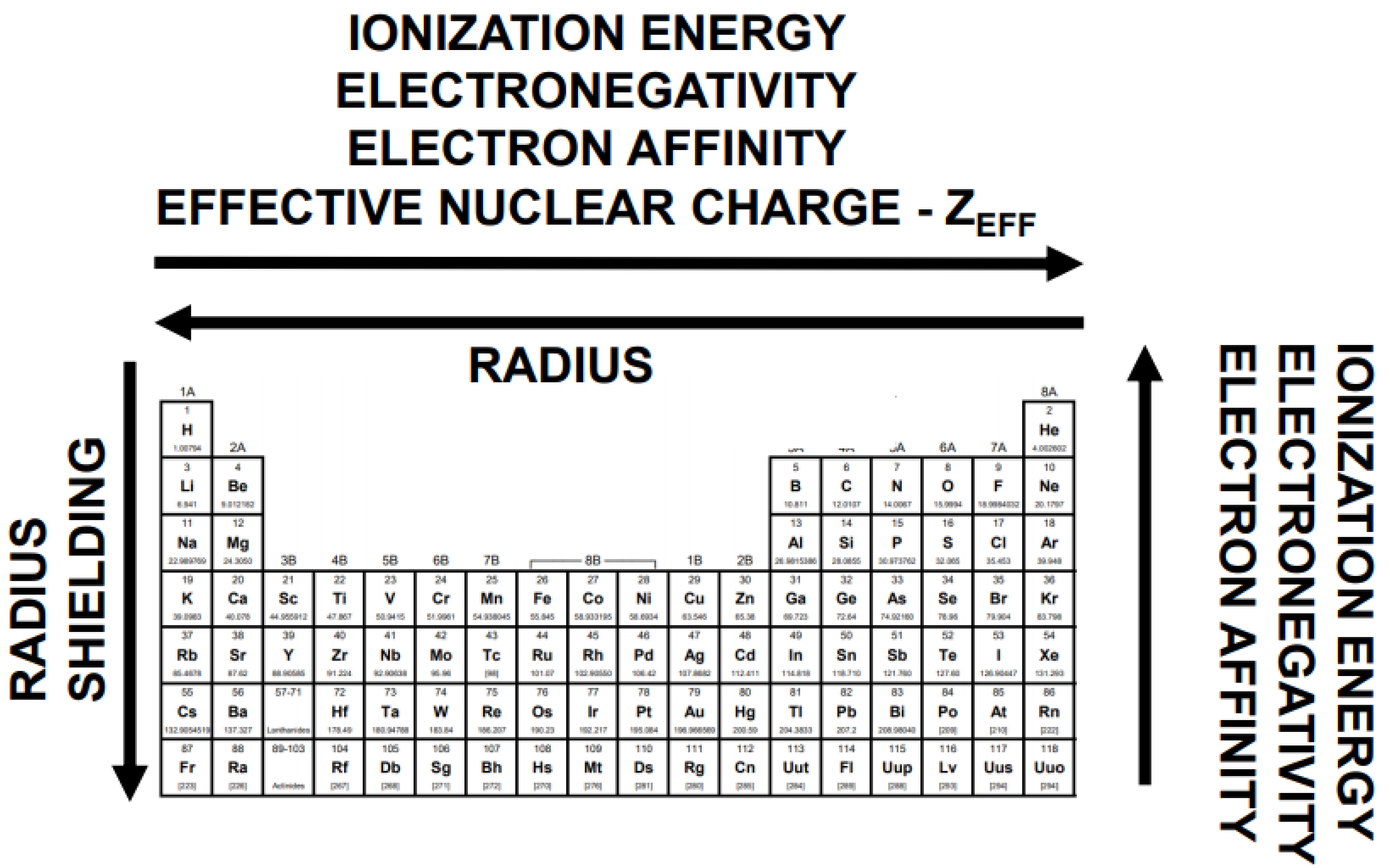
Jump back to title slide

REACTIVITY

What	How
Elements in the same group have similar types of behaviors because they have the same number of valence e- BUT The MAGNITUDE of their reactions changes!	 Metals and Non-metals are opposite trends! Noble gases are "INERT" or non-reactive

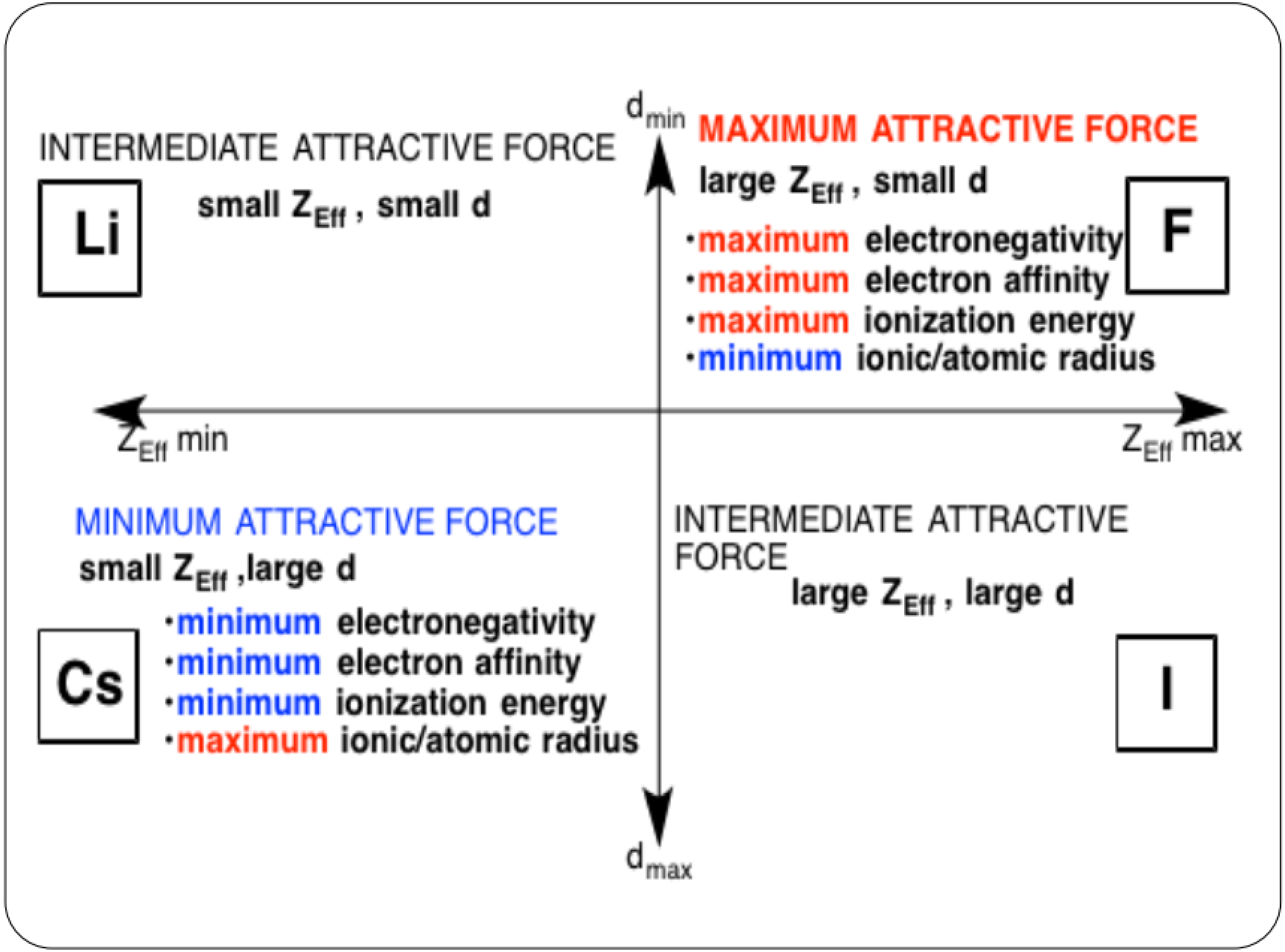
Periodic Trends

[Jump back to title slide]



Periodic Trends

Jump back to title slide

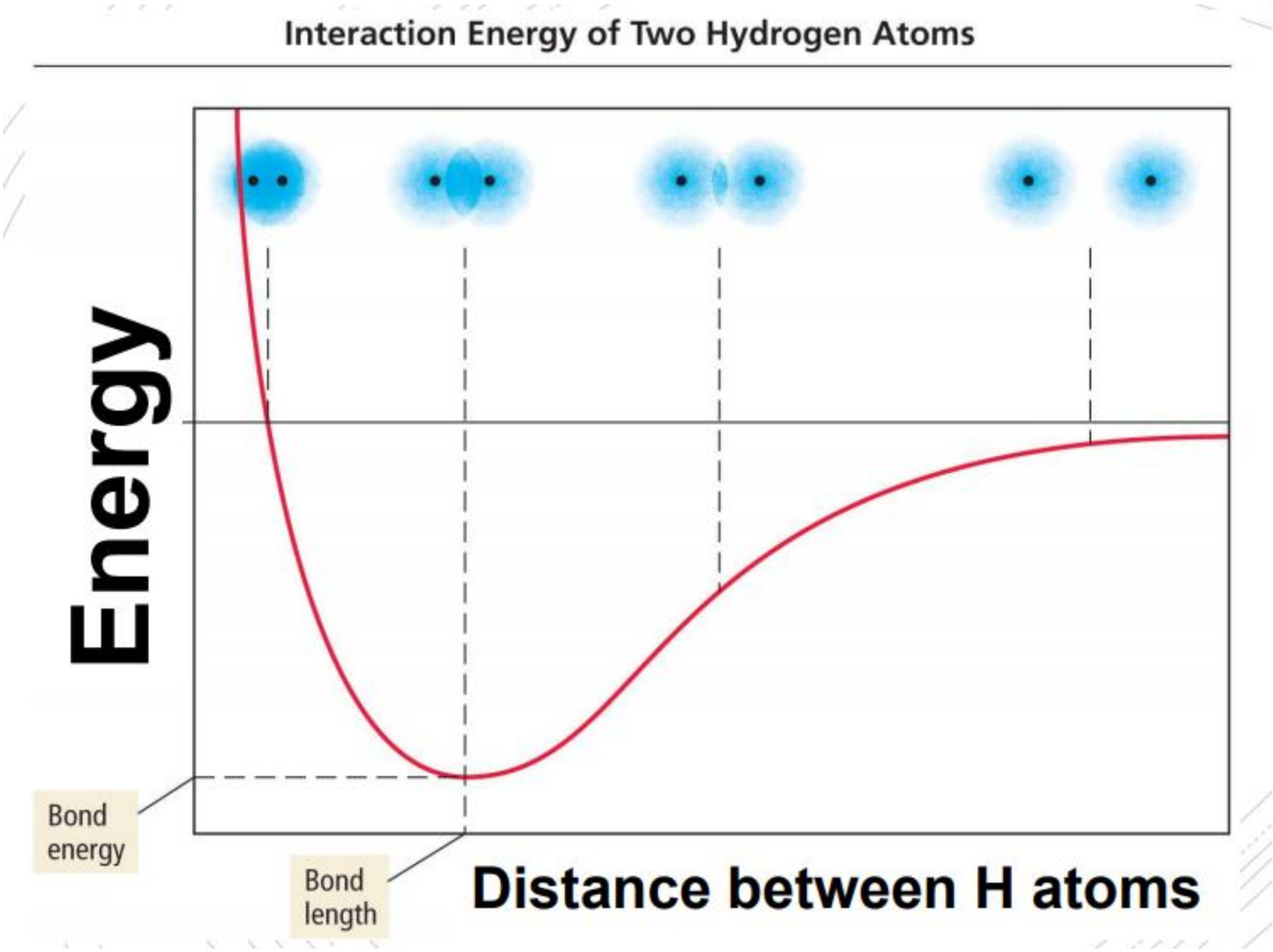


Unit #5
Bonding and Structure

- Why bonds form
- Types of bonds
- Naming formulas
- Writing neutral formulas
- Lewis structures
- VSPER
- Hybridization
- Polarity
- Intermolecular forces

Why Bonds Form

Jump back to title slide

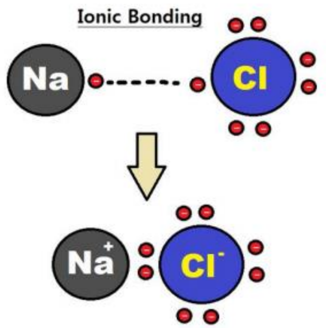


Types of Bonds

Jump back to title slide

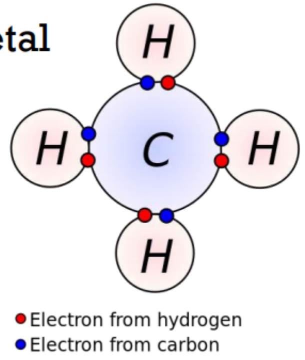
Ionic Bonds

- Transfer of electrons - makes charges
- Electrostatic bond between a positive charge and a negative charge
- Metal + Nonmetal
  Ca^{2+} O^{2-}
- Polyatomic Ions, even if nonmetals
  NH_4^+, SO_4^{2-}



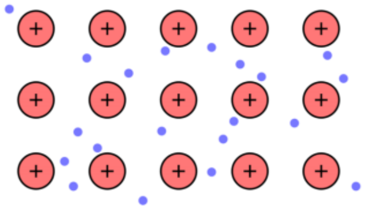
Covalent Bonds

- Atoms can't fully transfer electrons, so they share them
- Nonmetal + Nonmetal
  CH_4



Metallic Bonds

- Electrons "detach" from the atoms they came from
- Creates a "sea of electrons" that can flow when a charge is applied



Naming formulas

Jump back to title slide

Naming Ionic Compounds

- **Cation first, then anion**
- **Monatomic cation = name of the element**
  - Ca^{2+} = calcium ion
- **Monatomic anion = root + -ide**
  - Cl^{-} = chloride
  - $CaCl_2$ = calcium chloride

With Polyatomic Ions

- Poly atomic ions always keep their special names, don't change them!
  - $K_3(PO_3)$
  - Potassium phosphite

Metals with variable charges

- Some metal forms more than one cation
- **Use Roman numeral in name**
  - **$PbCl_2$**
    - Pb^{2+} is cation
    - $PbCl_2$ = lead(II) chloride
  - **FeO**
    - Fe^{2+} is cation
    - FeO = Iron(II) oxide

Naming formulas

Jump back to title slide

Naming Covalent Molecules

- Two (or more) nonmetals
- All elements keep their normal names EXCEPT the last element changes its ending to -ide
- Use prefixes
- NEVER use "mono" for the first element!

number of atoms	prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

- **Double vowels** – when using prefixes we don't like some double vowel combos – drop the last vowel from the prefix portion of the name
  - Any double vowel with an I is ok!
    - Diiodide = ok
    - Pentaiodide = ok
    - Monoiodide = ok
    - Monooxide = no! → monoxide

Naming formulas

Jump back to title slide

Naming Metallic Substances

SUPER EASY….

- Name the metal. The end.
    - Cu
    - Copper

Naming formulas

[Jump back to title slide]

Odds and Ends

Are the exceptions? Weird rules? YES. ALWAYS.

- **<u>Diatomic elements</u>** – some elements come as a pair and not by themselves

H_2, N_2, O_2,
F_2, Cl_2, Br_2, I_2

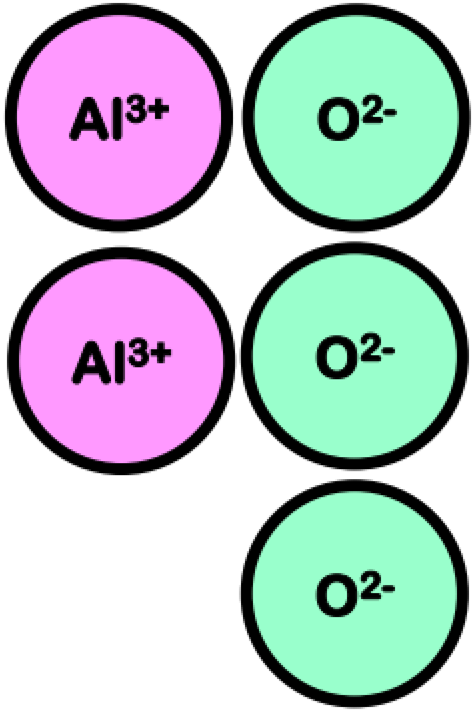
Horses Need
Oats For Clear
Brown "Eyes"

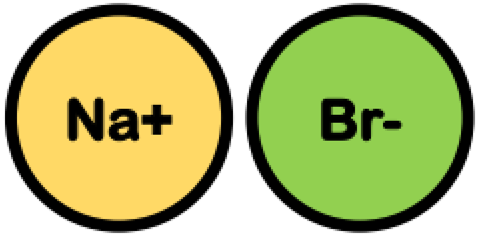
Neutral Formulas

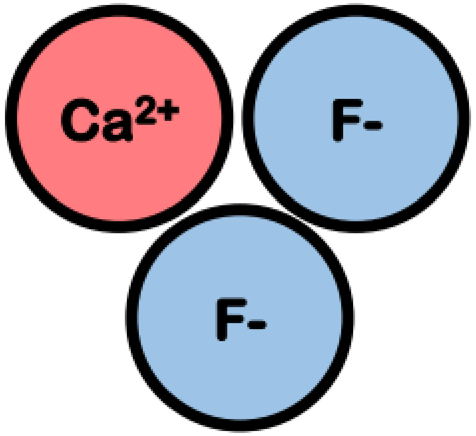
Jump back to title slide

Neutral Compounds

- **We need our compounds to be "electrically neutral"**
  - Charges need to cancel out
  - Not always a 1:1 ratio!







Neutral Formulas

Jump back to title slide

Barium Fluoride

Ba^{2+} F^{-}

1 2

BaF_2

Neutral Formulas

Jump back to title slide

Barium Nitrate

Ba^{2+} $(NO_3)^-$

1 2

$Ba(NO_3)_2$

Naming formulas

Jump back to title slide

Ammonium Sulfate

$(NH_4)^+$ $(SO_4)^{2-}$

2 1

$(NH_4)_2(SO_4)$

Neutral Formulas

Jump back to title slide

Iron(III) Chloride

Fe^{3+} Cl^{-}

1 3

$FeCl_3$

Neutral Formulas

Jump back to title slide

Magnesium Carbonate

Mg^{2+} $(CO_3)^{2-}$

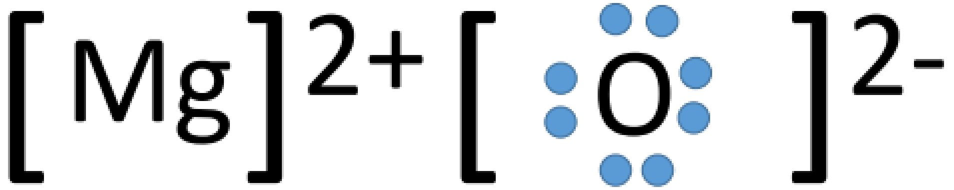
2 2

$Mg_2(CO_3)_2$

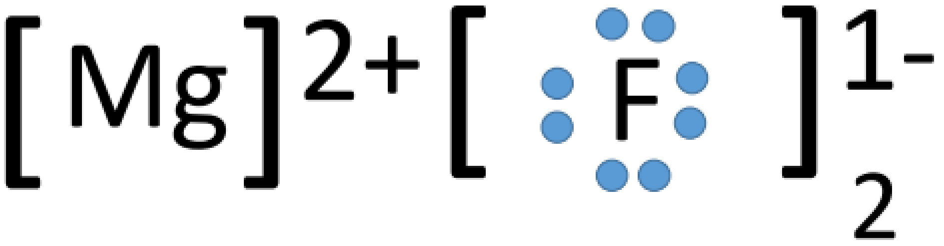
Jump back to title slide

Ionic Compounds

Super easy! Just draw the cation and anion next to each other. Done!



More than one of a particular ion? Then just add a subscript outside the brackets!



Lewis Structures

Jump back to title slide

Covalent Molecules

Covalent molecules will share electrons – they each donate one (or more) to a shared bond. **Do NOT just randomly throw dots all over your paper!!!!** **No "guessing and checking" allowed!** Follow a **systematic set of steps** so you never make mistakes!

STEPS

1) **Count & sum ve-**
2) **Place your atoms**
3) **Bond all atoms w/ a single bond**
4) **Give all atoms a full shell**
5) **Re-count the ve- you used**
6) **Used too few? Put extra on the central atom**
7) **Used to many ve-? Then try double or triple bonds to fix if needed**

Lewis Structures

[Jump back to title slide]

PLACEMENT "RULES"

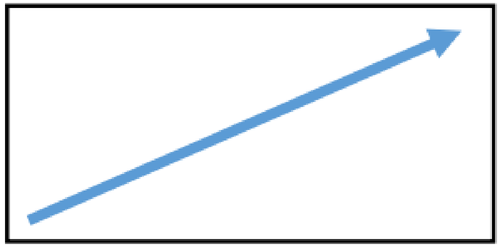
1) Hydrogen *always* goes on the outside of the molecule

- it is a "dead end"
- it "terminates" the molecule
- it "caps off" the molecule
- Because it can only make 1 bond

H	H	O	***no!***
H	O	H	***yes!***

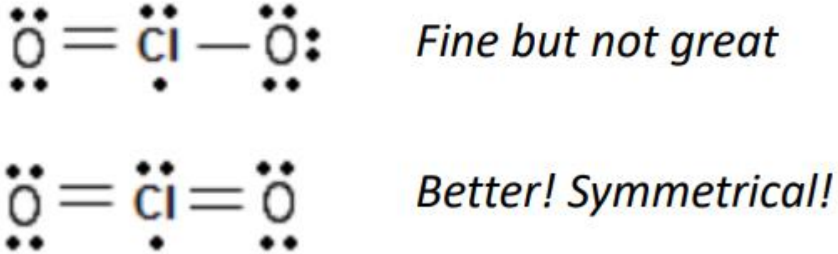
2) The *least* electronegative atom goes in the inside/center

- except for hydrogen!



3) Symmetry is good!

- When possible!



VSEPR

Jump back to title slide

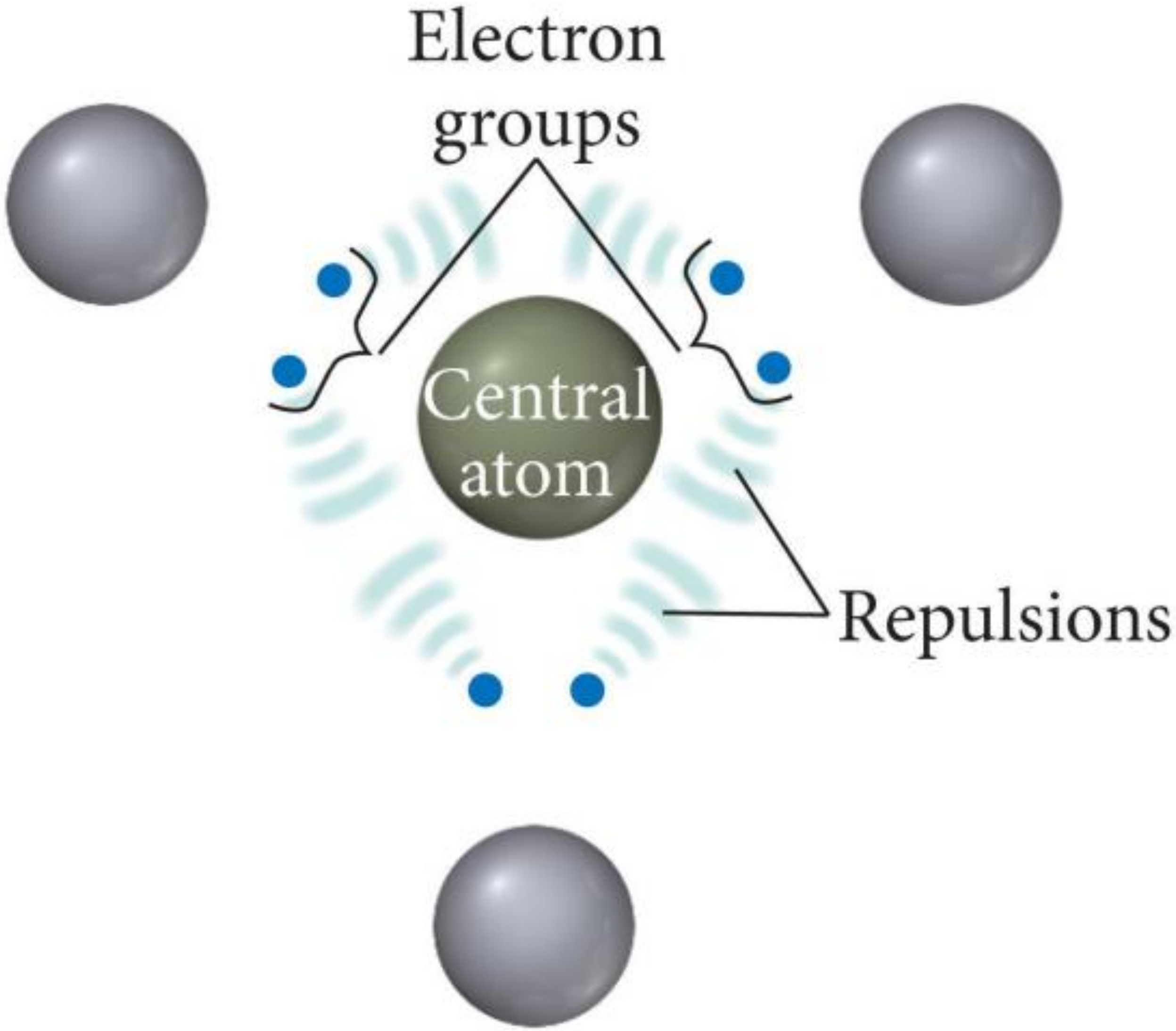
VSEPR Model

(Valence Shell Electron Pair Repulsion)

- The structure around a given atom is determined *mostly* by minimizing electron pair repulsions.
- They try to maximize the distance between electrons

VSEPR

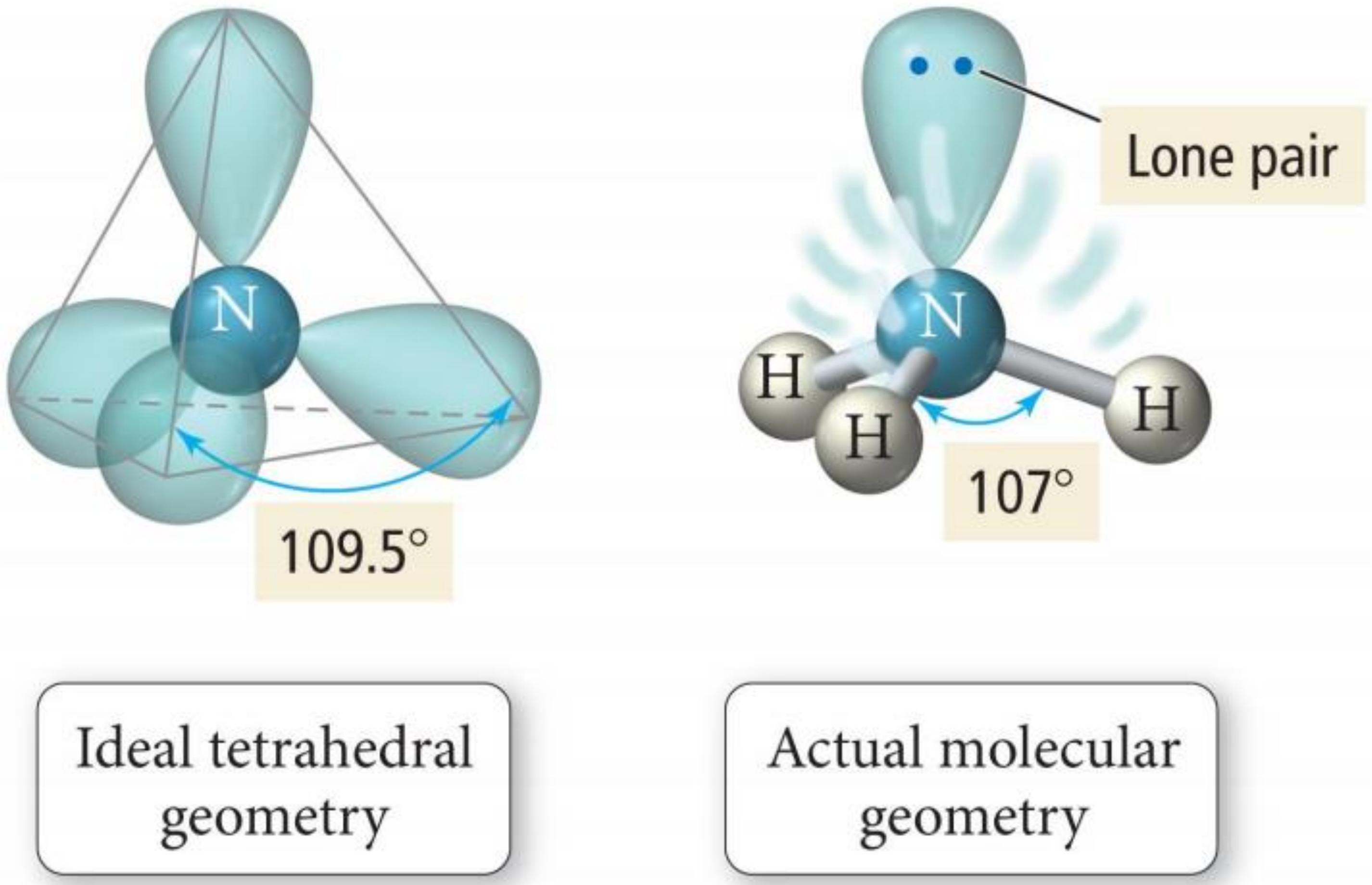
[Jump back to title slide]



VSEPR

Jump back to title slide

Bond Angle Distortion from Lone Pairs



VSEPR

Jump back to title slide

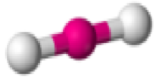
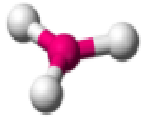
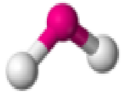
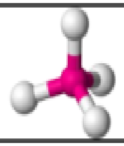
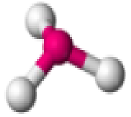
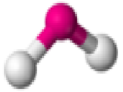
VSEPR – AXE Method

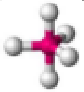
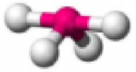
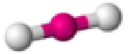
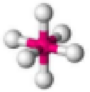
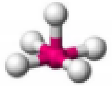
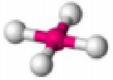
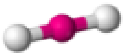
- The A represents the central atom.
- The X represents how many bonded atoms.
- The E represents the number of lone electron pairs present on the central atom.
- The sum of X and E, sometimes known as the steric number.

VSEPR

Jump back to title slide

Predicting Molecular Geometry and Hybridization

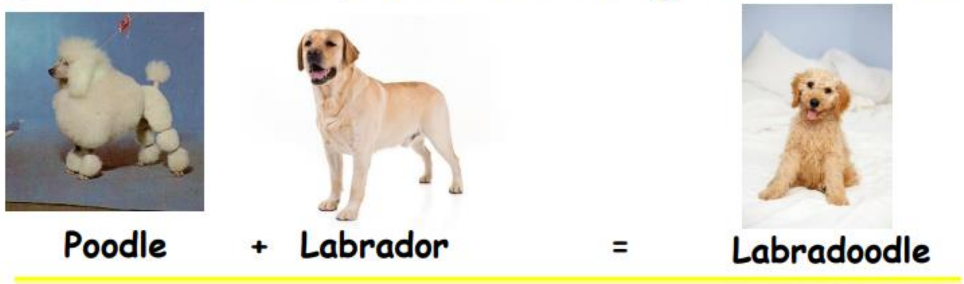
Electron Groups	Bonding Groups	Lone Pairs	Electron Geometry (Hybridization)	Molecular Geometry (VSEPR class)	Approximate Bond Angles	Geometry Examples
2	2	0	Linear *(sp)*	Linear *(AX_2)*	180	
3	3	0	Trigonal Planar *(sp^2)*	Trigonal Planar *(AX_3)*	120	
	2	1		Bent *(AX_2E)*		
4	4	0	Tetrahedral *(sp^3)*	Tetrahedral *(AX_4)*	109.5	
	3	1		Trigonal Pyramidal *(AX_3E)*		
	2	2		Bent *(AX_2E_2)*		

Electron Groups	Bonding Groups	Lone Pairs	Electron Geometry (Hybridization)	Molecular Geometry (VSEPR class)	Approximate Bond Angles	Geometry Examples
5	5	0	Trigonal Bipyramidal *(sp^3d)*	Trigonal Bipyramidal *(AX_5)*	120 (in plane) 90 (above and below)	
	4	1		Seesaw *(AX_4E)*		
	3	2		T-Shaped *(AX_3E_2)*		
	2	3		Linear *(AX_2E_3)*	180	
6	6	0	Octahedral *(sp^3d^2)*	Octahedral *(AX_6)*	90	
	5	1		Square Pyrimidal *(AX_5E)*		
	4	2		Square Planar *(AX_4E_2)*		
	3	3		T-Shaped *(AX_3E_3)*		
	2	4		Linear *(AX_2E_4)*		

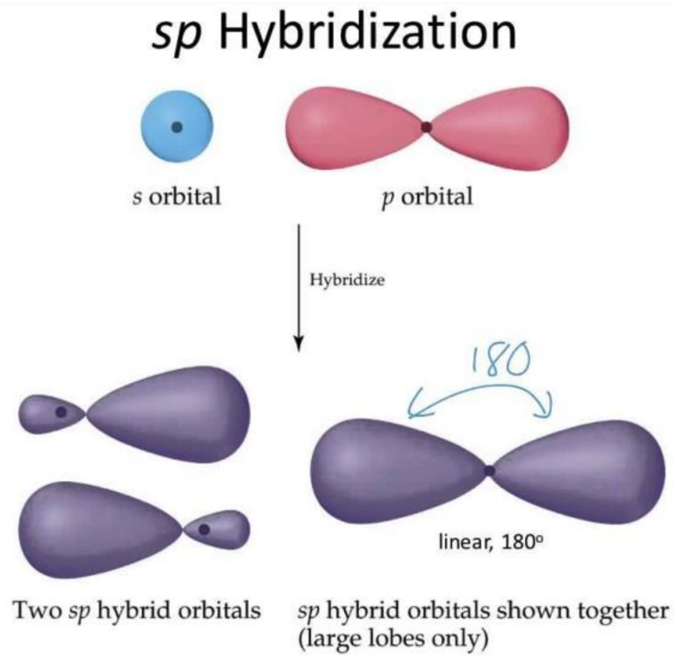
Hybrid-ization

Jump back to title slide

Hybridization - The Blending of Orbitals

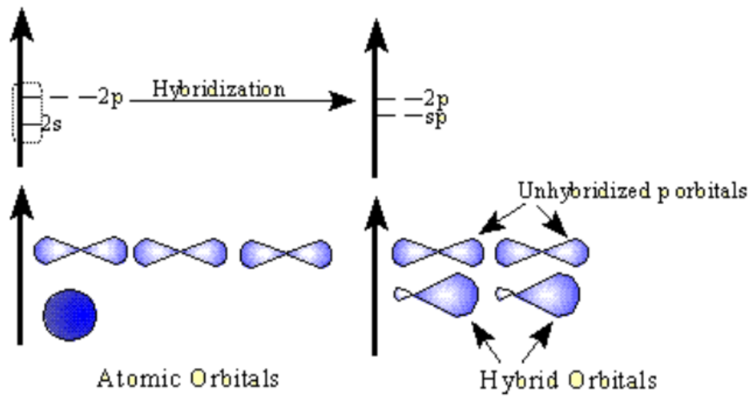


Hybridization is the combining of two or more orbitals of nearly equal energy within the same atom into orbitals of equal energy.



sp Hybrid Orbitals

One s orbital combines with one p orbital
Two p orbitals are left the same

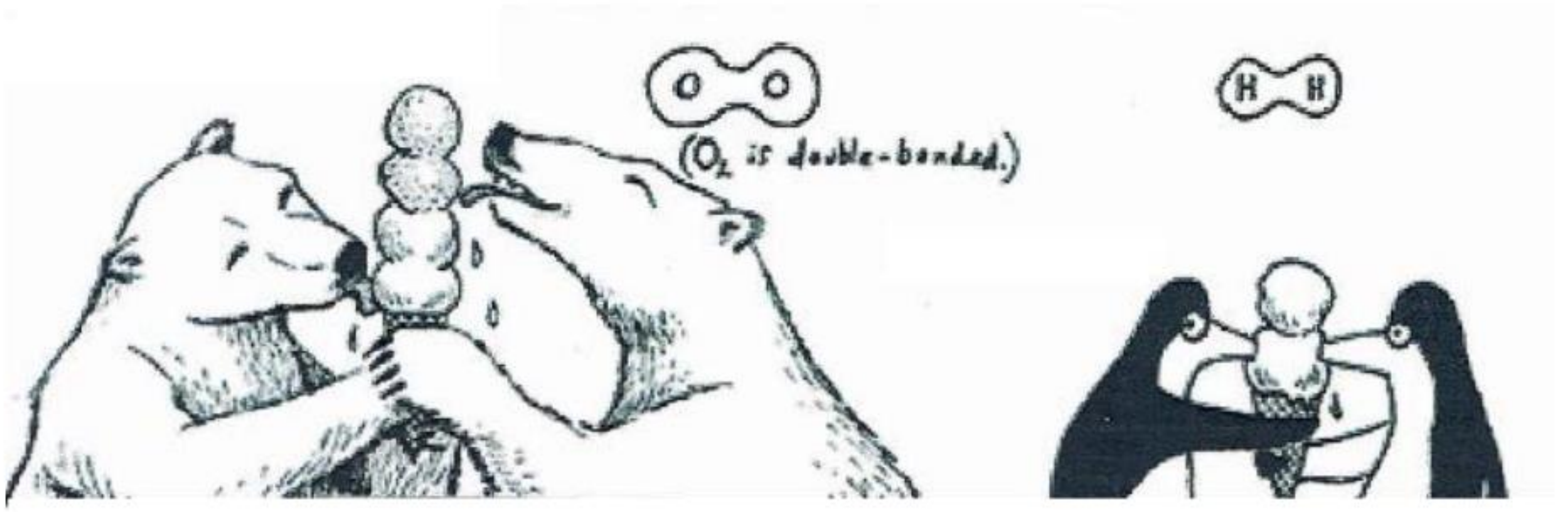


Polarity

Jump back to title slide

What's happening inside covalent molecules like O_2 or H_2?

Electrons are shared *equally*



Polarity

[Jump back to title slide](#)

Example: HF

HF is covalent but electrons are *not* shared equally

Molecules become *POLAR* when electrons are not shared equally

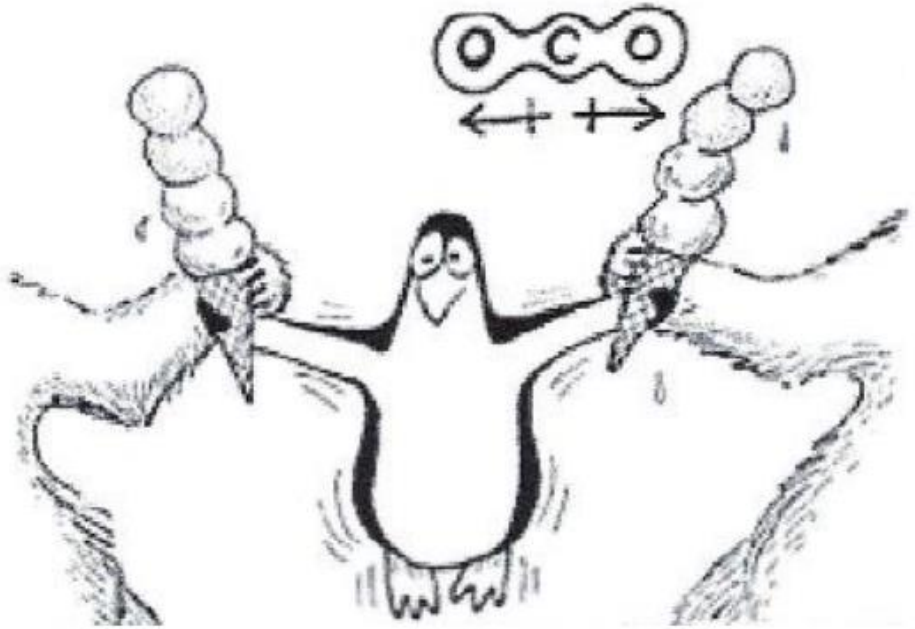
Polarity

Jump back to title slide

Symmetry…the pole destroyer!

CO_2

Has 1 carbon surrounded by 2 electronegative Oxygens, but is NOT polar?!?!



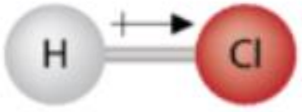
Electron density is still SYMETRICAL which makes it non-polar

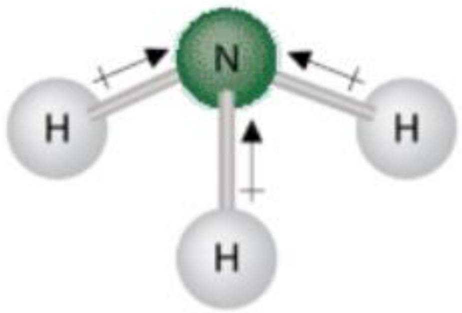
Polarity

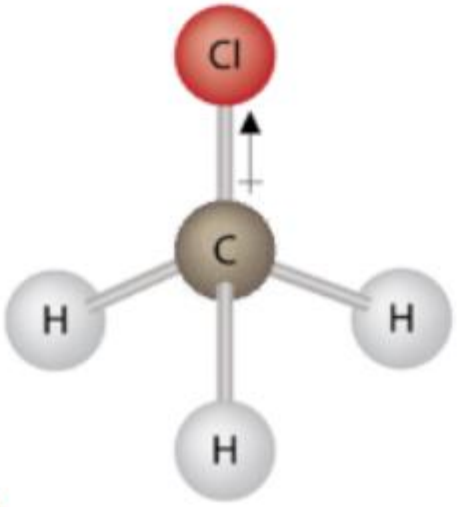
Jump back to title slide

Careful about polar BOND versus polar MOLECULE

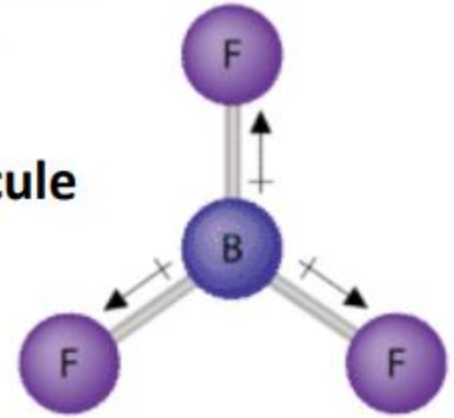
Polar bond AND Polar molecule

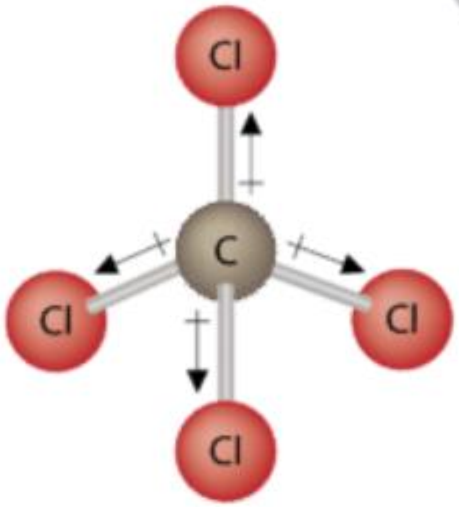






Polar bond AND NON-polar molecule

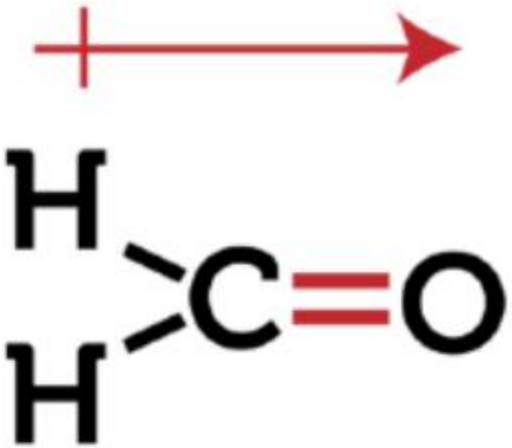


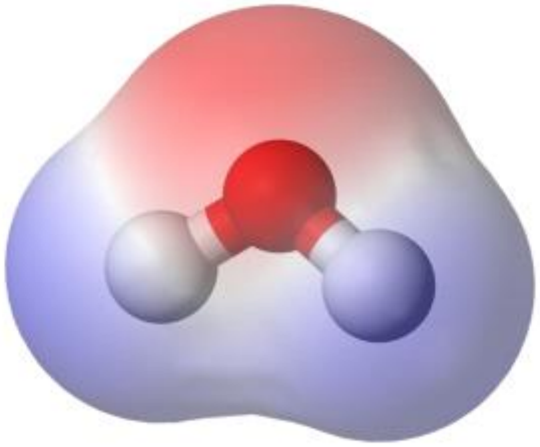


Polarity

Jump back to title slide

Three ways to diagram "dipoles"





IMFs

Jump back to title slide

Vocabulary

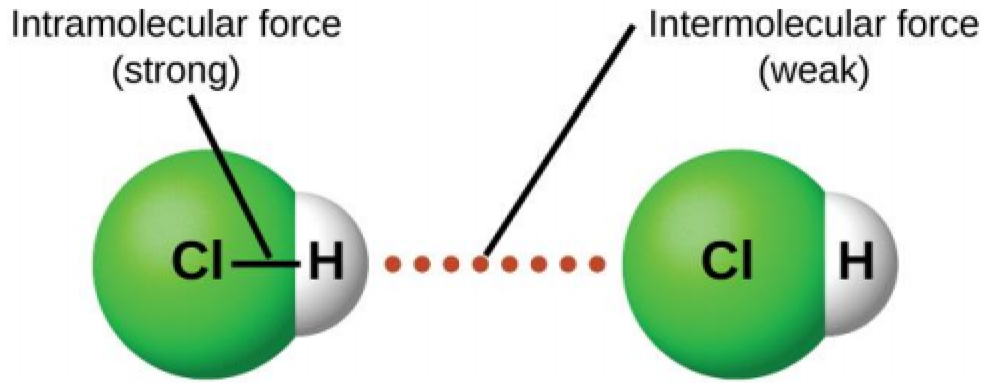
INTRAmolecular Forces

Forces holding together the atoms **INSIDE** a molecule or compound.

Types: Ionic forces, covalent forces

INTERmolecular Forces

Attractions or repulsions which act **between neighboring molecules**



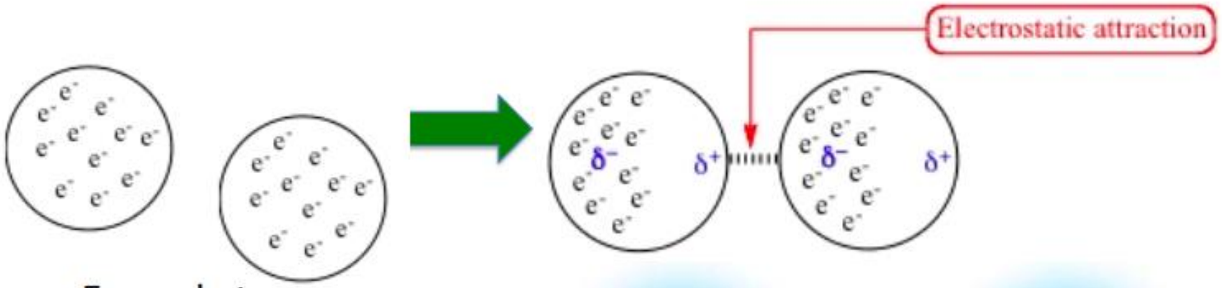
IMFs

Jump back to title slide

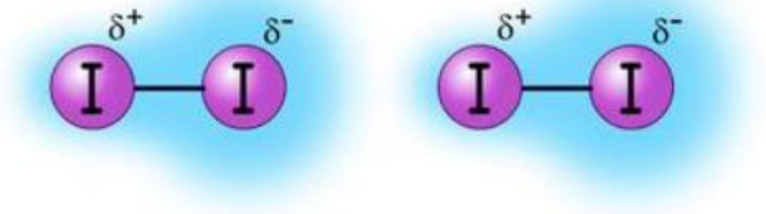
London Dispersion Forces

VERY WEAK and TEMPORARY!!!!

Caused by **temporary unequal** electron distribution that makes weak and temporary dipoles. Also called "instantaneous dipole"



Example I_2



London Dispersion Forces Continued…

EVERYTHING HAS LONDON DISPERSION FORCES BECAUSE EVERYTHING HAS ELECTRONS!

Bigger molecules will have more LDFs – more surface area to get temporary unequal electrons

C_8H_{18} will have more LDFs than C_3H_8

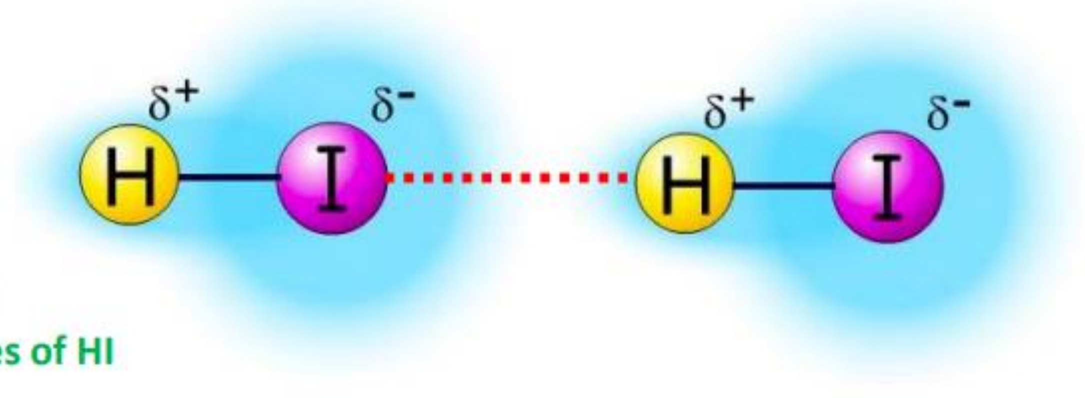
IMFs

Jump back to title slide

Dipole - Dipole

ONLY OCCURS IN POLAR MOLECULES

Partially negative portion of one polar molecule
attracted to
Partially positive portion of the second polar molecule



Example:
2 molecules of HI

IMFs

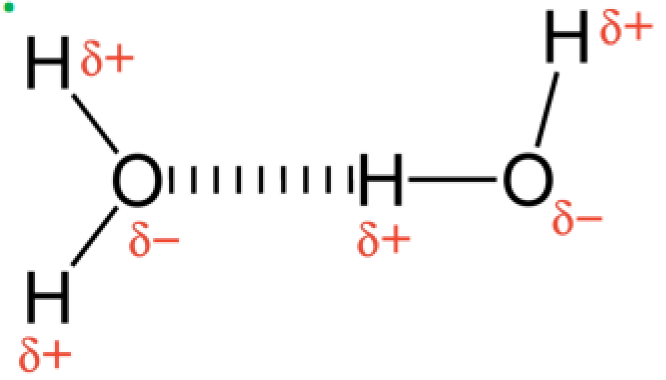
Jump back to title slide

Hydrogen Bonding

A TYPE OF DIPOLE-DIPOLE!
(Strongest Kind of IMF!)

Must have:

"H-NOF:"



ATTRACTION BETWEEN:

the partially negative part of a *lone pair* on an N, O, or F, atom (−)	....	(+) Hydrogen end of an O-H, N-H, or F-H bond

IMFs

Jump back to title slide

Some properties that relate to intermolecular forces

Boiling point Melting point Viscosity Surface tension	When you increase IMFs Properties increase too! More forces=higher props	
Miscibility (Mixing)	"Like dissolves like"	
	Polar with polar	Non-polar with non-polar

IMFs

[Jump back to title slide]

Bulk Solids

Interactions in solids

COMBINATION OF:
intramolecular AND intermolecular forces in a "large" or "bulk" scale

3 TYPES
Metallic *(weakest)*
Ionic Lattice *(middle)*
Network covalent *(strongest)*

Bulk solids have very high melting/boiling points because there are so many inter and intra molecular forces holding the atoms close together

IMFs

Jump back to title slide

Overall Ranking

Nonpolar Covalent LDF	Polar Covalent DP-DP	Polar Covalent H-Bond	Metallic Bond	Ionic Bond	Network Covalent

Weakest
Least
IMFs

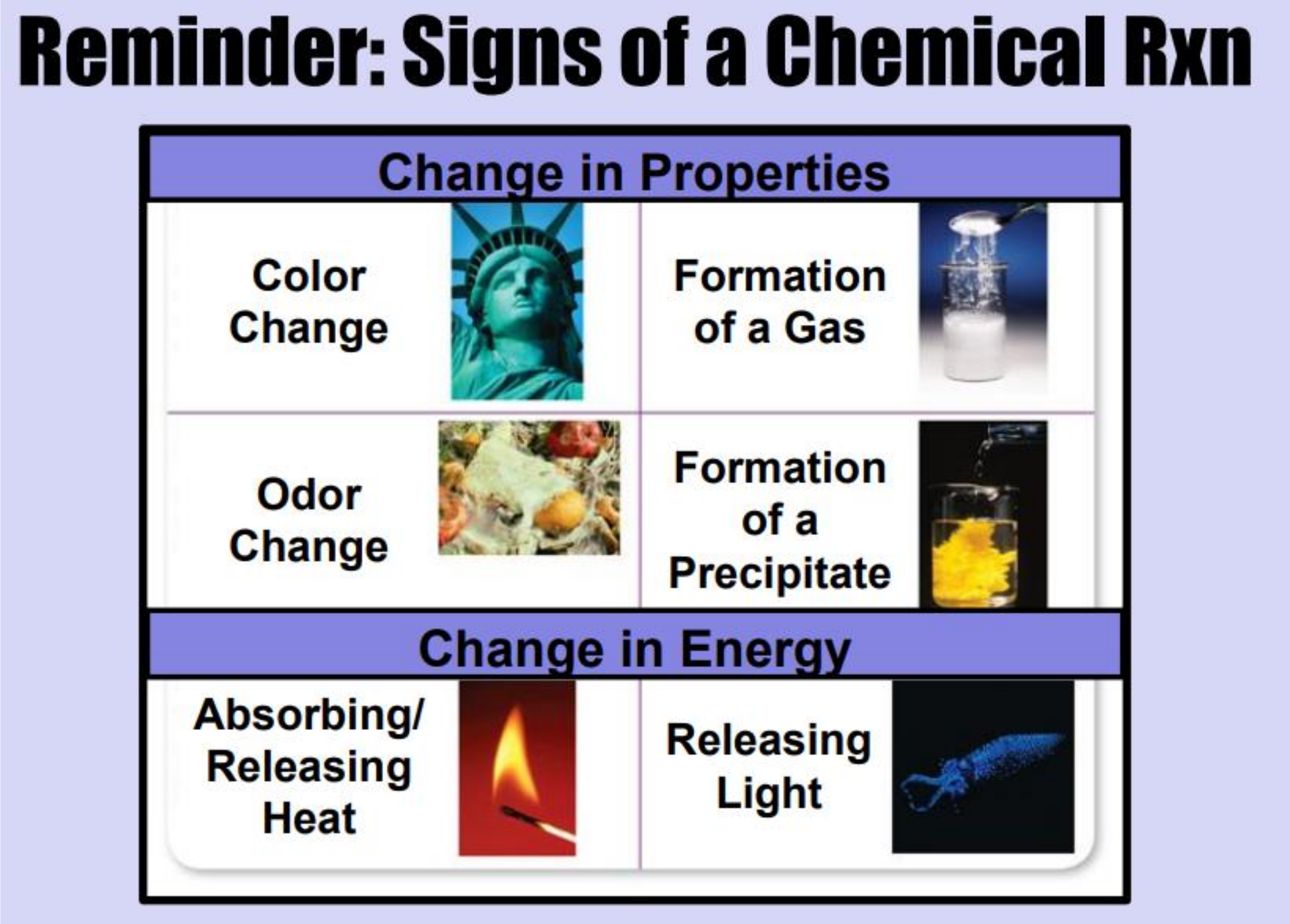
Strongest
Most
IMFs

Unit #6
Reactions

- Signs of a chemical reaction
- Balancing equations
- Types of reactions
- Predicting products
- Net ionic equations

Signs of a Reaction

Jump back to title slide



Balancing

Jump back to title slide

Law of Conservation of Mass

<u>In normal chemical reactions *(not nuclear rxns),*</u>

– Total mass of reactants is equal to total mass of products

– Nothing can magically appear

– Nothing can magically disappear

Science not Magic!

Balancing

Jump back to title slide

Diatomic Gases

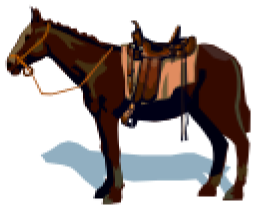
H_2 Cl_2

N_2 Br_2

O_2 I_2

F_2

Horses Need Oats For Clear Brown "Eyes"



Balancing

Jump back to title slide

Rules for Balancing

1) Write the skeleton equation

2) Count atoms on each side of arrow
   (look at the subscripts & the coefficients!)

3) Change <u>coefficients</u> so the atoms are balanced; ***<u>NEVER</u>* change subscripts!**

4) Make sure coefficients are in lowest ratio possible

5) Check your work!

USE PENCIL!!!

Balancing

Jump back to title slide

Tips for Balancing that (sometimes) Help!

K

- Stuck? Erase and start over!
- Try to balance atoms that appear in the fewest number of places first
- Try to leave any diatomics until the end
- Oxygens are often the hardest to balance
- Try to balance polyatomic ions as a "chunk"
- Combustion reactions – put a "2" in front of the hydrocarbon and THEN count & balance (may need to reduce your coefficients at the end, but it makes it easier!)

Balancing

Jump back to title slide

#1

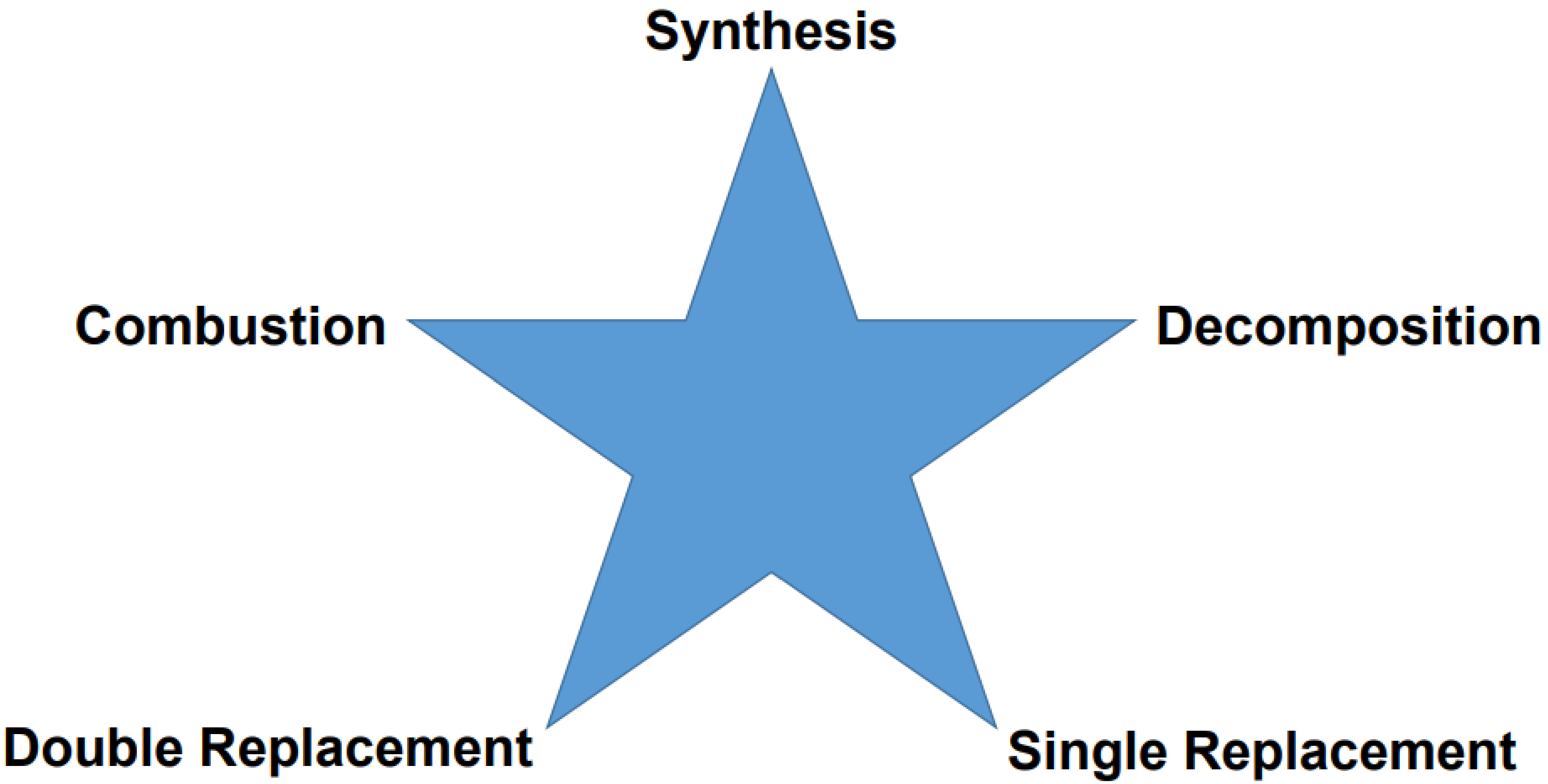
Count each atom – BEFORE, DURING, and AFTER!

__2__ ZnS (aq) + ______ O_2 (g) → __2__ ZnO (aq) + __2__ S (s)

Zn:	~~1~~	2	2		Zn:	~~1~~	2	2
S:	~~1~~	2	2		S:	~~1~~	2	2
O:	2		2		O:	~~1~~	2	2

Types of Reactions

Jump back to title slide



Jump back to title slide

Synthesis

Two things combining into one

Example:

$X + Y \rightarrow XY$

$O_2 + C \rightarrow CO_2$

What to look for:

More reactants than products

Jump back to title slide

Decomposition

One thing falling apart into two

Example:

$XY \rightarrow X + Y$

$CaCO_3 \rightarrow CaO + CO_2$

What to look for:

More products than reactants

Types of Reactions, Predicting Products

Jump back to title slide

Combustion

Burning

Example:

(almost always a hydrocarbon)

Hydrocarbon + O_2 → CO_2 + H_2O

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

What to look for: ***(Usually)***

Reactants = Hydrocarbon and O_2

Products = CO_2 and H_2O

Types of Reactions, Predicting Products

Jump back to title slide

Single Replacement

Swapping one element

Example:

$A + BC \rightarrow AC + B$

$2Al + 3Pb(NO_3)_2 \rightarrow 2Al(NO_3)_3 + 3Pb$

What to look for:

Reactants =1 element and 1 compound

Products = 1 element and 1 compound, but different ones

Jump back to title slide

Double Replacement

Swapping two elements

Example:

AB + CD → AD + CB

$AgNO_3 + KCl \rightarrow AgCl + KNO_3$

What to look for:

Reactants = 2 Compounds

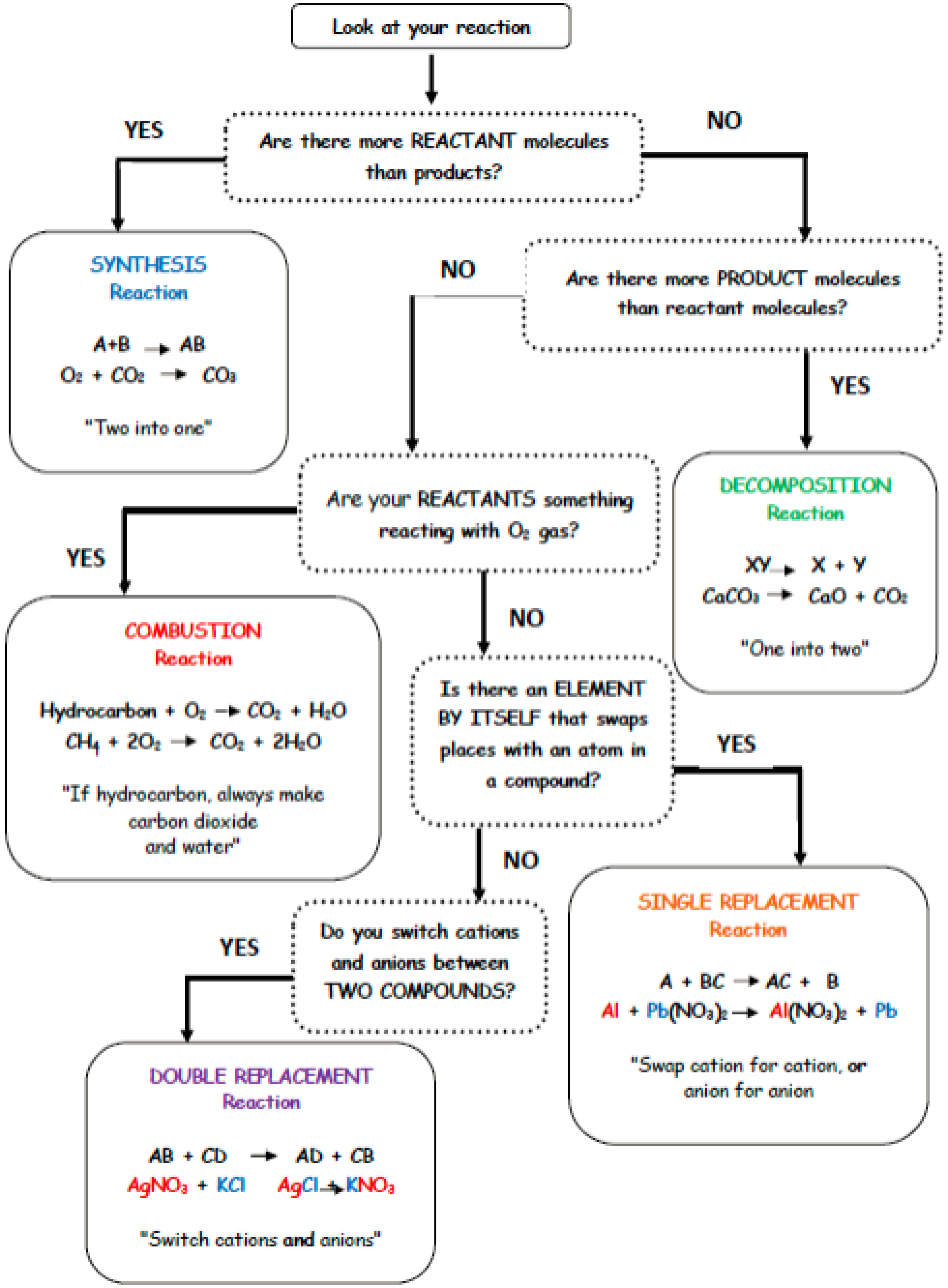
Products = 2 Compounds but different ones

For Replacement Rxns

- *If element is a cation, replace it with the other cation. If it is an anion, replace it with the other anion*
- *All neutral compounds need to have a cation and anion when finished (IN THAT ORDER)*
- *You need NEW subscripts – cross over FROM SCRATCH*
- *Careful about diatomic elements in single replacements – they need to be diatomic!*

Types of Reactions, Predicting Products

Jump back to title slide



Net Ionic

Jump back to title slide

Solubility Chart

- Na_2O
  SOLUBLE b/c it has Na^+ in it!
- $Mg(OH)_2$
  INSOLUBLE b/c OH^- insoluble and Mg^{2+} not one of the exceptions

Solubility of Some Ionic Compounds in Water

Always Soluble		
Alkali metals =	Li^+, Na^+, K^+, Rb^+, Cs^+	AAA CNP
Ammonium =	NH_4^+	
Acetate =	$C_2H_3O_2^-$	
Chlorate =	ClO_3^-	
Nitrate =	NO_3^-	
Perchlorate =	ClO_4^-	
Generally Soluble		
Cl^-, Br^-, I^-	Soluble *except*: Ag^+, Pb^{2+}, Hg_2^{2+}	AP-H
F^-	Soluble *except*: Ca^{2+}, Ba^{2+}, Sr^{2+}, Pb^{2+}, Mg^{2+}	CBS-PM
Sulfate = SO_4^{2-}	Soluble *except*: Ca^{2+}, Ba^{2+}, Sr^{2+}, Pb^{2+}	CBS-P
Generally Insoluble		
O^{2-}, OH^-	Insoluble *except*: Alkali metals and NH_4^+	AA
	Somewhat soluble: Ca^{2+}, Ba^{2+}, Sr^{2+}	CBS
CO_3^{2-} S^{2-}, SO_3^{2-} PO_4^{3-} CrO_4^{2-}, $Cr_2O_4^{2-}$	Insoluble *except*: Alkali metals and NH_4^+	AA

Not Soluble = forms precipitate **Soluble** = dissolves in water (aqueous)

Net Ionic

Jump back to title slide

NOT DONE!!!! NEED TO THINK ABOUT PHASES!

The Balanced Equation

$$2Al + 3Pb(NO_3)_2 \rightarrow 3Pb + 2Al(NO_3)_3$$

The Overall Equation

$$2Al_{(s)} + 3Pb(NO_3)_{2(aq)} \rightarrow 3Pb_{(s)} + 2Al(NO_3)_{3(aq)}$$

The Complete Ionic Equation

$$2Al_{(s)} + 3Pb^{2+}{}_{(aq)} + 6NO_3^-{}_{(aq)} \rightarrow 3Pb_{(s)} + 2Al^{3+}{}_{(aq)} + 6NO_3^-{}_{(aq)}$$

Spectator Ions

The Net Ionic Equation

$$2Al_{(s)} + 3Pb^{2+}{}_{(aq)} \rightarrow 3Pb_{(s)} + 2Al^{3+}{}_{(aq)}$$

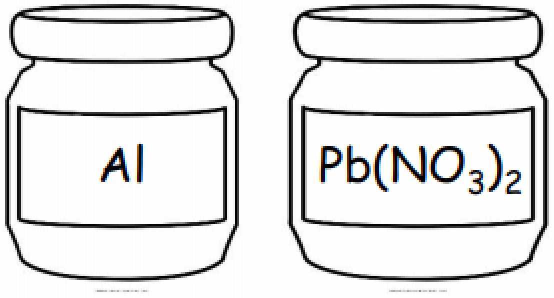
Net Ionic

Jump back to title slide

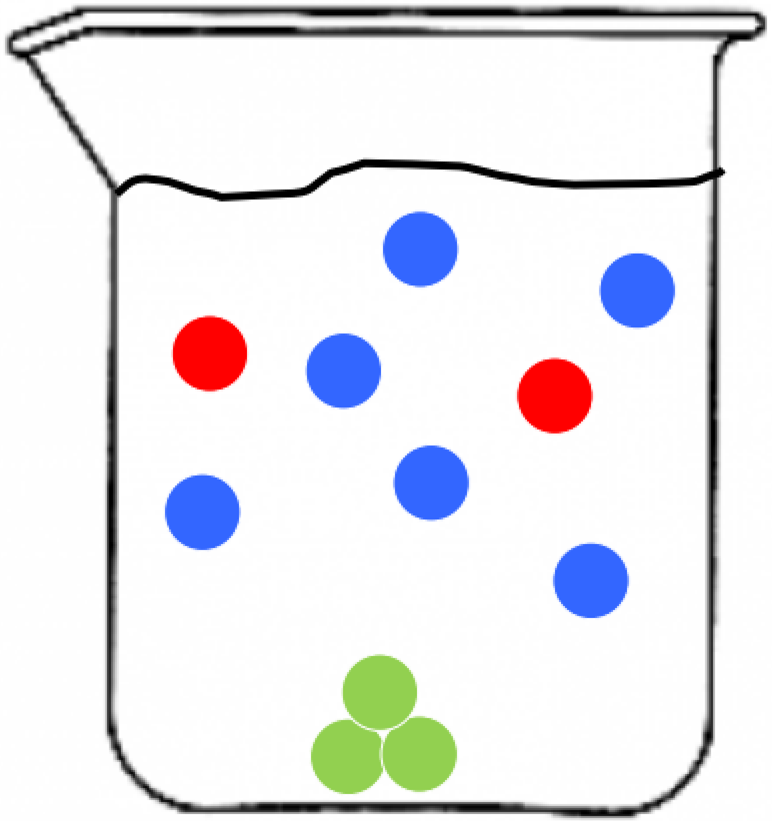
Particulate Diagrams help our brains!

The Balanced Equation

$$2Al + 3Pb(NO_3)_2 \rightarrow 3Pb + 2Al(NO_3)_3$$



Dump into beaker…



Jars of chemicals in stock room

Unit #7
Stoichiometry

- The mole
- Molar mass
- Molar conversions
- Mole ratio
- Stoichiometry

The Mole

Jump back to title slide

THE MOLE A.K.A AVOGADRO'S NUMBER

1 mole = 6.02×10^{23} objects

602,000,000,000,000,000,000,000

Amedeo Avogadro 1776 – 1856

Decided that:

6.02×10^{23} molecules per mole

Molar Mass

Jump back to title slide

MOLAR MASS

1 mole = 6.02 x 10^{23} objects

How much does ONE MOLE of something weigh?

1 atom of Hydrogen = 1.01 amu*
1 MOLE of Hydrogen = 1.01 grams

1 atom of Carbon = 12.01 amu
1 MOLE of Carbon = 12.01 grams

Use Periodic Table!

***"Atomic mass unit" = 1.661 x 10^{-24} grams**

Picking 1 mol = 6.02 x 10^{23} makes it so we don't need to manually do the conversion each time! That's why it's a random number!

Molar Mass

[Jump back to title slide]

Molar Mass

Multiple atoms in a molecule? Add up their individual masses to find molar mass of molecule

CO_2 = 1 carbon + 2 oxygens

Molar mass CO_2 = 12.01g + 2(16.00g)

= 44.01g ***per ONE mole***

= 44.01 g/mol

Use Periodic Table!

Molar Mass

Careful with parenthesis!

$(NH_4)_2S$ = 2N + 8H + 1S

Molar mass $(NH_4)_2S$ = 2(14.01) + 8(1.01) +1(32.07)

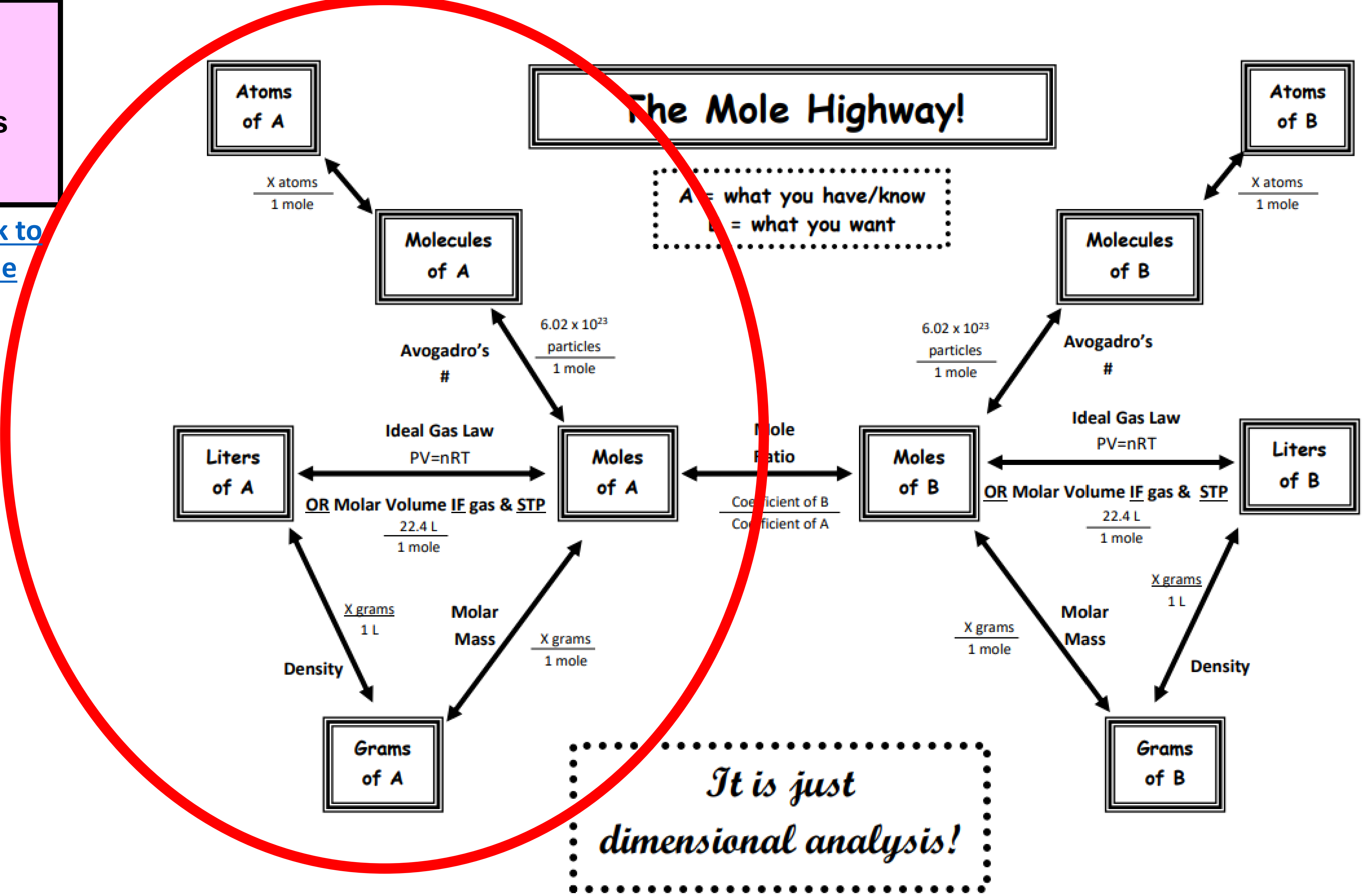
= 68.17g ***per ONE mole***

= 68.17 g/mol

Use Periodic Table!

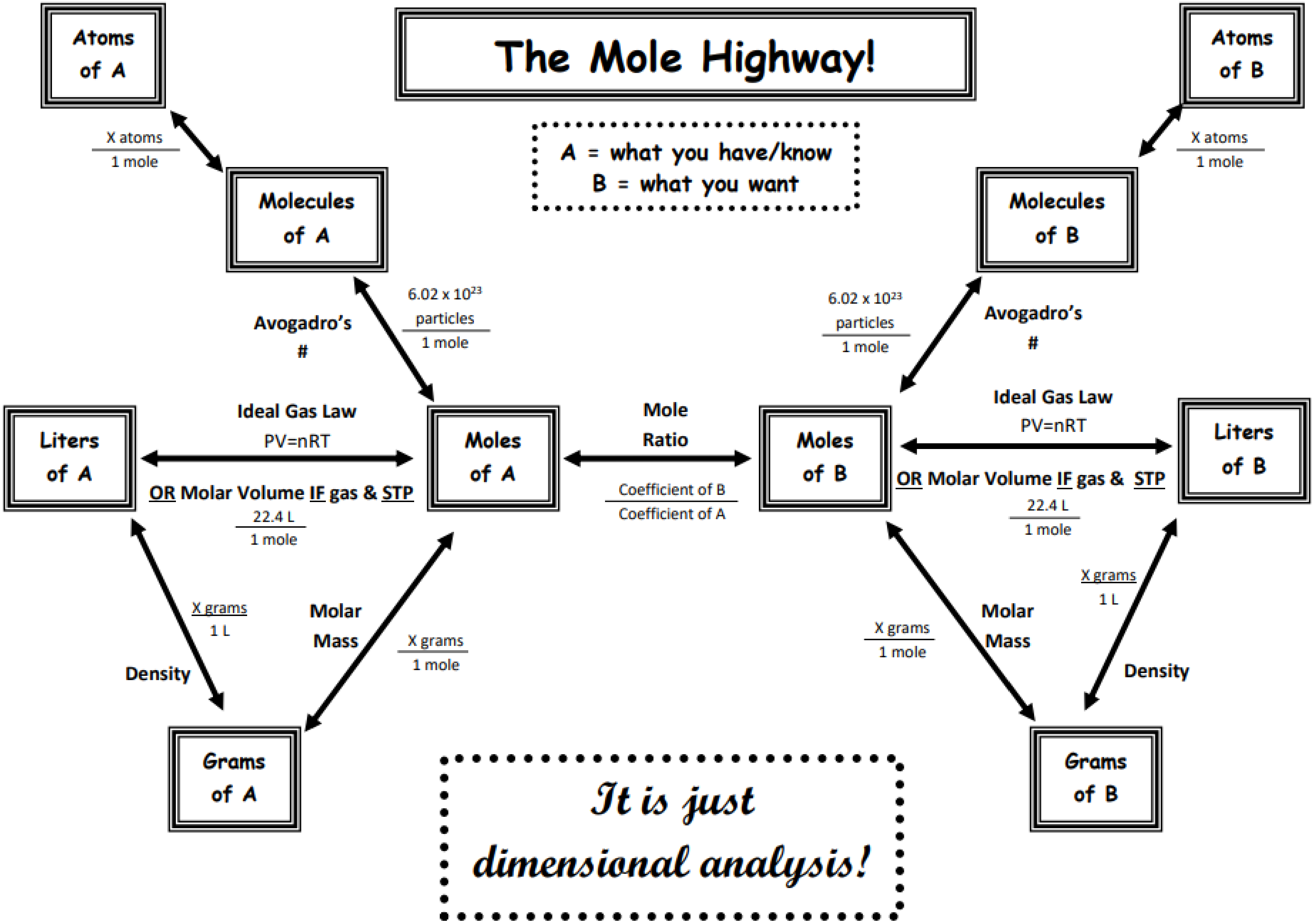
Molar Conv.s

Jump back to title slide



Stoich.

Jump back to title slide

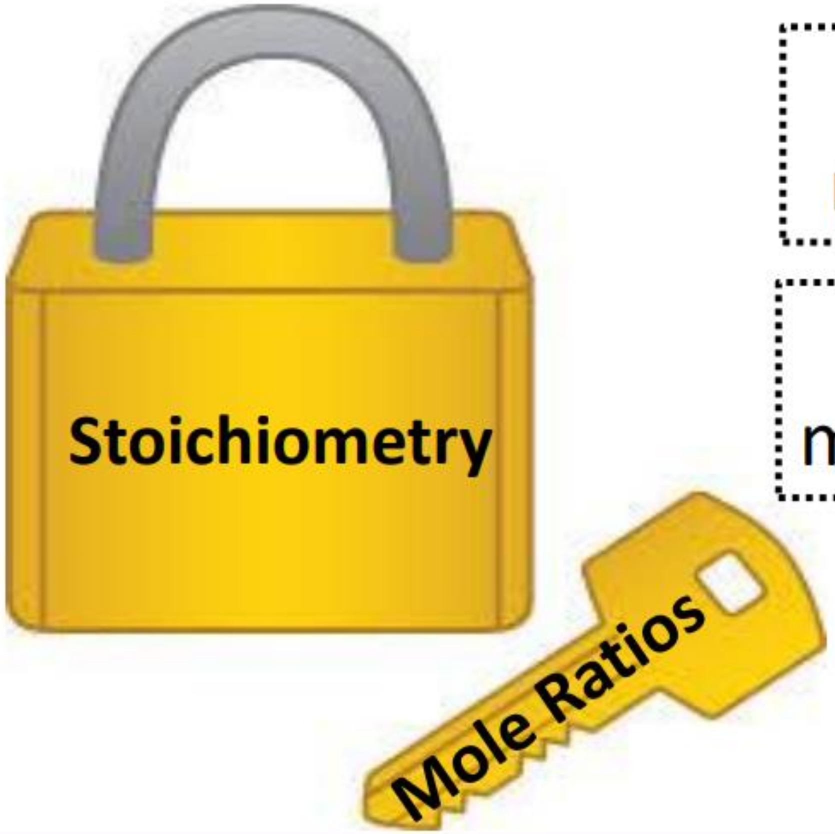


Mole Ratio

Jump back to title slide

Mole Ratios

The "KEY" to stoichiometry!



If I have 3 moles of this, how many moles of that do I have?

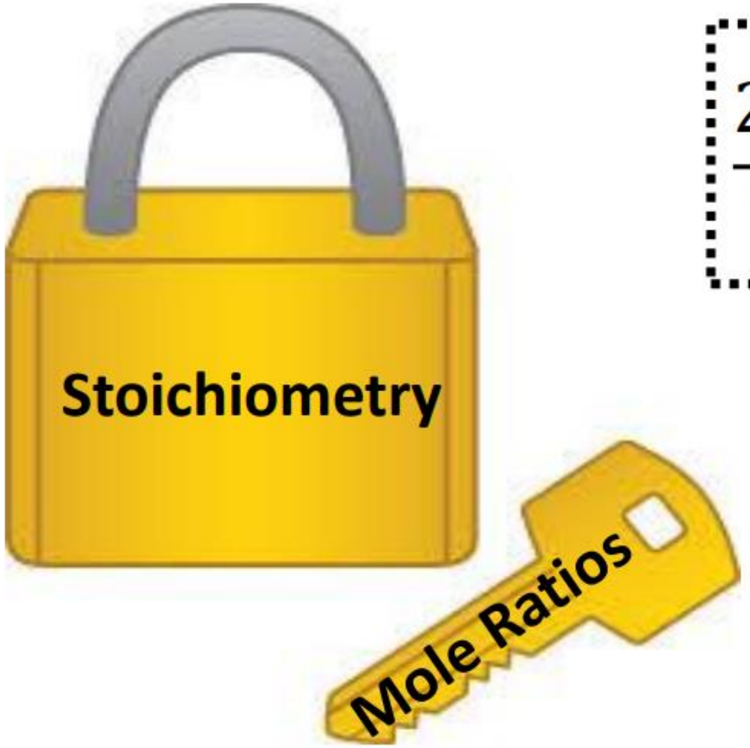
If I have 2 moles of this, how many moles of that can I make?

Mole Ratio

Jump back to title slide

Mole Ratios

$$2H_2 + O_2 \rightarrow 2H_2O$$



$$\frac{2\ moles\ H_2}{1\ mole\ O_2}$$

$$\frac{2\ moles\ H_2}{2\ moles\ H_2O}$$

$$\frac{1\ mole\ O_2}{2\ moles\ H_2O}$$

Mole Ratio

Jump back to title slide

Mole Ratios

You can flip all mole ratios

$$\frac{2\ moles\ H_2}{1\ mole\ O_2} \rightarrow \frac{1\ mole\ O_2}{2\ moles\ H_2}$$

$$\frac{2\ moles\ H_2}{2\ moles\ H_2O} \rightarrow \frac{2\ moles\ H_2O}{2\ moles\ H_2}$$

$$\frac{1\ mole\ O_2}{2\ moles\ H_2O} \rightarrow \frac{2\ moles\ H_2O}{1\ mole\ O_2}$$

Stoich.

Jump back to title slide

Q #2

$N_2 + 3H_2 \rightarrow 2NH_3$

75 grams $NH_3 \rightarrow$? g H_2

Pathway:

grams A → moles A → moles B → grams B

Molar mass of A	Mole Ratio	Molar mass of B
X g A / *1 mole A*	*moles B* / *moles A*	*X g B* / *1 mole B*

Stoich.

Jump back to title slide

Q #2

$N_2 + 3H_2 \rightarrow 2NH_3$

75 grams NH_3 → ? g H_2

75 g NH_3	1 mole NH_3	3 mole H_2	2.02 g H_2
	17.03 g NH_3	2 mole NH_3	1 mole H_2

= **13.34 g H_2**

Unit #8
Advanced Chemical Ratios

- Limiting reagent stoichiometry
- Percent composition
- Empirical formulas
- Combustion analysis**

Limiting Reagent Stoich.

[Jump back to title slide]

Limiting Reagent Stoichiometry:

A type of stoich problem where you run out of one chemcial too soon, and have extra of the other chemical left over

Limiting Reagent Stoich.

Jump back to title slide

Usually 3 types of problems:

1. Find Limiting Reagent
2. Find Amounts Made
3. Find how much XS left over

Limiting Reagent Stoich.

[Jump back to title slide](#)

Use mole ratios and dimensional analysis to compare…

What you *HAVE* versus What you *NEED*

Limiting Reagent Stoich.

Jump back to title slide

Steps

1. Grams to moles
2. Have vs. need
3. Identify limiting
4. Stoich with limiting (*if asked*)
5. Find xs left (*if asked*)

Limiting Reagent Stoich.

[Jump back to title slide]

If you reacted 150.0 g of K with 225 g of Br_2, how many g of KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

$$\frac{150.0\ \text{g K}}{} \left|\ \frac{1\ \text{mol K}}{39.10\ \text{g K}}\right. = 3.836\ \text{mol K}$$

$$\frac{225\ \text{g } Br_2}{} \left|\ \frac{1\ \text{mol } Br_2}{159.8\ \text{g } Br_2}\right. = 1.408\ \text{mol } Br_2$$

Steps

1. **Grams to moles**
2. Have vs. need
3. Identify limiting
4. Stoich with limiting
5. Find xs left

Limiting Reagent Stoich.

[Jump back to title slide]

If you reacted 150.0 g of K with 225 g of Br_2, how may g of KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

	2K	Br_2
HAVE:	3.836 mol	1.408 mol
NEED:	↓	1.918 mol

$$\frac{3.836 \text{ mol K} \times 1 \text{ mol } Br_2}{2 \text{ mol K}}$$

= 1.918 mol Br_2 NEEDED to use up all the K you have!

Steps
1. Grams to moles
2. **Have vs. need**
3. Identify limiting
4. Stoich with limiting
5. Find xs left

Nice thing – it doesn't matter which starting value you try first! Cuts down the length of the problems/work a lot! You could have started with 1.408 moles of Br_2 instead!

Limiting Reagent Stoich.

Jump back to title slide

If you reacted 150.0 g of K with 225 g of Br_2, how much KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

	2K	Br_2
HAVE:	**3.836** mol	**1.408** mol
NEED:		**1.918** mol

Steps
1. Grams to moles
2. Have vs. need
3. **Identify limiting**
4. Stoich with limiting
5. Find xs left

You don't have enough Br_2 – that makes it the "limiting regent" – you will run out of it first!

So K is your "excess reagent" – you will have some extra left over when done.

Limiting Reagent Stoich.

Jump back to title slide

If you reacted 150.0 g of K with 225 g of Br_2, how many g of KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

Steps

1. Grams to moles
2. Have vs. need
3. Identify limiting
4. **Stoich with limiting**
5. Find xs left

225 g Br_2	1 mol Br_2	2 mol KBr	119 g KBr
	159.8 g Br_2	1 mol Br_2	1 mol KBr

= 335.1 g KBr can be made

Limiting Reagent Stoich.

[Jump back to title slide]

If you reacted 150.0 g of K with 225 g of Br_2, how many g of KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

Or…realize you already did part of it right?!

1.408 mol Br_2	2 mol KBr	119 g KBr
	1 mol Br_2	1 mol KBr

= 335.1 g KBr can be made

Steps
1. Grams to moles
2. Have vs. need
3. Identify limiting
4. **Stoich with limiting**
5. Find xs left

***Just be careful not to round too much early on if you want to use your earlier answer to continue doing your stoichiometry – you have to use your judgement**

Limiting Reagent Stoich.

Jump back to title slide

If you reacted 150.0 g of K with 225 g of Br_2, how may g of KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

	2K	Br_2
HAVE:	3.836 mol	**1.408 mol**
NEED:	**2.816 mol**	1.918 mol

Br_2 is Limiting, so use it to find amount of XS used

Steps
1. Grams to moles
2. Have vs. need
3. Identify limiting
4. Stoich with limiting
5. **Find xs left**

$$\frac{1.408 \text{ mol } Br_2 \times 2 \text{ mol K}}{1 \text{ mol } Br_2}$$

= 2.816 mol K used during the reaction

Limiting Reagent Stoich.

[Jump back to title slide]

If you reacted 150.0 g of K with 225 g of Br_2, how many g of KBr can be made? How much excess reagent is left?

$$2K + Br_2 \rightarrow 2KBr$$

	2K	Br_2
HAVE:	**3.836** mol	**1.408** mol
NEED:	**2.816** mol	**1.918** mol
LEFT:	**1.02** mol	

Now subtract to see what is left!

Steps
1. Grams to moles
2. Have vs. need
3. Identify limiting
4. Stoich with limiting
5. **Find xs left**

*** If it doesn't specify a unit (common) – then just leave in moles! Otherwise, just do more dimensional analysis to convert**

Percent Comp.

Jump back to title slide

Percent Composition

Determining how much of a molecule's mass is from each element

$$\frac{\text{Part}}{\text{Whole}} \times 100 = \%$$

$$\frac{\text{Element's Mass}}{\text{Molecule's Mass}} \times 100 = \%\ \text{Composition}$$

Percent Comp.

Jump back to title slide

Example

$$\frac{\text{Element's Mass}}{\text{Molecule's Mass}} \times 100 = \%\ \text{Composition}$$

Calculate the % composition of Magnesium Carbonate

Molar Mass of Molecule 24.31 + 12.01 + 3(16.00) = 84.32 g/mol

$$Mg = \left(\frac{24.31}{84.32}\right) \bullet 100 = 28.83\%$$

$$C = \left(\frac{12.01}{84.32}\right) \bullet 100 = 14.24\%$$

$$O = \left(\frac{48.00}{84.32}\right) \bullet 100 = 56.93\%$$

3 x 16 because there are 3 oxygens!

Check that it adds up to 100% !!!

Empirical Formulas

Jump back to title slide

Empirical Formula

The simplest, reduced version of a formula.

Smallest whole number ratios possible.

Molecular Formula

The real version of the formula – may or may not be in the simplest most reduced form, just depends on the specific formula.

Empirical Formulas

Jump back to title slide

Ionic Formulas

Are always empirical! NaCl, $MgCl_2$, $Al_2(SO_4)_3$

Covalent Formulas

Sometimes empirical, sometimes not.

Molecular:	H_2O	$C_6H_{12}O_6$	$C_{12}H_{22}O_{11}$
	↓	↓	↓
Empirical:	H_2O	CH_2O	$C_{12}H_{22}O_{11}$

Jump back to title slide

Determining Empirical Formula

1) Given: % composition

2) Assume you have 100g sample to make #s easy

3) Use the poem!

Percent to mass
Mass to moles
Divide by small
Multiply 'till whole

Empirical Formulas

Jump back to title slide

Adipic acid contains 49.32% C, 43.84% O, and 6.85% H by mass. What is the empirical formula of adipic acid?

1. **Percent to mass** – 49.32g C, 43.84g O, 6.85g H
2. **Mass to mole**

$$\frac{49.32\,g\,carbon}{} \Big| \frac{1\,mol\,carbon}{12.01\,g\,carbon} = 4.107\,mol\,carbon$$

$$\frac{6.85\,g\,hydrogen}{} \Big| \frac{1\,mol\,hydrogen}{1.01\,g\,hydrogen} = 6.78\,mol\,hydrogen$$

$$\frac{43.84\,g\,oxygen}{} \Big| \frac{1\,mol\,oxygen}{16.00\,g\,oxygen} = 2.74\,mol\,oxygen$$

Empirical Formulas

Jump back to title slide

3. Divide by small – divide the mole values by the smallest mole value found… gets you the simplest ratios!

Carbon: $$\frac{4.107\,mol\,carbon}{2.74\,mol} = 1.50$$

Hydrogen: $$\frac{6.78\,mol\,hydrogen}{2.74\,mol} = 2.47$$

Oxygen: $$\frac{2.74\,mol\,oxygen}{2.74\,mol} = 1.00$$

Empirical Formulas

Jump back to title slide

4. **Multiply 'till whole** – If necessary, multiply the values found until they are whole numbers. The numbers may not be perfect, might have to round a little bit! ***YOU HAVE TO MULTIPLY THEM ALL BY THE SAME # !***

Hydrogen: 2.47 → 2.50 x 2 = 5

Carbon: 1.50 x 2 = 3

Oxygen: 1.00 x 2 = 2

Empirical formula: $C_3H_5O_2$

Empirical Formulas

Jump back to title slide

Determining Molecular Formula

1) Find molar mass of the empirical formula

2) Divide molecular formula mass by empirical formula mass

3) Multiply empirical formula subscripts by the multiplier # found in step 2

No cute rhyme this time…sorry! ☺

Empirical Formulas

Jump back to title slide

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

1. **Molar mass of empirical formula**

   3(12.01 g) + 5(1.01) + 2(16.00) = 73.08 g/mol

2. **Divide molecular by empirical masses**

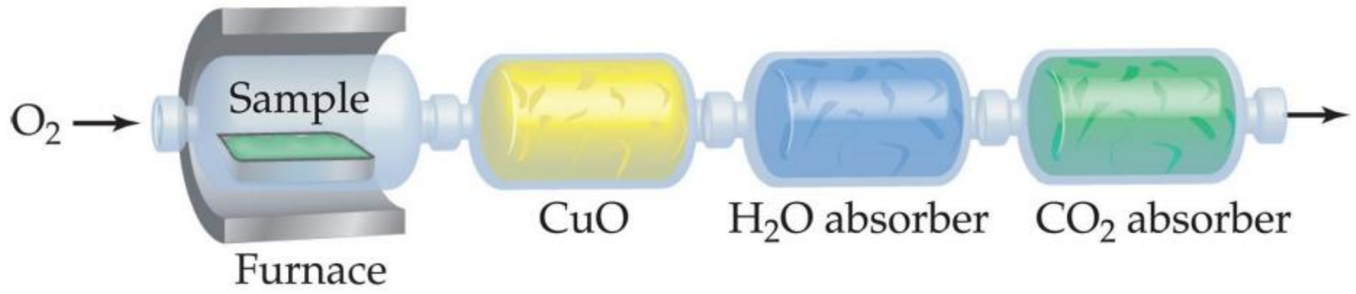
   $\frac{146}{73.08} = 1.997 \rightarrow 2$ **you will usually have to round a bit**

3. **Multiply empirical by multiplier found in step 2**

$$(C_3H_5O_2) \times 2 = \mathbf{C_6H_{10}O_4}$$

Jump back to title slide

Combustion Analysis



Compounds containing C, H and O are routinely analyzed through combustion in a chamber like this.

- C is determined from the mass of CO_2 produced.
- H is determined from the mass of H_2O produced.
- O is determined by difference after the C and H have been determined.

Combust. Analysis

Jump back to title slide

So now it will be like this!

- ~~% to mass~~
- Mass to mole
- Divide by small
- Multiply til whole

Use Combustion Analysis Data and Dimensional Analysis to find grams

Combust. Analysis

Jump back to title slide

The amount of CO_2 gives the amount of C originally present in the sample compound

The amount of H_2O gives the amount of H originally present in the sample

The amount of O originally present in the sample can be found by simple subtraction

- Mass of sample
  Mass of C
  – Mass of H
  = Mass of Oxygen!

Combust. Analysis

Jump back to title slide

Important Points to Know

- Must know the mass of the unknown substance before burning it
- The unknown will be burnt in pure oxygen, present in large excess
- The amount of oxygen will be determined by subtraction.
- The combustion products always have CO_2 and H_2O. Might have extra products if other elements are present!
- Nitrogen product can come in different forms. N_2, NH_3, etc. Will be given more info if needed. Often given as a separate experiment – will need to convert all to %'s if this is the case! Nitrogen is the problem child in combustion analysis.
- All the carbon winds up as CO_2 and all the hydrogen winds up as H_2O.

Combust. Analysis

Jump back to title slide

Steps to Solve

1) Determine the mass of each element present in the original compound using dimensional analysis
   - Carbon is always in CO_2 in the ratio of 1 mole CO2 = 1 mole C
   - Hydrogen is always in H_2O in the ratio of 1 mole H2O = 2 mole H
   - Nitrogen can be (NH_3, N_2, N, NO_2, etc…). If data from a separate experiment, make sure to convert masses to % values!
2) Subtract to solve for oxygen

   Sample mass – (C_{mass}+H_{mass}+$N_{\text{mass if necessary, or any other random element}}$)
3) Now continue with the Rhyme from before!
   - Mass to moles
   - Divide by small
   - Multiply until whole

Combust.
Analysis

Jump back to title slide

Example #1

Original sample = 8.38 g and yielded 16.0 g CO_2 and 9.80 g H_2O

Moles of Carbon

16.0 g CO_2	1 mole CO_2	1 mole C	= 0.364 mole C
	44.0 g CO_2	1 mole CO_2	

Moles of Hydrogen

9.80 g H_2O	1 mole H_2O	2 mole H	= 1.09 mole H
	18.0 g H_2O	1 mole H_2O	

Combust. Analysis

Jump back to title slide

Example #1

Original sample = 8.38 g and yielded 16.0 g CO_2 and 9.80 g H_2O

Moles to Mass to Calculate Oxygen

$$\frac{0.364 \text{ mole C}}{} \left| \frac{12.0 \text{ g C}}{1 \text{ mole C}} \right. = 4.37 \text{ g C}$$

$$\frac{1.09 \text{ mole H}}{} \left| \frac{1.01 \text{ g H}}{1 \text{ mole H}} \right. = 1.10 \text{ g H}$$

Grams of Oxygen

8.38 g Sample – 4.37 g C – 1.10 g H = 2.91 g Oxygen

Combust. Analysis

Jump back to title slide

Example #1

Original sample = 8.38 g and yielded 16.0 g CO_2 and 9.80 g H_2O

Back to the Rhyme! *Mass to moles, divide by small, multiply till whole!*

$$\frac{2.91\text{ g O}}{} \times \frac{1\text{ mole O}}{16.00\text{ g O}} = 0.182\text{ mole O}$$

Therefore

0.364 mole C

1.09 mole H

0.182 mole O

Divide by small, multiply till whole (if needed)

$$\frac{0.364\text{ C}}{0.182} = 2$$

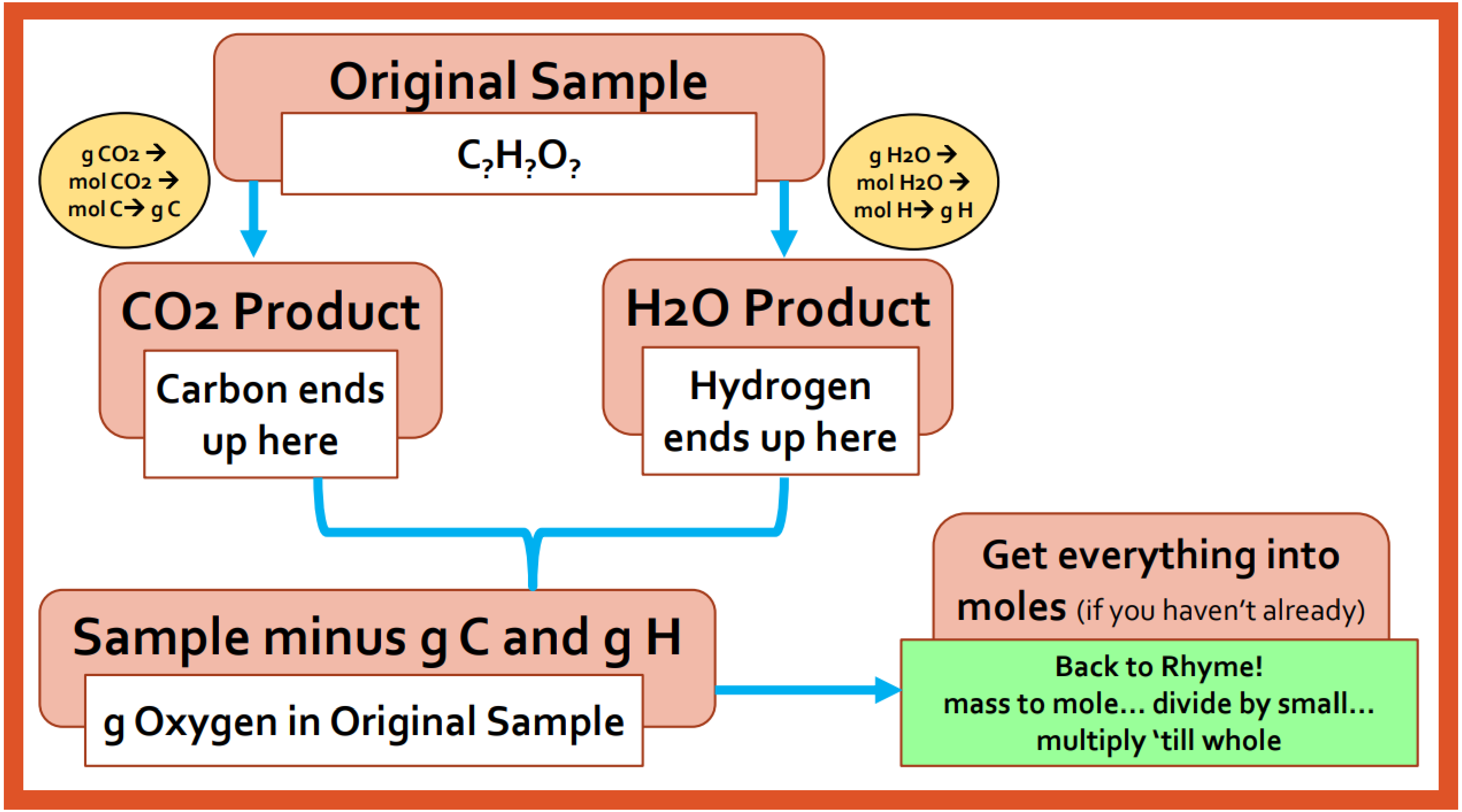
$$\frac{1.09\text{ H}}{0.182} = 5.989 \rightarrow 6$$

$$\frac{0.182\text{ O}}{0.182} = 1$$

C_2H_6O

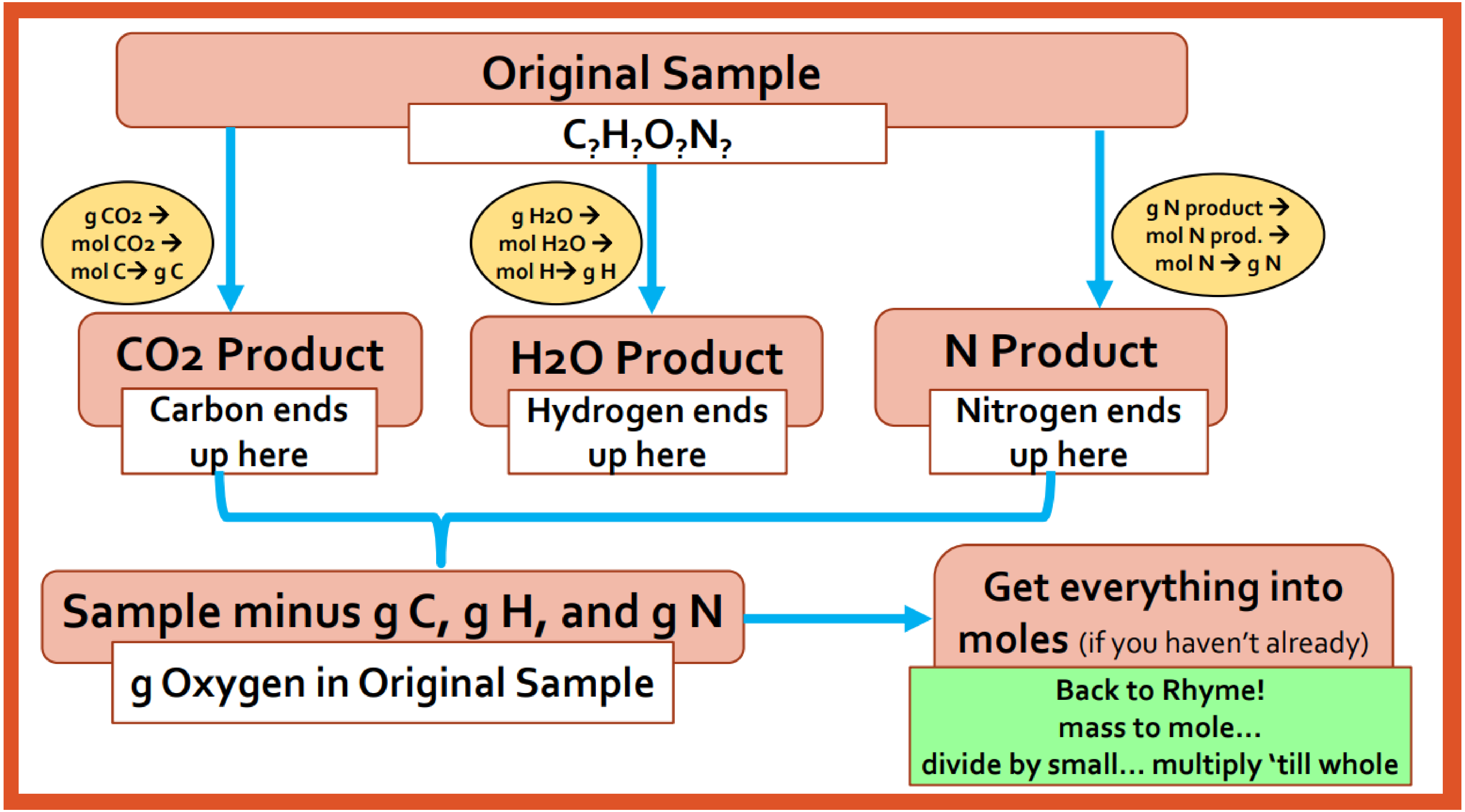
Combust. Analysis

Jump back to title slide



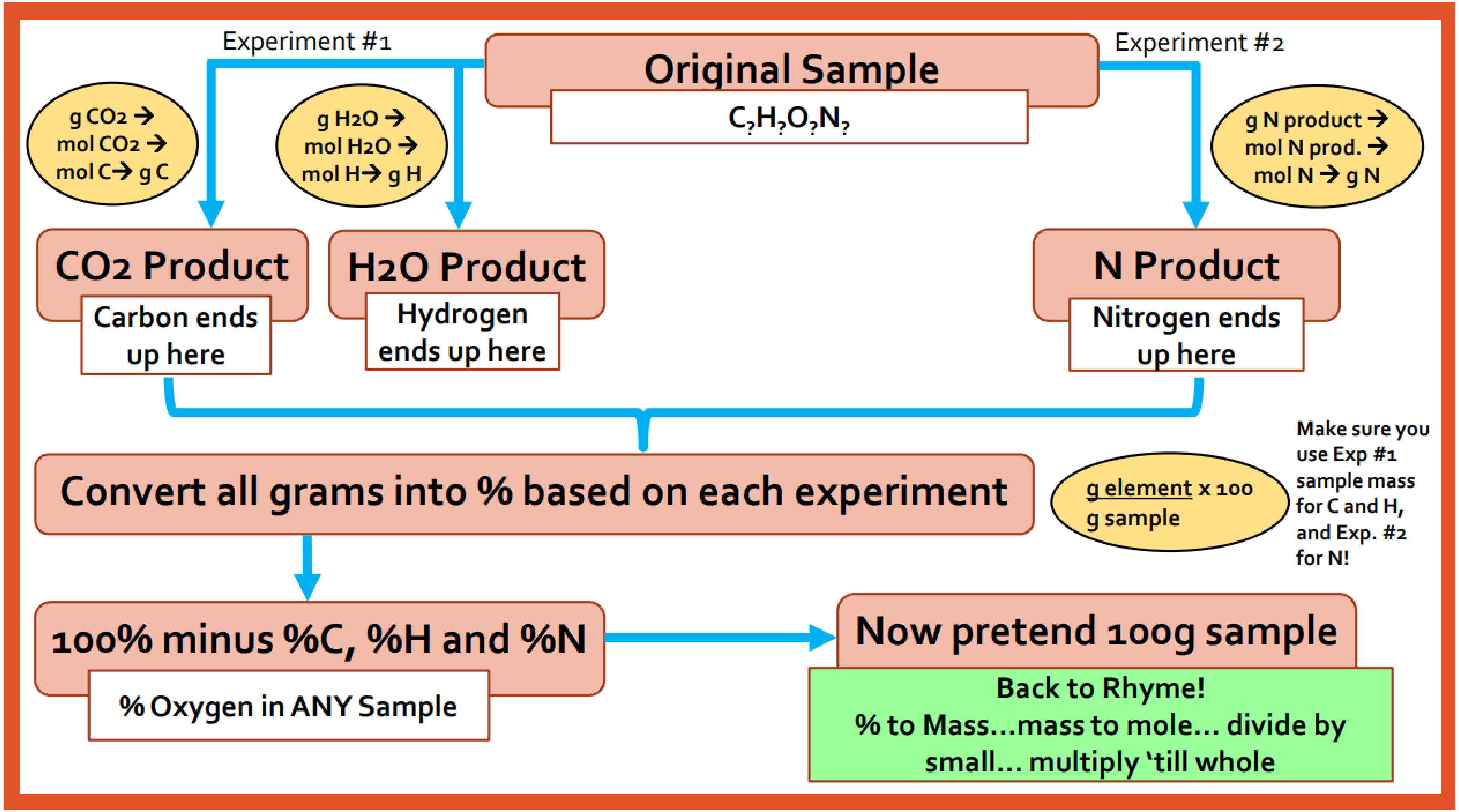
Combust. Analysis

Jump back to title slide



Combust. Analysis

Jump back to title slide



Unit #9
Gas Laws

- KMT theory
- Basic gas law equations
- Ideal gas law equation
- Dalton’s law of partial pressures **
- Gas stoichiometry **

KMT Theory

Jump back to title slide

The Kinetic Molecular Theory applies to what type of gases?

IDEAL GASES

A hypothetical gas that follows all the rules of KMT

- Doesn't really exist!!!
- Allows us to estimate a lot of things, but they are not exactly real

REAL GASES can behave like ideal gases, but only under certain conditions

- High temperature
- Low pressure
- Best to be low IMFs, nonpolar

KMT Theory

[Jump back to title slide](#)

5 assumptions of KMT

1) **Gases consist of large #s of tiny particles that are far apart relative to their size**
   - Most of the volume if a gas is empty space.
   - Gas particles themselves, are so small they don't actually have a "volume"
   - Gas particles are further apart than in a solid or a liquid

2) **Collisions between gas particles and between particles and container walls are *elastic collisions***
   - When two molecules collide with each other, they transfer their kinetic energy, but they don't lose any energy overall.

KMT Theory

Jump back to title slide

3) **Gas particles are in continuous, rapid, random motion. They therefore, possess kinetic energy, which is energy of motion.**

- They move in all random directions, non-stop

4) **There are no forces of attraction between gas particles**

- They behave like billiard balls

5) **The temperature of a gas depends on the average kinetic energy of the particles of the gas.**

$$KE = \frac{1}{2}mv^2$$

↑Temperature = ↑velocity = ↑kinetic energy

Gas Laws

[Jump back to title slide]

Use Kelvins!

Just another unit of measurement.

$K = °C + 273$

"Absolute Zero"

At 0 K there is NO MOLECULAR MOVEMENT!

Zero really means zero!

Units of Pressure

Lots of choices, just convert

Conversions	
1 atm =	1.01325×10^5 Pa
	101.325 kPa
	760 mmHg
	760 torr
	14.7 psi

STP

"Standard" Temperature & Pressure

0° C → 273 K

1 atm → 760 mmHg

Gas Laws

Jump back to title slide

Boyle's Law

$$P_1V_1 = P_2V_2$$

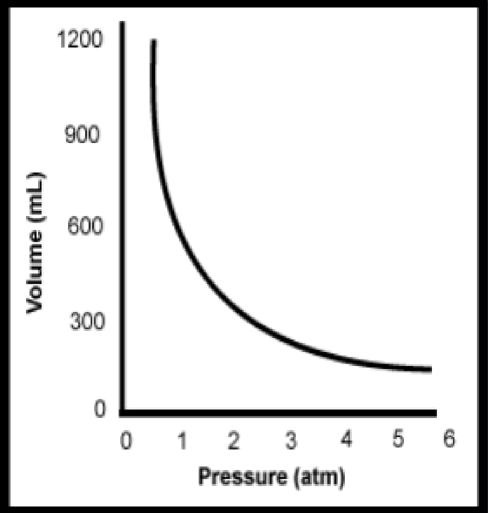
Boyle's Law

$$P_1V_1 = P_2V_2$$

- Temperature and # moles held constant
- Indirect (or inverse) relationship

  If pressure goes ↑

  Then volume goes ↓



Gas Laws

Jump back to title slide

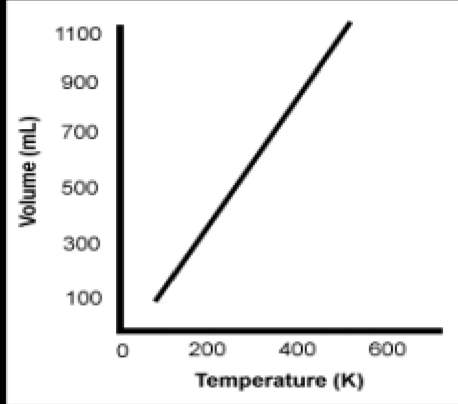
Charles' Law

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

Charles' Law

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

- Pressure and # moles held constant
- Direct relationship
  If temperature goes ↑
  Then volume goes ↑



**note* Graph doesn't go all the way to zero because the molecules will eventually get as close as possible and they will still always take up space*

Gas Laws

[Jump back to title slide]

Gay-Lussac's Law

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

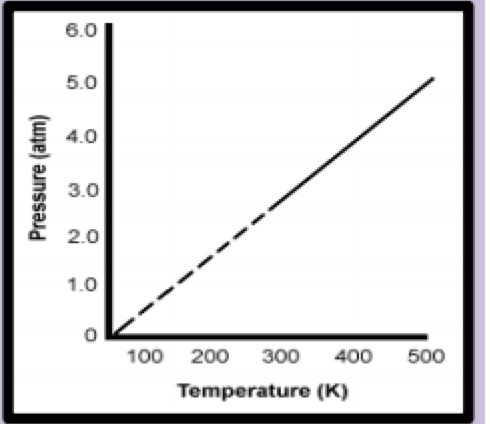
Gay-Lussac's Law

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

- **Volume and # moles held constant**
- **Direct relationship**

  If temperature goes ↑

  Then pressure goes ↑



**note* Graph doesn't go all the way to zero because at low temperatures and pressures it won't be a gas anymore, it will turn into a solid or a liquid. We use a dotted line to show the portions that are not gas phase*

Gas Laws

[Jump back to title slide](#)

Avogadro's Law

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

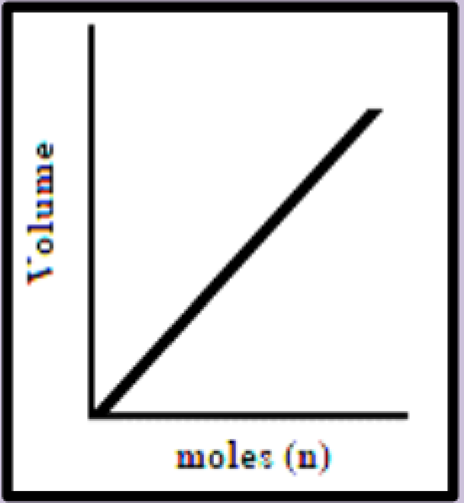
Avogadro's Law

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

- Pressure and temperature held constant
- Direct relationship

  If # of moles goes ↑

  Then volume goes ↑



Gas Laws

[Jump back to title slide]

Combined Gas Law

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

Combined Gas

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

- # of moles held constant
- Combines most common variables together – not common to change moles of gas

Ideal Gas Law

Jump back to title slide

Ideal Gas Law

$$PV = nRT$$

"Piv-nert"

Ideal Gas Law

$$PV = nRT$$

- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant
- T = temperature

Ideal Gas Constant

Values of the Universal Gas Constant R

Values of R	Units	Values of R	Units
8.314472	$J \cdot K^{-1} \cdot mol^{-1}$	83.14472	$L \cdot mbar \cdot K^{-1} \cdot mol^{-1}$
0.082057	$L \cdot atm \cdot K^{-1} \cdot mol^{-1}$	8.314472×10^{-5}	$m^3 \cdot bar \cdot K^{-1} \cdot mol^{-1}$
8.205745×10^{-5}	$m^3 \cdot atm \cdot K^{-1} \cdot mol^{-1}$	10.73159	$ft^3 \cdot psi \cdot {}^\circ R^{-1} \cdot lb\text{-}mol^{-1}$
8.314472	$L \cdot kPa \cdot K^{-1} \cdot mol^{-1}$	0.73024	$ft^3 \cdot atm \cdot {}^\circ R^{-1} \cdot lb\text{-}mol^{-1}$
8.314472	$m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}$	1.98588	$Btu \cdot {}^\circ R^{-1} \cdot lb\text{-}mol^{-1}$
82.05745	$cm^3 \cdot atm \cdot K^{-1} \cdot mol^{-1}$	62.36367	$L \cdot torr \cdot K^{-1} \cdot mol^{-1}$

Ideal Gas Law

Jump back to title slide

$$M = \frac{DRT}{P}$$

$$D = \frac{MP}{RT}$$

$$M = \frac{mRT}{PV}$$

Molar Mass Kitty always puts DIRT over its PEE

Dalton's Law

Jump back to title slide

Dalton's Law

$$P_{Total} = P_1 + P_2 + P_3 + \cdots$$

Dalton's Law

Jump back to title slide

Mole Fractions

$$X_{gas\,1} = \frac{n_{gas\,1}}{n_{total}}$$

$$X_{gas\,2} = \frac{n_{gas\,2}}{n_{total}}$$

Etc…

Dalton's Law

Jump back to title slide

Partial Pressure

$$P_{gas\,1} = (X_{gas\,1}) \bullet (P_{total})$$

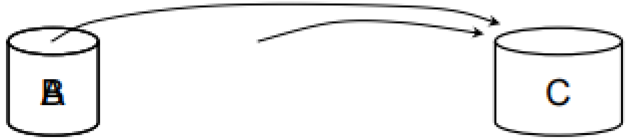
$$P_{gas\,2} = (X_{gas\,2}) \bullet (P_{total})$$

Etc…

Dalton's Law

[Jump back to title slide]

Two 1.0 L containers, A and B, contain gases under 2.0 and 4.0 atm, respectively. Both gases are forced into Container C (w/vol. 2.0 L). Find total pres. of mixture in C.



$$P_{1A}V_{1A} = P_{2CA}V_{2CA}$$

$$2.0\text{ atm }(1.0\text{ L}) = P_{2CA}\,(2.0\text{ L})$$

$$P_{2CA} = 1.0\text{ atm}$$

$$P_{1B}V_{1B} = P_{2CB}V_{2CB}$$

$$4.0\text{ atm }(1.0\text{ L}) = P_{2CB}\,(2.0\text{ L})$$

$$P_{2CB} = 2.0\text{ atm}$$

	P_1	V_1	V_{2C}	P_{2C}
A	2.0 atm	1.0 L	2.0 L	1.0 atm
B	4.0 atm	1.0 L		2.0 atm

$$P_{2CTotal} = 3.0\text{ atm}$$

Now do a partial pressure problem and add up your two partial pressures to find total pressure!

Dalton's Law

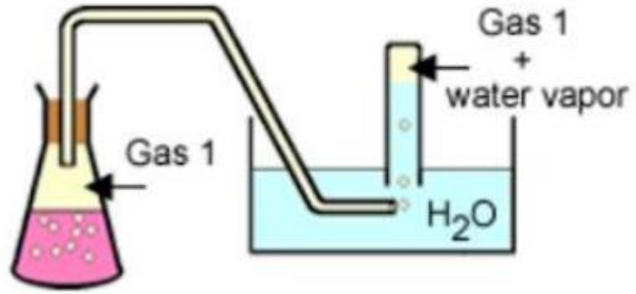
Jump back to title slide

Collecting Gas Over Water via Displacement

The gas being created will push the water out of the collection container and "displace" it – allows you to find the volume collected.

The total pressure in the collection container is the same as atmospheric pressure in the room.

Water vapor is a bit of a problem though…



The collected gas will have water vapor in it as well. The amount of water vapor will change based on the temperature.

Dalton's Law

Jump back to title slide

"Wet Gas" versus "Dry Gas"

The total pressure will be a result of the partial pressure of the desired collected gas being generated by the reaction, and the partial pressure of the water vapor.

$$P_{total} = P_{dry\ gas} + P_{H_2O}$$

$$P_{dry\ gas} = P_{total} - P_{H_2O}$$

Example #1

Hydrogen gas is collected over water at 22°C. Find the pressure of the dry gas if the atmospheric pressure is 708 mmHg.

Remember: *The total pressure in the collection bottle is equal to atmospheric pressure and is a mixture of H_2 and water vapor.*

GIVEN:	WORK:
P_{H_2} = ? P_{total} = 708 mmHg P_{H_2O} = 19.8 mmHg *Look up water-vapor pressure on chart for 22°C.*	$P_{total} = P_{H_2} + P_{H_2O}$ 708 mmHg = P_{H_2} + 19.8 mmHg P_{H_2} = 688.2 mmHg

Gas Stoich.

[Jump back to title slide]

Gas Stoichiometry

- **"Normal" stoichiometry**
  = using molecules, masses & molar masses.
- We can use stoichiometry for gas reactions!
- ***STILL need mole ratios…might need gas laws to help you find # of moles though!***

molar mass of A ↓ | mole ratio from balanced equation ↓ | molar mass of B ↓

grams A ↔ moles A ↔ moles B ↔ grams B

↕ ← PV = nRT → ↕

P, V, T (A)   P, V, T (B)

At times you will be able to use 22.4 L/mol at STP or 24.8 L/mol at SATP as shortcuts (SATP=298K instead of 273K)

Gas Stoich.

Jump back to title slide

Sample problem 1

CH_4 burns in O_2, producing CO_2+ $H_2O(g)$. A 1.22 L CH_4 cylinder, at 15°C, has a pressure of 328 kPa.

a) What volume of O_2 at 100kPa and 298K will be required to react completely with all of the CH_4?

First: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

Pathway:

L of A → mol A → mol B → L of B

PV = nRT *of A*

Mole Ratio

PV = nRT *of B*

Gas Stoich.

Jump back to title slide

L of A → mol A

PV = nRT *of A*

P = 328 kPa, V = 1.22 L, T = 288 K

PV = nRT

$$\frac{(328\ \text{kPa})(1.22\ \text{L})}{(8.31\ \text{kPa•L/K•mol})(288\ \text{K})} = \mathbf{n = 0.167\ mol\ CH_4}$$

moles of A → moles of B ***mol CH_4 → mol O_2 :***

Mole Ratio

$$\frac{0.167\ \text{mol}\ CH_4}{} \left| \frac{2\ \text{mol}\ O_2}{1\ \text{mol}\ CH_4} \right. = \mathbf{0.334\ mol\ O_2}$$

mol B → L of B *P= 100 kPa, n= 0.334 mol, T= 298 K*

PV = nRT *of B*

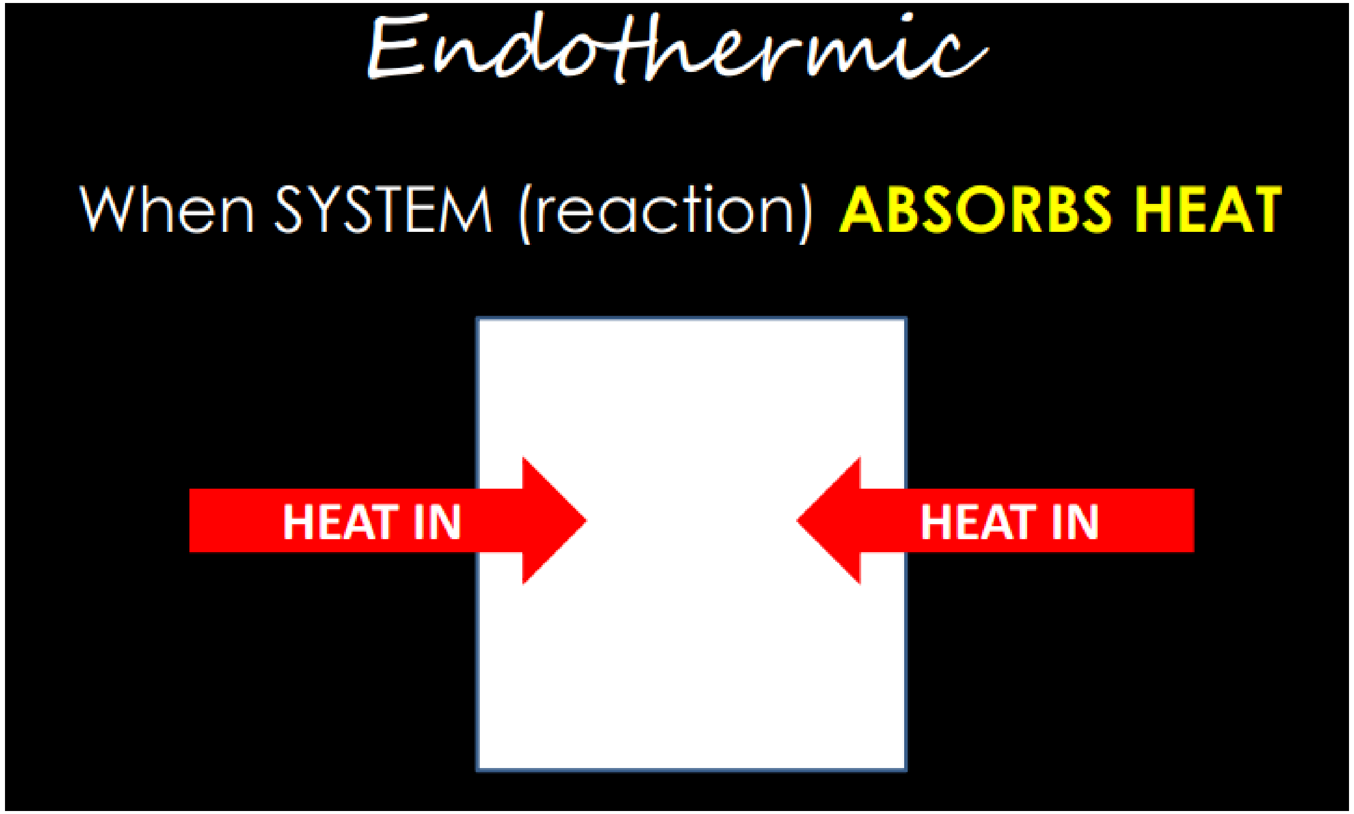
$$\frac{(0.334\ \text{mol})(8.31\ \text{kPa•L/K•mol})(298\ \text{K})}{(100\ \text{kPa})} = \mathbf{V\ of\ O_2 = 8.28\ L}$$

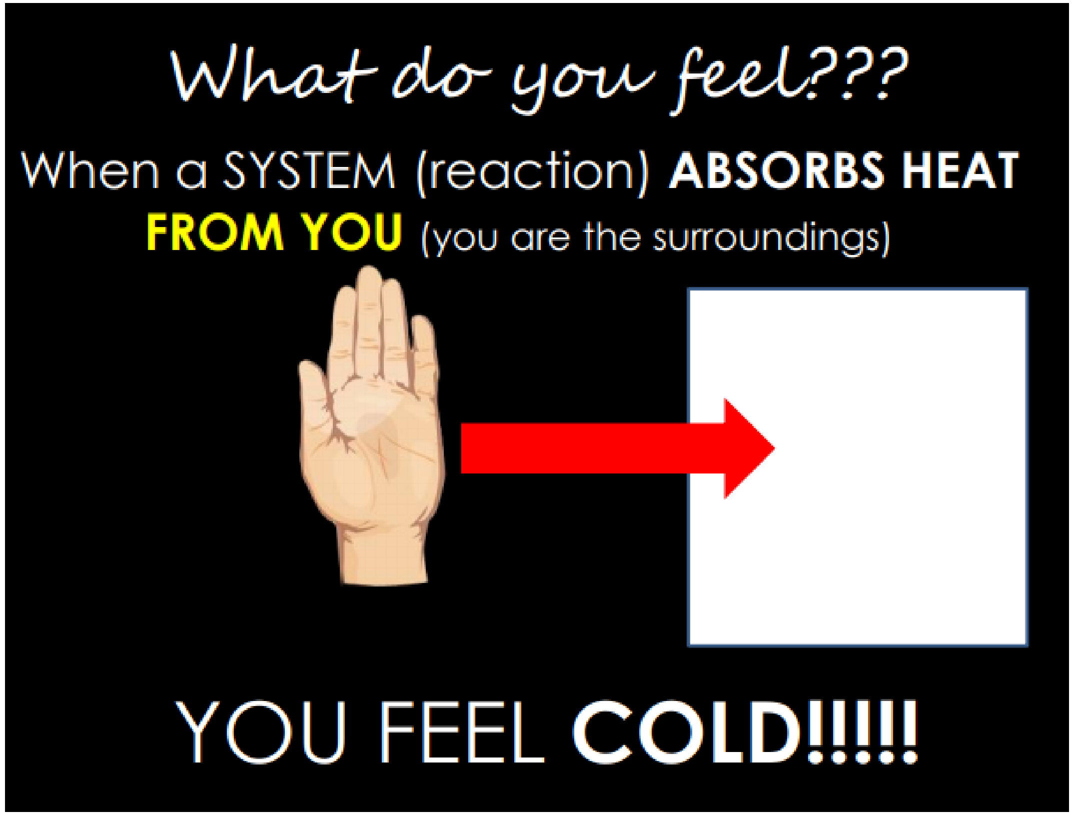
Unit #10
Thermochemistry *

- Endo versus Exo
- Specific heat
- Calorimetry
- Heating/cooling curves
- Heat of Reaction
- Reaction Diagrams
- Heat of Formation
- Bond Energy
- Hess's Law

Endo vs. Exo

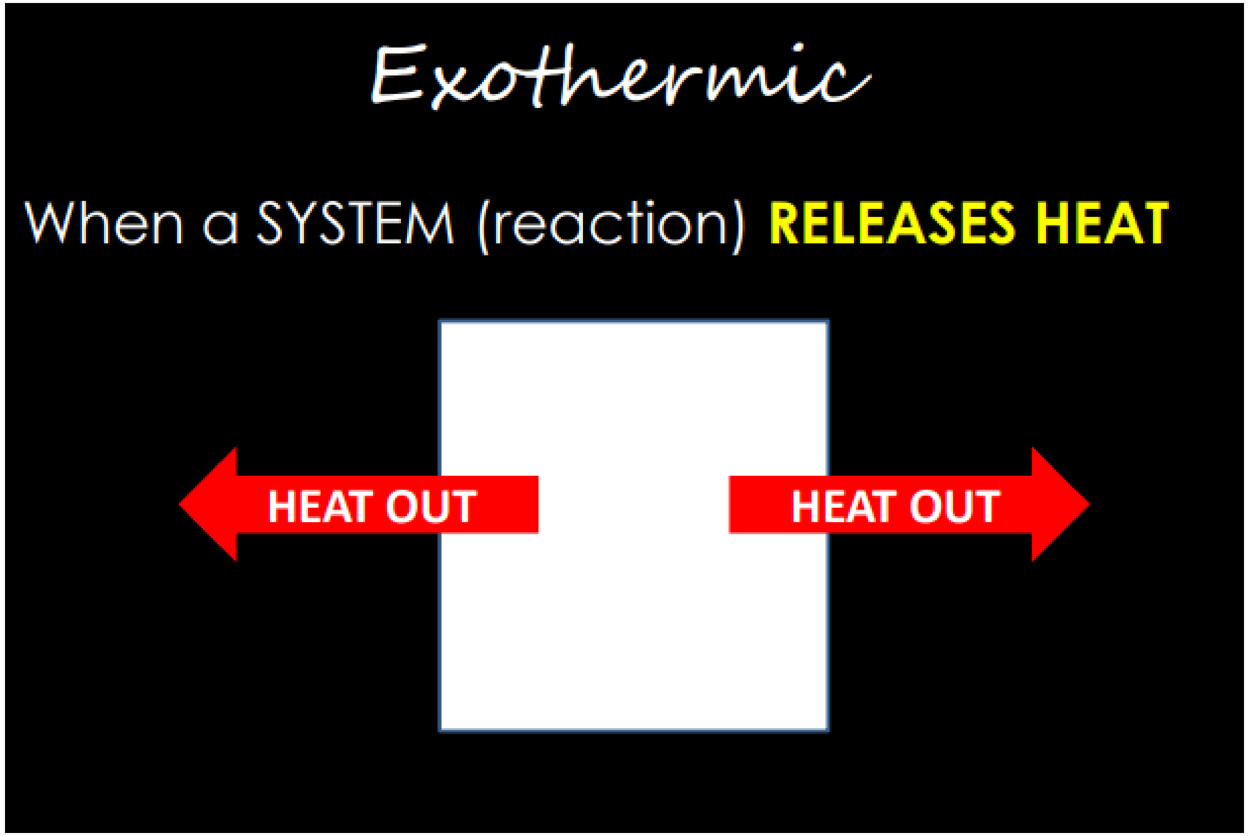
Jump back to title slide

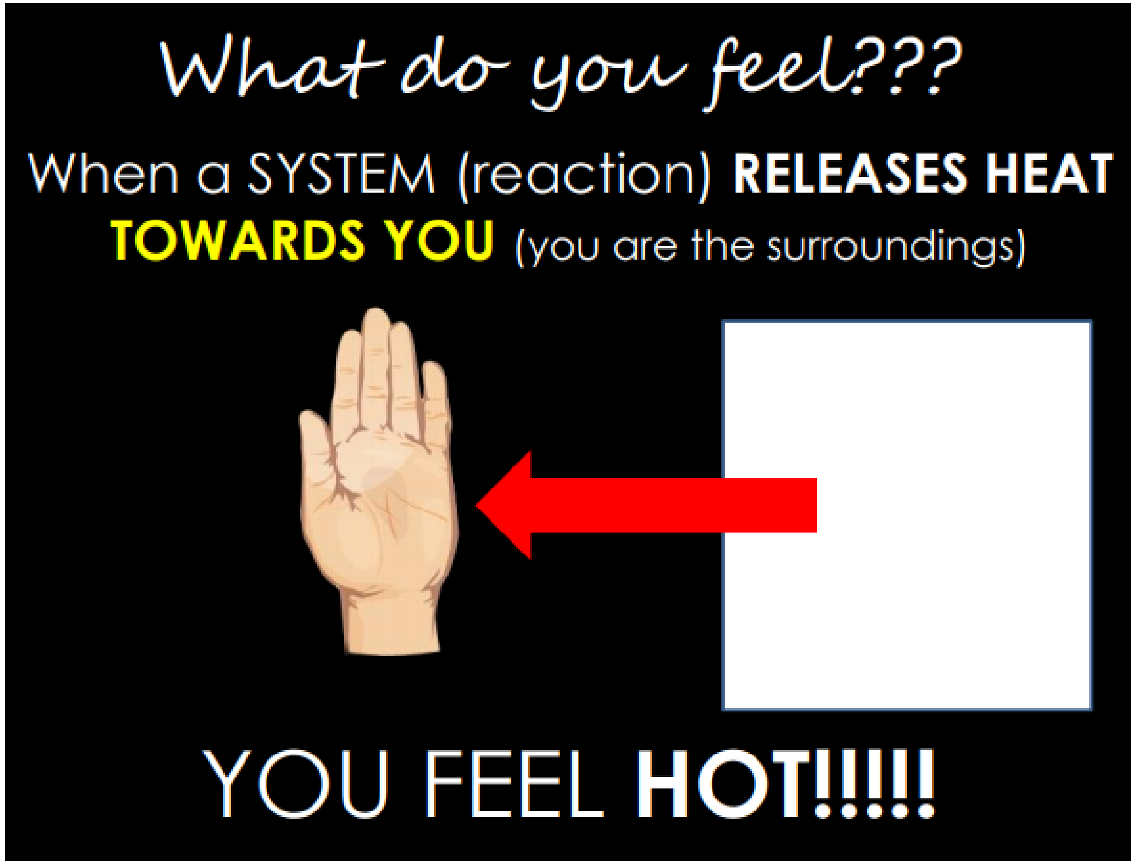




Endo vs. Exo

Jump back to title slide





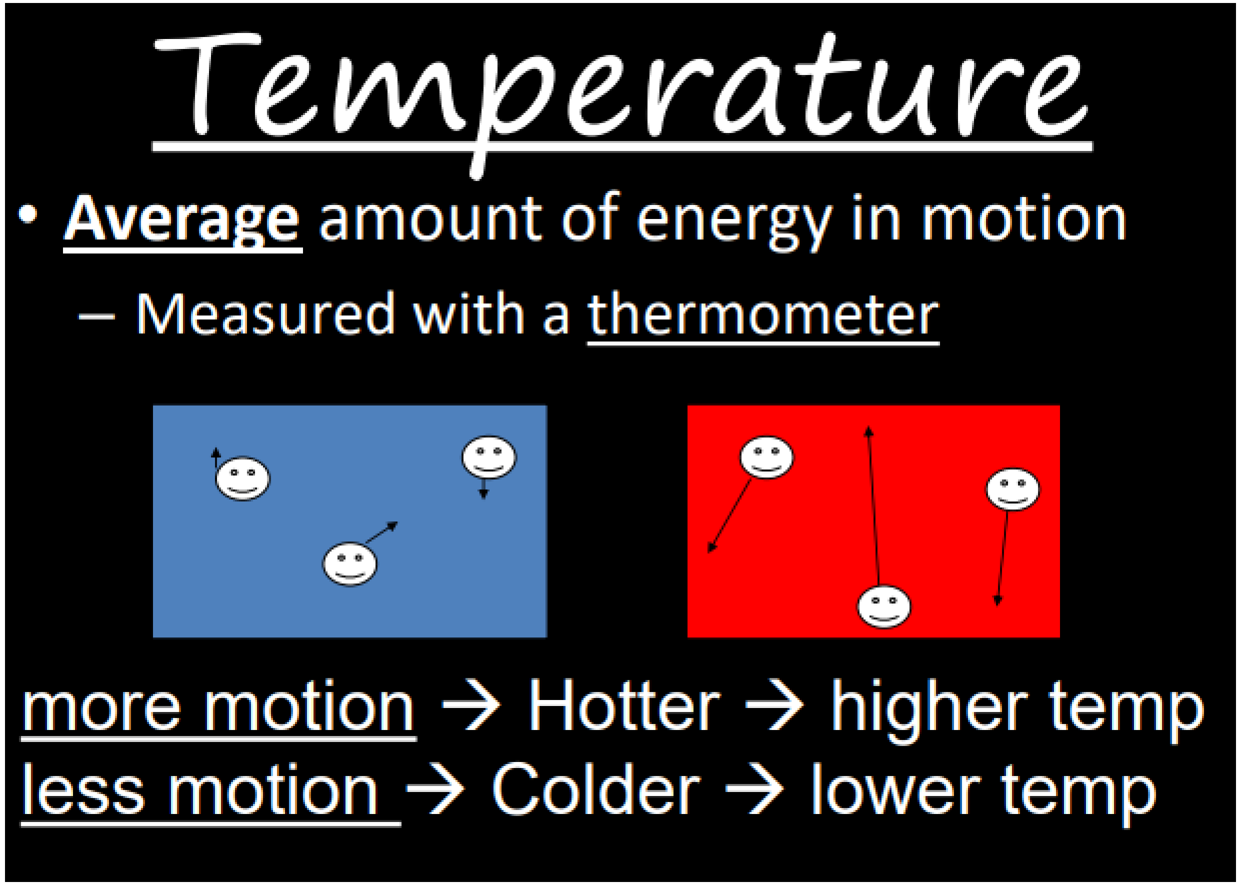
Endo vs. Exo

Jump back to title slide

Gaining Heat	Endothermic	Q = +	ΔT = +
Losing Heat	Exothermic	Q = -	ΔT = -
m and C are always positive			

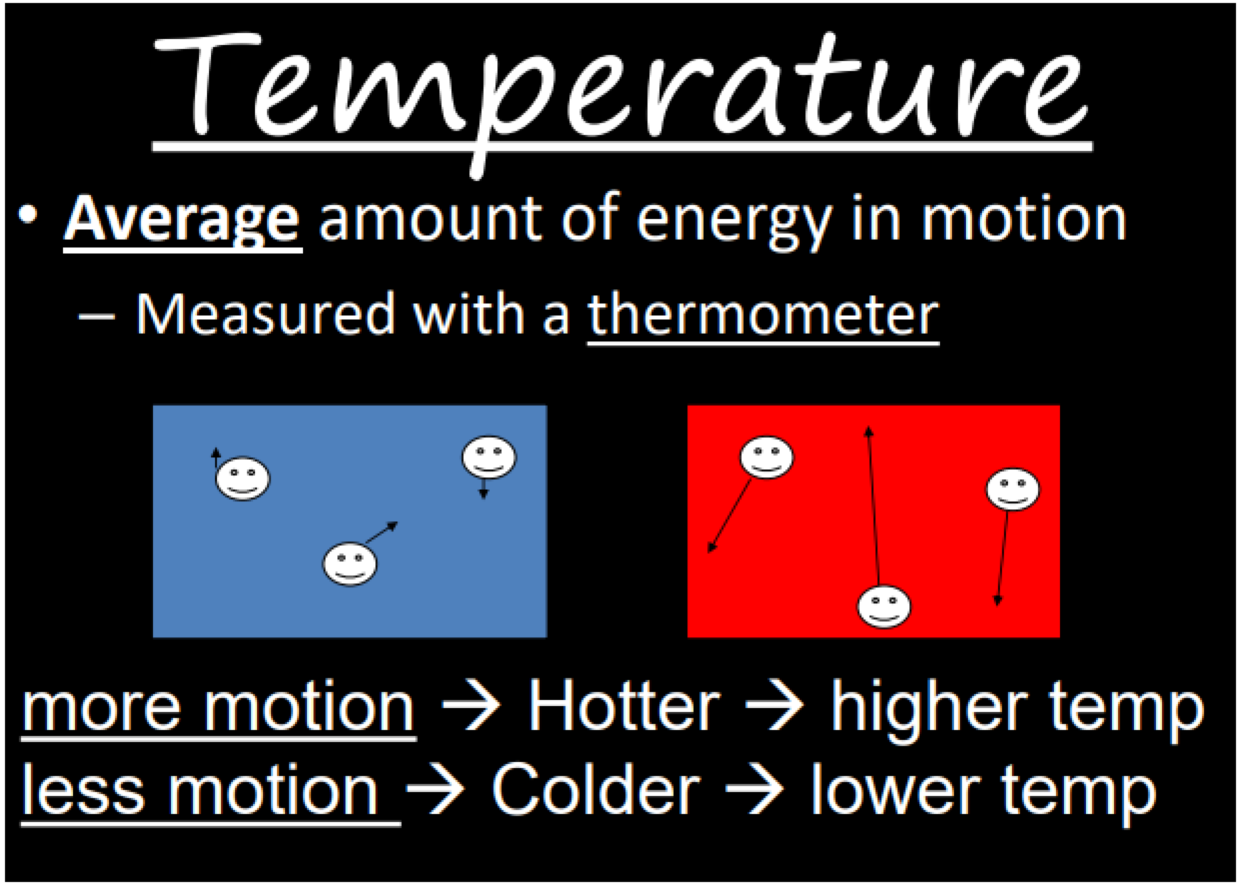
Thermo

Jump back to title slide



Thermo

[Jump back to title slide]



Specific Heat

Jump back to title slide

Specific Heat

The amount of energy it takes to raise the temperature of 1 gram of something by 1 °C

Units:

$$\frac{J}{g\ °C}$$

$$Q = mC\Delta T$$

C = specific heat

Q = energy lost or gained

m = mass

ΔT = "delta" T or change in temp

$$Q = m \times C \times (T_{final} - T_{starting})$$

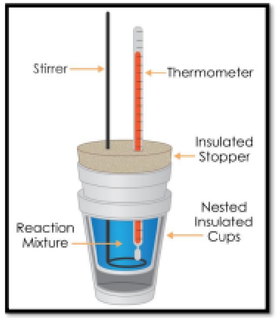
Calorimetry

Jump back to title slide

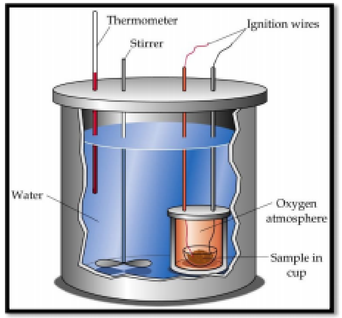
Purpose of Calorimetry

Measure heat transferred from one object to another, or the energy transferred during a reaction.

Coffee Cup Calorimeter



Bomb Calorimeter



Energy In = Energy Out

Energy Absorbed = Energy Released

$$Q_{substance\ 1} = - Q_{substance\ 2}$$

Negative sign will stand for "OPPOSITE" not necessarily negative. Makes it so it doesn't really matter which material you start with.

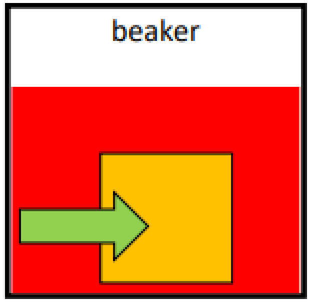
Calorimetry

Jump back to title slide

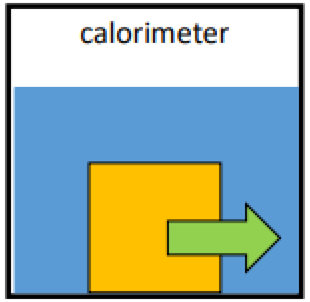
ENERGY IN = ENERGY OUT

Energy absorbed → Q = +
Energy released → Q = -

Qmetal = +
Qwater = -



Hot Water
Metal is heating up
Energy transfer into METAL



Cold Water
Water is heating up
Energy transfer into WATER

Qmetal = -
Qwater = +

$$\mathbf{Tfinal_{water} = Tfinal_{metal}}$$

Calorimetry

Jump back to title slide

Q_{water} = ?	$Q_{metal} = -Q_{water}$ *Energy IN must = energy OUT!* *(opposite sign, not necessarily negative)*
m_{water} = From the water you put in the calorimeter 1mL = 1g	m_{metal} = From your scale
C_{water} = 4.184 J/g°C	C_{metal} = ?
ΔT_{water} = Tf – Ti *(From your thermometer readings)*	ΔT_{metal} = Tf – Ti Tf (From water) - 100°C (From boiling) *(At the end the metal and water will be same temp)* *(The metal was put in the boiling water so it reached 100℃)*

Heating Curves

Jump back to title slide

Heating	Phase Changes
Issue: **SPEED**	Issue: **POSITION**
All the energy is going towards **SPEEDING UP** the molecules	All the energy is going towards **SPREADING OUT** the molecules
Results in a temperature change	Results in **NO** temperature change

(Cooling would just be the opposite of these things!)

HEATING/COOLING

- $Q = mC\Delta T$
- $C = J/g°C$ → Has a temperature component.
- So…. Cant use it for phase changes

PHASE CHANGES

- $\Delta T = 0$ BUT $Q \neq 0$
- Get rid of ΔT, and replace C with something else
- **$Q = mL$**
- L = "Latent Heat" → J/g
  The energy required to phase change one gram of substance

Heating Curves

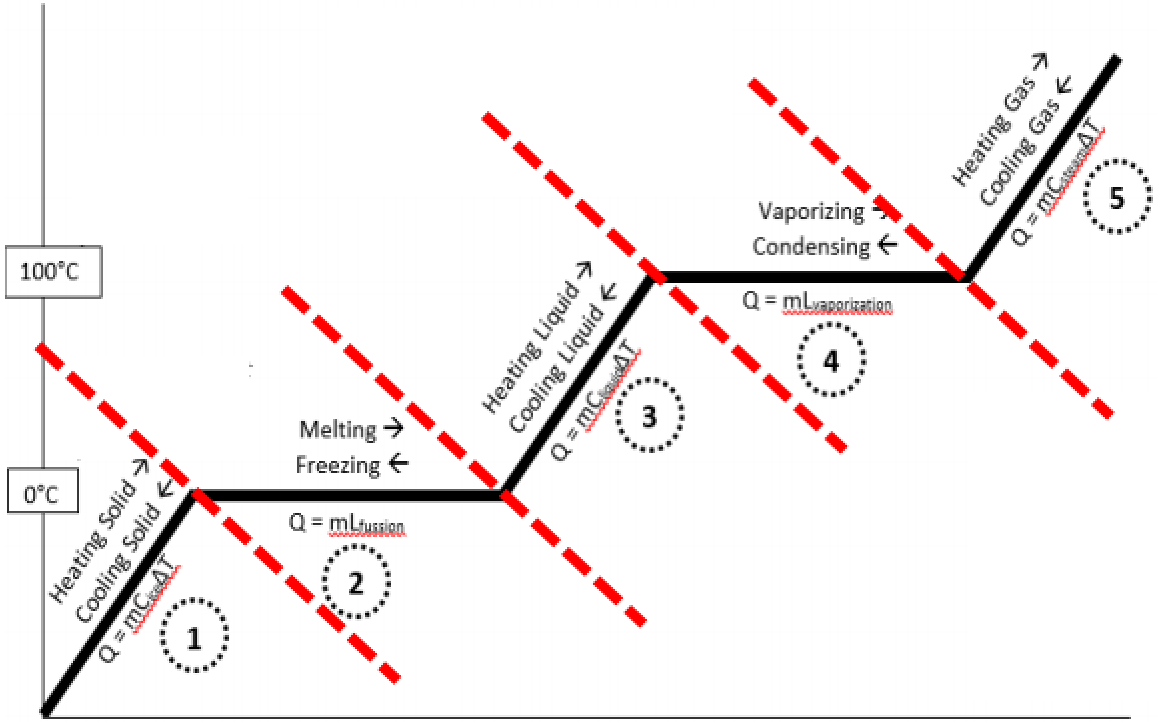
Jump back to title slide

Heating/Cooling		Phase Changes	
C_{ice}	2.09 J/g°C	L_{fus}	334 J/g
C_{liq}	4.18 J/g°C	L_{vap}	2260 J/g
C_{steam}	1.87 J/g°C		

L is (+) or (–) depending on direction!

Heating Curves

[Jump back to title slide]



Calculate everything separately and then add up your answers. You could have up to five Q values to add up!

Use ONLY the temperature change on the ONE LINE you are working with at a time!

Heating Curves

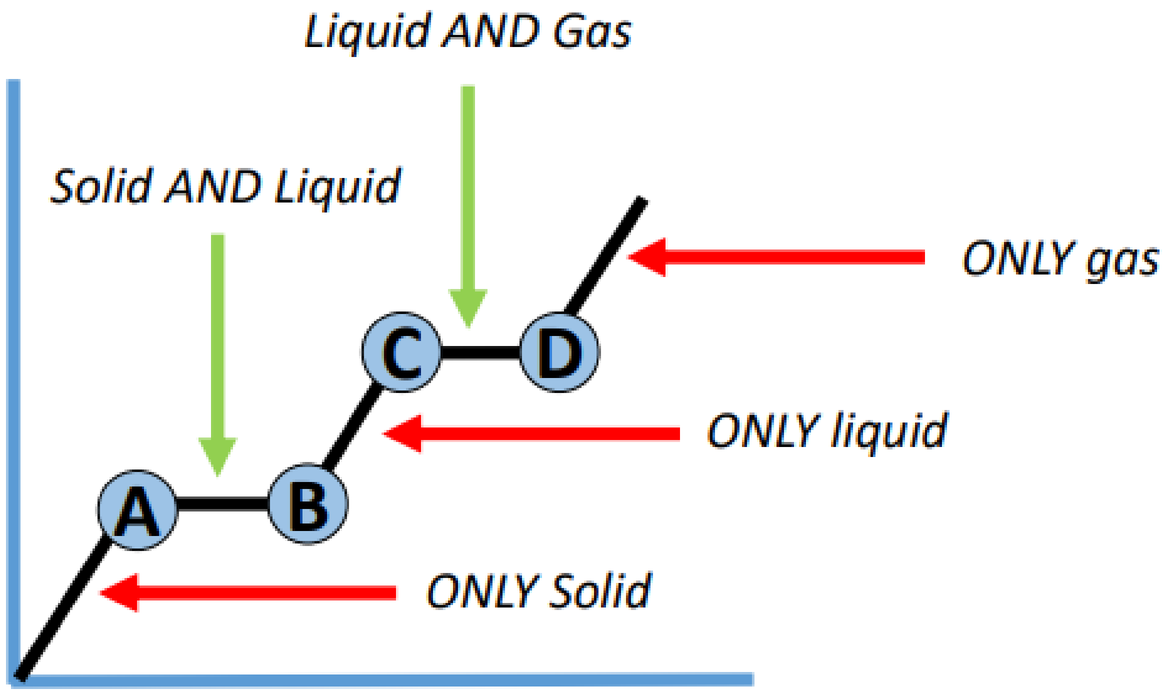
[Jump back to title slide]

Ⓐ *ONLY Solid at 0°C*

Ⓑ *ONLY Liquid at 0°C*

Ⓒ *ONLY Liquid at 100°C*

Ⓓ *ONLY Gas at 100°C*



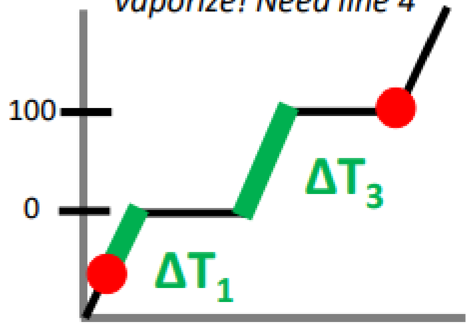
Heating Curves

[Jump back to title slide]

2. Determine the energy required to convert 21.1 grams of ice at -6°C to steam at 100°C

1. Heat ice
2. Melt ice
3. Heat liquid
4. Vaporize

Steam @ 100, have to vaporize! Need line 4



Double Negative! Be Careful!

$Q_1 = mC\Delta T = (21.1g)(2.09_{J/gC})(0° - -6°) =$ *264.59 J*

$Q_2 = mL = (21.1g)(334\ J/g) =$ *7047.4 J*

$Q_3 = mC\Delta T = (21.1g)(4.18_{J/gC})(100° - 0°) =$ *8819.8 J*

$Q_4 = mL = (21.1g)(2260\ J/g) =$ *47686 J*

$Q_T = Q_1 + Q_2 + Q_3 + Q_4$

= *63817.79 J*

Heat of Reaction

Jump back to title slide

Molar Heat Capacity

Energy required to raise the temperature of one **MOLE** of a substance one degree

$$Q = nC\Delta T$$

**If you make sure your units cancel, this is easy!!*

Heat of Reactions

Amount of energy involved in a reaction

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3 \qquad \Delta H_{rxn} = -851.5kJ$$

(Remember, ΔH is basically Q)

ΔH negative → exothermic → product

ΔH positive → endothermic → reactant

Heat of Reaction

[Jump back to title slide]

Heat of Reactions per mole

Sometimes you want it per mole of a certain substance. Just take mole ratios into account!

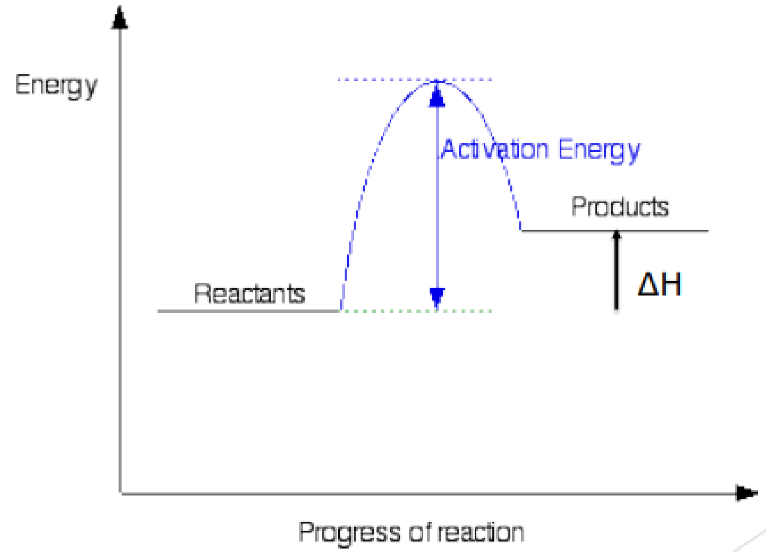
$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3 \qquad \Delta H_{rxn} = -851.5kJ$

$$\frac{-851.5kJ}{1\ rxn} \times \frac{1\ rxn}{2\ mol\ Al} = -425.75\ \frac{kJ}{mol\ Al}$$

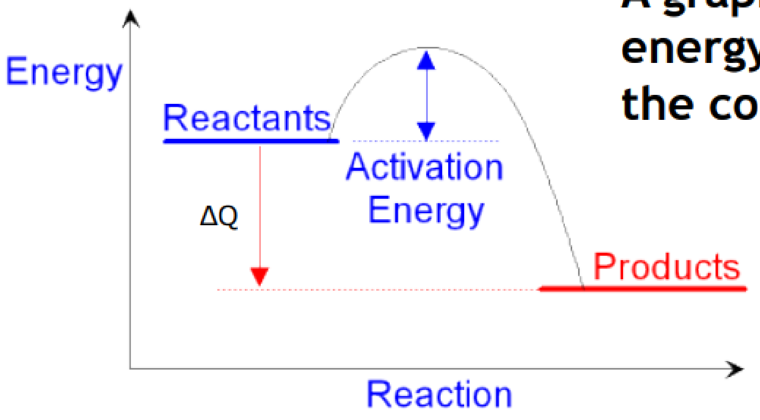
Reaction Diagrams

[Jump back to title slide]

Draw and label an ENDOTHERMIC reaction diagram.



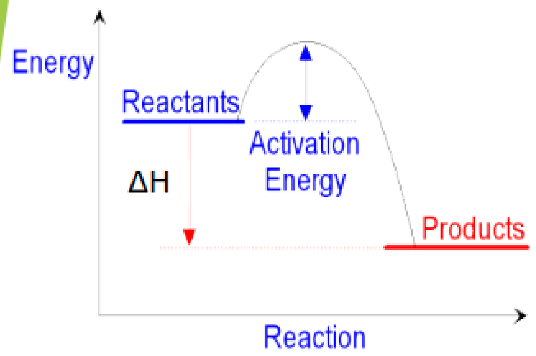
Reaction Diagrams



A graph representing energy changes during the course of a reaction

*Is this reaction endo or exothermic? How do you know???

But what is "Activation Energy?"



Activation energy:
the smallest amount of energy required for molecules to be "activated" in order to undergo a specific chemical change

- *Speed them up to hit hard enough*
- *Proper orientation to collide in the right spot*

Heat of Formation

[Jump back to title slide]

Heat of Formation

If you know how much energy it takes to form each substance in a reaction, you can calculate the Heat of Reaction!

$$\Delta H^{\circ} = \Sigma n \Delta H^{\circ}_{f}(products) - \Sigma n \Delta H^{\circ}_{f}(\text{reactants})$$

- Σ means sum.
- n is the coefficient of the reaction.
- values will be given to you in a chart.

Calculating Heat of Rxn from Heats of Formation

Calculate ΔH for the combustion of methane, CH_4

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

$$\Delta H^{\circ} = \Sigma n \Delta H^{\circ}_{f}(products) - \Sigma n \Delta H^{\circ}_{f}(\text{reactants})$$

Substance	ΔH_f (kJ)
CH_4	-74.80
O_2	0
CO_2	-393.50
H_2O	-285.83

$$\Delta H_{rxn} = [-393.50kJ + 2(-285.83kJ)] - [-74.80kJ + 2(0kJ)]$$

$$\Delta H_{rxn} = -890.36\ kJ/mol_{rxn}$$

Bond Energy

Jump back to title slide

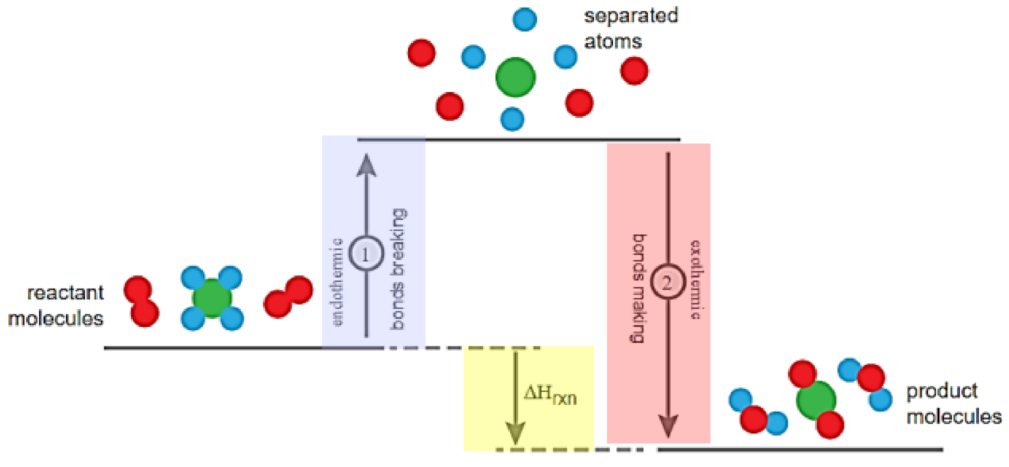
Bond Energy

It TAKES energy to break a bond – ENDO

- Otherwise they would just break by themselves!

Energy is RELEASED when a new bond forms – EXO

- If the new bond isn't more stable, lower energy, it wouldn't want to form!



Use Bond Energy Chart

Action	Algebraic Sign	How to Remember
Break a Bond	+	Takes to Break
Form a Bond	-	Free to Form

$2H_2 + O_2 \rightarrow 2H_2O$

You have to break: 2 H-H bond and 1 O=O bond
You have to form: 4 H-O bonds

2(436) + (498) + 4(- 463)= **- 482 kJ/mol** (exo)

Single Bond Energies (kJ/mol of bonds)

	H	C	N	O	S	F	Cl	Br	I
H	436								
C	413	346							
N	391	305	163						
O	463	358	201	146					
S	347	272	—	—	226				
F	565	485	283	190	284	155			
Cl	432	339	192	218	255	253	242		
Br	366	285	—	201	217	249	216	193	
I	299	213	—	201	—	278	208	175	151

Multiple Bond Energies (kJ/mol of bonds)

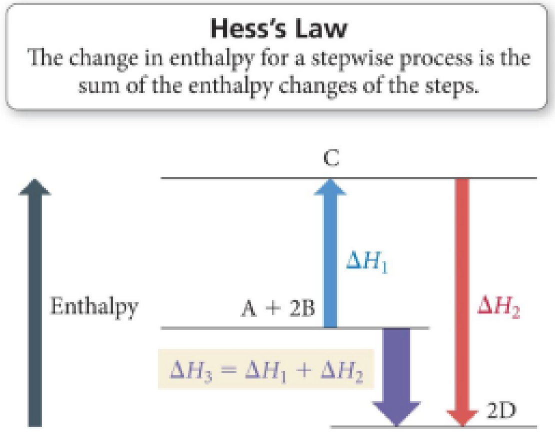
C=C 602	C=N 615	C=O 799
C≡C 835	C≡N 887	C≡O 1072
N=N 418	N=O 607	
N≡N 945	O=O 498	

Hess's Law

Jump back to title slide

Hess's Law

"In going from a particular set of reactants to a particular set of products, the change in enthalpy is the same whether the reaction takes place in one step or a series of steps."



Relationships Involving ΔH_{rxn}

Multiplying Rxn by a # to Change Coefficients

ΔH_{rxn} is multiplied by that factor.

- Because ΔH_{rxn} is *extensive* – depends on the amount of substance

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ

2 $C(s)$ + **2** $O_2(g) \rightarrow$ **2** $CO_2(g)$ $\Delta H =$ **2 x** $(-393.5 \text{ kJ}) = -787.0$ kJ.

Reversing a rxn to flip which side the products/reactants are on

Flip the sign of ΔH, if positive now negative, if negative, now positive

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ

$CO_2(g) \rightarrow C(s) + O_2(g)$ $\Delta H = -(-393.5) = +\ 393.5$ kJ

Hess's Law

Jump back to title slide

Hess's Law Example Problem #1

Calculate ΔH for the combustion of methane, CH_4:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

#	Reaction	ΔH°
1	$C + 2H_2 \rightarrow CH_4$	-74.80 kJ
2	$C + O_2 \rightarrow CO_2$	-393.50 kJ
3	$H_2 + ½ O_2 \rightarrow H_2O$	-285.83 kJ

Step #4:

Cross out things that show up on both sides, then sum up your ΔH values

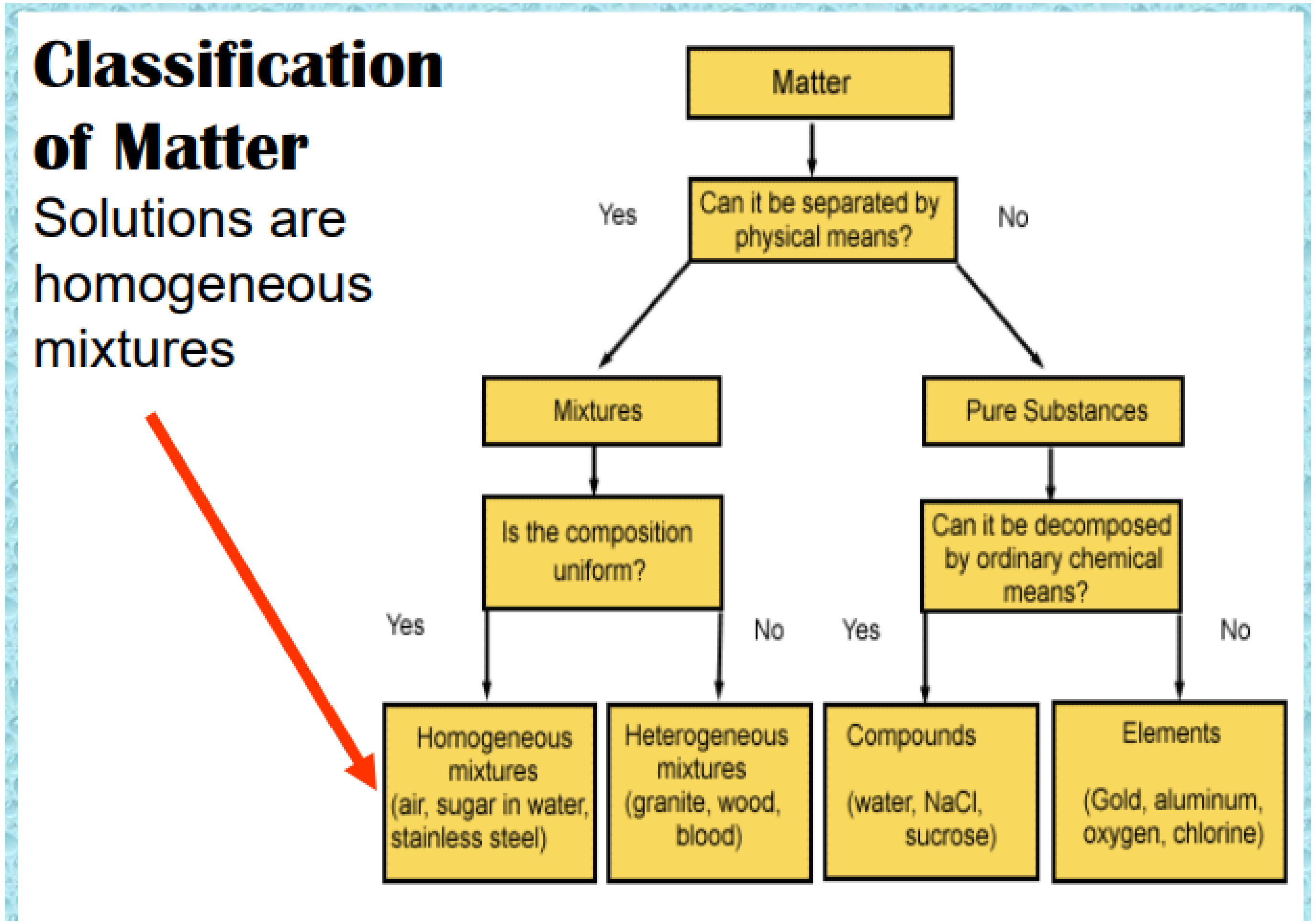
- rxn 1	$CH_4 \rightarrow \cancel{C} + 2\cancel{H_2}$	-(-74.80 kJ)
rxn 2	$\cancel{C} + O_2 \rightarrow CO_2$	-393.50 kJ
2 x rxn 3	$2\cancel{H_2} + O_2 \rightarrow 2H_2O$	2 x (-285.83 kJ)
	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	-890.36 kJ

<u>Unit #11</u>
Solutions *

- Solution vocabulary
- Solubility
- Solutions calculations

Solutions Vocabulary

Jump back to title slide



Solutions Vocabulary

Jump back to title slide

Solute

A solute is the substance that is being dissolved in a solution.

Salt in salt water	*Sugar in soda drinks*
Carbon dioxide in soda drinks	

Solvent

A solvent is the thing that something is being dissolved into.

Water in salt water	*Water in soda*

Solution

The solute + solvent combined is then called the "solution"

Salt water	*Soda*

Solubility

The amount of solute that can be dissolved at a given temperature.

Solutions Vocabulary

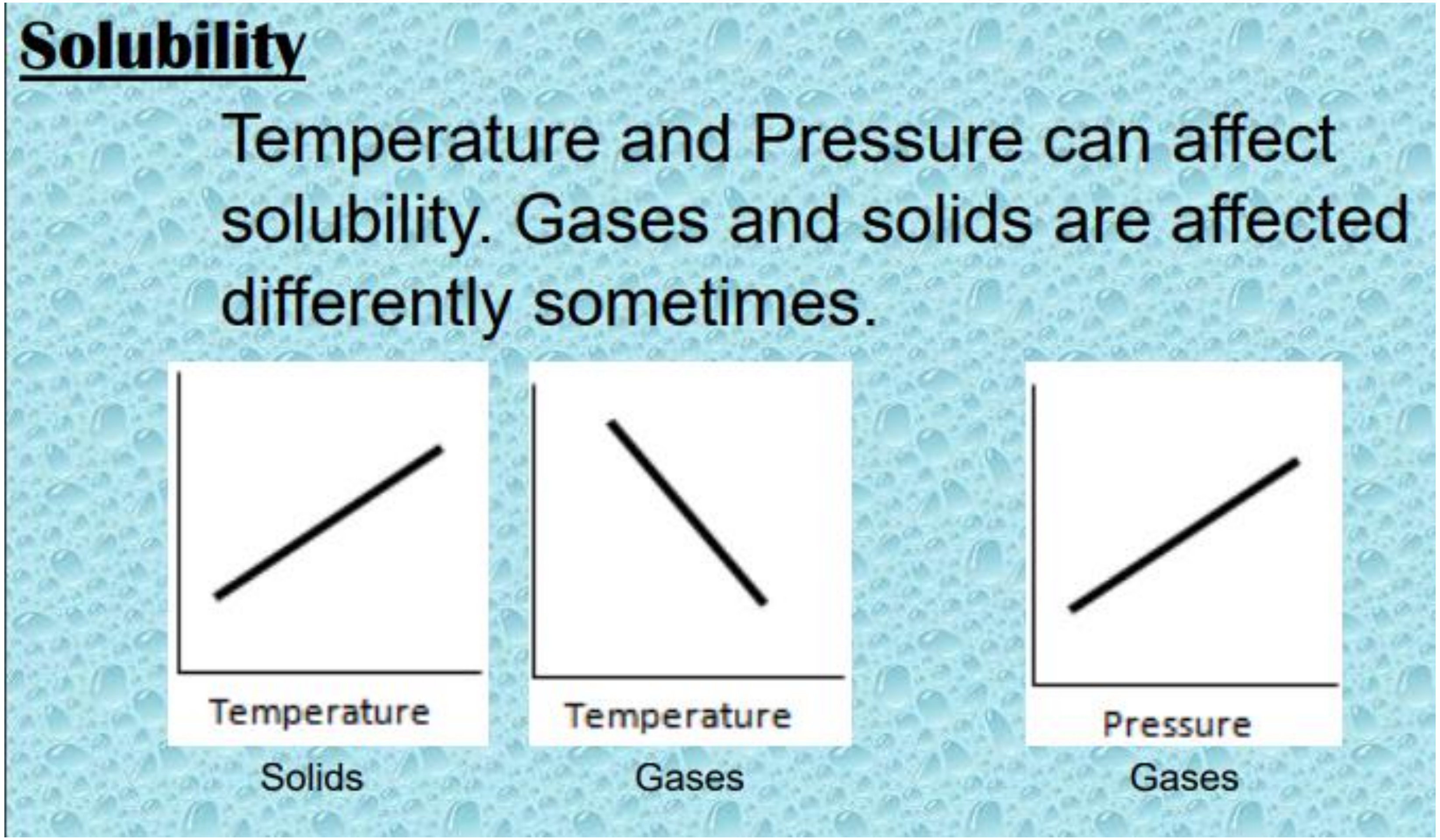
Jump back to title slide

Saturation…

- **Saturated solution:** The maximum amount of solute dissolved
- **Unsaturated solution:** Less than the maximum amount of solute dissolved
- **Supersaturated solution:** More than the maximum amount of solute dissolved

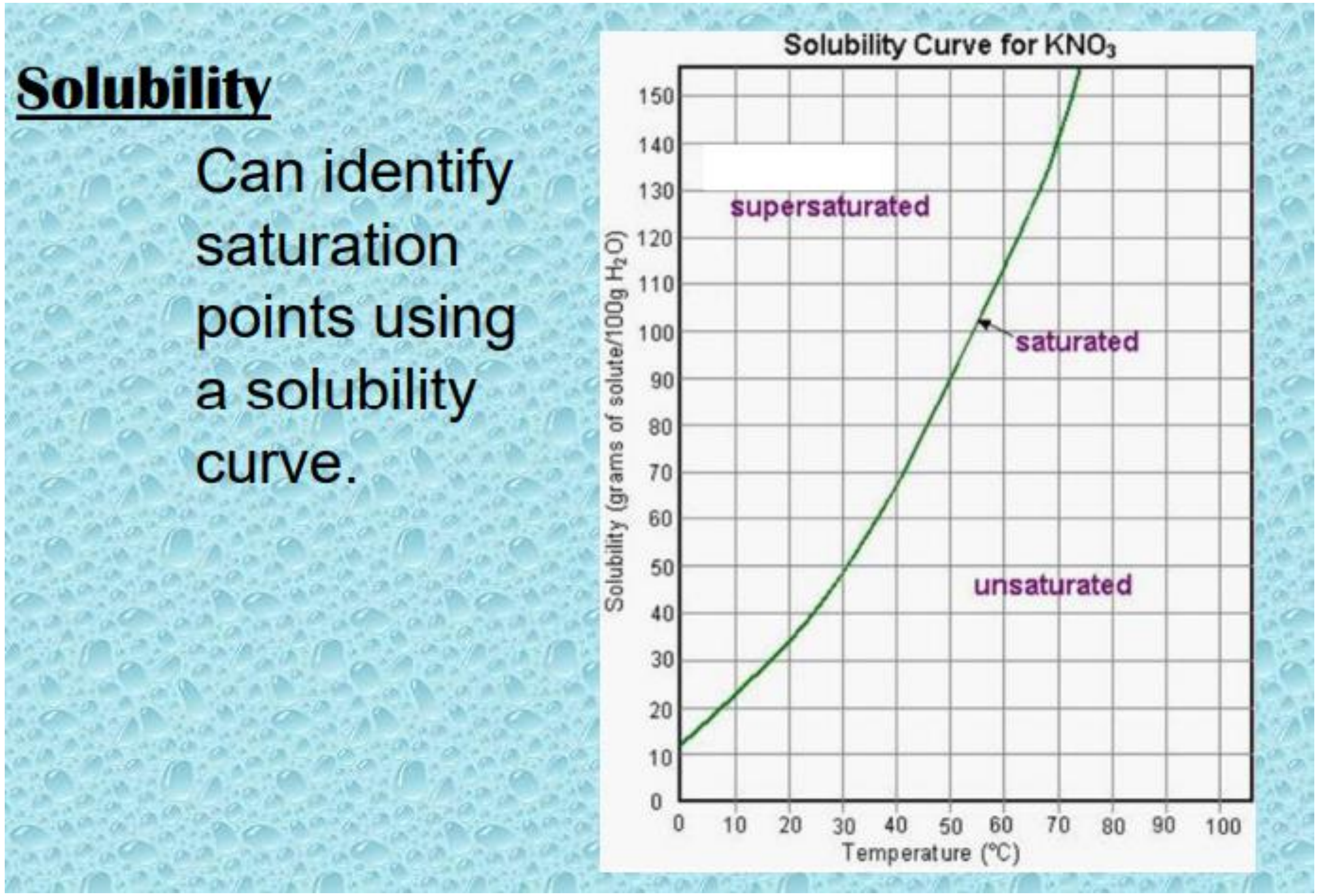
Solubility

Jump back to title slide



Solubility

Jump back to title slide



Solubility

[Jump back to title slide]

Solubility

Solubility curve is going to be more accurate than our general chart

Solubility of Some Ionic Compounds in Water

Always Soluble		
Alkali metals =	Li^+, Na^+, K^+, Rb^+, Cs^+	AAA CNP
Ammonium =	NH_4^+	
Acetate =	$C_2H_3O_2^-$	
Chlorate =	ClO_3^-	
Nitrate =	NO_3^-	
Perchlorate =	ClO_4^-	
Generally Soluble		
Cl^-, Br^-, I^-	Soluble *except*: Ag^+, Pb^{2+}, Hg_2^{2+}	AP-H
F^-	Soluble *except*: Ca^{2+}, Ba^{2+}, Sr^{2+}, Pb^{2+}, Mg^{2+}	CBS-PM
Sulfate = SO_4^{2-}	Soluble *except*: Ca^{2+}, Ba^{2+}, Sr^{2+}, Pb^{2+}	CBS-P
Generally Insoluble		
O^{2-}, OH^-	Insoluble *except*: Alkali metals and NH_4^+	AA
	Somewhat soluble: Ca^{2+}, Ba^{2+}, Sr^{2+}	CBS
CO_2^{2-}, CO_3^{2-} S^{2-}, SO_3^{2-} PO_4^{3-} CrO_4^{2-}, $Cr_2O_4^{2-}$	Insoluble *except*: Alkali metals and NH_4^+	AA

Not Soluble = forms precipitate **Soluble** = dissolves in water (aqueous)

Solubility

Jump back to title slide

Electrolytes:

- Ionic solutes that dissociate (come apart) into ions in a solution

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

They can conduct electricity because there are charged particles for the electrons to move between!

Non-Electrolytes:

- Covalent solutes that do not dissociate, but that can still potentially dissolve in a solvent

$$C_6H_{12}O_6(s) \rightarrow C_6H_{12}O_6(aq)$$

Solubility

Jump back to title slide

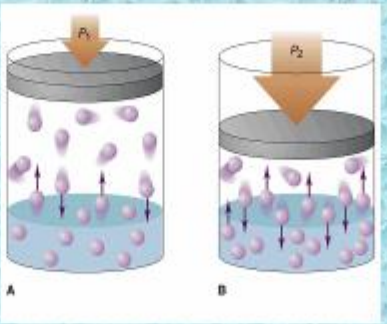
Increasing Dissolution (how fast something dissolves)

Solids

- Increase temperature for more collisions
- Stir it to expose more surface area
- Crush it up so more surface area

Gases

- Decrease temperature
- Increase pressure



Jump back to title slide

Mass Percent or Percent Composition

Ratio of masses expressed as a %

$$Mass\ percent = \left(\frac{mass\ of\ solute}{mass\ of\ solution} \right) x100$$

Solutions Calcs.

Jump back to title slide

Parts per Million - ppm

Ratio of masses but not expressed as a %, but rather out of one million – used when very low levels are significant like for pollution.

$$ppm = \left(\frac{mass\ of\ solute}{mass\ of\ solution}\right) x\ 1{,}000{,}000$$

Solutions Calcs.

Jump back to title slide

Grams/Liter

Ratio of mass of solute to volume of solution. Easy for when measuring a solid solute dissolved in a liquid. Used to test solubility. “Quick and dirty” unit.

$$Grams\ per\ Liter = \left(\frac{mass\ of\ solute}{Volume\ of\ solution}\right)$$

Jump back to title slide

Mole Fraction

Ratio of moles of solute n_A, to moles of total solution (solute n_A + solvent n_B)

$$Mole\ fraction\ of\ A = \chi_A = \frac{n_A}{n_A + n_B}$$

Jump back to title slide

Molarity – the best one! ☺

Ratio of moles of solute to liters of solution. Similar to grams/L but converting it to moles lets us perform chemistry calculations better. Always trying to get to moles anyway!

$$Molarity = M = \frac{moles\ of\ solute}{Liter\ of\ solution}$$

Solutions Calcs.

Jump back to title slide

Making Dilutions

When you take one more concentrated solution and take a small amount of it and dilute it down by adding more solvent.

$$M_1V_1 = M_2V_2$$

Solutions Calcs.

Jump back to title slide

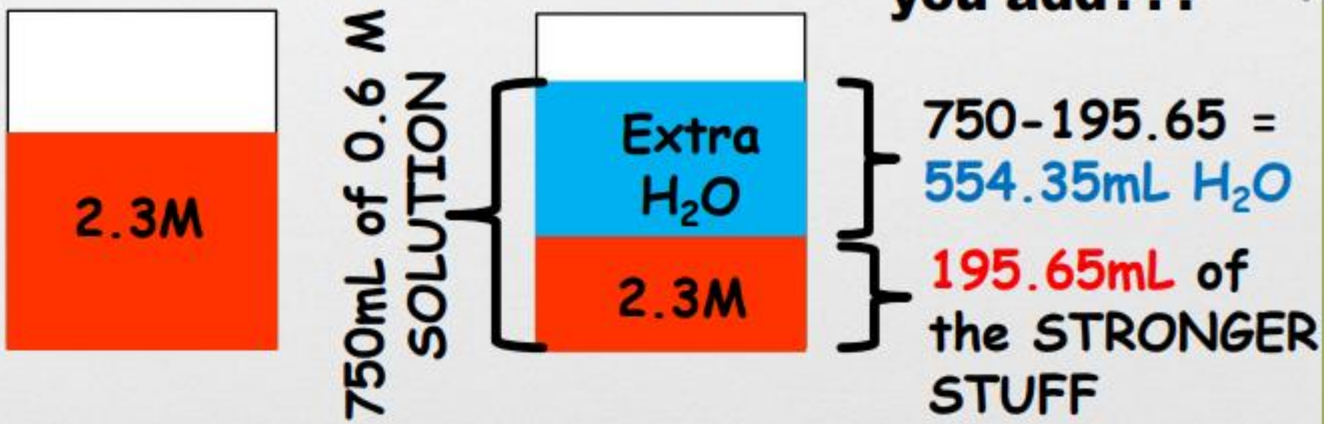
Practice #1

How much of a 2.3 M solution do you have to use in order to make 750mL of a 0.6 M solution?

$$(2.3M)(V_1) = (0.6M)(750mL)$$

$$V_1 = 195.65\ mL\ of\ the\ 2.3M\ solution\ is\ needed$$

How much water did you add???



Unit #12
Kinetics *

- Collision Theory
- Rate affecting factors
- Average rates
- Rate expressions
- Instantaneous rates
- Rate laws
- Method of initial rates

Collision Theory

Jump back to title slide

Collision theory

Reactants must collide in order to react

Activation energy

Minimum amount of energy colliding particles need in order to react.

Fast Enough AND Correct Orientation

Rate Affecting Factors

Jump back to title slide

Factors of Reaction Rate

1. Temperature
2. Concentration/Pressure
3. Surface area
4. Catalysts

(Typically)
Increase any of these, you get more effective collisions…
so it goes faster!

Rate Affecting Factors

Jump back to title slide

Catalysts

What is it?

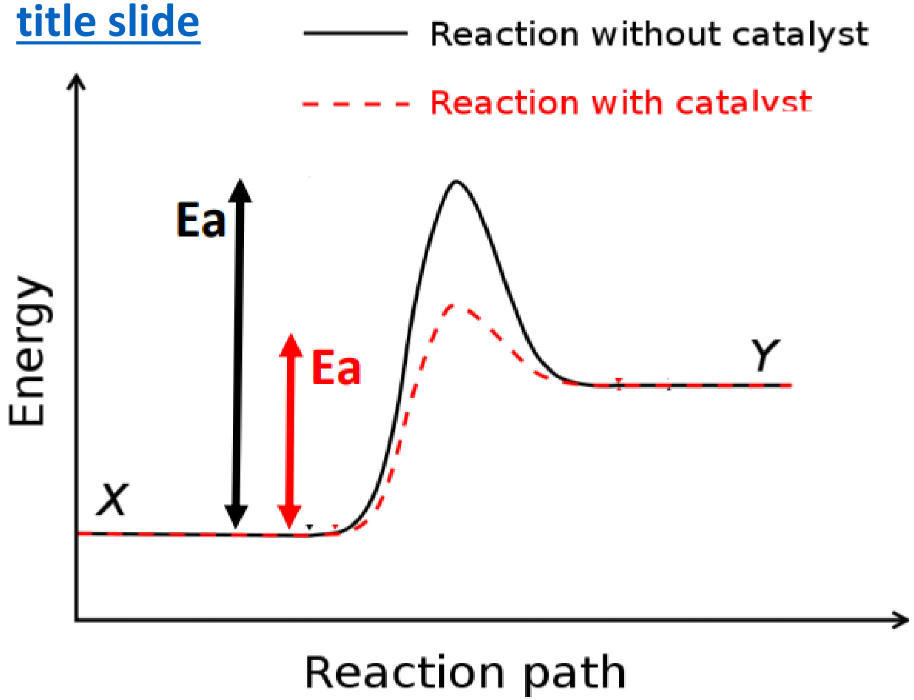
- A chemical that you add to rxn
- Does NOT get used up during reaction
- Helps orient molecules to reach transition state easier
    - So you do not need as much energy
        - **Lowers Activation Energy**

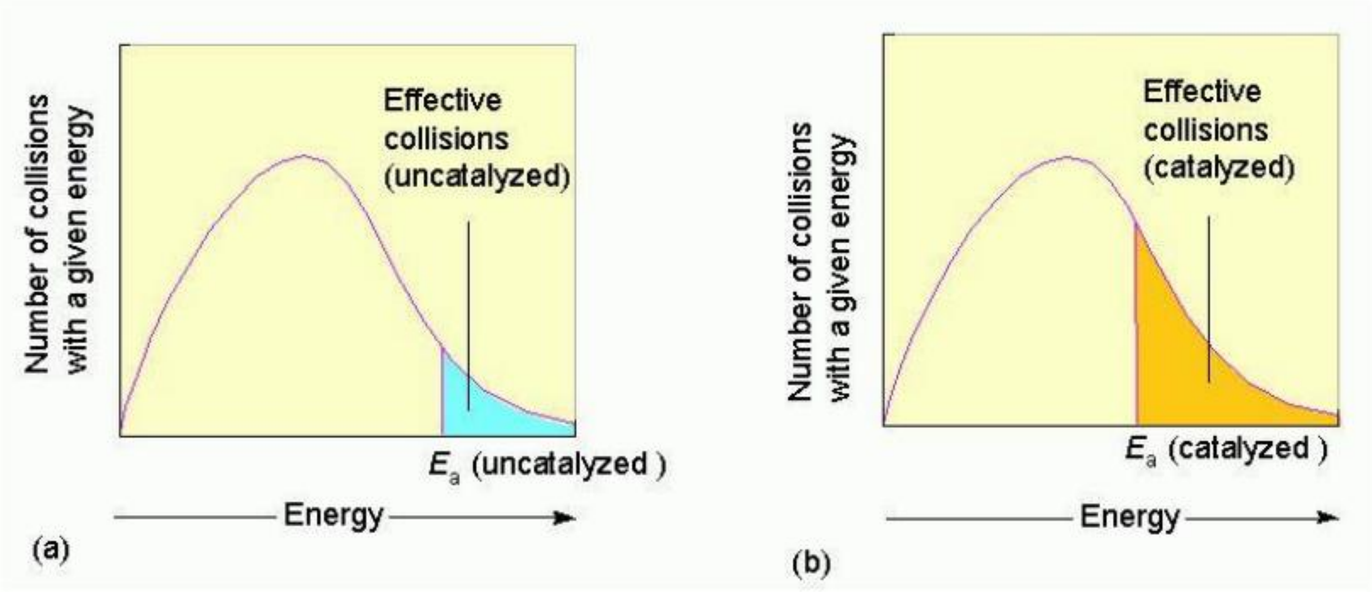
          = faster reaction BECAUSE more molecules will have the needed energy to get over Ea

You don't get "more" collisions – you just get more collisions that will be EFFECTIVE!

Rate Affecting Factors

Jump back to title slide

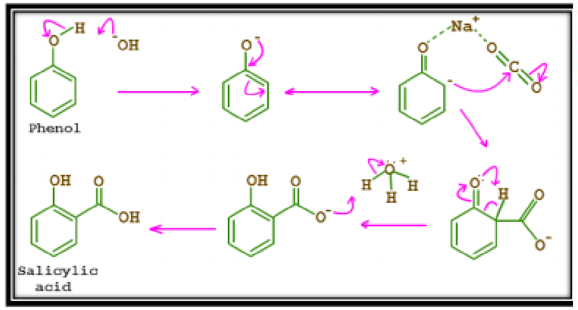




Rate Affecting Factors

Jump back to title slide

Reaction Mechanism

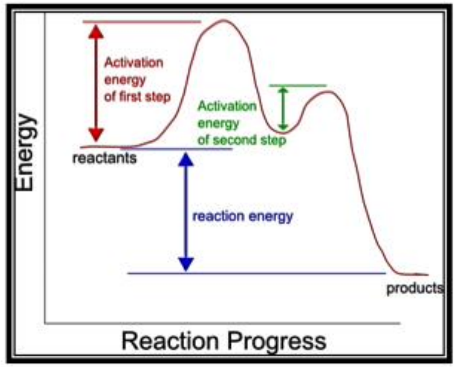


- A chemical equation does not tell us **HOW** reactants become products; just a summary of the overall process.
- The reaction mechanism is the series of steps by which a chemical reaction occurs.
- Some reactions take place in one step, two steps, three steps etc.

Rate Determining Step

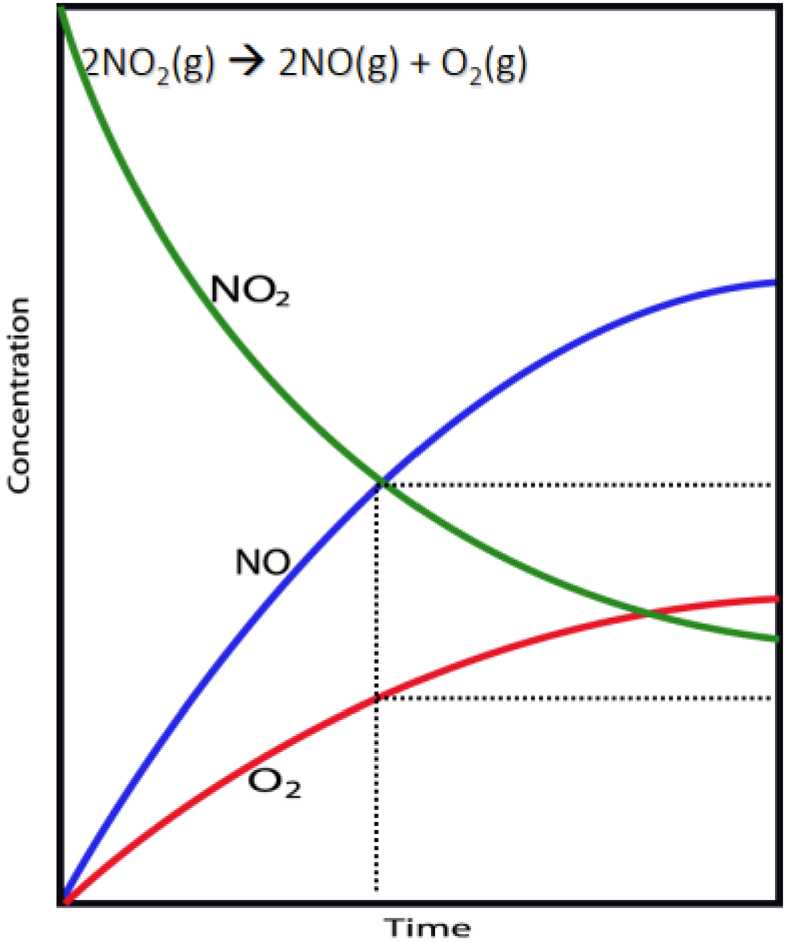
In a multi-step reaction, the *slowest* step is the rate-determining step. It determines the rate of reaction.

Can only go as fast as your slowest step!



Rate

Jump back to title slide



Reaction Rates

1) Can measure disappearance of reactants (NO_2)

2) Can measure appearance of products (NO and O_2)

3) Are proportional stoichiometrically

Have to take coefficients into account! We make twice as much NO as O_2 ever second

Average Rate

Jump back to title slide

Average Rate

- Rate is not always constant!
- Can start fast and slow down, or start slow and speed up
- Sometimes it is sufficient to just calculate the *average rate* over a given time period

$$\boldsymbol{Average\ Rate = \frac{\Delta[X]}{\Delta t} = \frac{[X]_{final} - [X]_{initial}}{t_{final} - t_{initial}}}$$

Rate Expression

Jump back to title slide

Reaction Rates and Stoichiometry

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

$$\text{Rate} = \frac{-\Delta[N_2]}{\Delta t} = \frac{-1\,\Delta[H_2]}{3\,\Delta t} = \frac{1\,\Delta[NH_3]}{2\,\Delta t}$$

Entire thing is the RATE EXPRESSION

REMEMBER!

Reactants are negative, Products are positive. Your double negatives will work themselves out so the REACTION rate comes out positive. Its all semantics in kinetics!

Rate Expression

Jump back to title slide

Practice Problem #1

$$\text{Rate} = \frac{-1}{2}\frac{\Delta[N_2O]}{\Delta t} = \frac{1}{2}\frac{\Delta[N_2]}{\Delta t} = \frac{\Delta[O_2]}{\Delta t}$$

- The disappearance of N_2O occurs at a rate of $-3.25 \times 10^6\ Ms^{-1}$. What is the rate of N_2 and O_2 appearance.

THIS IS $\frac{\Delta[N_2O]}{\Delta t}$

$$\frac{-1\,[-3.25 \times 10^6 Ms^{-1}]}{2} = \frac{1}{2}\frac{\Delta[N_2]}{\Delta t}$$

Rate $N_2 = 3.25 \times 10^6\ Ms^{-1}$

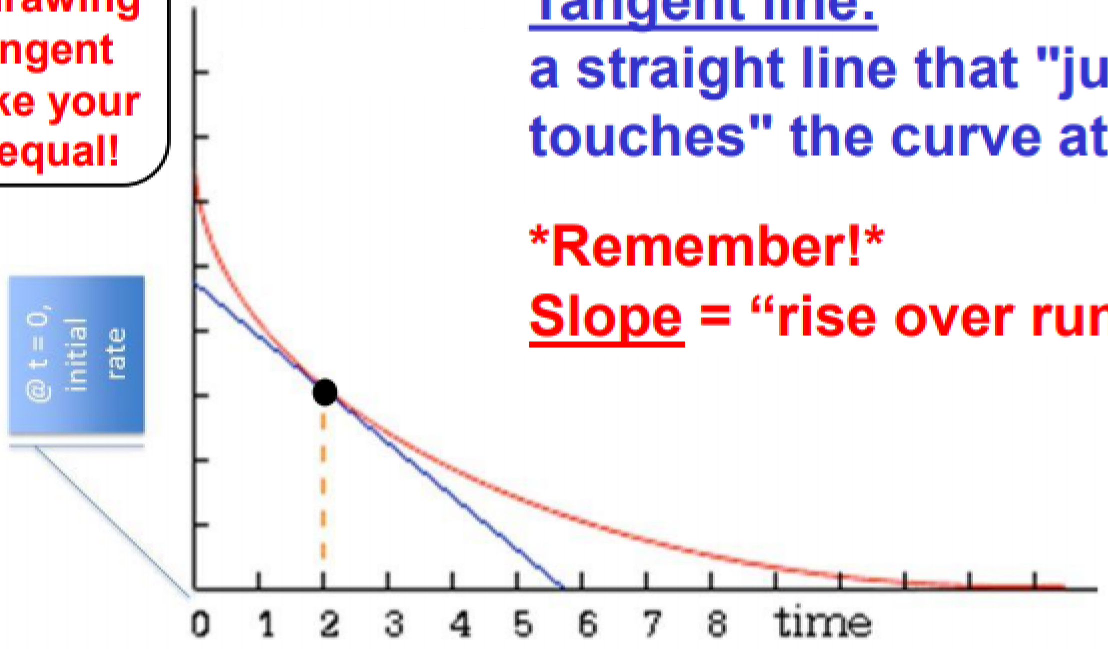
The "Reaction Rate" would be ½ the rate of appearance of $N_2 = 1.63 \times 10^6$, or – ½ the rate of N_2O disappearance = 1.63×10^6 also! See how that works out?

Instan-taneous Rate

[Jump back to title slide]

Instantaneous rate = slope of tangent line to curve at a specific point

Don't be sloppy drawing your tangent line! Make your angles equal!



Tangent line:
a straight line that "just touches" the curve at that point

Remember!
Slope = "rise over run"

Rate Law

[Jump back to title slide]

The Rate Law

The **rate law** (really just an equation) expresses the mathematical relationship between the ***rate*** of a chemical reaction and the ***concentration of reactants***

$$aA + bB \longrightarrow cC + dD$$

$$\text{Rate} = k\,[A]^x[B]^y$$

Notice **ONLY** reactants are used in the rate law!

Rate Law

Jump back to title slide

Reaction Orders

BUT WHAT DOES THAT EVEN MEAN???

$aA + bB \rightarrow cC + dD$ Rate = $k\,[A]^x[B]^y$

Exponents in the rate law tell us:

- The "**order**" with respect to the concentration of that reactant
- The mathematical **effect** an individual reactant's concentration has on the overall rate – how much does a Δ[ ] affect the overall rate

How do we talk about it?

- The reaction is **x^{th} order with respect to A**
- The reaction is **y^{th} order with respect to B**
- The reaction is **$(x+y)^{th}$ order overall**

What is this "k" thing?

$aA + bB \rightarrow cC + dD$ Rate = $k\,[A]^x[B]^y$

k is called the "rate constant"

- A numerical value that relates reaction rate and concentration of reactants at a given temperature
- Different for different reactions!
- Large value of *k* means the reaction proceeds quickly

What would small value for k indicate?

Rate Law

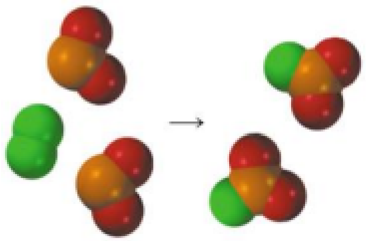
Jump back to title slide

Rate Laws

- Rate laws are **always** determined experimentally.
- Reaction order is **always** defined in terms of reactant (not product) concentrations.

$$F_2\,(g) + 2ClO_2\,(g) \longrightarrow 2FClO_2\,(g)$$

$$\text{rate} = k\,[F_2][ClO_2]^1$$



Exponents are NOT the coefficients from the *overall* balanced reaction!

They are coming from the *rate determining step* of the reaction!

Rate Law

Jump back to title slide

Rate Laws

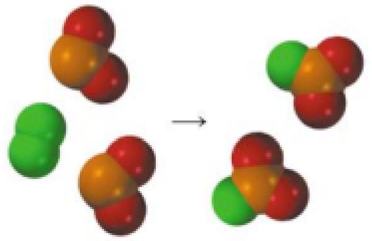
Coefficients from *rate determining step* are the exponents.

So…if only a SINGLE step reaction…the overall equation IS the rate determining step, then yes the coefficients are the exponents.

See how the coefficients don't match the exponents? That means that this must not have been a single step reaction!

$$F_2\,(g) + 2ClO_2\,(g) \longrightarrow 2FClO_2\,(g)$$

$$\text{rate} = k\,[F_2][ClO_2]^1$$



Method of Initial Rates

Jump back to title slide

Practice Question #1

$F_2\ (g) + 2ClO_2\ (g) \rightarrow 2FClO_2\ (g)$

Table 13.2 Rate Data for the Reaction between F_2 and ClO_2

	$[F_2](M)$	$[ClO_2](M)$	Initial Rate (M/s)
1.	0.10	0.010	1.2×10^{-3}
2.	0.10	0.040	4.8×10^{-3}
3.	0.20	0.010	2.4×10^{-3}

rate = $k\ [F_2]^x[ClO_2]^y$

↓

Rate doubles so put a 2

$2 = k\ [F_2]^x[ClO_2]^y$

↓

$[F_2]$ doubles so put a 2

$2 = k\ [2]^x[ClO_2]^y$

→

$[ClO_2]$ is constant so get rid of it,

$2 = k\ [2]^x$

↓

k is constant so get rid of it

↓

$$2 = [2]^x$$

Order with respect to $[F_2]$ is 1!

Method of Initial Rates

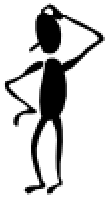
Jump back to title slide

Practice Question #4

Determine the rate law ***AND*** calculate the rate constant for the following reaction from the following data:

$S_2O_8^{2-}\ (aq) + 3I^-\ (aq) \rightarrow 2SO_4^{2-}\ (aq) + I_3^-\ (aq)$

Experiment	$[S_2O_8^{2-}]$	$[I^-]$	Initial Rate (*M*/s)
1	0.08	0.034	2.2×10^{-4}
2	0.08	0.017	1.1×10^{-4}
3	0.16	0.017	2.2×10^{-4}



$\text{rate} = k\,[S_2O_8^{2-}]^x[I^-]^y$

$x = 1 \quad y = 1$

$\text{rate} = k\,[S_2O_8^{2-}][I^-]$

To solve for K, rearrange your rate law then plug in values!

Double $[I^-]$, rate doubles
(experiment 1 & 2)

Double $[S_2O_8^{2-}]$, rate doubles
(experiment 2 & 3)

$$k = \frac{\text{rate}}{[S_2O_8^{2-}][I^-]} = \frac{2.2 \times 10^{-4}\ M/s}{(0.08\ M)(0.034\ M)}$$

$= 0.08/M{\bullet}s$

Careful with units for k! They depend on order!

Unit #13
Equilibrium *

- Le Chatelier's principle
- Equilibrium constant
- Equilibrium quotient
- ICE Tables

Equilibrium

Jump back to title slide

WHAT IS A REVERSIBLE REACTION?

Some reactions can go forwards AND backwards

N_2 (g) + $3H_2$ (g) → $2NH_3$ (g) + 92.05 KJ

OR

$2NH_3$ (g) + 92.05 KJ → N_2 (g) + $3H_2$ (g)

Use a "double headed arrow" so you don't have to write it both ways! ↔

Equilibrium

Jump back to title slide

REACTIONS WILL REACH "EQUILIBRIUM"

EQUILIBRIUM = the point at which the forward reaction is happening at the same ***RATE*** as the reverse reaction

Are the CONCENTRATIONS of reactants and products the same?????

- NO!!!!! (well *maybe*, but it doesn't have to be! If they are the same then it is a coincidence!)

Equilibrium

Jump back to title slide

"FINDING" EQUILIBRIUM POINT

<u>EQUILIBRIUM POINT</u>

We use ratios of [products] to [reactants]

You can have different ratios that all result in the rate forward being the same as the rate backwards!

There isn't just <u>one</u> equilibrium point!

If you are pushed away from the original equilibrium point, then find a NEW ratio of concentrations that is "at equilibrium!"

Le Chatelier

Jump back to title slide

LE CHATELIER'S PRINCIPLE

If a stress is applied to a reaction at equilibrium the reaction changes to relieve that stress, it will find a *new* equilibrium point where the forward and backwards reactions are equal again. It will try to "undo" whatever you did!

- *Took something away? Make more of it!*
- *Added extra of something? Use some up!*

Le Chatelier

Jump back to title slide

STRANGE FACTS…

- ONLY changes to aqueous and gas phases affect equilibrium
  - *Solids and liquids do NOT affect equilibrium!*
    - They do not have "concentrations" so they can't factor in.
    - We will see this better when we get to the math portion of the chapter!
- Adding an Noble Gas, an INERT gas, does NOTHING because it doesn't change the PARTIAL PRESSURES of the gases involved!
- Adding a catalyst does NOTHING! You will reach equilibrium faster but it won't change the equilibrium point.

Le Chatelier

Jump back to title slide

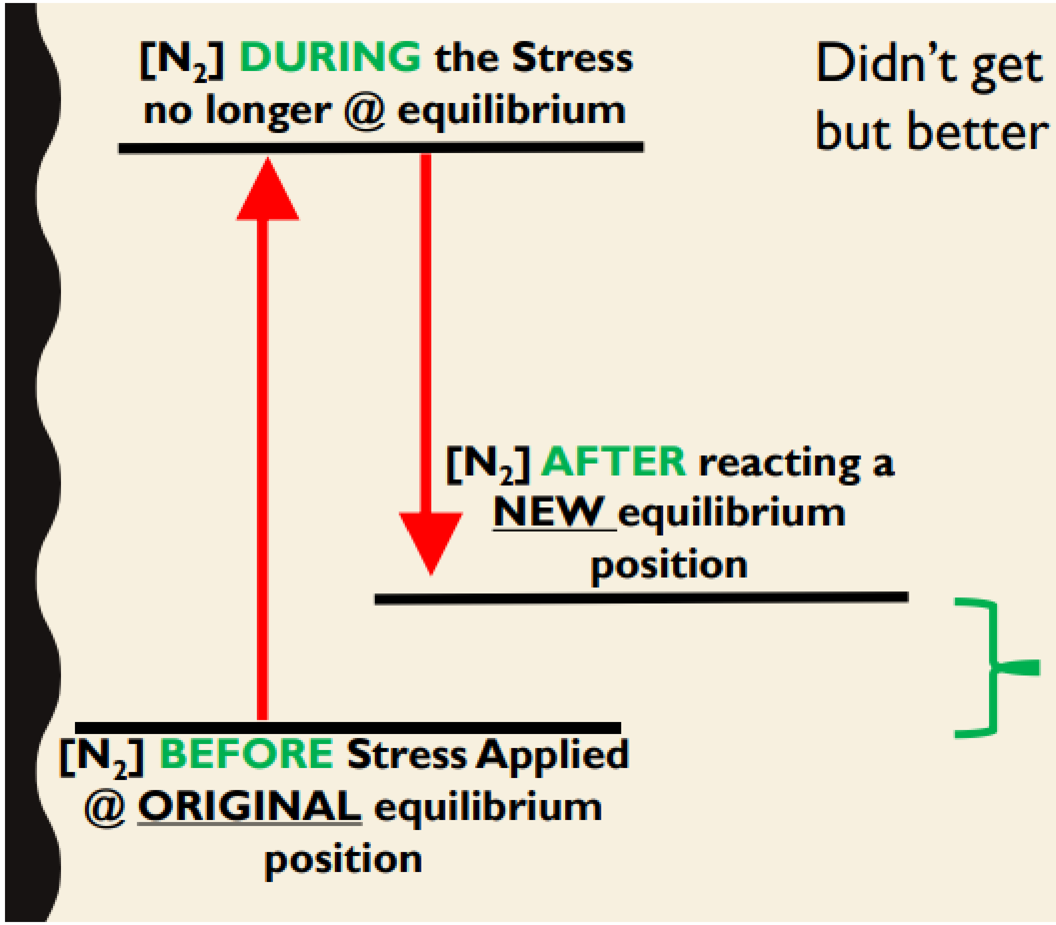
QUICK EXAMPLE

$N_2 + 3H_2 \leftrightarrow 2NH_3 + 92.05\ KJ$

- Add more N_2
  - Shift to the right, use up the extra by making more products!
- Remove H_2
  - Shift to the left, replace what you took away by making more reactants!

Le Chatelier

Jump back to title slide



Didn't get back to starting point, but better than during the stress!

So comparing BEFORE stressor to AFTER stressor, there is a ***SLIGHT*** increase to the thing you added extra of.

Le Chatelier

Jump back to title slide

WHAT ABOUT CHANGING PRESSURE?

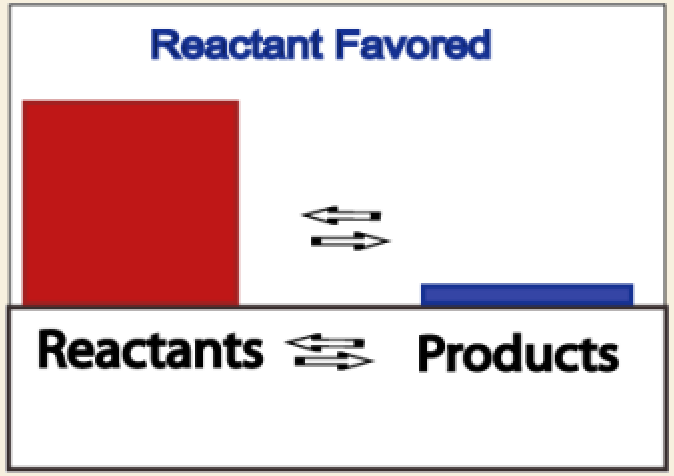
- Increasing pressure causes molecules to be too crowded, too close together
- If you can reduce the *number of moles of gas particles* it will make things less crowded and relieve some of the pressure
  - *Move to the side with fewer moles of gas!*
- Reducing pressure?
  - *Move to the side with more moles to get the pressure back up!*

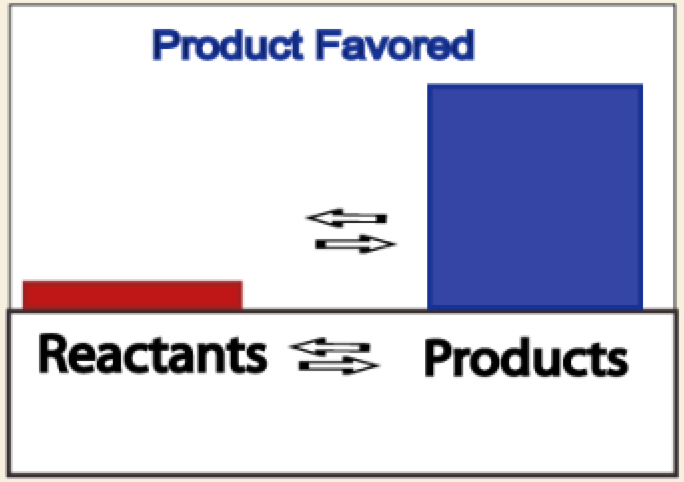
Equilibrium Constant

Jump back to title slide

PRODUCT OR REACTANT FAVORED?

Once equilibrium is reached, you may have more products present, or you may have more reactants present.





Equilibrium Constant

Jump back to title slide

PRODUCT FAVORED OR REACTANT FAVORED?

K_{eq} is a value (with no units) that allows us to determine if more products or reactants are being made. It is a ratio of products to reactants.

SIMPLIFIED VERSION FIRST: $K_{eq} = \frac{[Products]}{[Reactants]}$

- K > 1 then more products!
- K < 1 then more reactants!

Equilibrium Constant

Jump back to title slide
Jump back to title slide

CALCULATING K_{eq}

- The "Law of Mass Action" will allow us to calculate K_{eq} – **Ratio of Products over Reactants**

$$aA + bB \leftrightarrow cC + dD$$

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

Still simplified, there is an additional part that we wont use that helps "fix" the units so Keq can have no units. Don't worry about it!

* Remember how solids and liquids don't factor into equilibrium? They don't have true concentrations so there is nowhere to plug them into this equation is there!

Equilibrium Constant

Jump back to title slide

PRACTICE PROBLEM:

- Write the equilibrium expression for the reaction:

$2NO_{2(g)} \leftrightarrow 2NO_{(g)} + O_{2(g)}$

$$K_{eq} = \frac{[NO]^2[O_2]^1}{[NO_2]^2}$$

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

Equilibrium Constant

Jump back to title slide

ASSUME FORWARD REACTION…BUT WHAT IF ASKED FOR BACKWARDS RXN?

- Just flip it! Write K as K' for backwards reaction.

$2NO_{2(g)} \leftrightarrow 2NO_{(g)} + O_{2(g)}$

$$K'_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]^1}$$

$$K'_{eq} = \frac{1}{K_{eq}}$$

Don't even bother writing the equation flipped!
Just flip your Law of Mass Action!

Equilibrium Constant

Jump back to title slide

WHAT IF I HAVE PRESSURES NOT [ ] ?

- Just use partial pressures the same way you use concentrations!

$$aA + bB \leftrightarrow cC + dD$$

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

Equilibrium Constant

Jump back to title slide

REMEMBER…

These things DON'T CHANGE K_{eq}

- –Changing Concentrations
- –Changing Pressures
- –Adding Solids or Liquids
- –Adding Catalysts

These things DO CHANGE K_{eq}

- –Temperature

Equilibrium Constant

Jump back to title slide

CAN IT CHANGE ANYTHING?

Factor	Rate of Reaction	Rate Constant k	Equilibrium Point	Equilibrium Constant Keq
Δ [ ]	✓	✗	✓	✗
Δ Pressure	✓	✗	✓	✗
Δ Surface Area	✓	✗	✗	✗
Δ Amount of s/l	✗	✗	✗	✗
Inert Gas	✗	✗	✗	✗
Catalyst	✓	✓	✗	✗
Temperature	✓	✓	✓	✓

Equilibrium Quotient

Jump back to title slide

HOW CAN YOU TELL IF IT IS AT EQUILIBRIUM OR NOT?

- Calculate the values you have, and compare them to the K_{eq} value
  - Reaction Quotient is what it is called if it isn't at equilibrium

$$aA + bB \leftrightarrow cC + dD$$

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

Equilibrium Quotient

Jump back to title slide

SO WHAT DOES Q TELL YOU?

- **K = Q then you are at equilibrium!**
- **K < Q you have too many products!**
  - SHIFT LEFT until you make enough reactants to get back to equilibrium
- **K > Q you have too many reactants!**
  - SHIFT RIGHT until you make enough product to get back to equilibrium

Jump back to title slide

DETERMINING CONCENTRATIONS AT EQUILIBRIUM

What if you wanted to determine the concentrations of your reactants and products at equilibrium, but only know the initial concentrations?

USE AN ICE TABLE!

ICE Tables

Jump back to title slide

WHAT IS AN ICE TABLE?

- A strategy for organizing information about a reaction in order to solve for [ ]'s at equilibrium

A + B ↔ C

- **<u>ICE stands for:</u>**
  - –Initial
  - –Change
  - –Equilibrium

Rxn	A + B ↔ C		
I			
C			
E			
5%			
Answer			

ICE Tables

[Jump back to title slide]

5% RULE

What is it?

- A way for us to simplify the math involved when solving ICE table problems.

When can I use it?

- When X is small enough to be considered negligible
- The change ends up being so small that it isn't even considered valid when you take significant figures into account so you might as well ignore it!

ICE Tables

Jump back to title slide

5% RULE

What counts as "negligible?"

- Required: $K < 1$
- When x ends up being 5% or less of the initial concentrations
  - *Can't know that until the end when you solve for x! Ugh!*
  - *Good guestimate… if K is at least1000x smaller that initial concentrations, you have a good chance of the 5% rule working*
- *You MUST check at the end to show that* $\frac{x}{[initial]} x\ 100 \leq 5\%$

ICE Tables

Jump back to title slide

5% RULE EXAMPLE

Set up your ICE table as normal through the equilibrium row. $2\ NO_{2(g)} \rightarrow N_2O_{4(g)}$

Rxn	$2\ NO_2$ ↔	N_2O_4
I	3	0
C	- 2x	+ x
E	3 – 2x	x
5%		
Answer		

← Careful to use the coefficients! It's stoich right?!

ICE Tables

Jump back to title slide

5% RULE EXAMPLE

Now check to see that K is at least 1000x smaller than initial [ ]'s ($K_{eq} = 9.3x10^{-7}$ vs. 3)

Rxn	$2\ NO_2$ $\leftrightarrow$	N_2O_4
I	3	0
C	- 2x	+ x
E	3 – 2x	x
5%	3	x
Answer		

Yes it is! Probably can use the 5% rule! Ignore any subtraction or addition of x values.

Leave any x values that are by themselves alone!

ICE Tables

5% RULE EXAMPLE

Now plug your 5% equilibrium values into the Equilibrium Expression and solve for x! Math is easier! Woohoo!

$$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2}$$

$$9.3 \times 10^{-7} = \frac{x}{3^2}$$

$$X = 8.37 \times 10^{-6}$$

Rxn	$2\ NO_2$ $\leftrightarrow$	N_2O_4
I	3	0
C	- 2x	+ x
E	3 – 2x	x
5%	3	x
Answer	**3 M**	**8.37×10^{-6}M**

Plug your x value into your 5% row to find your final answers!

Unit #14
Acids and Bases *

- Acid Base concepts
- pH calculations
- Strong acids and bases
- Self ionization of water
- Weak acids and bases **
- Salts **
- Titrations **

Concepts

Jump back to title slide

THREE DIFFERENT DEFINITIONS OF ACIDS/BASES

Arrhenius

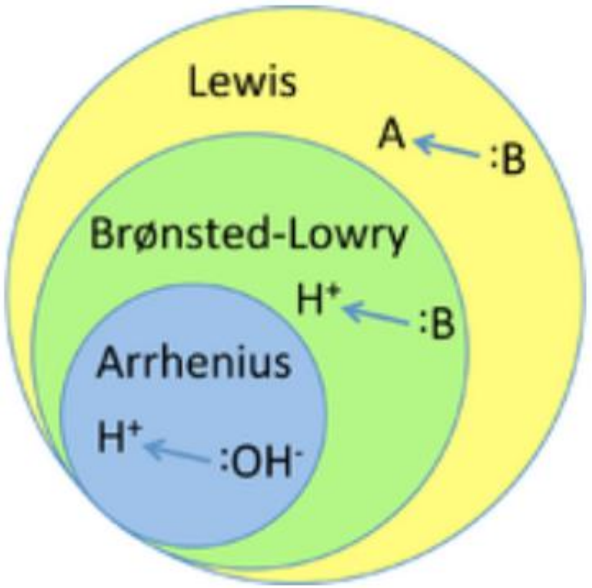
- Acids make H^+ ions in aqueous solutions
- Bases make OH^- ions in solution

Bronsted-Lowry

- Acids donate protons
- Bases accept protons

Lewis

- Acids accept electron pairs
- Bases donate electron pairs



Concepts

[Jump back to title slide]

Water can act as an acid or a base!

$NH_3 + H(OH) \rightarrow NH_4^+ + OH^-$

Water is donating a proton…

ACID!

$HCl + H(OH) \rightarrow H_3O^+ + Cl^-$

Water is accepting a proton…

BASE!

WEIRD FACT!

Amphoteric!

Greek amphoteros = "each of two"

Concepts

[Jump back to title slide]

Which type of acid/base???

HBr
Arrhenius Acid

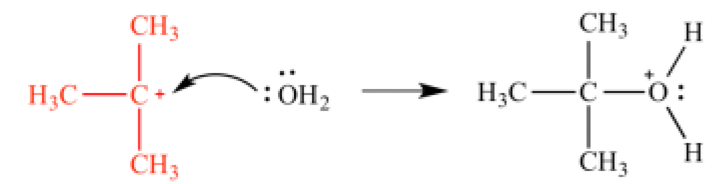
LiOH
Arrhenius Base

CO_3^{2-} + $2H^+$ → H_2CO_3

Bronsted-Lowry Base

$C_6H_5OH + NH_2^- \rightarrow C_6H_5O^- + NH_3$

Bronsted-Lowry Acid

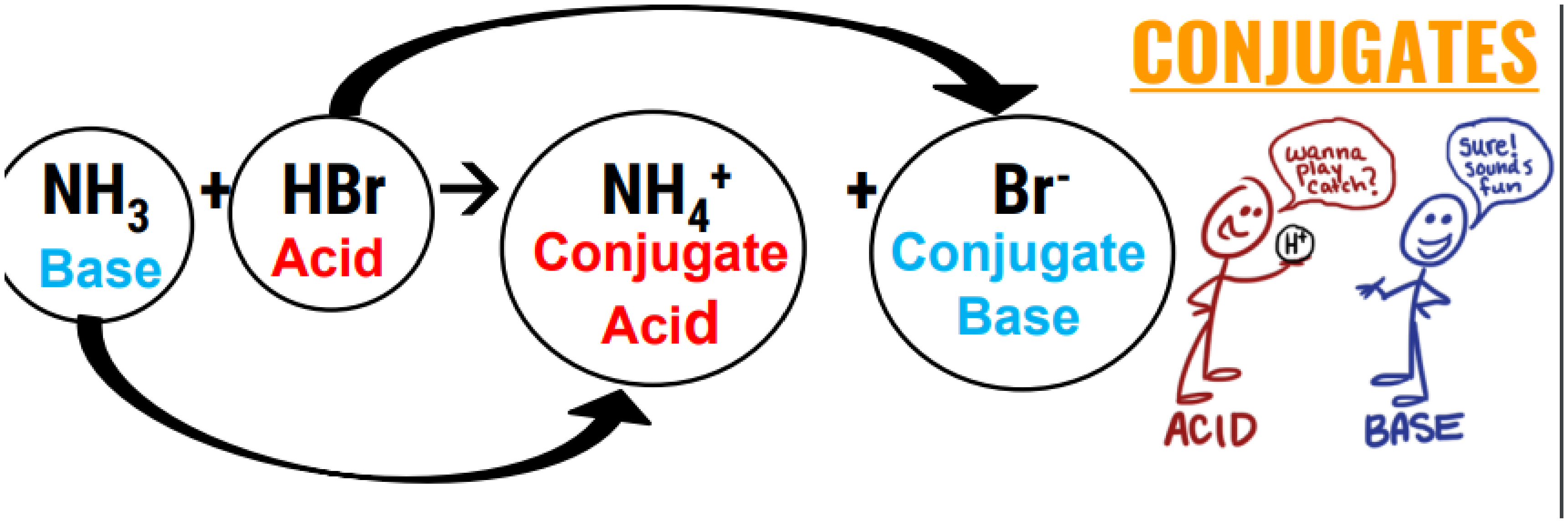


Lewis Acid

Lewis Base

Concepts

Jump back to title slide



$HF + SO_3^{2-} \rightarrow F^- + HSO_3^-$

HF	SO_3^{2-}	F^-	HSO_3^-
ACID	BASE	CONJ. BASE	CONJ. ACID

$H_2O + CH_3COOH \rightarrow H_3O^+ + CH_3COO^-$

H_2O	CH_3COOH	H_3O^+	CH_3COO^-
BASE	ACID	CONJ. ACID	CONJ. BASE

pH Calcs.

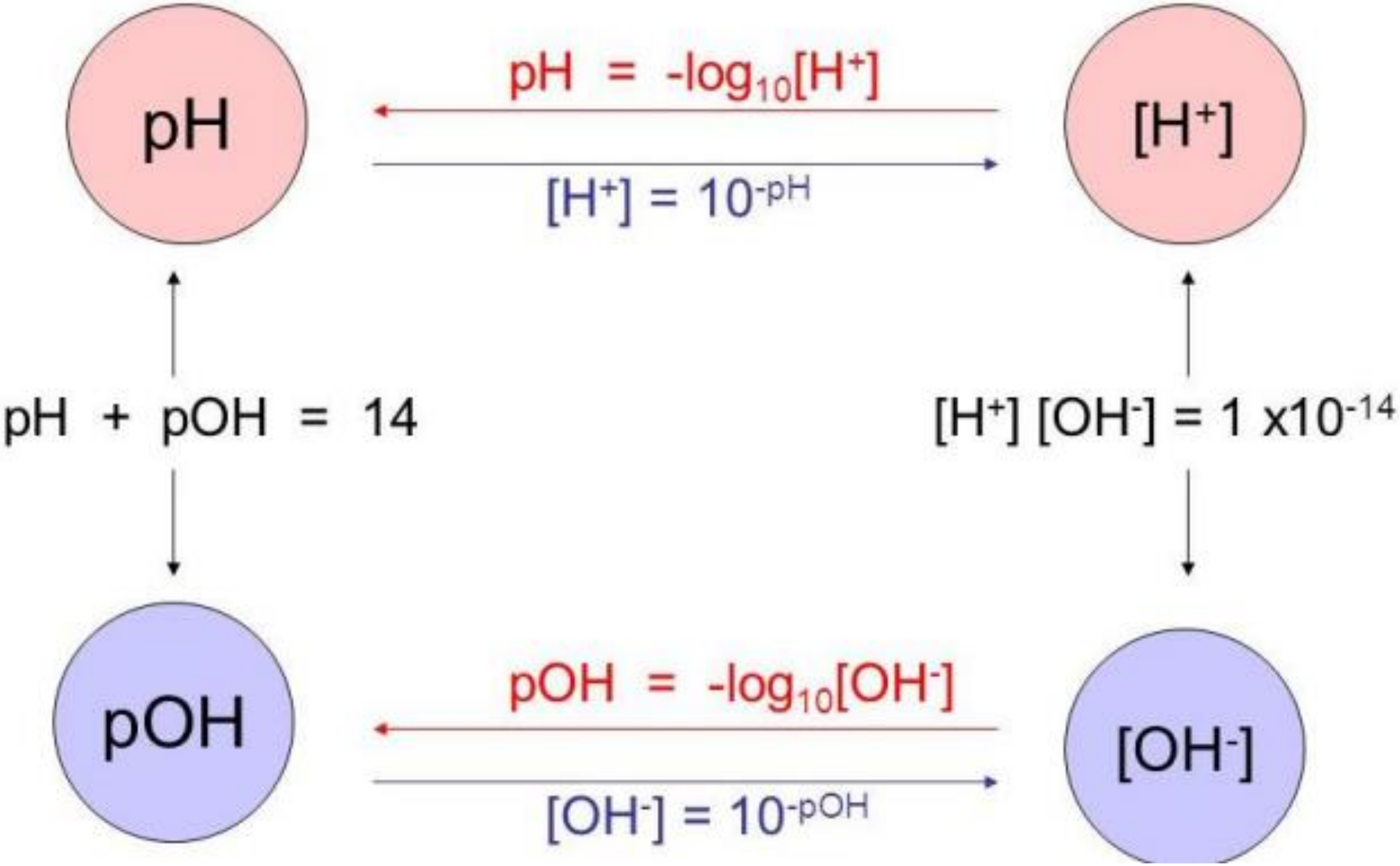
[Jump back to title slide]

Various pH Calculations

$pH = -\log [H^+]$	$pOH = -\log [OH^-]$
$[H^+] = 10^{-pH}$	$[OH^-] = 10^{-pOH}$
$pH + pOH = 14$	
$[H^+][OH^-] = 1 \times 10^{-14}$	
With these calculations you can plug in, rearrange, substitute and find everything no matter what you are given in the problem!	

pH Calcs.

Jump back to title slide



Strong Acids and Bases

[Jump back to title slide]

STRONG?

They dissociate completely

$HCl \rightarrow H^+ + Cl^-$

HCl is a strong acid so LOTS of ions in solution!

Strong Acids and Bases are the easy ones…assuming the dissociate completely makes our math easier ☺

Strong Acids and Bases

Strong Acids and Bases

Jump back to title slide

MEMORIZE!

The Seven Strong Acids

1) HCl – Hydrochloric Acid
2) HBr – Hydrobromic Acid
3) HI – Hydriodic Acid

Binary Acids

4) H_2SO_4 – Sulfuric Acid
5) HNO_3 – Nitric Acid
6) $HClO_4$ – Perchloric Acid
7) $HClO_3$ – Chloric Acid

Oxyacids

Strong Acids and Bases

[Jump back to title slide]

MEMORIZE!

The Eight Strong Bases

They are all hydroxides!

Alkali Metals

1) $LiOH$ – Lithium Hydroxide
2) $NaOH$ – Sodium Hydroxide
3) KOH – Potassium Hydroxide
4) $RbOH$ – Rubidium Hydroxide
5) $CsOH$ – Cesium Hydroxide

Alkaline Metals

6) $Ca(OH)_2$ – Calcium Hydroxide
7) $Sr(OH)_2$ – Strontium Hydroxide
8) $Ba(OH)_2$ – Barium Hydroxide

Strong Acids and Bases

[Jump back to title slide]

Neutralization Reactions

What happens when you mix a strong acid and strong base?

It is always the same!

Acid + Base → Water + Ionic Salt

$HCl + NaOH \rightarrow H_2O + NaCl$

$H_2SO_4 + 2KOH \rightarrow 2H_2O + K_2SO_4$

Self Ionization of Water

Jump back to title slide

Self Ionization of Water

What is the equilibrium expression for water?

$$H_2O_{(l)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$$

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

Remember!

Pure liquids aren't included in equilibrium expressions!

$[H_3O^+]$ and $[OH^-]$ are both equal to $1.0x10^{-7}M$ at 25^oC.

NOTICE ANYTHING???

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

$$1.0x10^{-14} = [1.0x10^{-7}] x [1.0x10^{-7}]$$

Self Ionization of Water

Jump back to title slide

Self Ionization of Water

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

$$1.0\times10^{-14} = [1.0\times10^{-7}] \times [1.0\times10^{-7}]$$

The concentration of $[H_3O^+]$ and $[OH^-]$ are equal…
So it is neutral!

Also - The pH and the pOH of any aqueous solution are related through the K_w. That's why if you know one you can find the other! And why they add to 14…look at the exponents!

Weak Acids and Bases

Jump back to title slide

Weak Acids and Bases

What do chemists mean by WEAK?

The do not completely ionize in water.

Only a **LITTLE BIT** will be dissociated.

Jump back to title slide

Connection back to...Equilibrium!

Dissociation is a reversible reaction right?

So…

We can use equilibrium constants, expressions, ice tables to determine [ ]'s which let us find…

pH values!

Weak Acids and Bases

Jump back to title slide

Ka and Kb

Remember that Keq is just generic. Could be Kc, Kp, Ksp if you are trying to be specific. So for acid bases use:

- K_a *(for acids)*
- K_b *(for bases)*

Still $\frac{Products}{Reactants}$ *which will be*

$$\frac{[Dissociated\ Ions]}{[Undissociated\ Molecule]}$$

$$HA \leftrightarrow H^+ + A^-$$

$$BOH \leftrightarrow B^+ + OH^-$$

Weak Acids and Bases

Jump back to title slide

Size of Ka for Weak Acids

$$Ka = \frac{[H_3O^+][OAc^-]}{[HOAc]} = 1.8 \times 10^{-5}$$

Why is the Ka so small for acetic acid???

- Small Ka means equilibrium lies to the LEFT
- Reactant Favored – not much dissociated
- It is a WEAK acid!
- Weak acids have Ka < 1
    - *Leads to low $[H^+]$ → pH from 2 - 6.9*

Size of Kb for Weak Bases

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

$$B(aq) + H_2O(\ell) \rightleftharpoons BH^+(aq) + OH^-(aq)$$

Weak Bases have small Kb values

- Small Kb means equilibrium lies to the LEFT
- Reactant Favored – not much dissociated
- It is a WEAK base!
- Weak bases have Kb < 1
    - *Leads to low $[OH^-]$ → pH from 12 – 7.1*

Weak Acids and Bases

Jump back to title slide

You have 1.00 M HOAc. Calc. the equilibrium concentrations of HOAc, H_3O^+, OAc^-, and the pH if Ka = $1.8x10^{-5}$. HOAc + H_2O ↔ H_3O + OAc^-

Reaction	[HOAc]	$[H_3O^+]$	$[OAc^-]$
I	1.00	0.00	0.00
C	-x	+x	+x
E	1.00-x	x	x
5%	1.00	x	x
Answer	1.00	4.2×10^{-3}	4.2×10^{-3}

Now Solve for pH – Don't forget!!!

pH = - log $[H_3O^+]$

pH = -log (4.2×10^{-3})

pH = 2.37

$$Ka = \frac{[H_3O^+][OAc^-]}{[HOAc]}$$

$$1.8 \; x \; 10^{-5} = \frac{x^2}{1.00}$$

x = 4.2×10^{-3}

Salts

Jump back to title slide

HOW DO SALTS BEHAVE WHEN YOU PUT THEM IN WATER?

They dissociate – the ions separate

$NaCl \rightarrow Na^+ + Cl^-$

$NH_4Cl \rightarrow NH_4^+ + Cl^-$

Salts

Jump back to title slide

HOW DO THE IONS BEHAVE ONCE THEY HAVE DISSOCIATED?

The ions can sometimes "hydrolyze"

Meaning they can react with the water.

$$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$$

The ion has to be "strong" enough for this to happen *(we will explain which ions are strong in a minute!)*

Salts

Jump back to title slide

WHAT IS THE RESULT OF THIS (POTENTIAL) HYDROLYSIS?

Once the ion hydrolyzes with the water it can make the salt solution acidic, basic, or neutral

$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$ solution is ACIDIC

$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$ solution is BASIC

$Cl^- + H_2O \rightarrow Cl^- + H_2O$ Cl- is not strong enough to hydrolyze so solution is NEUTRAL

Salts

Jump back to title slide

HOW DO YOU KNOW IF IT IS "STRONG" ENOUGH TO HYDROLYZE?

Have to think about the properties of the acids/bases that the ion came from

	Turns into a…	Hydrolyzes?
Strong Acid	**Weak** conjugate **base**	No
Weak Acid	**Strong** conjugate **base**	Yes
Strong Base	**Weak** conjugate **acid**	No
Weak Base	**Strong** conjugate **acid**	Yes

Salts

Jump back to title slide

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weak** conjugate **base**	No	Neutral
Weak Acid	**Strong** conjugate **base**	Yes	Basic
Strong Base	**Weak** conjugate **acid**	No	Neutral
Weak Base	**Strong** conjugate **acid**	Yes	Acidic

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

$Ka_{(ion)} > Kb_{(ion)}$	Acidic
$Ka_{(ion)} < Kb_{(ion)}$	Basic
$Ka_{(ion)} = Kb_{(ion)}$	Neutral

Salts

Jump back to title slide

FINDING $K_{A(ION)}$ AND $K_{B(ION)}$

$Kw = Ka \times Kb$

If you want Ka of an ion → need Kb of the base it came from

If you want Kb of an ion → need Ka of the acid it came from

Practice Problem: What is the Ka of NH_4^+ ?

Use Kb of NH_3 (1.8×10^{-5})

plug in and solve for $Ka_{(ion)}$

$(1 \times 10^{-14}) = Ka_{(ion)} \times (1.8 \times 10^{-5})$

$Ka_{(ion)}\ NH_4^+ = 5.56 \times 10^{-10}$

Salts

Jump back to title slide

Is K_2CO_3 an acidic, basic, or neutral salt?

K^+ CO_3^{2-}

K^+ → KOH Strong Base → so K^+ is Weak acid → No Hydrolysis → Neutral effect

CO_3^{2-} → H_2CO_3 Weak Acid → so CO_3^{2-} is Strong Base → Hydrolysis → Basic effect

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weak** conjugate base	No	Neutral
Weak Acid	**Strong** conjugate base	Yes	Basic
Strong Base	**Weak** conjugate acid	No	Neutral
Weak Base	**Strong** conjugate acid	Yes	Acidic

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

So K_2CO_3 is a BASIC SALT!

Salts

Jump back to title slide

Is NH_4CN an acidic, basic, or neutral salt?

$NH_4^+ \rightarrow NH_3$ Weak Base → so NH_4^+ is Strong acid → Hydrolysis → **Acidic effect**

$CN^- \rightarrow HCN$ Weak Acid → so CN^- is Strong Base → Hydrolysis → **Basic effect**

$Kb\ NH_3 = 1.8 \times 10^{-5}$ ⟶ $Ka\ NH_4^+ = (1.0 \times 10^{-14})/(1.8 \times 10^{-5})$

$Ka\ HCN = 4.9 \times 10^{-10}$ ⟶ $Kb\ CN^- = (1.0 \times 10^{-14})/(4.9 \times 10^{-10})$

$Ka_{(NH4+)} = 5.56 \times 10^{-10}$

$Kb_{(CN-)} = 2.04 \times 10^{-5}$

$Ka_{(NH4+)} < Kb_{(CN-)}$

NH_4CN is a Basic Salt!

Salts

Jump back to title slide

WHAT IF YOU WANT THE ACTUAL pH VALUE?

1. Do all the steps needed to determine which ion is the "strong" one – which one is being hydrolyzed?
2. Write the hydrolysis reaction for that ion (or ions)
3. ICE Table time! Yes! More ICE tables! They just wont go away! ☺ Use your hydrolysis rxn for ICE Table
4. Find $[H_3O^+]$ or $[OH^-]$ from ICE Tables
5. Continue on with normal pH type calculations

Titrations

Jump back to title slide

What is titration?

A way to determine the concentration of an unknown substance.

- Uses the fact that acids and bases react with each other in “neutralization reactions”

- At the point where the neutralization reaction is finished
  # moles Acid = # moles Base

Titrations

[Jump back to title slide]

How do you know you reached the end point?

Use an **INDICATOR**

Turns colors based on pH – can show you visually when you have reached the end point.

Key Terms

Titrand
The unknown solution you are interested in

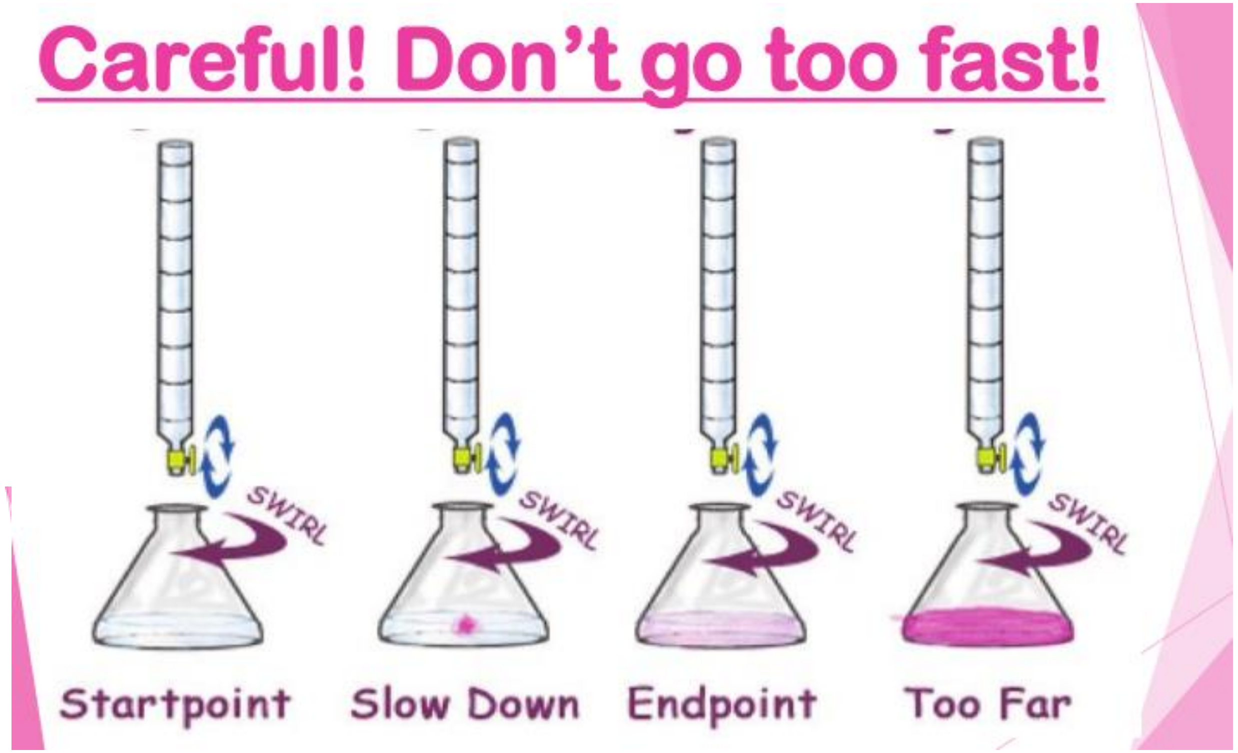
Titrant
The solution with the known concentration

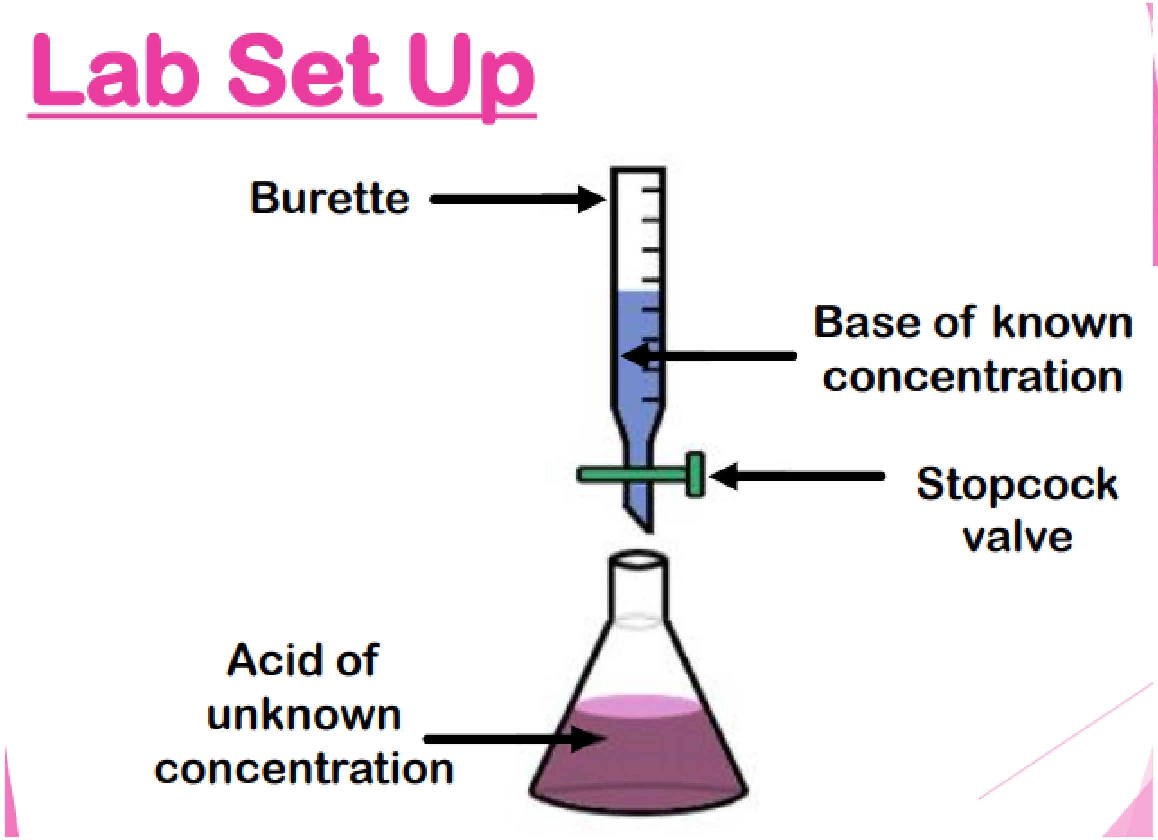
Equivalence Point
The point at which all the titrand has reacted with the titrant.
Moles Acid = # Moles Base

End Point
The point at which your titration seems finished during the lab – a color change happens for example

Titrations

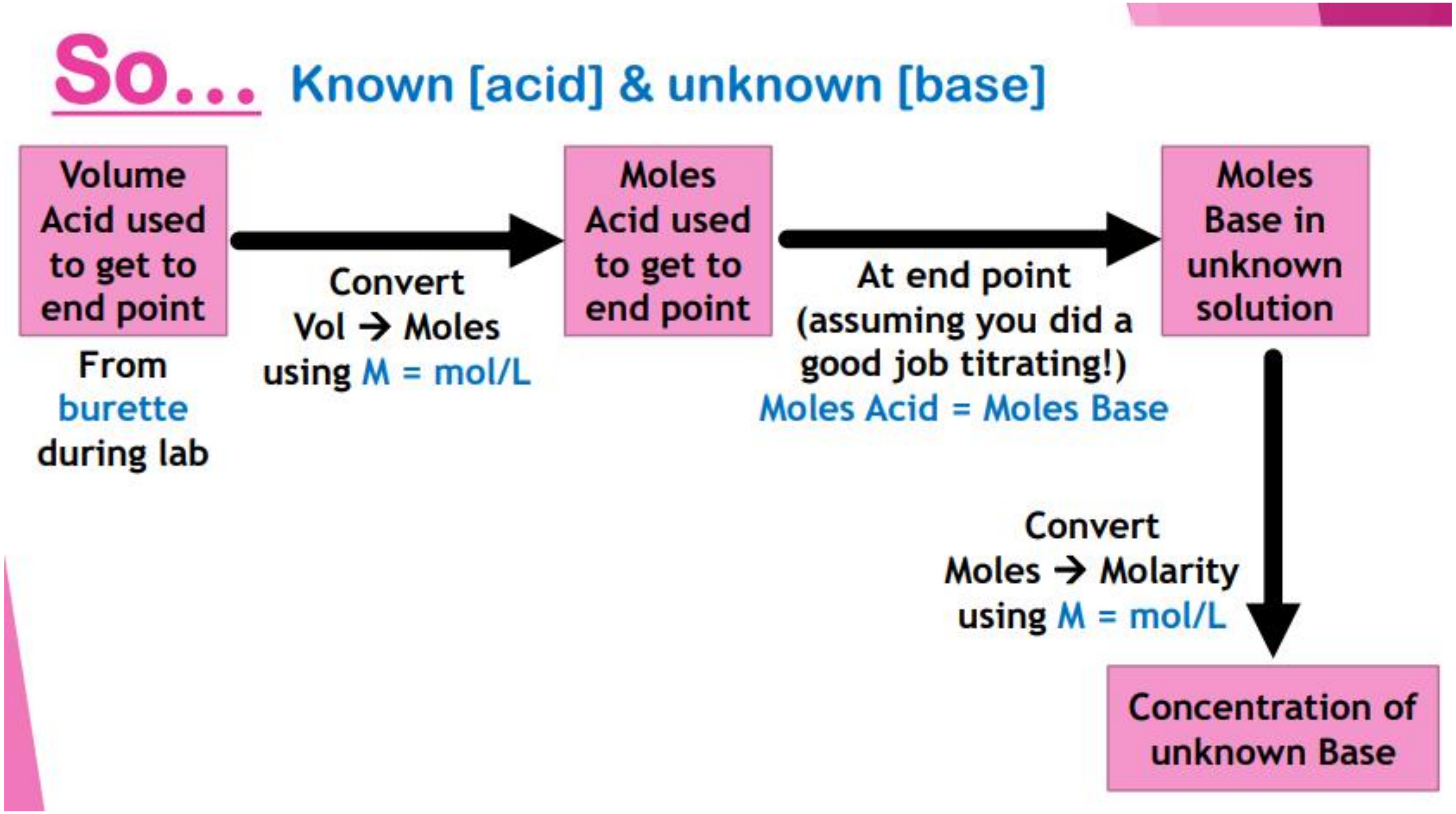
[Jump back to title slide]





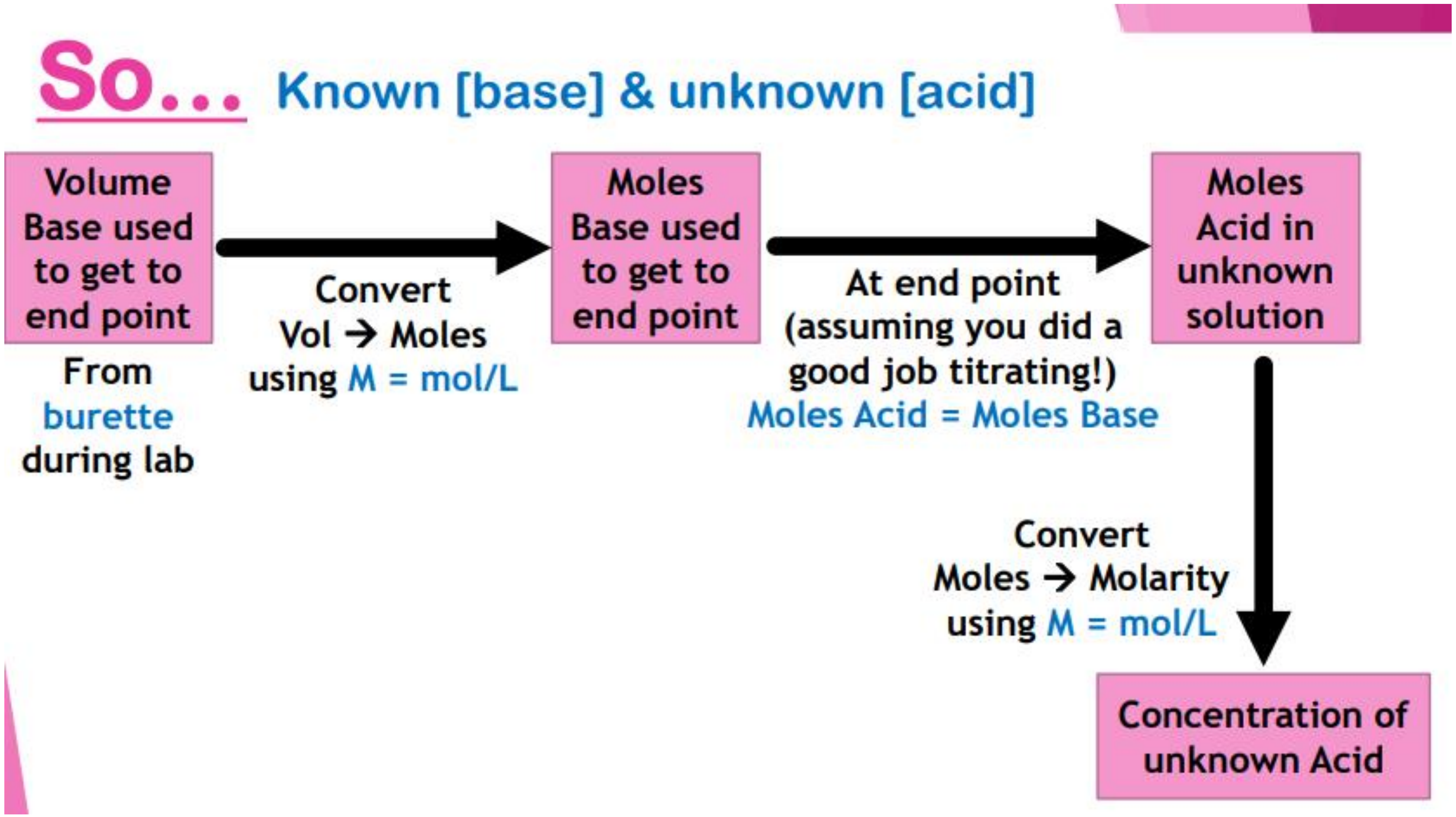
Titrations

[Jump back to title slide]



Titrations

[Jump back to title slide]



Titrations

Jump back to title slide

Calculate how many moles of NaOH you used

Molarity = Moles / Liters

From burette in the lab

Moles used = Volume used x Molarity NaOH

Known [ ] given to you

$$\text{Moles} = \text{L} \times \frac{\text{mol}}{\text{L}}$$

$$\text{Moles NaOH} = \frac{x\ \text{mL}}{} \times \frac{1\text{L}}{1000\ \text{mL}} \times \frac{Y\ \text{mol}}{1\ \text{L}}$$

Titrations

Jump back to title slide

Calculate the unknown concentration of the acid

At End Point → Moles NaOH = Moles HCl

Molarity = Moles / Liter

Same as mol NaOH used!

$$\text{Molarity Acid} = \frac{\text{Moles Acid}}{\text{Liters Acid Used}}$$

The amount in your Erlenmeyer flask!

Unit #15
Redox (part of Summer Assignment always)

- Oxidation and Reduction
- Oxidation number
- Oxidation vs reduction
- Writing half reactions
- Balancing redox reactions in an acidic or basic solution

Oxidation and Reduction

Jump back to title slide

Electrochemistry

Study of the interchange of chemical and electrical energy

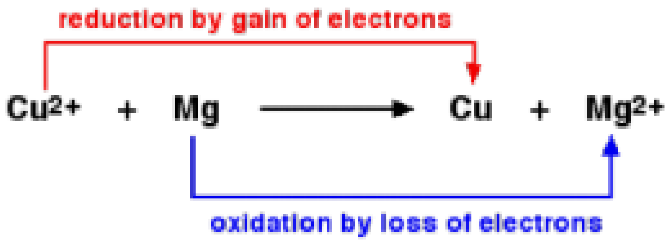
- Electron transfer reactions are called oxidation-reduction reactions or REDOX reactions
- Electrochemical processes that result in the generation of an electric current (electricity) or can be caused by imposing an electric current

Oxidation and Reduction

Jump back to title slide

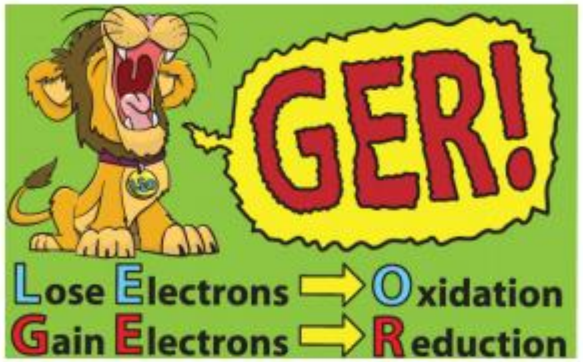
Redox Reactions

- **OXIDATION NUMBER:** Assigned charge on an atom
- **OXIDATION:** Loss of electrons (increase in oxidation number or charge… "+")
- **REDUCTION:** Gain of electrons (decrease in oxidation number or charge… "-")

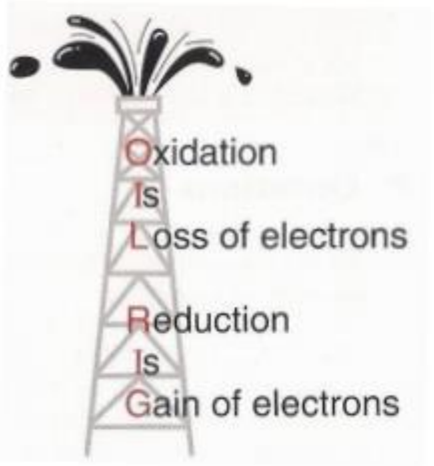


- **OXIDIZING AGENT:** electron acceptor… species that is reduced (an agents facilitates something / ex: travel agent)
- **REDUCING AGENT:** electron donor… species that is oxidized

LEO THE LION GOES GER!



OIL RIG!



Half Reactions

Jump back to title slide

- Oxidation and reduction go hand in hand... need one to have the other
- Cannot have 2 oxidations or 2 reductions in the same equation
- Written as two **HALF-REACTIONS** (one for oxidation and one for reduction)

$2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$ Overall

$2\ Mg \rightarrow 2\ Mg^{2+} + 4\ e^-$ OXIDATION

$O_2 + 4\ e^- \rightarrow 2\ O^{2-}$ REDUCTION

Oxidation Numbers

Jump back to title slide

Oxidation Numbers

Assigned charge on an atom

1) Elements not bonded to another different element have an oxidation number of ZERO (ex: Na, Fe, O_2, N_2)

2) In monatomic ions, oxidation number is equal to the charge on the ion (ex: Li^{+} = +1, Fe^{3+} = +3, P^{3-} = -3)

3) Oxidation number of oxygen is USUALLY -2… in H_2O_2 and O_2^{2-} it is -1

4) Oxidation number of hydrogen is +1 EXCEPT when bonded to metals in binary compounds then it is -1 (ex: CaH_2, LiH)

5) Group IA metals are always +1, IIA always +2, etc… remember transition metals vary

6) Oxidation numbers of a molecule must add up to ZERO or add up to the charge on a polyatomic ion

Ex: HCO_3^-

Oxidation Numbers

Jump back to title slide

Examples

CO_2	CO	C	CH_4	H_2	Cl_2	HCl
(+4)(-2)	(+2)(-2)	(0)	(-4)(+1)	(0)	(0)	(+1)(-1)

$NaCl$	$KMnO_4$	ZnO	CaF_2
(+1)(-1)	(+1)(+7)(-2)	(+2)(-2)	(+2)(-1)

O_2	O_3	HO_2	H_2O_2	H_2O	OF_2
(0)	(0)	(+1)(-1/2)	(+1)(-1)	(+1)(-2)	(+2)(-1)

Half Reactions, Balancing

[Jump back to title slide]

Writing a Redox Reaction

1) Write the NET IONIC equation
2) Assign oxidation numbers
3) Determine what is being oxidized and reduced

- **EXAMPLE:** Lead foil is immersed in silver nitrate

$$\underset{0}{Pb(s)} + 2\,\underset{+1}{Ag^{+}(aq)} \rightarrow \underset{+2}{Pb^{2+}(aq)} + 2\,\underset{0}{Ag(s)}$$

Balancing a Redox Reaction

1) Write the half reactions
2) Balance the non H's and O's first
3) Use H_2O to balance the O's and use H^+ to balance the H's
4) Use e- to balance the charges
5) Get common multiple for e- and multiply
6) Cancel and add up the half reactions (e- must cancel as well as all like species)... Verify # of atoms and charges are balanced
7) In basic solutions, add OH^- to BOTH sides for every H^+ in final equation... make H_2O

Half Reactions, Balancing

Jump back to title slide

Write the balanced equation for the oxidation of Fe^{2+} to Fe^{3+} by $Cr_2O_7^{2-}$ to Cr^{3+} in acidic solution.

$Fe^{2+} \rightarrow Fe^{3+}$

$Cr_2O_7^{2-} \rightarrow Cr^{3+}$

STEP #1

$Fe^{2+} \rightarrow Fe^{3+}$

$Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+}$

STEP #2

$Fe^{2+} \rightarrow Fe^{3+}$

$Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

STEP #3

$Fe^{2+} \rightarrow Fe^{3+}$

$14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

STEP #3

$Fe^{2+} \rightarrow Fe^{3+} + 1\ e^-$

$6\ e^- + 14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

STEP #4

$6\ Fe^{2+} \rightarrow 6\ Fe^{3+} + 6\ e^-$

$6\ e^- + 14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

STEP #5

$6\ Fe^{2+} \rightarrow 6\ Fe^{3+} + \cancel{6\ e^-}$

$\cancel{6\ e^-} + 14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

$14\ H^+ + Cr_2O_7^{2-} + 6\ Fe^{2+} \rightarrow 6\ Fe^{3+} + 2\ Cr^{3+} + 7\ H_2O$

STEP #6

Are all atoms and charges balanced?

Electro
chem

Electro
chem