Video Instructions if Interested

- https://youtu.be/2KJuI4YnTGU

Basics and Atomic Structure
Nuclear Chemistry
Electrons
Periodic Table
Bonding and Structure
Reactions
Stoich.

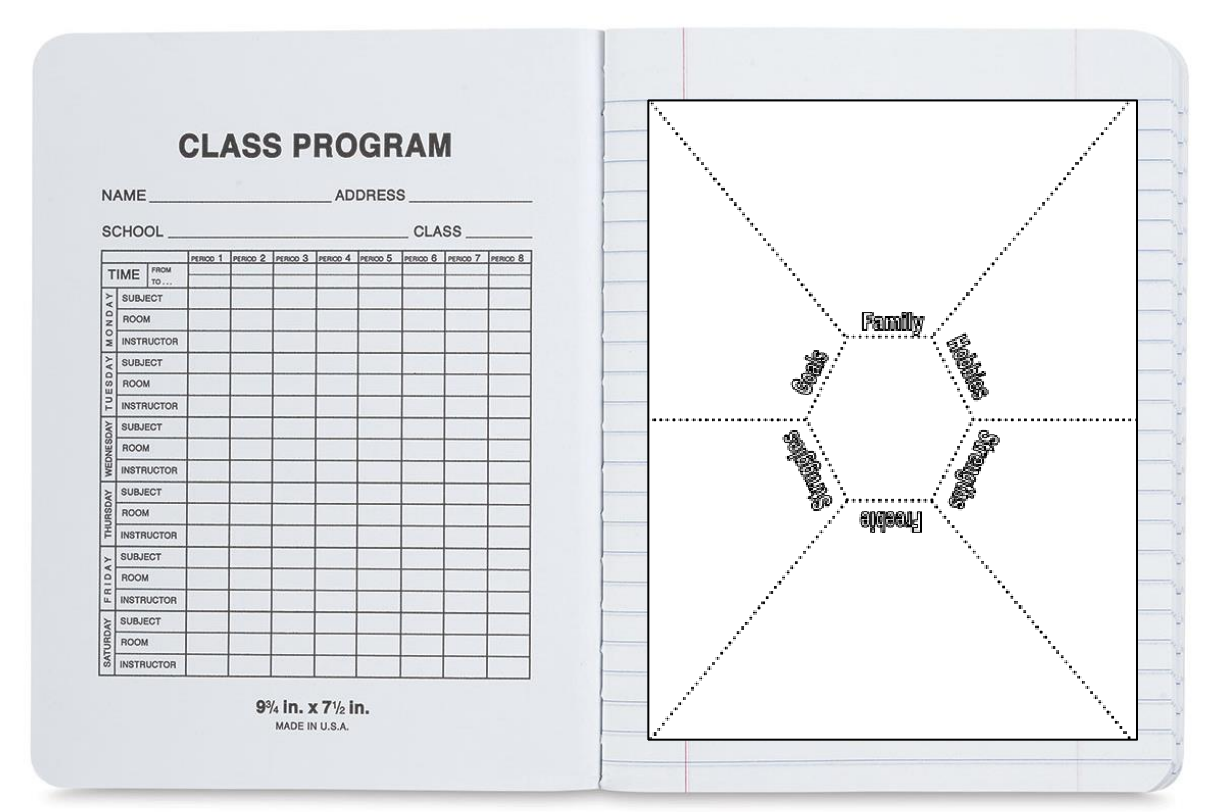
Crash Course:

N1 - Honors Chem Review

Advanced Chemical Ratios
Gas Laws
Thermo.
Solutions
Kinetics
Equilibrium
Acids and Bases
Redox

How to set up your composition notebook

Your notebook should look like this so far…



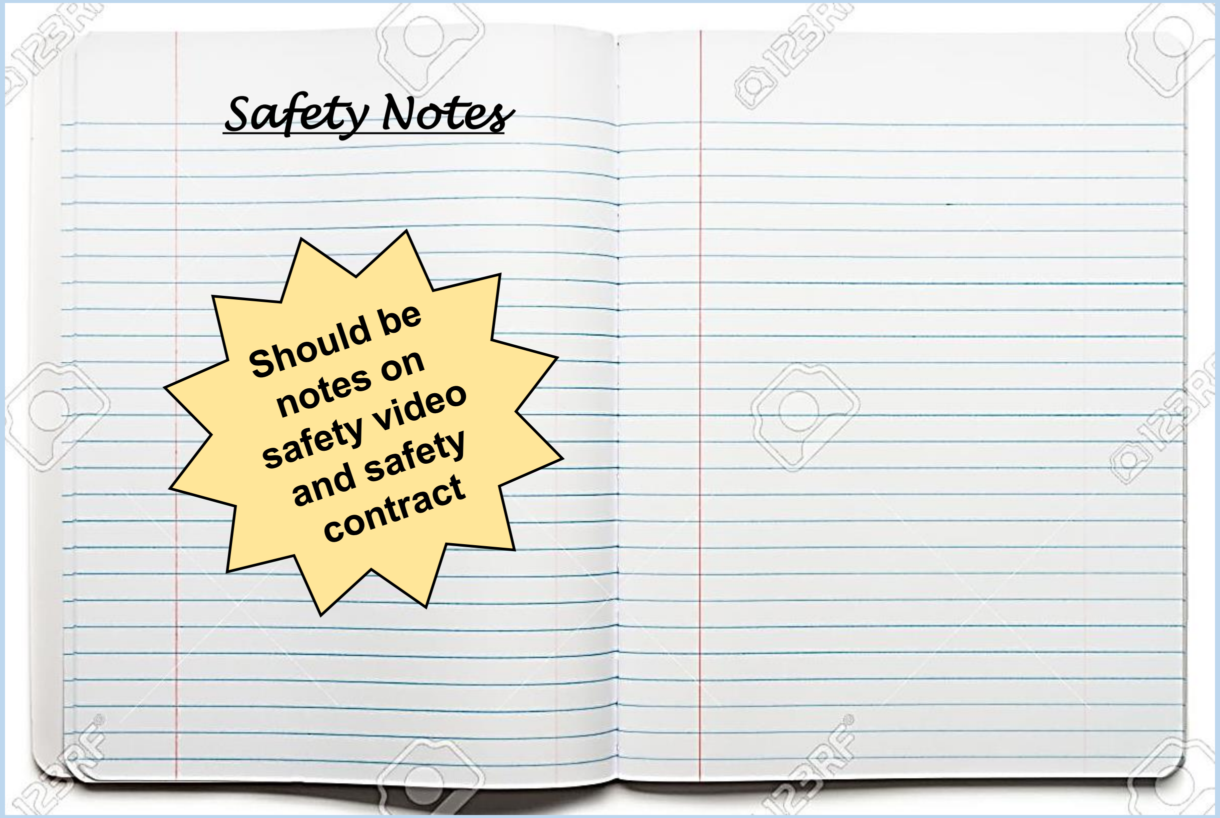
CLASS PROGRAM

NAME ____________ ADDRESS ____________

SCHOOL ____________ CLASS ____________

		PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6	PERIOD 7	PERIOD 8
TIME	FROM TO…								
MONDAY	SUBJECT								
	ROOM								
	INSTRUCTOR								
TUESDAY	SUBJECT								
	ROOM								
	INSTRUCTOR								
WEDNESDAY	SUBJECT								
	ROOM								
	INSTRUCTOR								
THURSDAY	SUBJECT								
	ROOM								
	INSTRUCTOR								
FRIDAY	SUBJECT								
	ROOM								
	INSTRUCTOR								
SATURDAY	SUBJECT								
	ROOM								
	INSTRUCTOR								

9¾ in. x 7½ in.
MADE IN U.S.A.



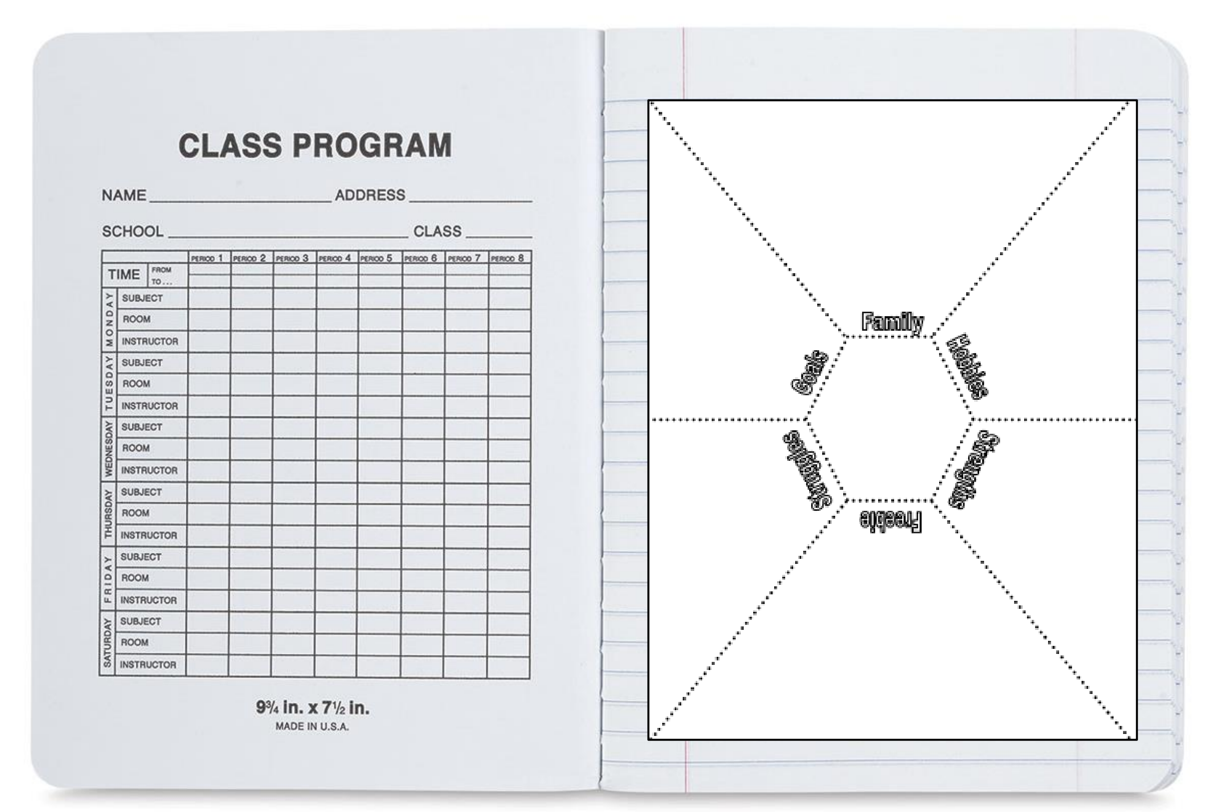
Safety Notes

Should be notes on safety video and safety contract

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

Add the N1 "Glue In" to page 3

Now your notebook should look like this!



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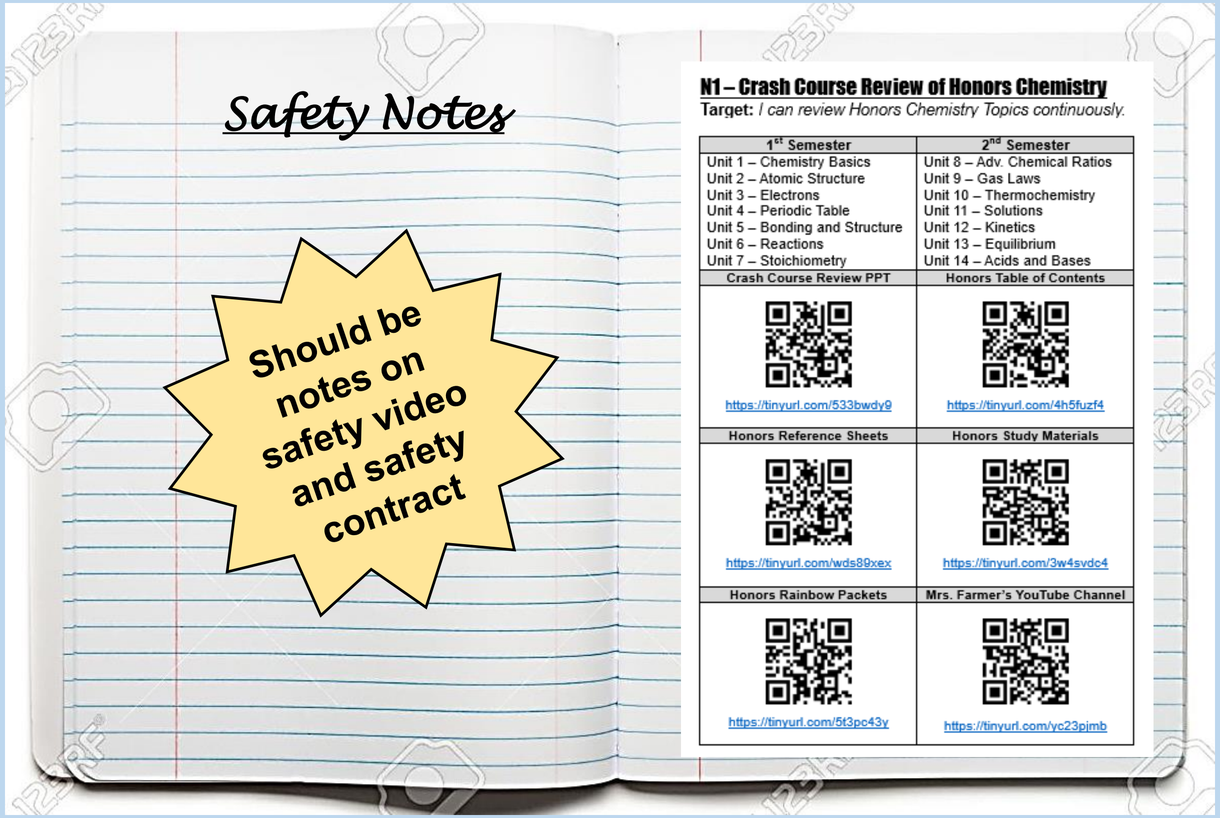

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N1 – Crash Course Review of Honors Chemistry

Target: *I can review Honors Chemistry Topics continuously.*

1^{st} Semester	2^{nd} Semester
Unit 1 – Chemistry Basics Unit 2 – Atomic Structure Unit 3 – Electrons Unit 4 – Periodic Table Unit 5 – Bonding and Structure Unit 6 – Reactions Unit 7 – Stoichiometry	Unit 8 – Adv. Chemical Ratios Unit 9 – Gas Laws Unit 10 – Thermochemistry Unit 11 – Solutions Unit 12 – Kinetics Unit 13 – Equilibrium Unit 14 – Acids and Bases
Crash Course Review PPT	**Honors Table of Contents**
https://tinyurl.com/533bwdy9	https://tinyurl.com/4h5fuzf4
Honors Reference Sheets	**Honors Study Materials**
https://tinyurl.com/wds89xex	https://tinyurl.com/3w4svdc4
Honors Rainbow Packets	**Mrs. Farmer's YouTube Channel**
https://tinyurl.com/5t3pc43y	https://tinyurl.com/yc23pjmb

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

You MUST remember your Honors Chem material !!!
It is SO important.
You need to know it AND be able to do it FAST !

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

Time for some self guided review !

- The rest of this PowerPoint has screen shots of key pieces of info from the Honors Chem Lectures. Your glue in has links to the full Honors Lectures if you want/need more detail.
- **PLEASE** scroll through and review things as needed!
- When we start a new AP Chem chapter, **PLEASE** go back and review the Honors version of the chapter!
- I cannot stress enough how important this is!
- Make mature choices about what and when to review old material! **Set yourself up for success!**

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^{EXPONENT}" is the same a

E

$3.54E^{2}$

One #

•

Rest of the #s

x

10

Exponent

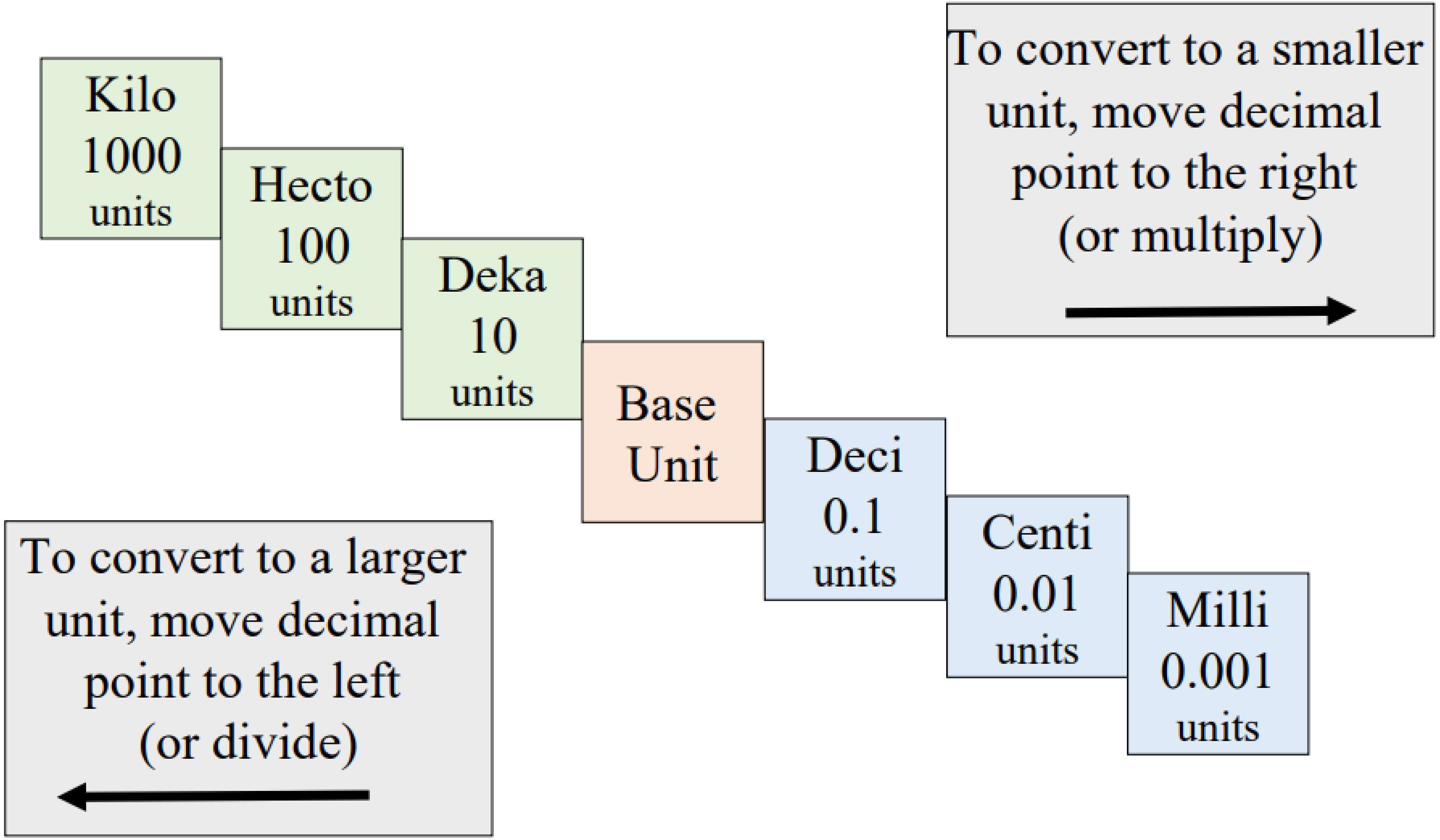
(telling how many times to move the decimal, and which way to move it!)

Metric System

Jump back to title slide

Converting Metric System

- Just move the decimal!



To convert to a smaller unit, move decimal point to the right (or multiply)

Kilo
1000 units

Hecto
100 units

Deka
10 units

Base Unit

Deci
0.1 units

Centi
0.01 units

Milli
0.001 units

To convert to a larger unit, move decimal point to the left (or divide)

Jump back to title slide

How do I remember the prefixes?

King **H**enry **D**ied **By** **D**rinking **C**hocolate **M**ilk

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

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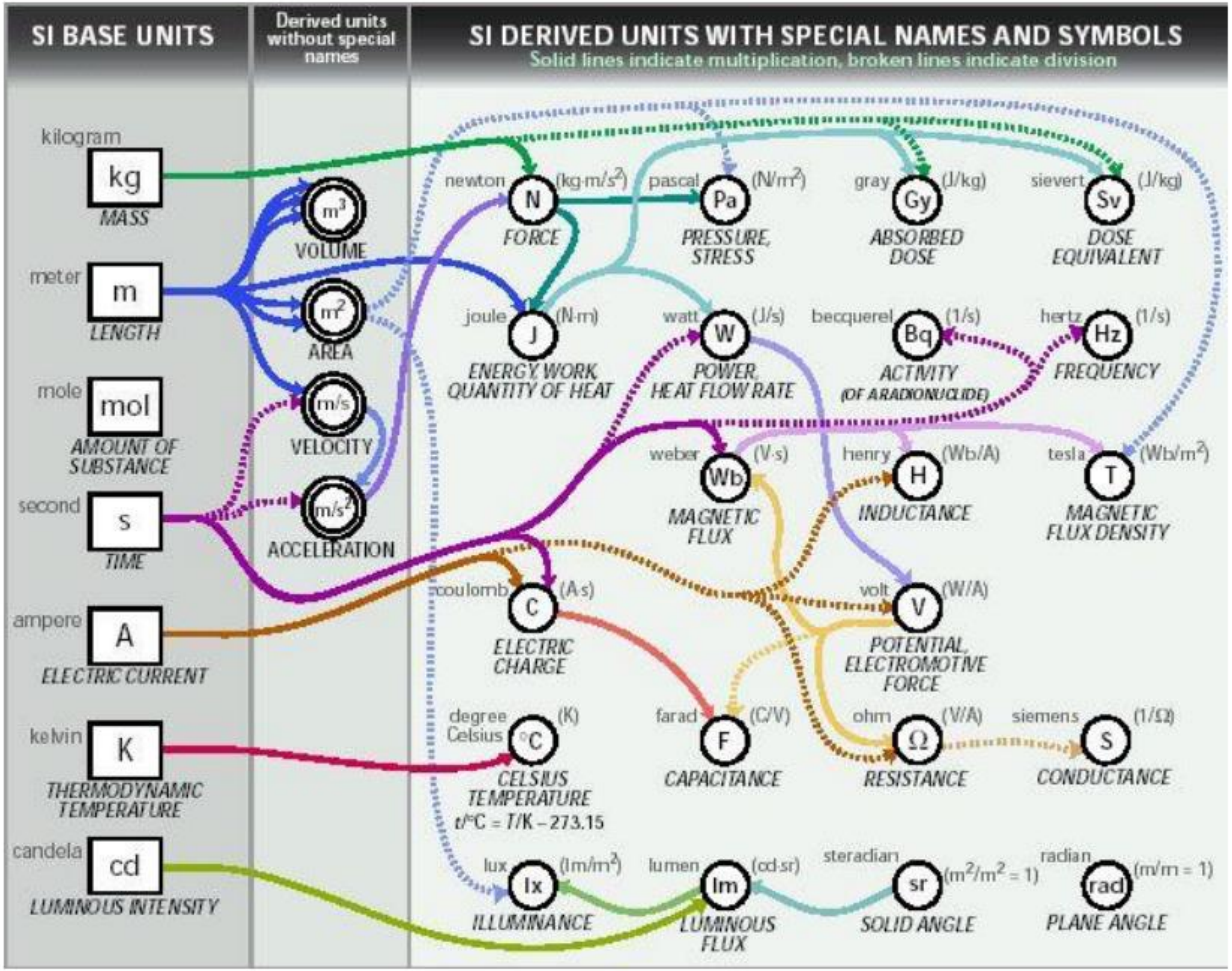

Dimensional Analysis

Jump back to title slide

Remember - Canceling Units

One on top cancels with one on the bottom

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

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

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

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

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

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

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

$$\begin{array}{c|c|c|c} 15\text{ yrs} & 365\text{ days} & 24\text{ hr} & 60\text{ min} \\ \hline & 1\text{yr} & 1\text{ day} & 1\text{ hr} \end{array} = 7.9 \text{ x } 10^6\text{ min}$$

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.

$$\begin{array}{c|c|c|c|c} 20\cancel{mi} & 5280\cancel{ft} & 12\,in & 1\cancel{hr} & 1\cancel{min} \\ \hline 1\cancel{hr} & 1\cancel{mi} & 1\cancel{ft} & 60\cancel{min} & 60\,sec \end{array} = 352\,\frac{in}{sec}$$

Significant Figures

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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)*

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.*

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

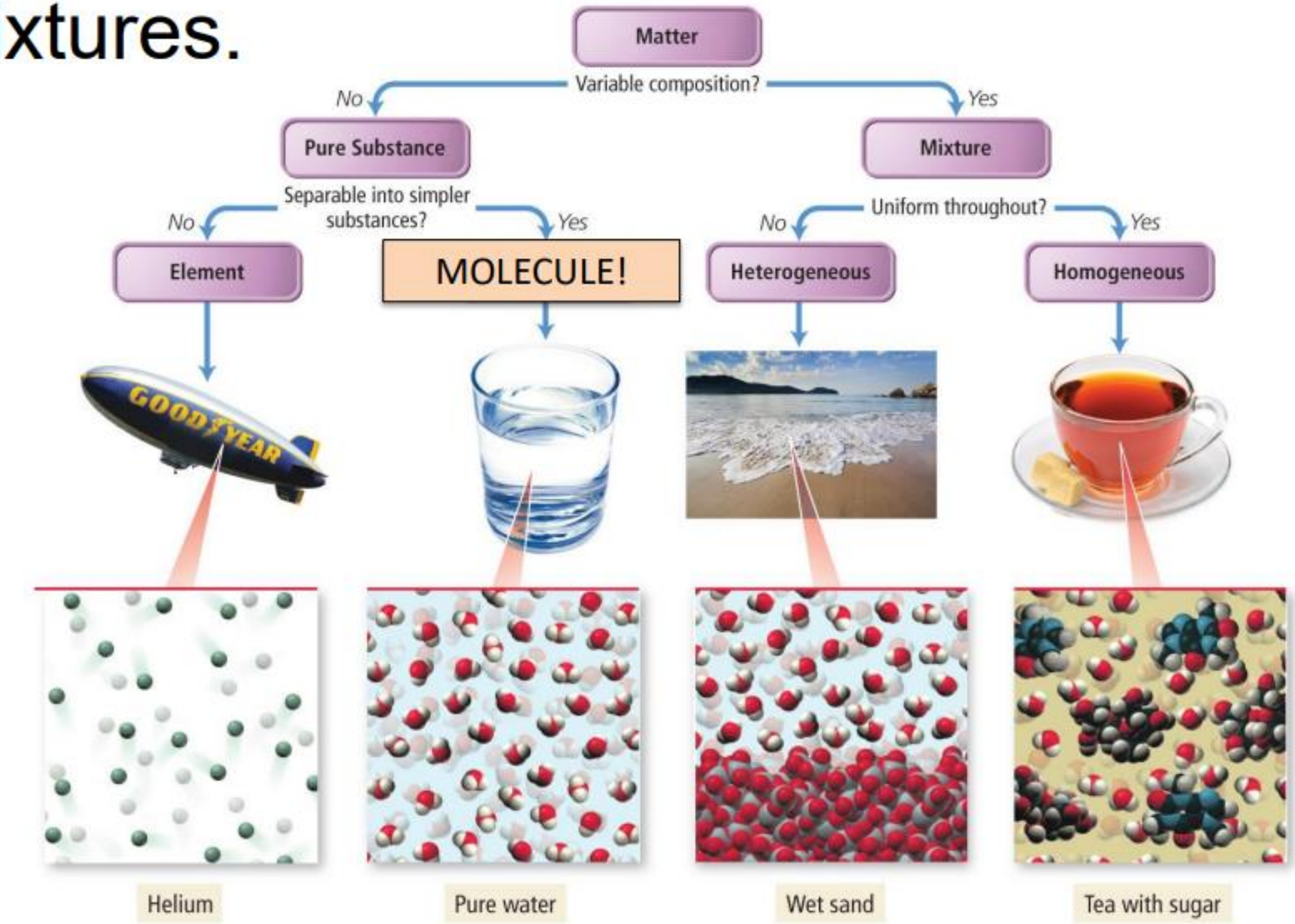
- Atoms rearrange, transforming the original substances into **different substances**.

Types of Matter

[Jump back to title slide]

The Classification of Matter by Components

- Elements, compounds, and types of mixtures.



Matter

Variable composition?

No

Yes

Pure Substance

Mixture

Separable into simpler substances?

No

Yes

Uniform throughout?

No

Yes

Element

MOLECULE!

Heterogeneous

Homogeneous

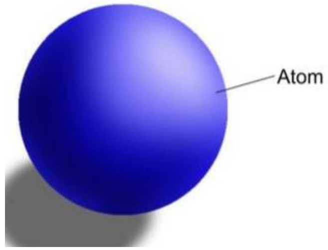
Helium

Pure water

Wet sand

Tea with sugar

Atomic Models



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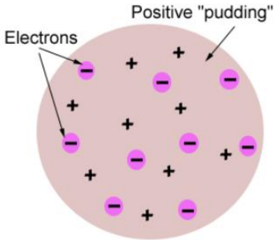
DALTON'S BILLIARD BALL MODEL

John Dalton

THOMSON'S ATOMIC MODEL

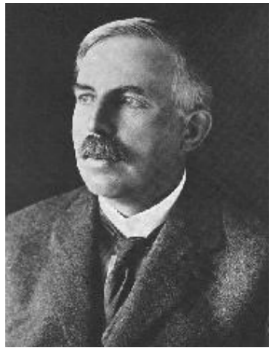


Thomson believed that the electrons were like plums embedded in a positively charged "pudding," thus it was called the "plum pudding" model. We don't usually eat plum pudding in this country, so I like to call it the chocolate chip cookie model.

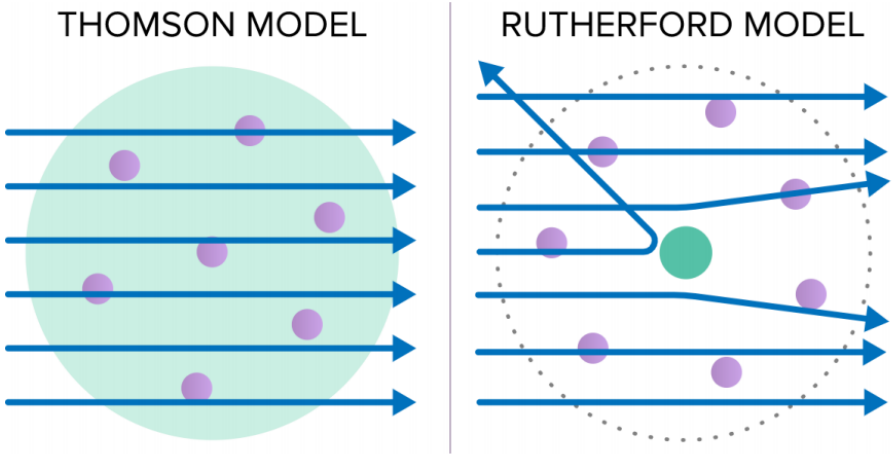
RUTHERFORD'S FINDINGS

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

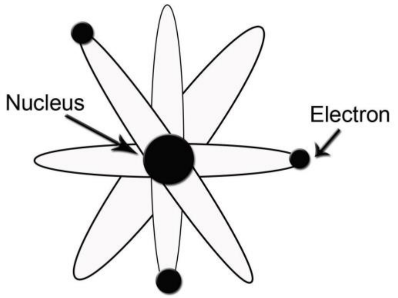
CONCLUSIONS:



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

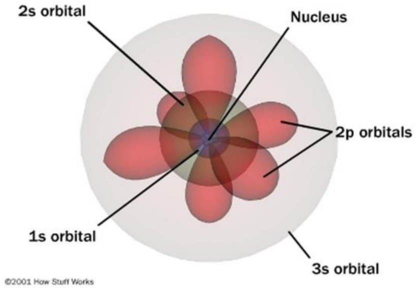


THE BOHR MODEL



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



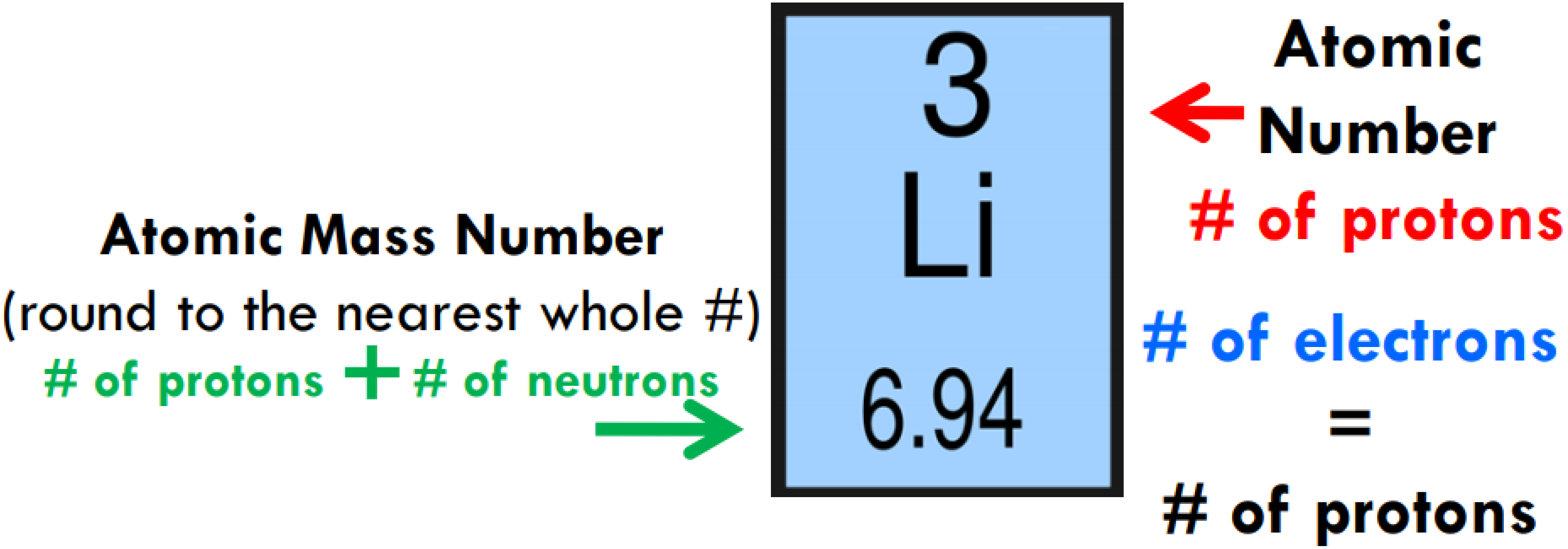
This is a hard model to understand.
The Electrons don't follow paths, they are not objects at all! Instead they are pure charge that has a probability of being somewhere in those orbitals.

Jump back to title slide

ATOMIC NUMBERS

We know: 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

Atomic Mass Number

(round to the nearest whole #)

# of protons + # of neutrons

Atomic Numbers

Jump back to title slide

IONS!

Oxygen

O^{-2}

Negative

Anion

Gained electrons

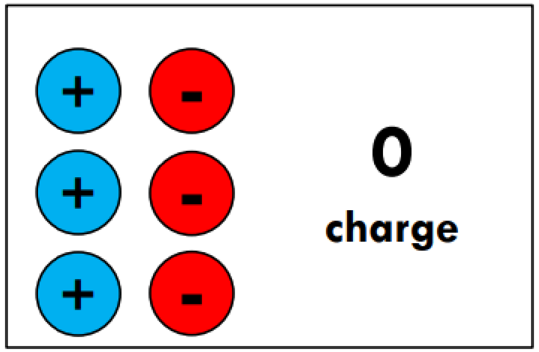
Sodium

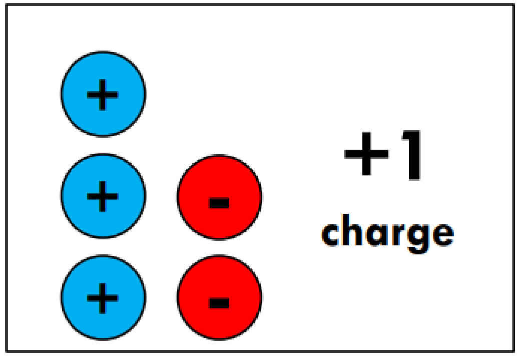
Na^{+1}

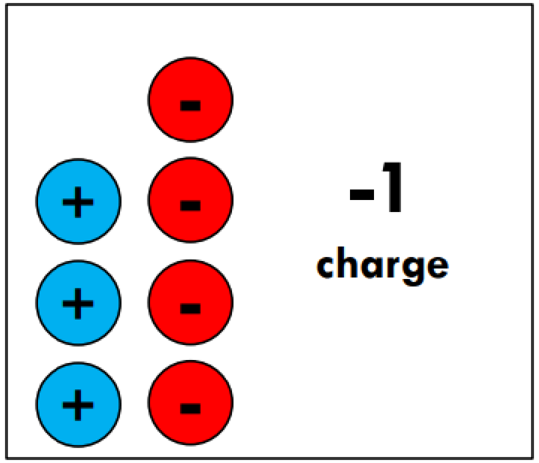
Positive

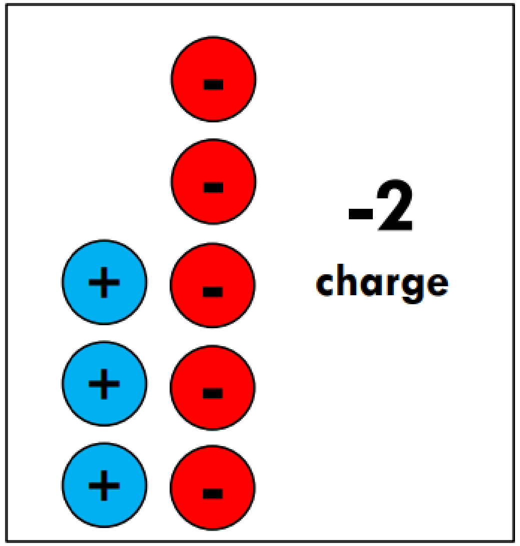
Cation

Took away electrons









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

Unit #2
Nuclear Chemistry

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

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

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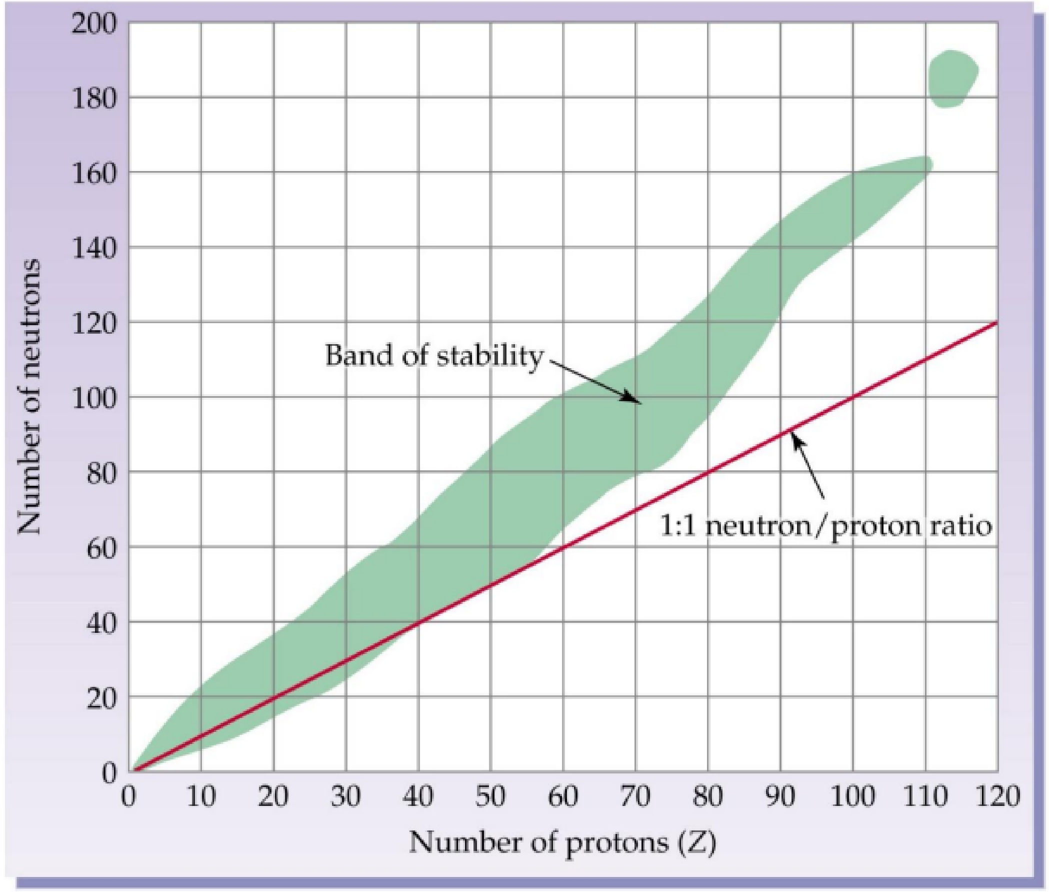
Band of Stability and Island of Stability



Radioactive particles

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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 #

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

Atomic #

Beta

Mass #

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

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

$$U^{238}_{92} \xrightarrow{\alpha} Th^{234}_{90} \xrightarrow{\beta} Pa^{234}_{91} \xrightarrow{\beta} U^{234}_{92}$$

$$\xrightarrow{\alpha} Th^{230}_{90} \xrightarrow{\alpha} Ra^{226}_{88} \xrightarrow{\alpha} Rn^{222}_{86} \xrightarrow{\alpha} Po^{218}_{84}$$

$$\xrightarrow{\alpha} Pb^{214}_{82} \xrightarrow{\beta} Bi^{214}_{83} \xrightarrow{\beta} Po^{214}_{84} \xrightarrow{\alpha} Pb^{210}_{82}$$

$$\xrightarrow{\beta} Bi^{210}_{83} \xrightarrow{\beta} Po^{210}_{84} \xrightarrow{\alpha} Pb^{206}_{82}$$

Decay Series

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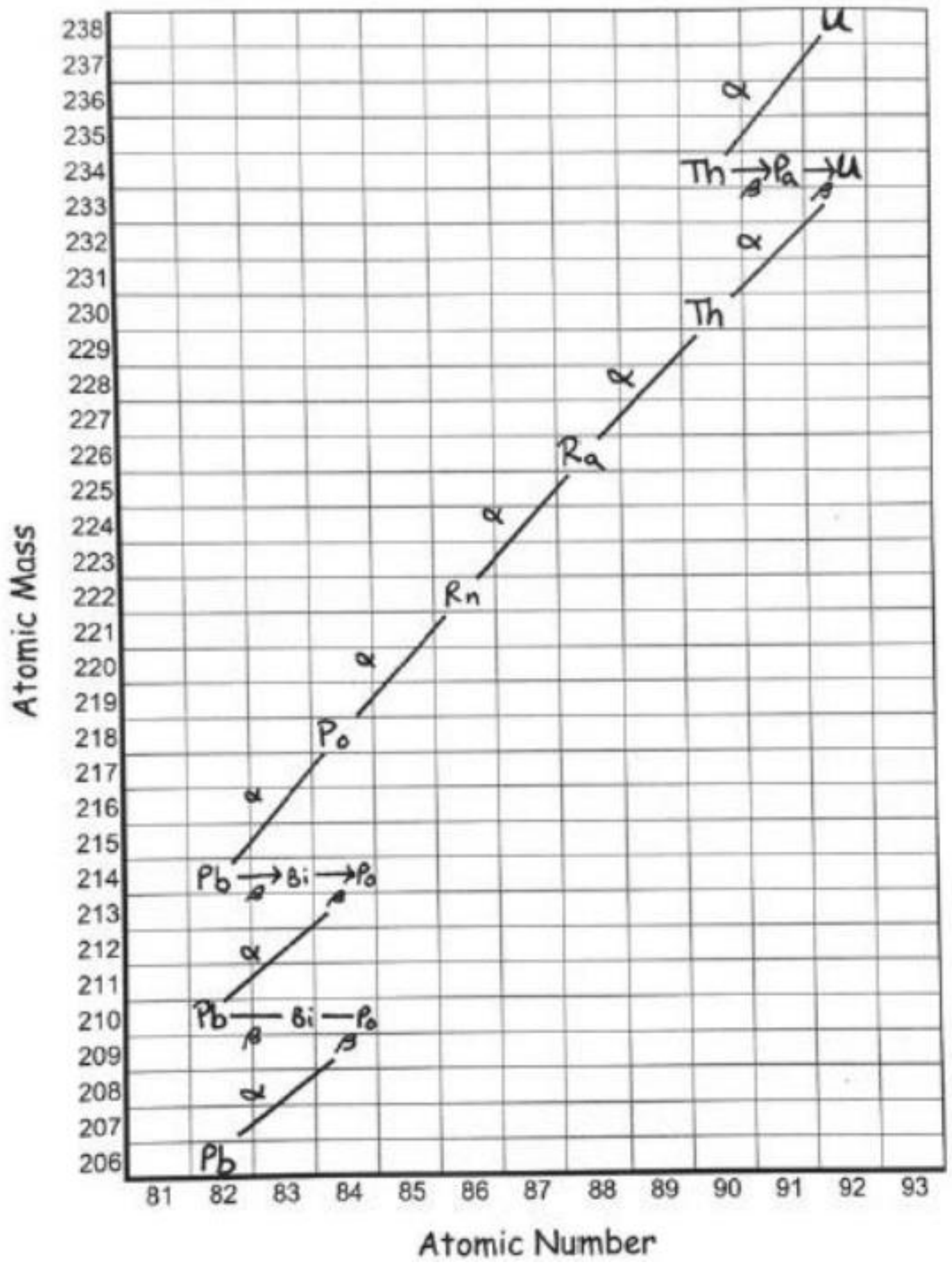

Half Life

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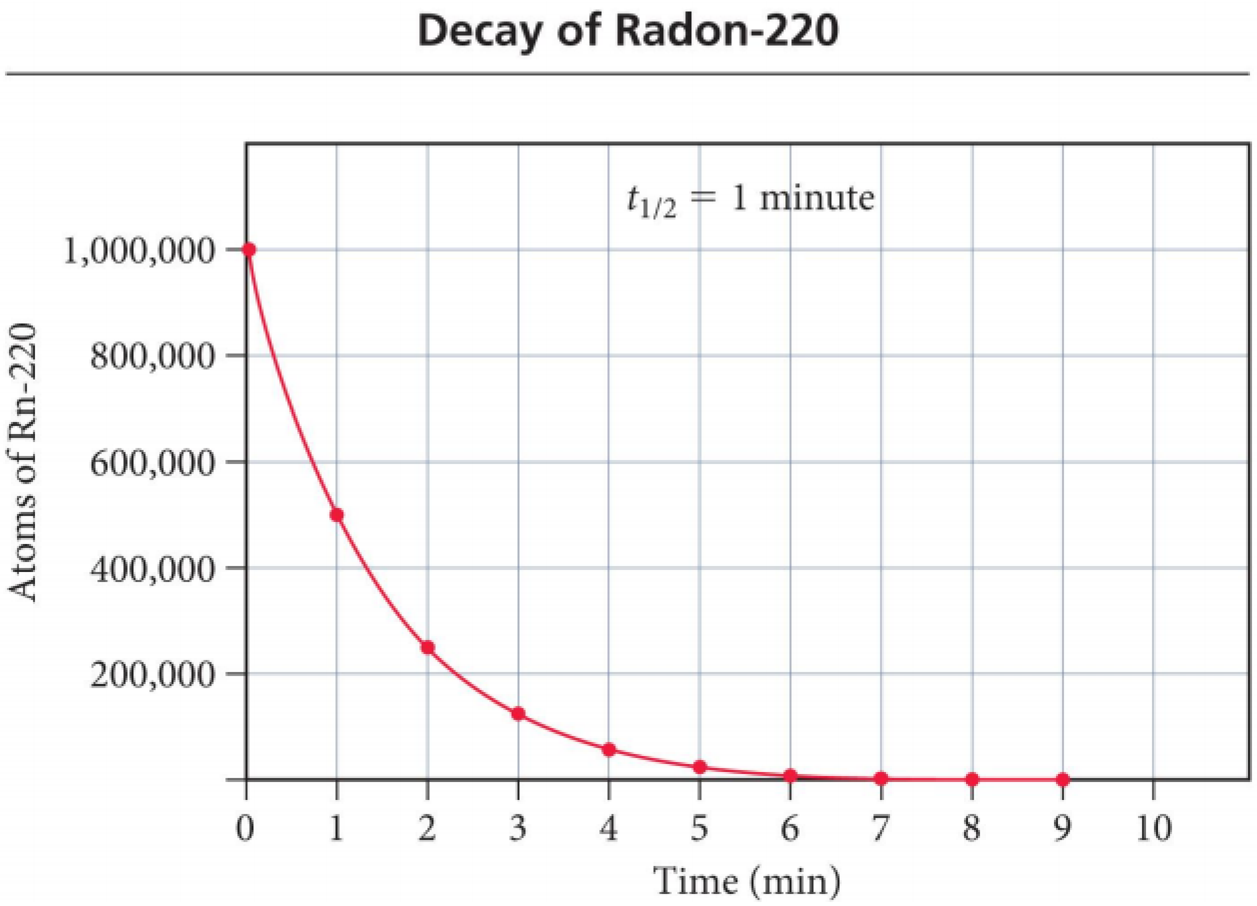
Half of the radioactive atoms decay each half-life.



Half-Life Equation

- ☐ Use a handy dandy equation!

Amount Starting

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

# of half-lives

Amount Ending

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

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

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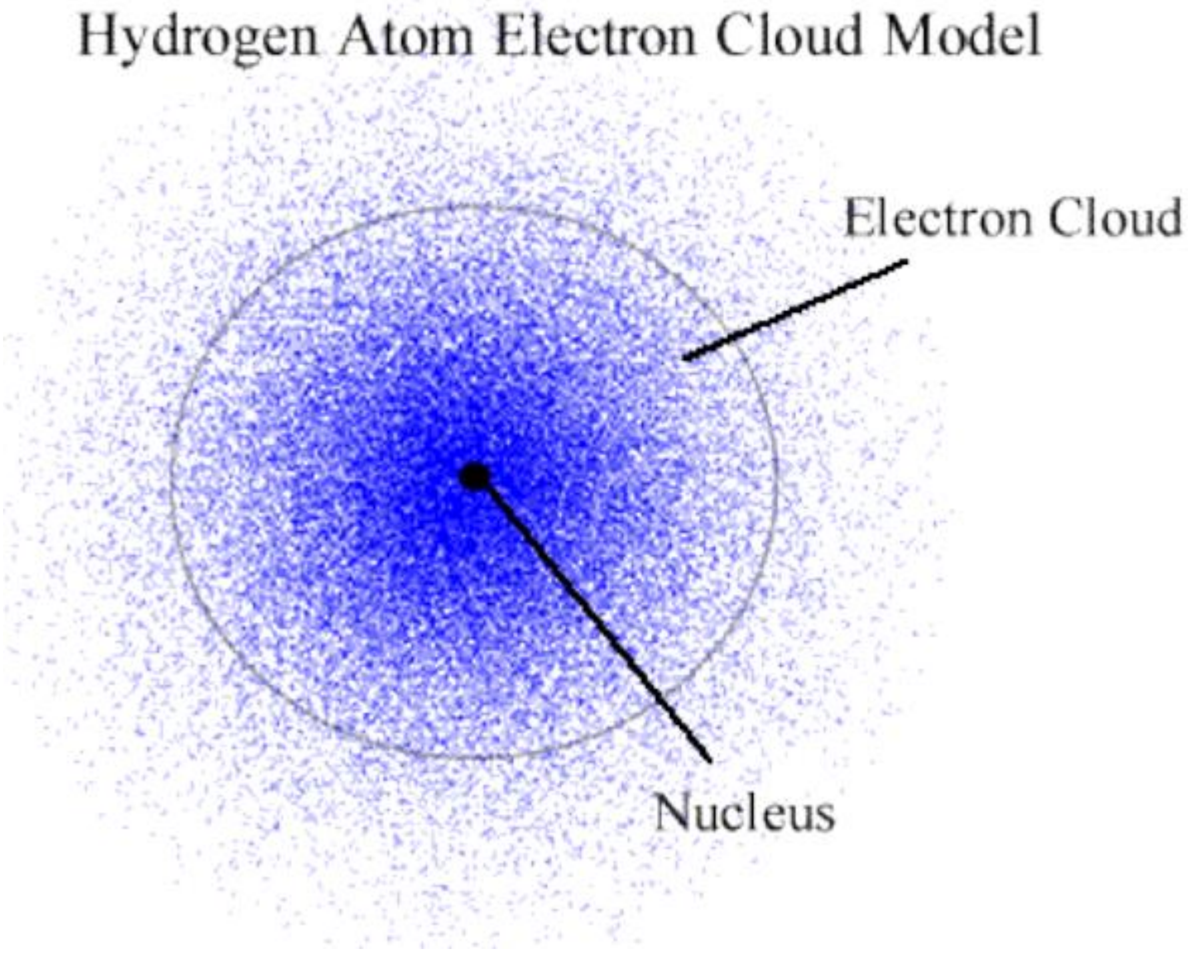

Orbital Diagrams

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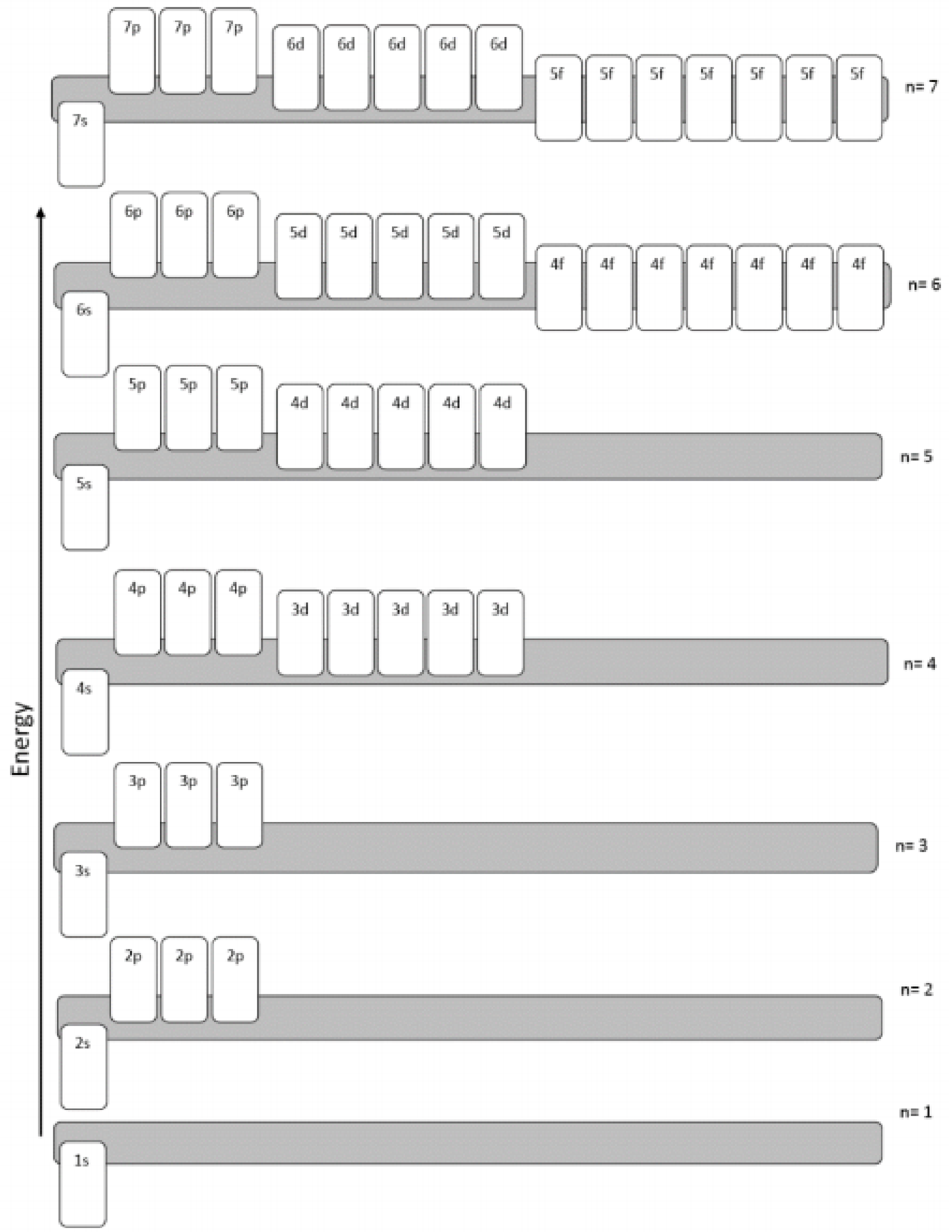
Orbital Diagram

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



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.

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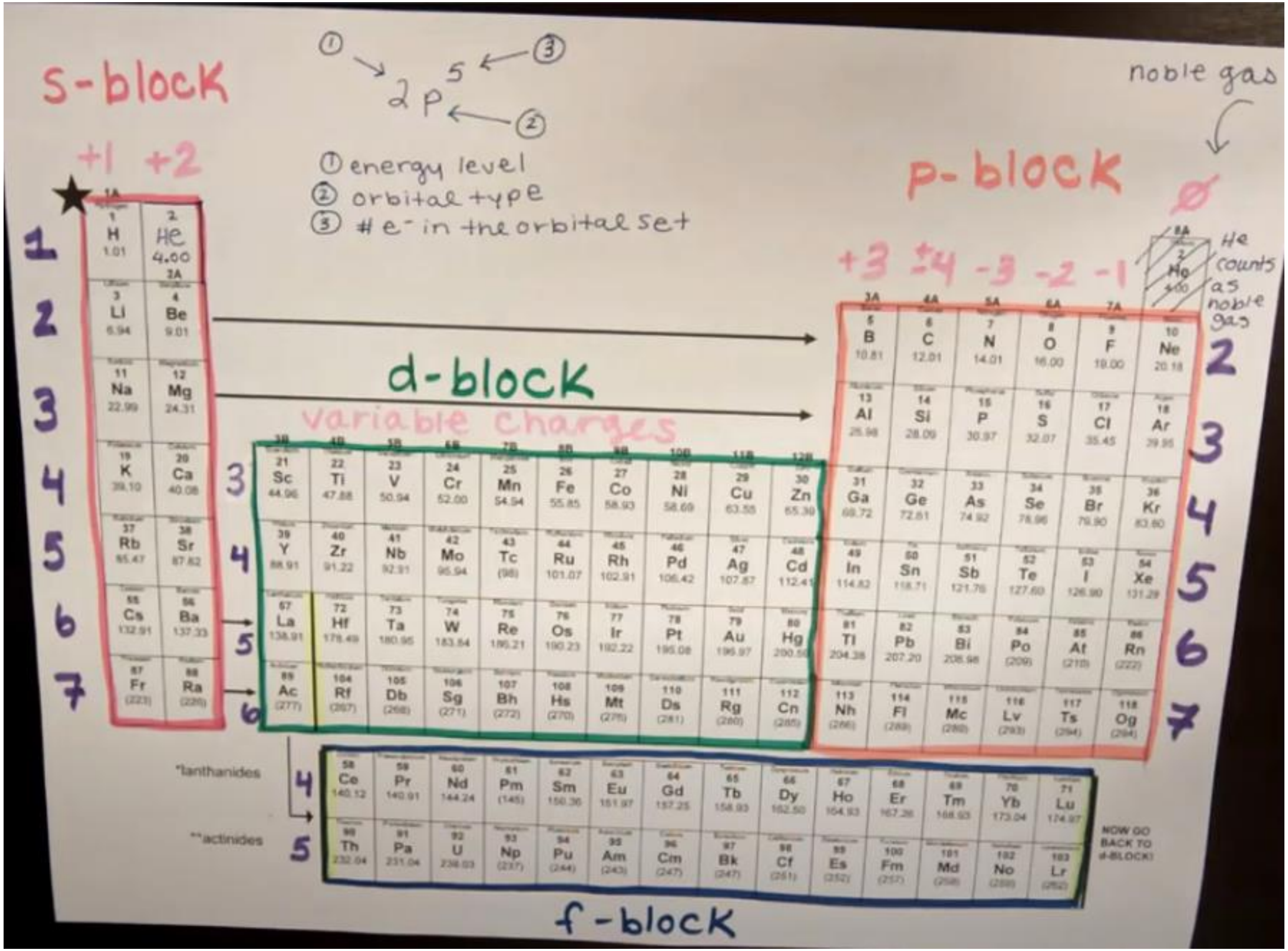

① → $2p^5$ ← ③

② ↑

① energy level
② orbital type
③ # e⁻ in the orbital set

	1A	2A	3B	4B	5B	6B	7B	8B	8B	10B	11B	12B	3A	4A	5A	6A	7A	8A	
1	1 H 1.01	2 He 4.00																~~2 He 4.00~~	
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18	2
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	3
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	4
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29	5
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)	6
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (272)	108 Hs (270)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)	7

*lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
**actinides	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

NOW GO BACK TO d-BLOCK!

Noble Gas Config.

Jump back to title slide

He: $1s^2$

Lithium

$\boxed{1s^2}\ 2s^1$

Helium + extra!

$\boxed{[He]\ 2s^1}$

He: $1s^2$

Nitrogen

$\boxed{1s^2}\ 2s^2 2p^3$

Helium + extra!

$\boxed{[He]\ 2s^2 2p^3}$

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

Sodium

$\boxed{1s^2 2s^2 2p^6}\ 3s^1$

Neon + extra!

$\boxed{[Ne]\ 3s^1}$

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

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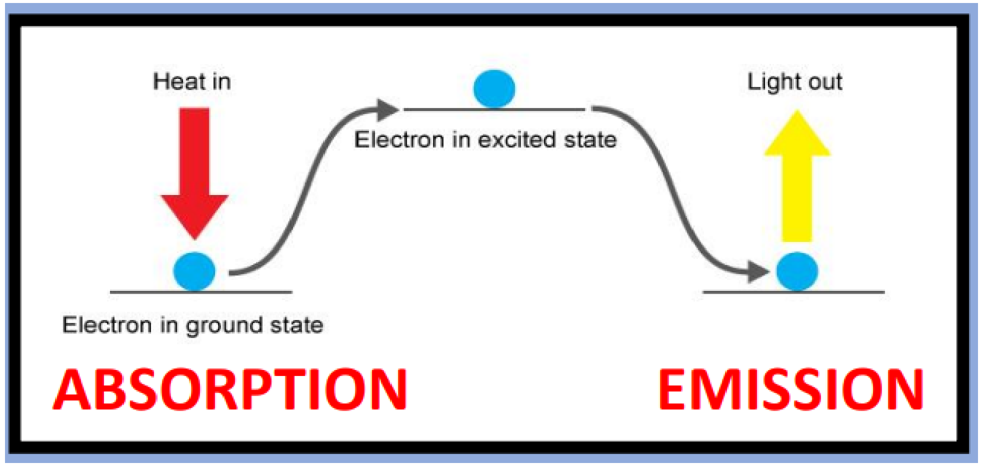
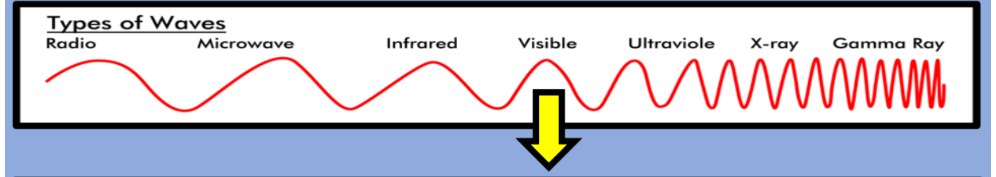


ENERGY SPECTRUM

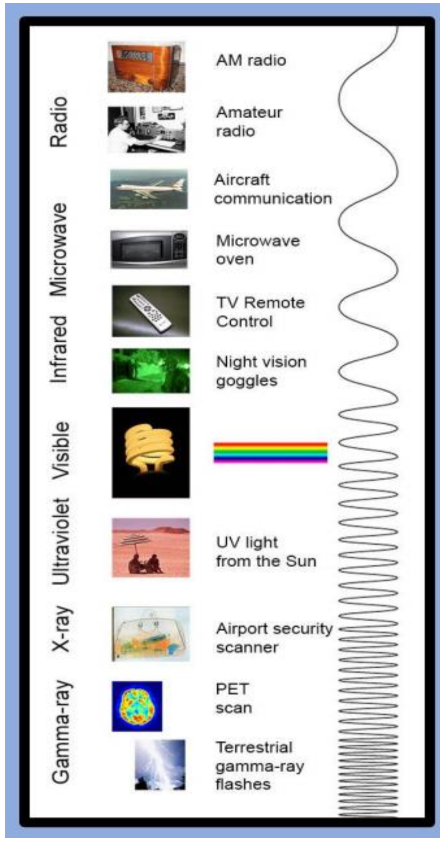
You can measure the exact wavelength and it can tell you how big the energy gap was that the e- fell from



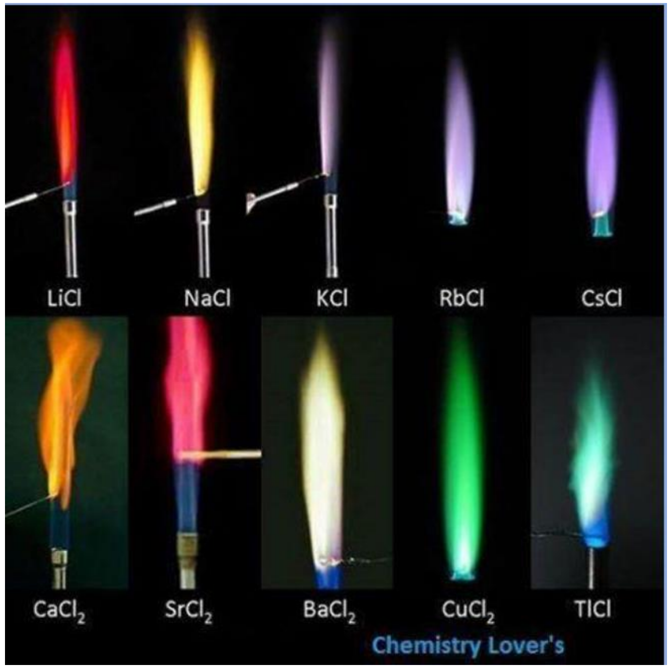
Red Orange Yellow Green Blue Purple

LOW energy

HIGH energy



We can only see this little range here

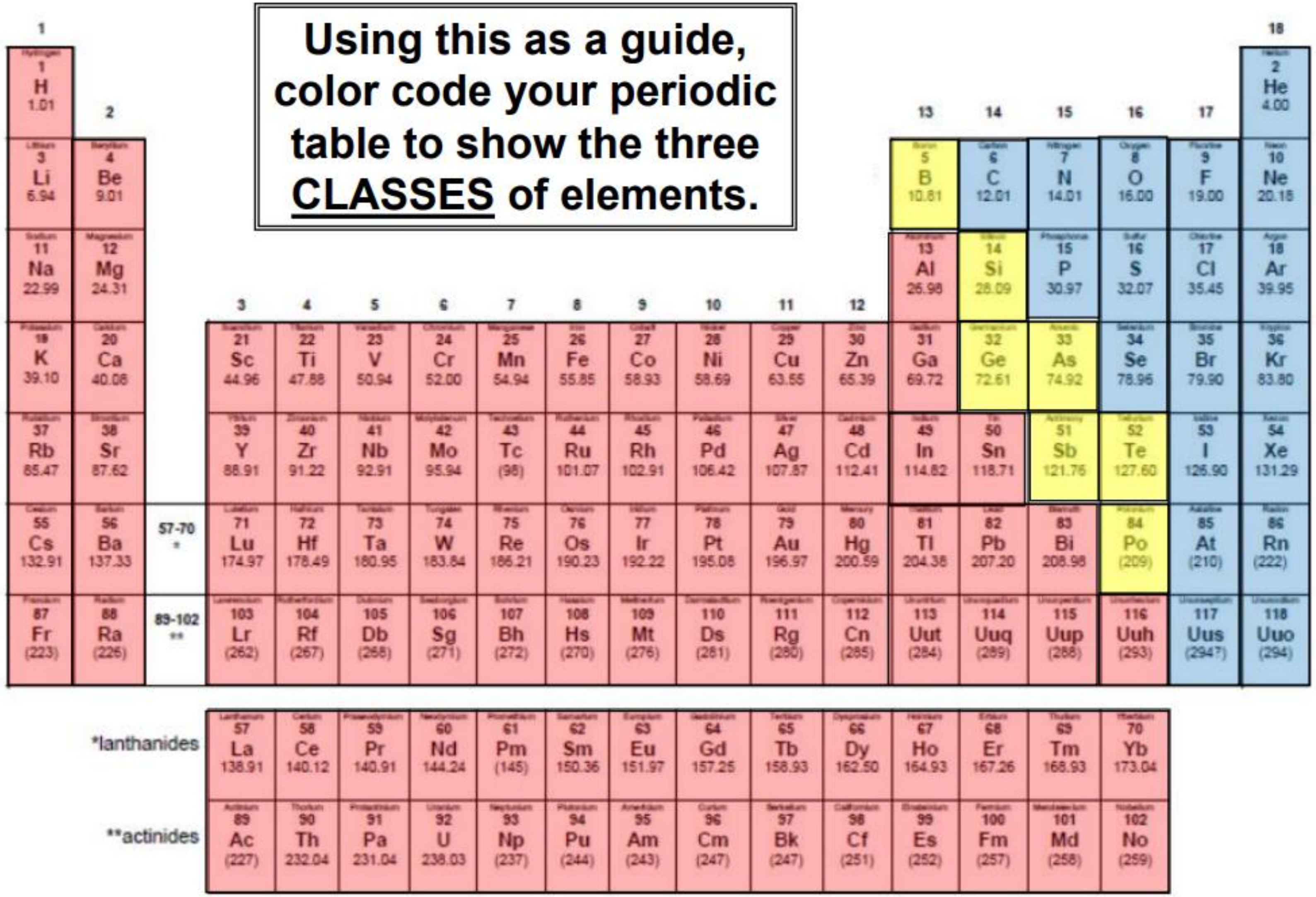


Unit #4
Periodic Table

- 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.

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																		2 He 4.00
3 Li 6.94	4 Be 9.01												5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31												13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08		21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62		39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-70 *	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-102 **	103 Lr (262)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (272)	108 Hs (270)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294?)	118 Uuo (294)

*lanthanides	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
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🟥 **Metals**

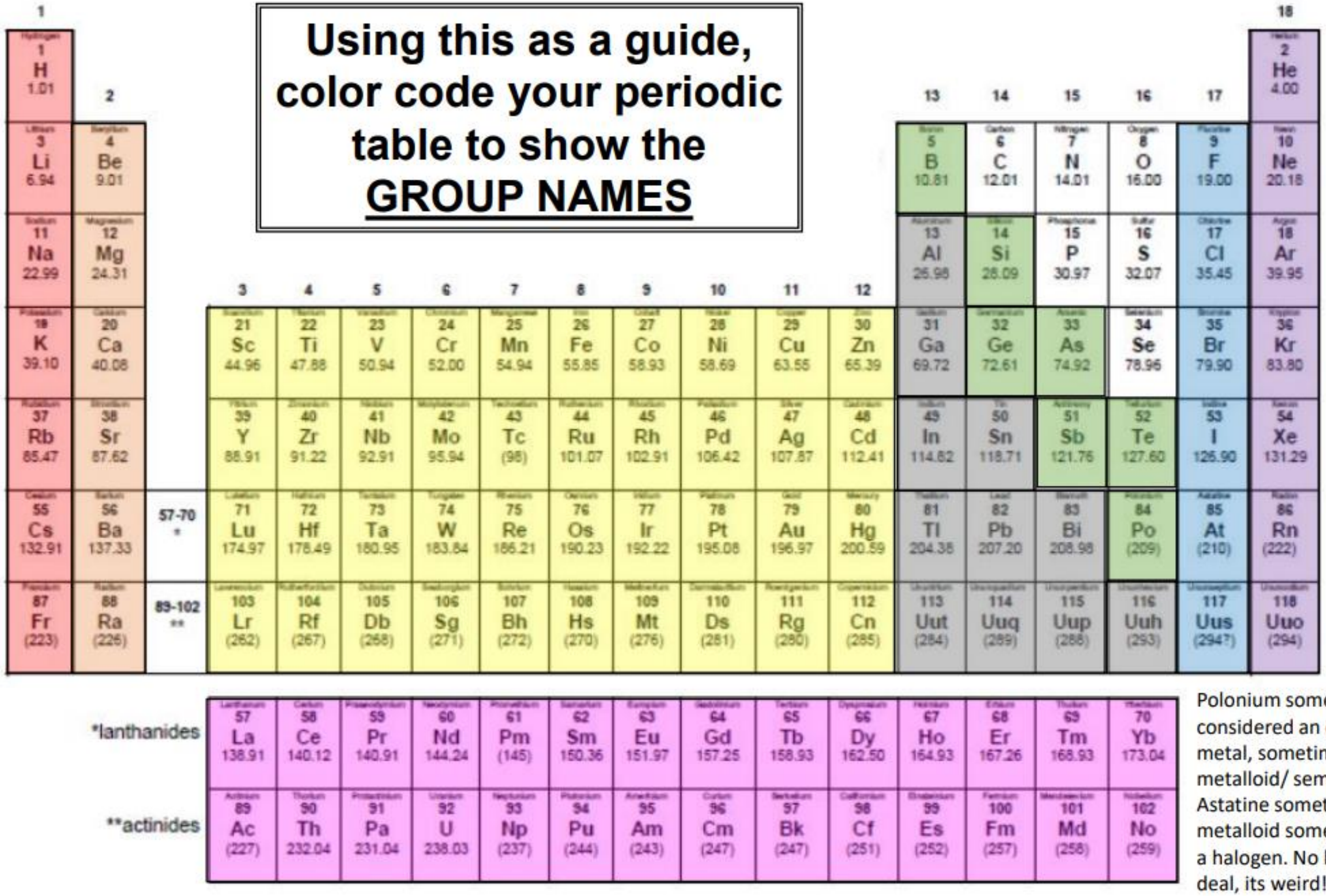
🟦 **Non-metals**

🟨 **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

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																		2 He 4.00
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		*lanthanides	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04		
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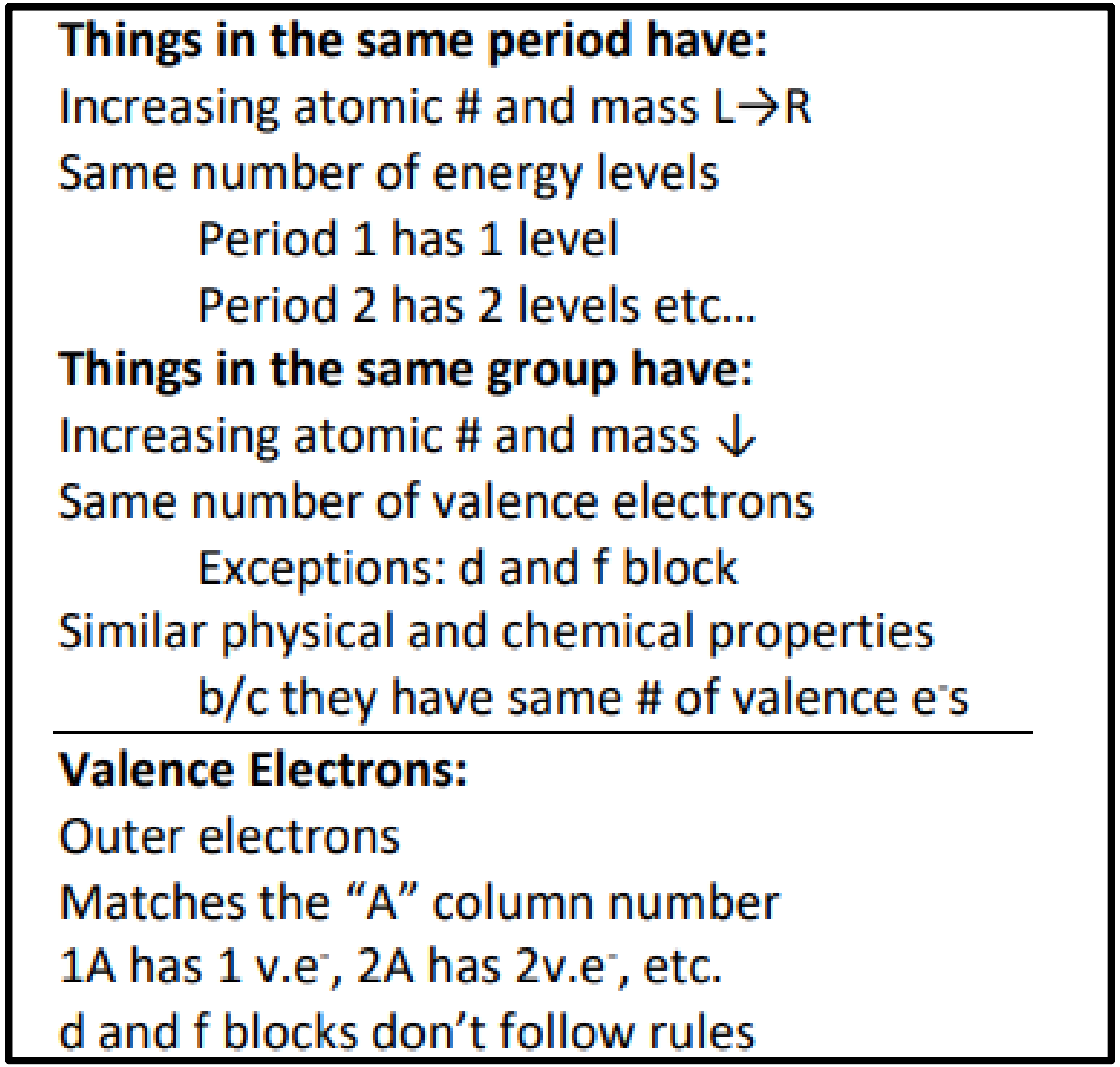
Polonium sometimes considered an other metal, sometimes a metalloid/ semimetal. Astatine sometimes a metalloid sometimes a halogen. No big deal, its weird!

- 🟥 **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

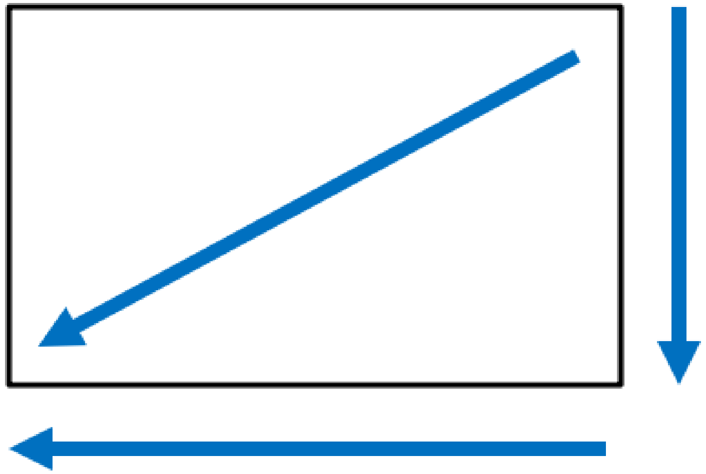
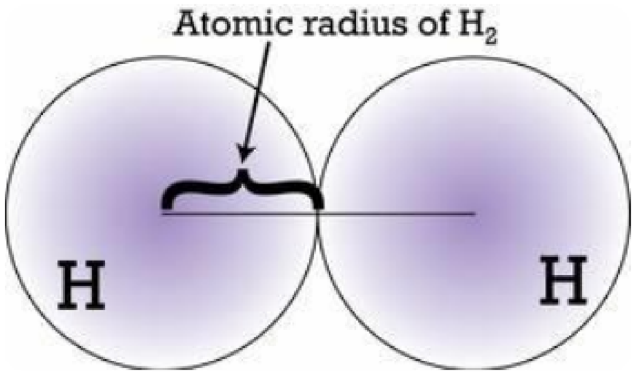
1A has 1 v.e^-, 2A has 2v.e^-, etc.

d and f blocks don't follow rules

Periodic Trends

Jump back to title slide

ATOMIC RADIUS

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

Periodic Trends

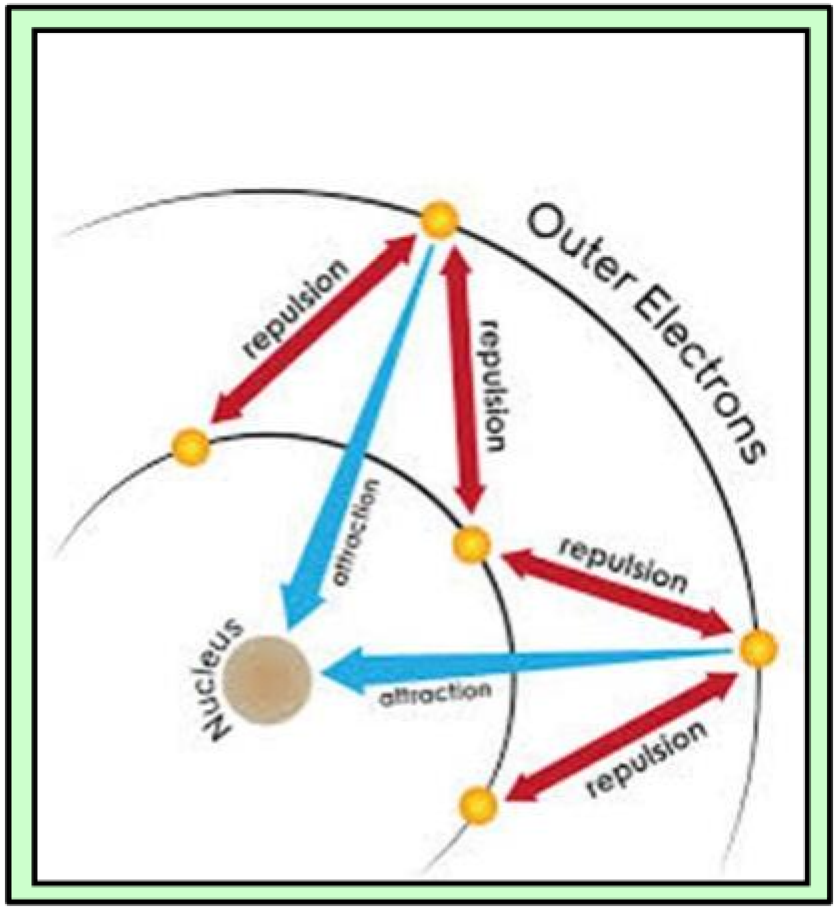
Jump back to title slide

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-.

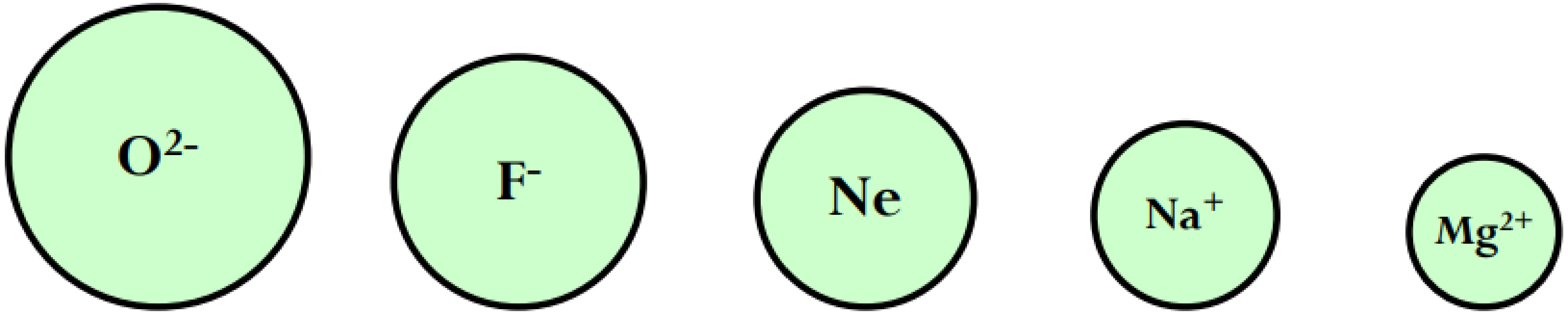


Jump back to title slide

Isoelectric Species

Atoms/Ions that have the same number of e-

All these examples are $1s^22s^22p^6$

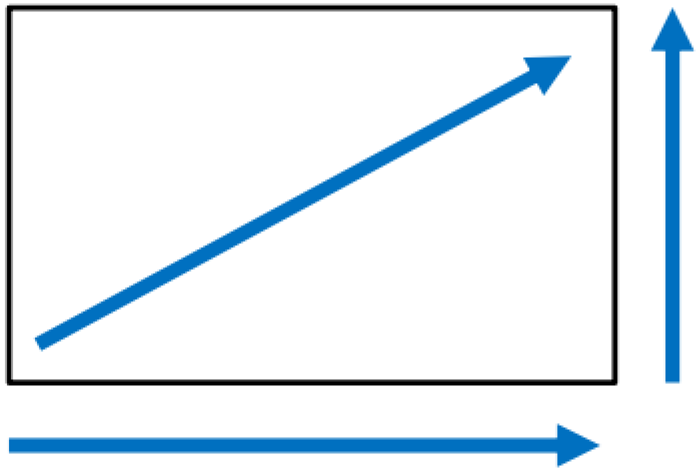


Increased protons can pull harder on the valence electrons – greater effective nuclear charge – so the radius is smaller even though they have the same number of electrons and energy levels

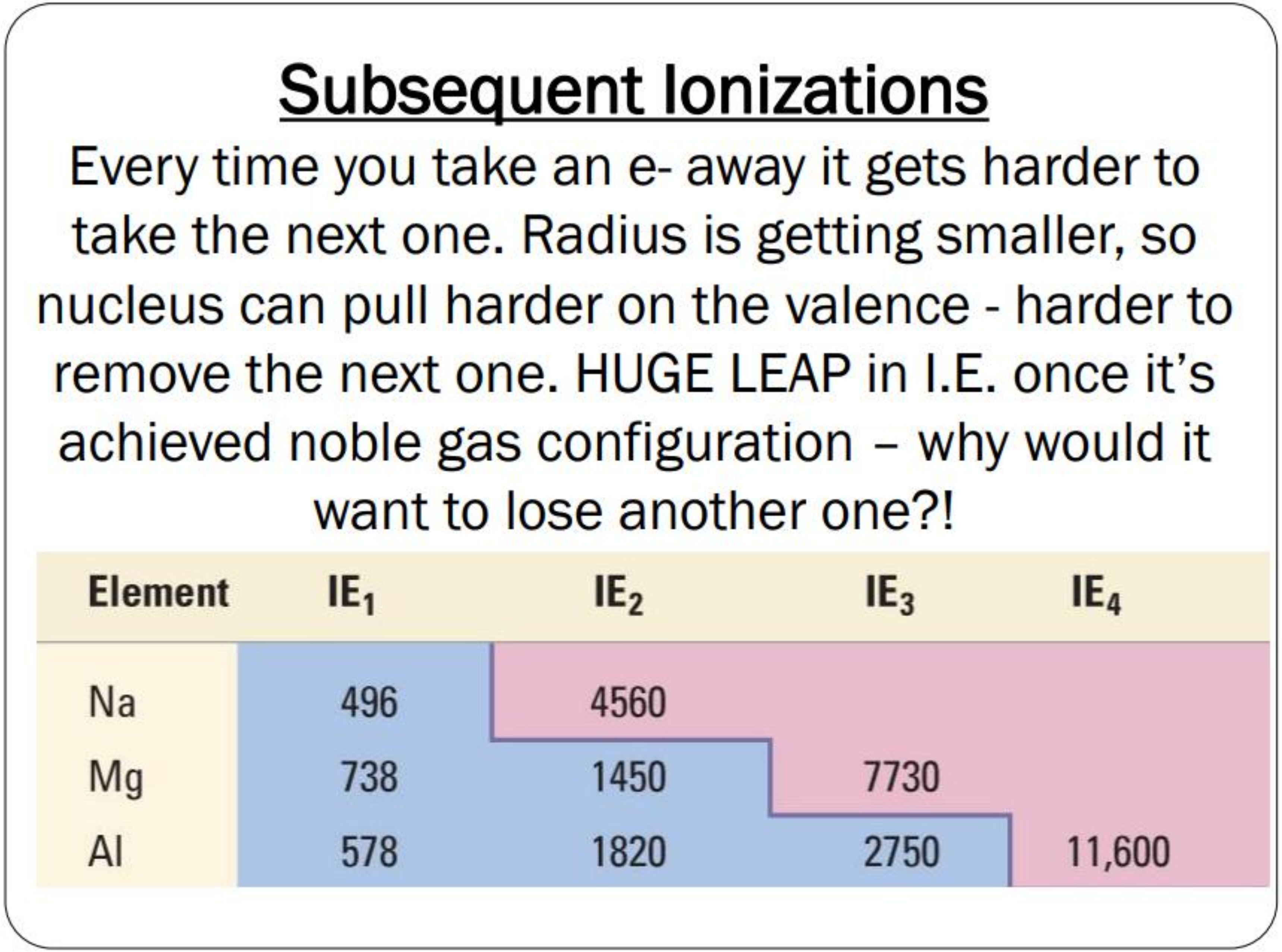
Periodic Trends

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-

Jump back to title slide



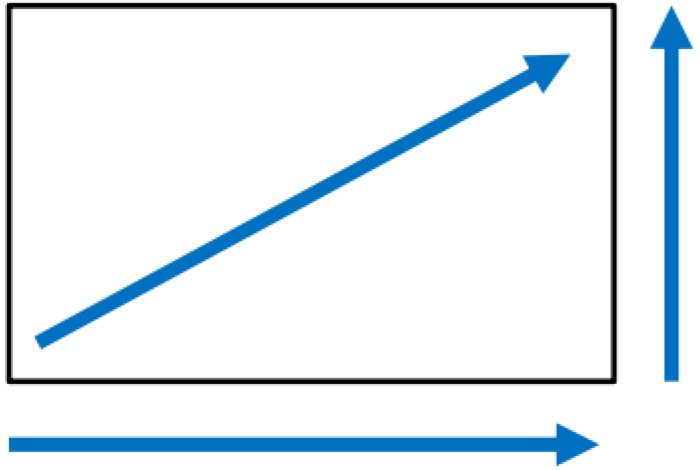
Subsequent Ionizations

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

Jump back to title slide

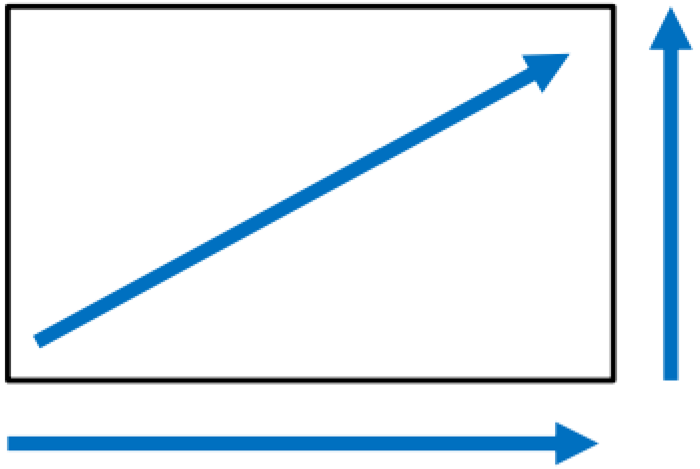
ELECTRONEGATIVITY

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 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

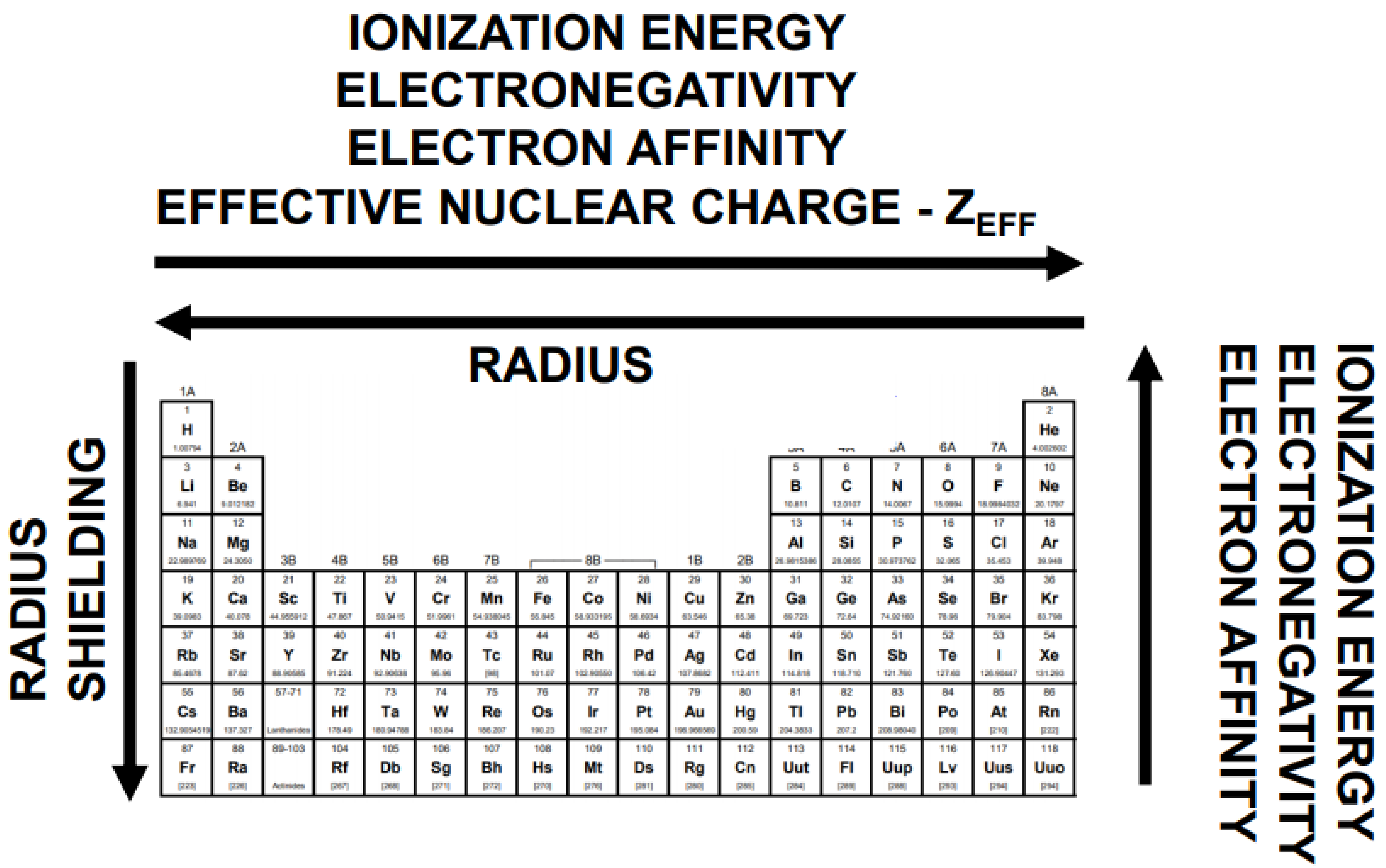
Jump back to title slide

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]



IONIZATION ENERGY
ELECTRONEGATIVITY
ELECTRON AFFINITY
EFFECTIVE NUCLEAR CHARGE - Z_{EFF}

RADIUS

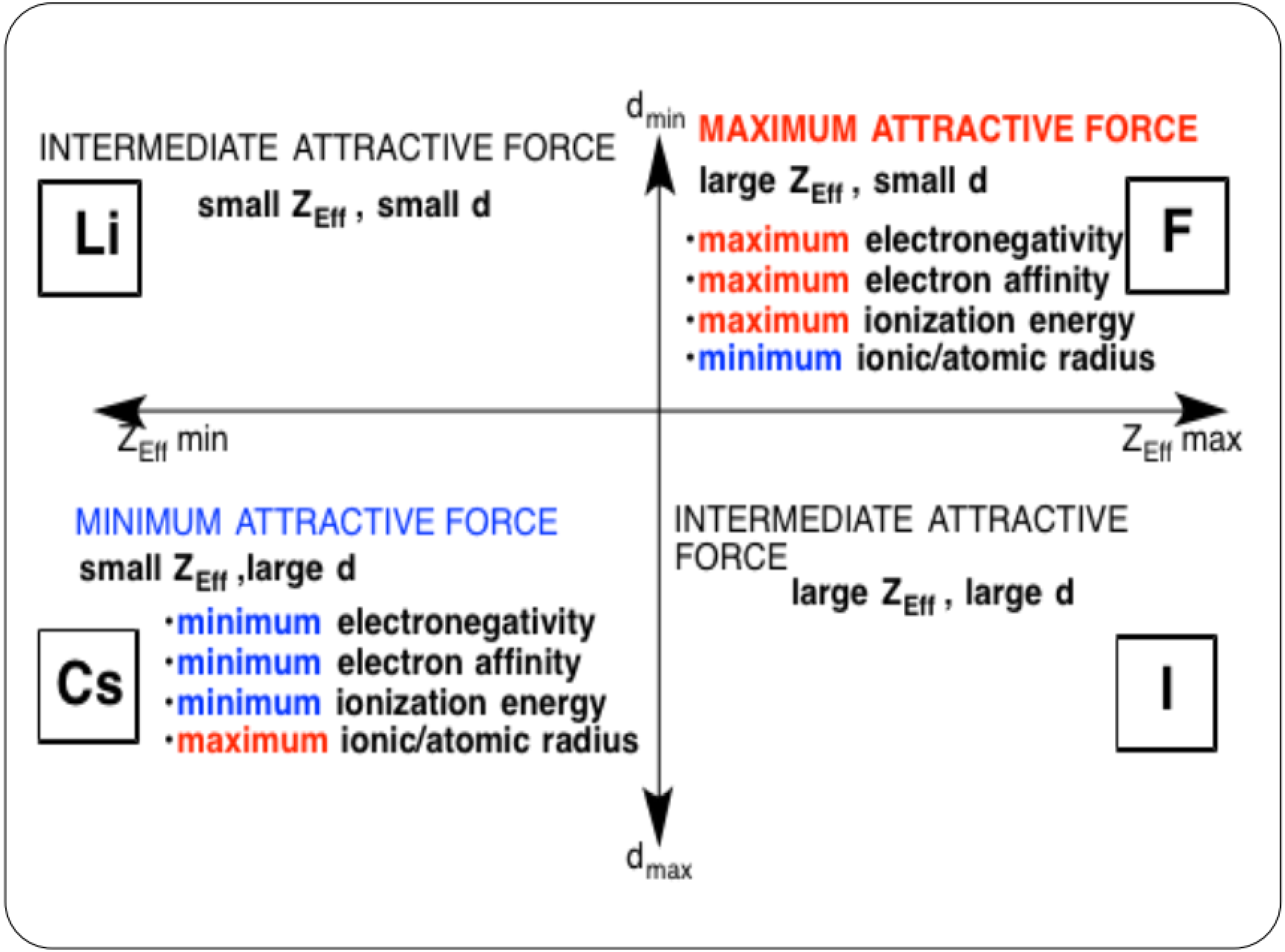
RADIUS
SHIELDING

IONIZATION ENERGY
ELECTRONEGATIVITY
ELECTRON AFFINITY

1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71 Lanthanides	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103 Actinides	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

Periodic Trends

Jump back to title slide



INTERMEDIATE ATTRACTIVE FORCE

small Z_{Eff}, small d

MAXIMUM ATTRACTIVE FORCE

large Z_{Eff}, small d

- maximum electronegativity
- maximum electron affinity
- maximum ionization energy
- minimum ionic/atomic radius

MINIMUM ATTRACTIVE FORCE

small Z_{Eff}, large d

- minimum electronegativity
- minimum electron affinity
- minimum ionization energy
- maximum ionic/atomic radius

INTERMEDIATE ATTRACTIVE FORCE

large Z_{Eff}, large d

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

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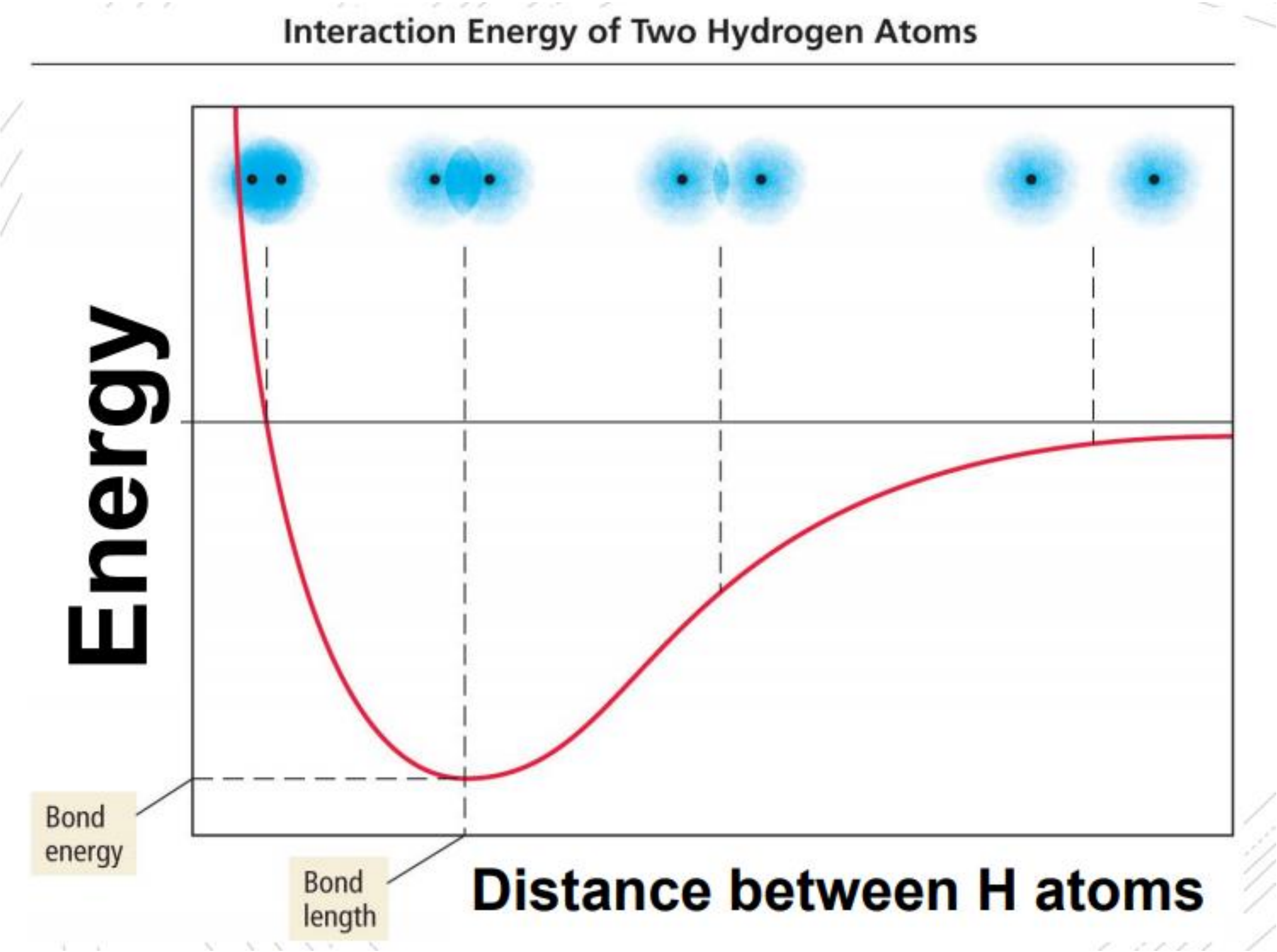
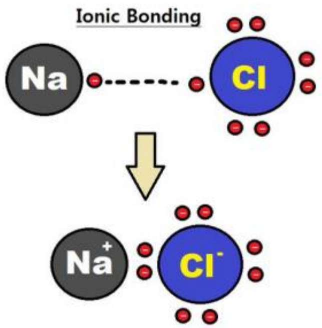


Types of Bonds

[Jump back to title slide]

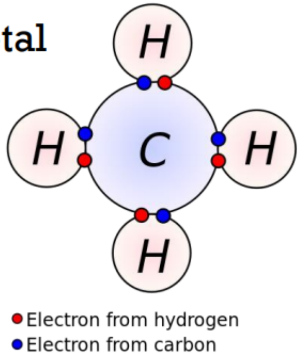
Ionic Bonds

- 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-}



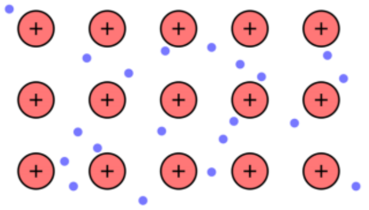
Covalent Bonds

- 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

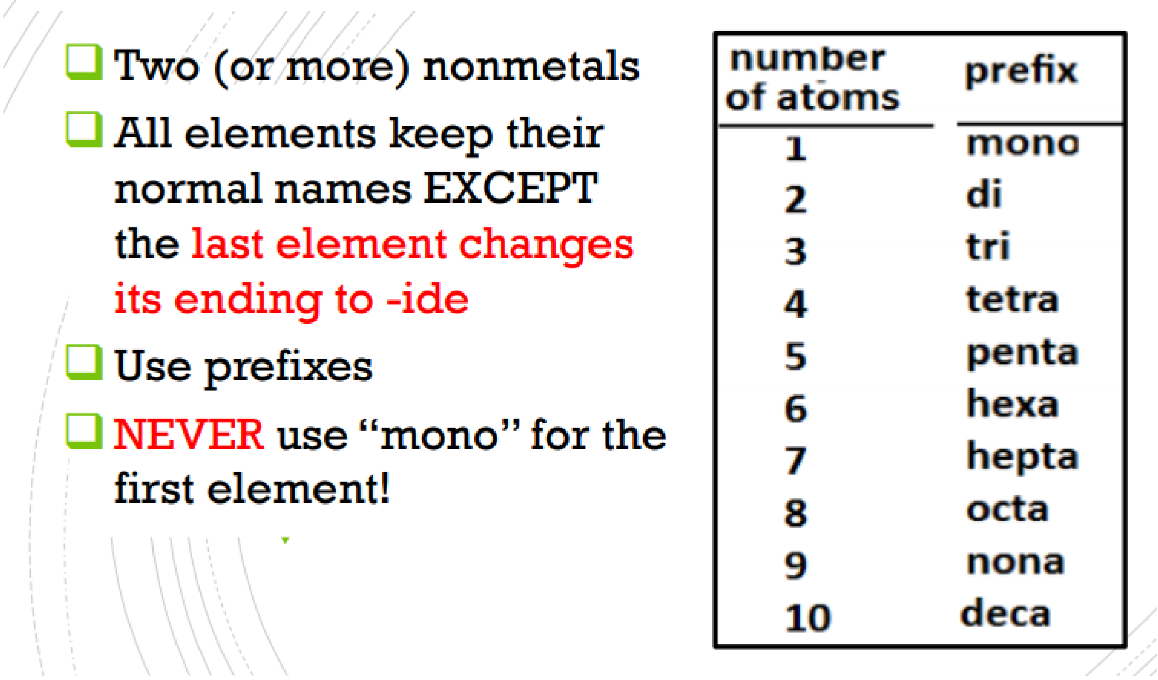
Metals with variable charges

- 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.

- **Diatomic elements** – some elements come as a pair and not by themselves

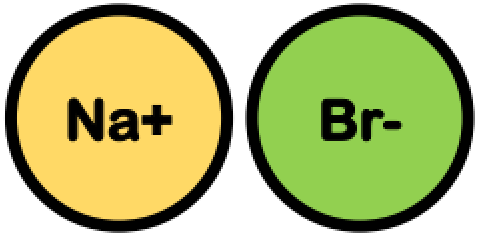
H_2, N_2, O_2,
F_2, Cl_2, Br_2, I_2

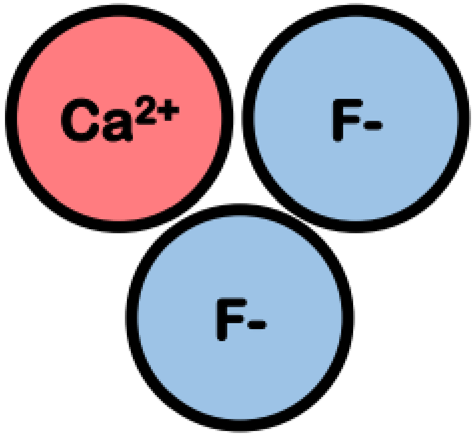
Horses Need
Oats For Clear
Brown “Eyes”

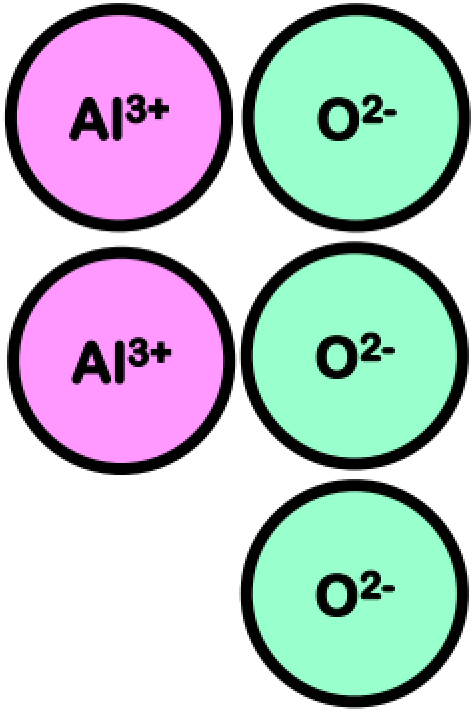
Jump back to title slide

Neutral Compounds

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

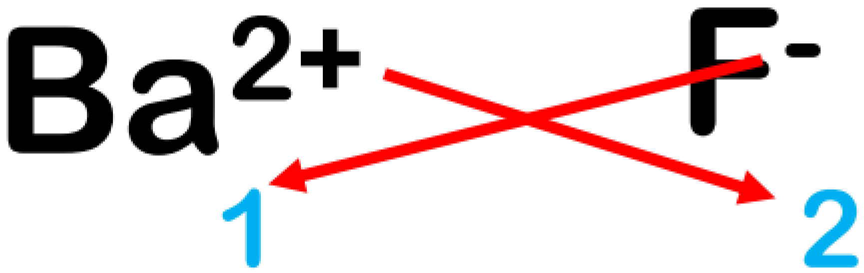






Jump back to title slide

Barium Fluoride



Ba^{2+} F^{-}

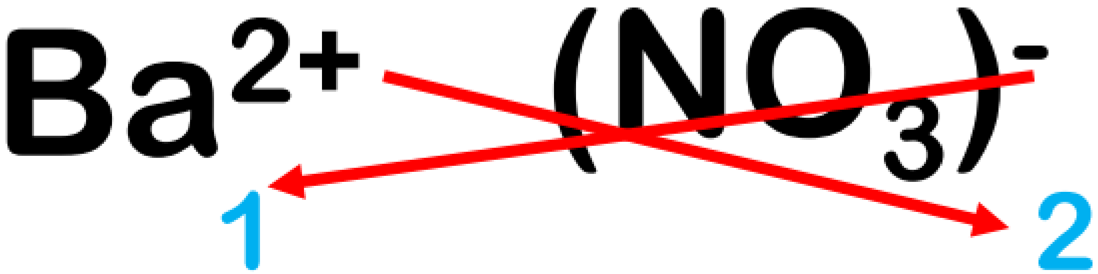
1 2

BaF_2

Neutral Formulas

[Jump back to title slide]

Barium Nitrate



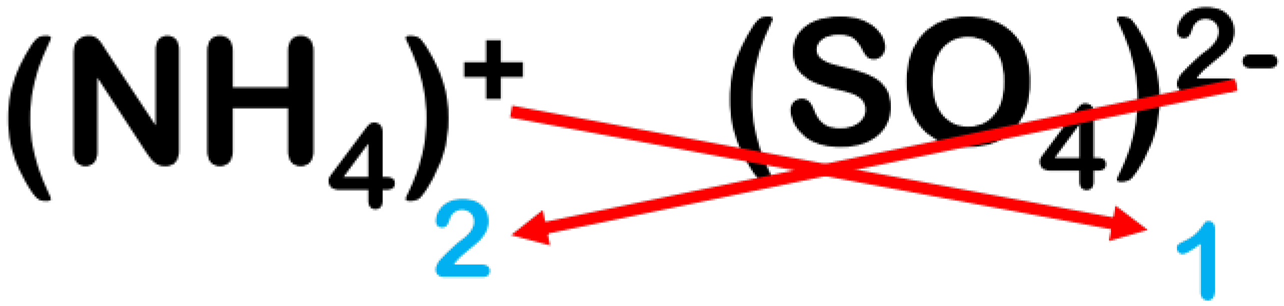
Ba^{2+} $(NO_3)^-$

$Ba(NO_3)_2$

Naming formulas

Jump back to title slide

Ammonium Sulfate



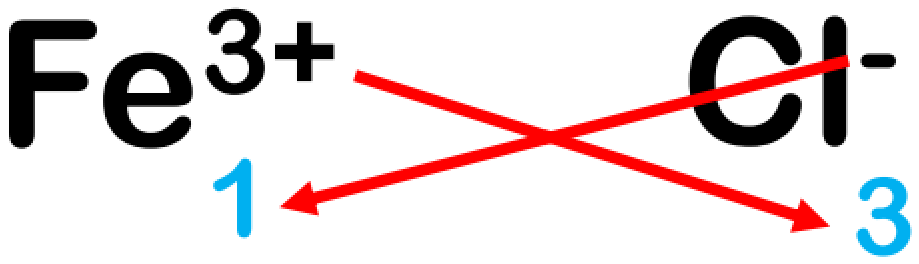
$(NH_4)^{+}$ $(SO_4)^{2-}$

$(NH_4)_2(SO_4)$

Neutral Formulas

Jump back to title slide

Iron(III) Chloride



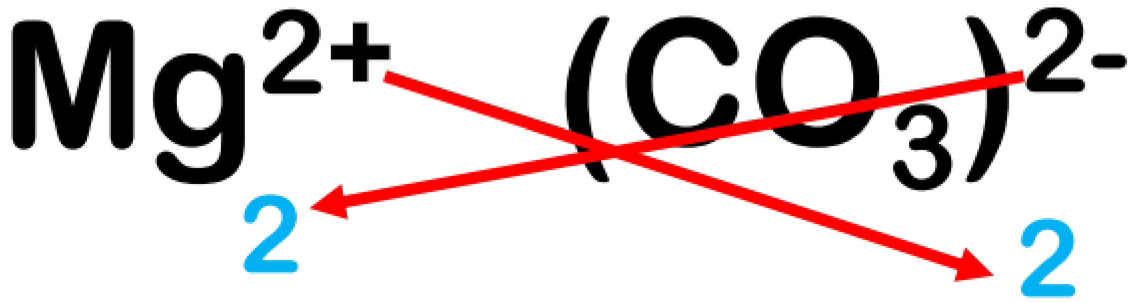
Fe^{3+} Cl^{-}

1 3

$FeCl_3$

Jump back to title slide

Magnesium Carbonate



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

2 2

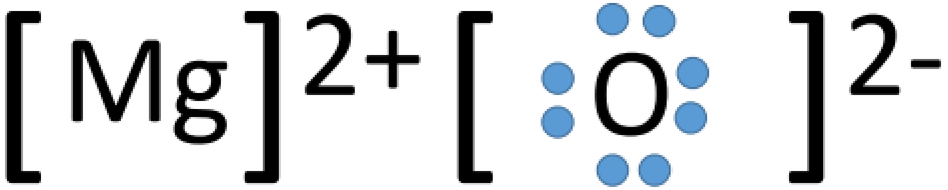
$Mg_{\cancel{2}}(CO_3)_{\cancel{2}}$

Lewis Structures

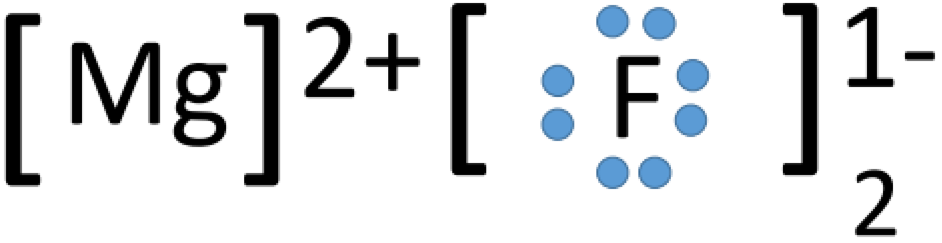
Jump back to title slide

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**

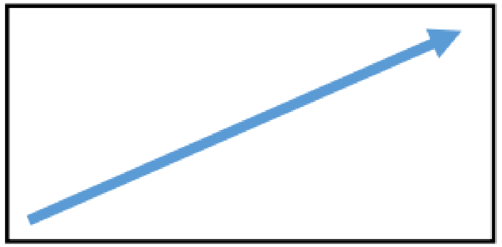
Jump back to title slide

PLACEMENT "RULES"

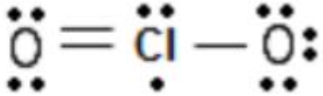
1) **Hydrogen *always* goes on the outside of the molecule**
- it is a "dead end"
- it "terminates" the molecule
- it "caps off" the molecule
- Because it can only make 1 bond

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

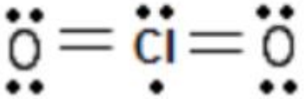
2) **The *least* electronegative atom goes in the inside/center**
- except for hydrogen!



3) **Symmetry is good!**
- When possible!



Fine but not great



Better! Symmetrical!

VSEPR

Jump back to title slide

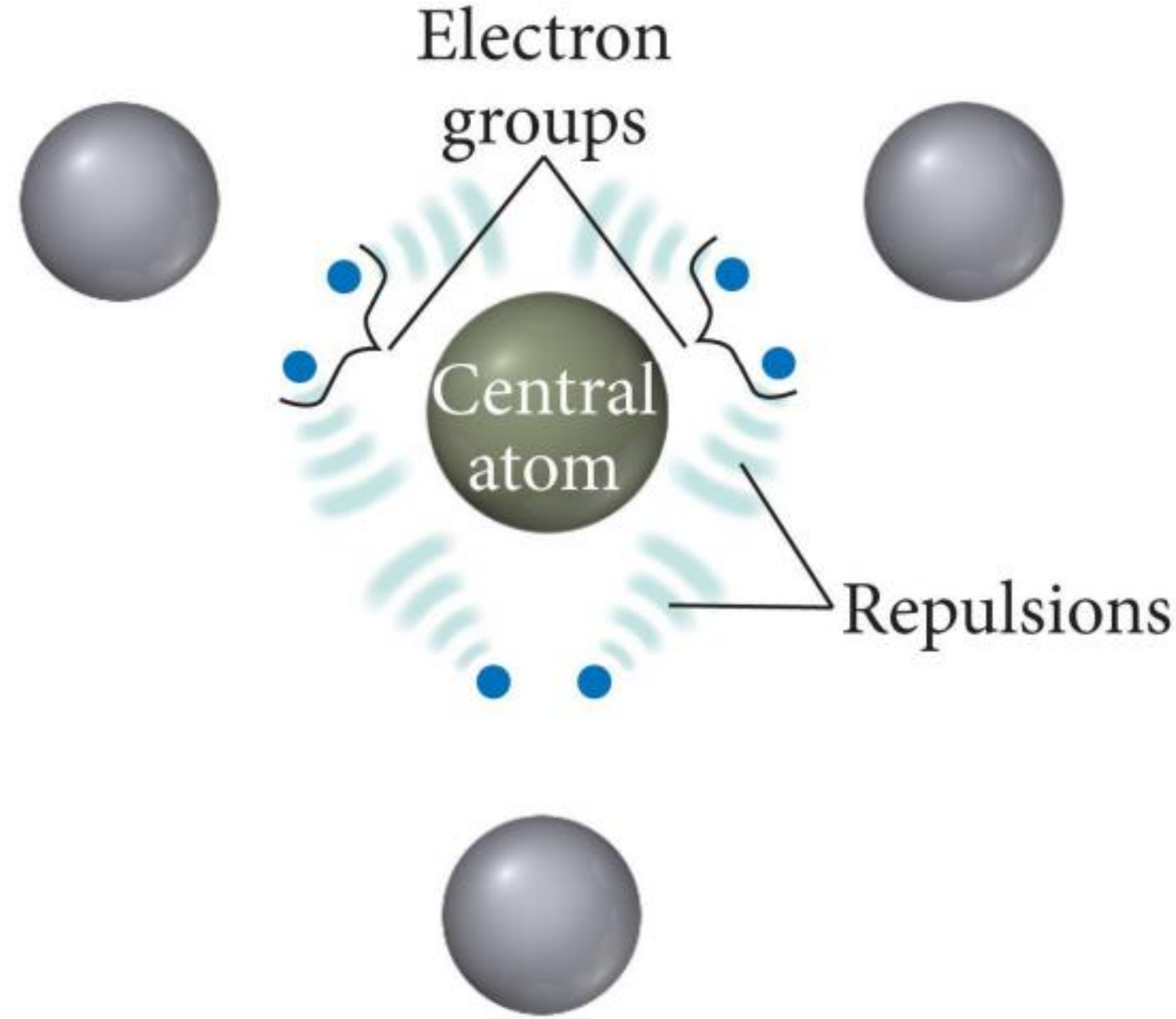
VSEPR Model

(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

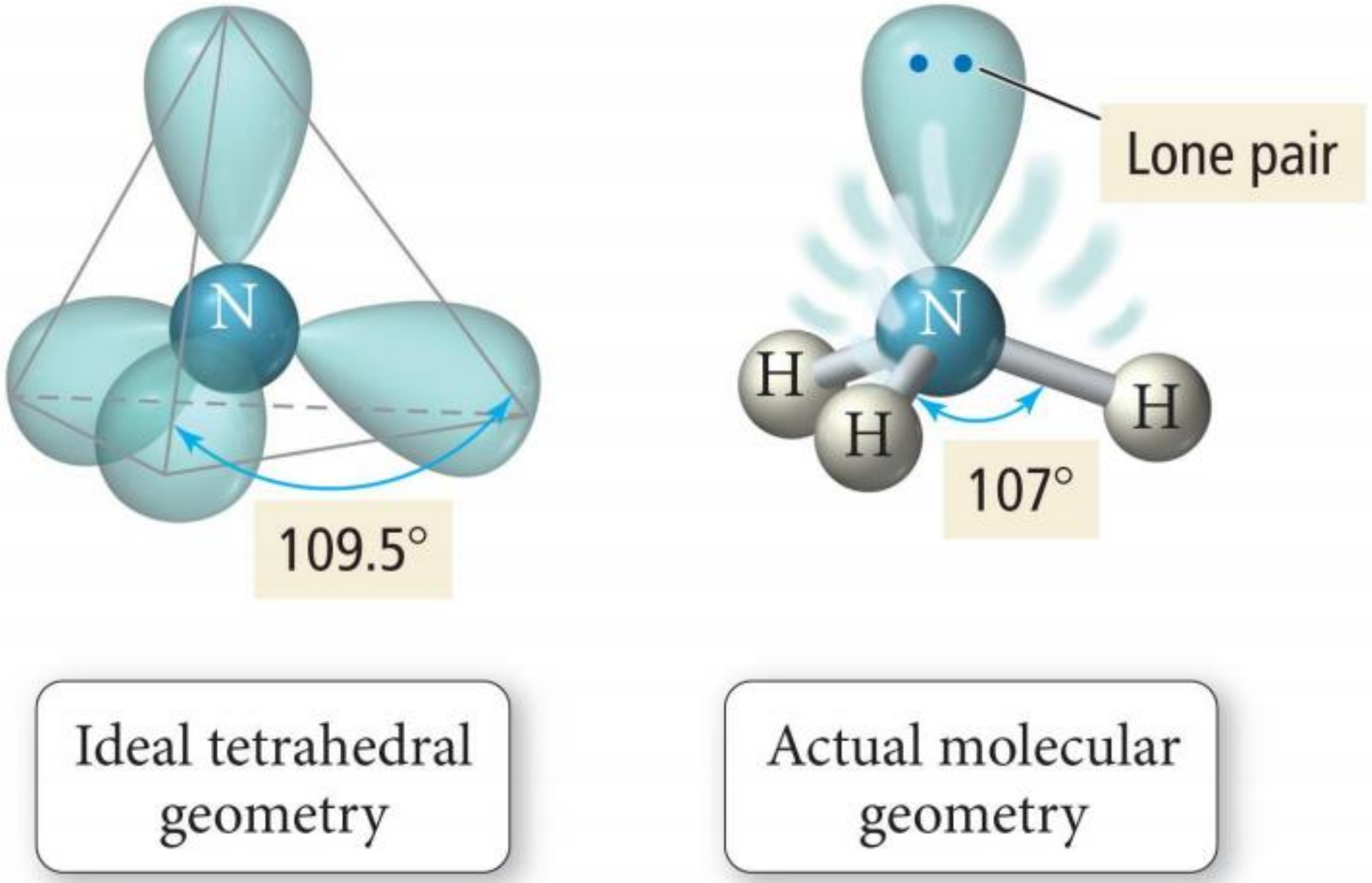
Jump back to title slide



VSEPR

Jump back to title slide

Bond Angle Distortion from Lone Pairs



VSEPR

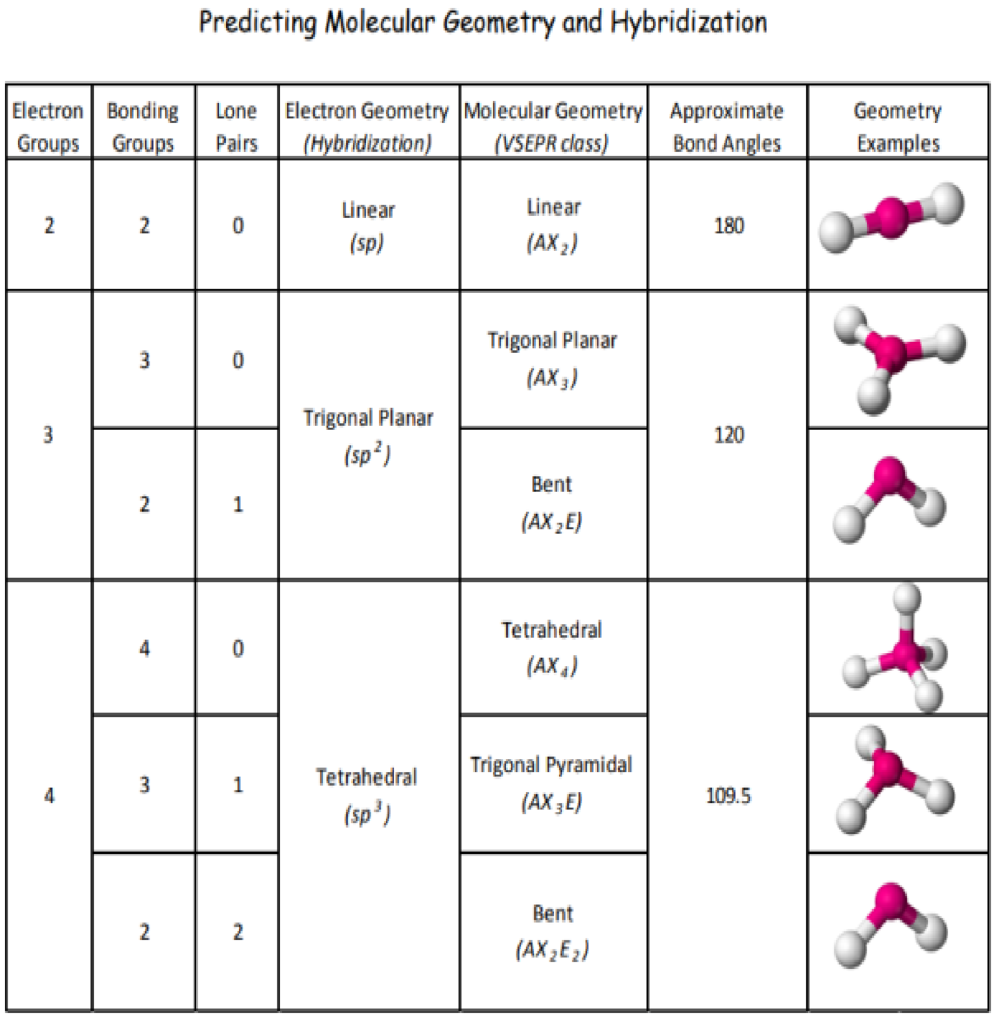
Jump back to title slide

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.

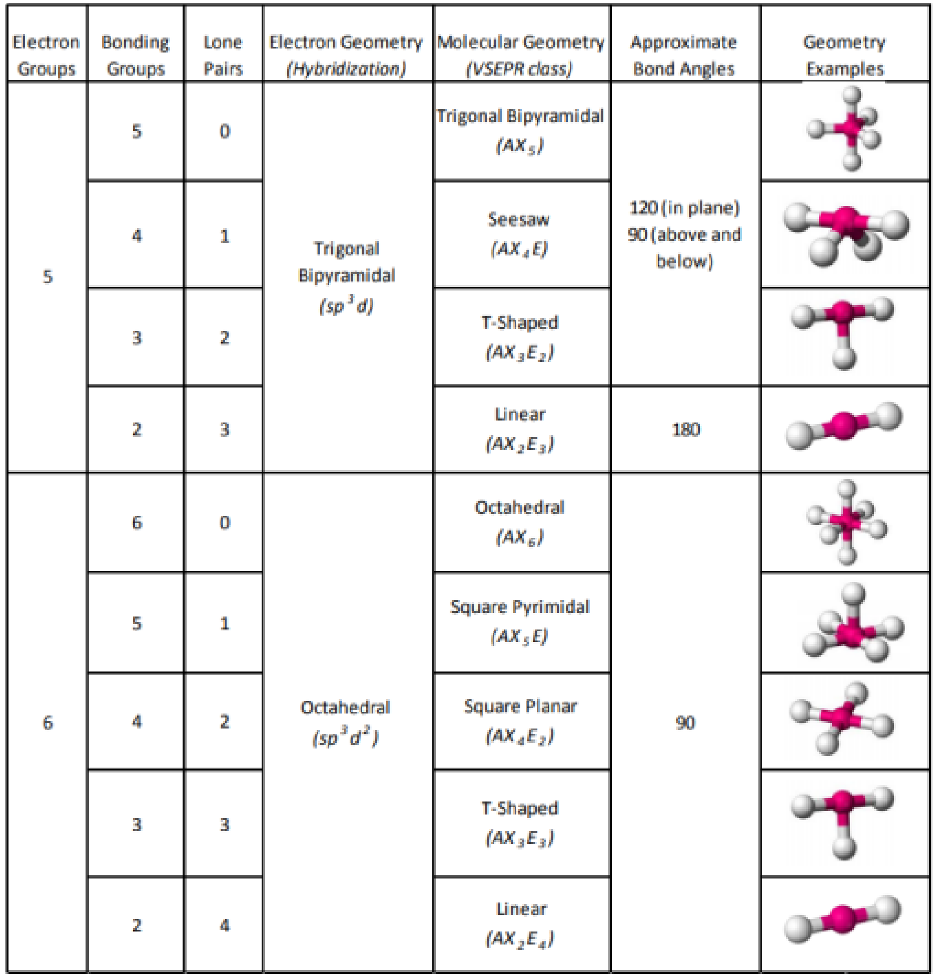
VSEPR

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)		

Hybridization

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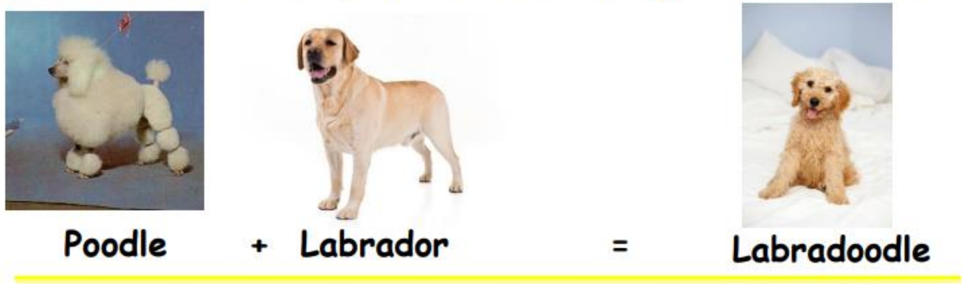
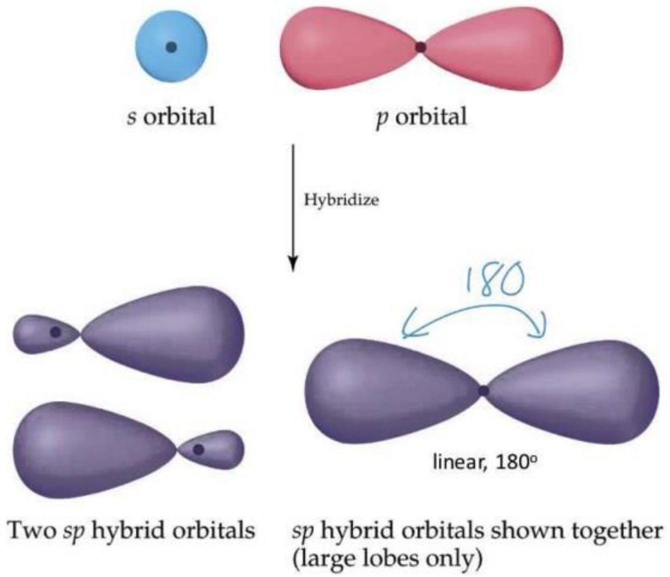
Hybridization - The Blending of Orbitals



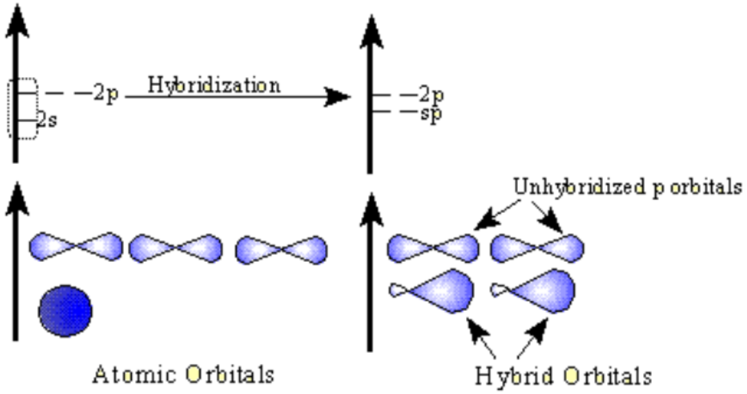
Hybridization is the combining of two or more orbitals of nearly equal energy within the same atom into orbitals of equal energy.

sp Hybridization



sp Hybrid Orbitals

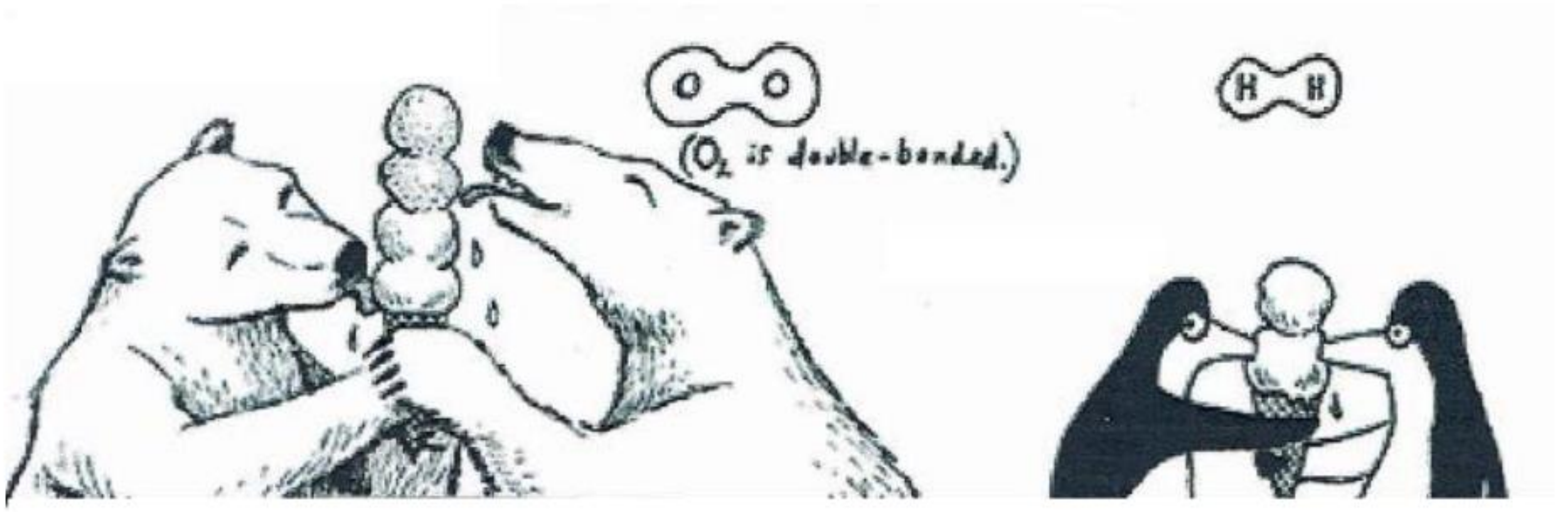
One s orbital combines with one p orbital
Two p orbitals are left the same



Jump back to title slide

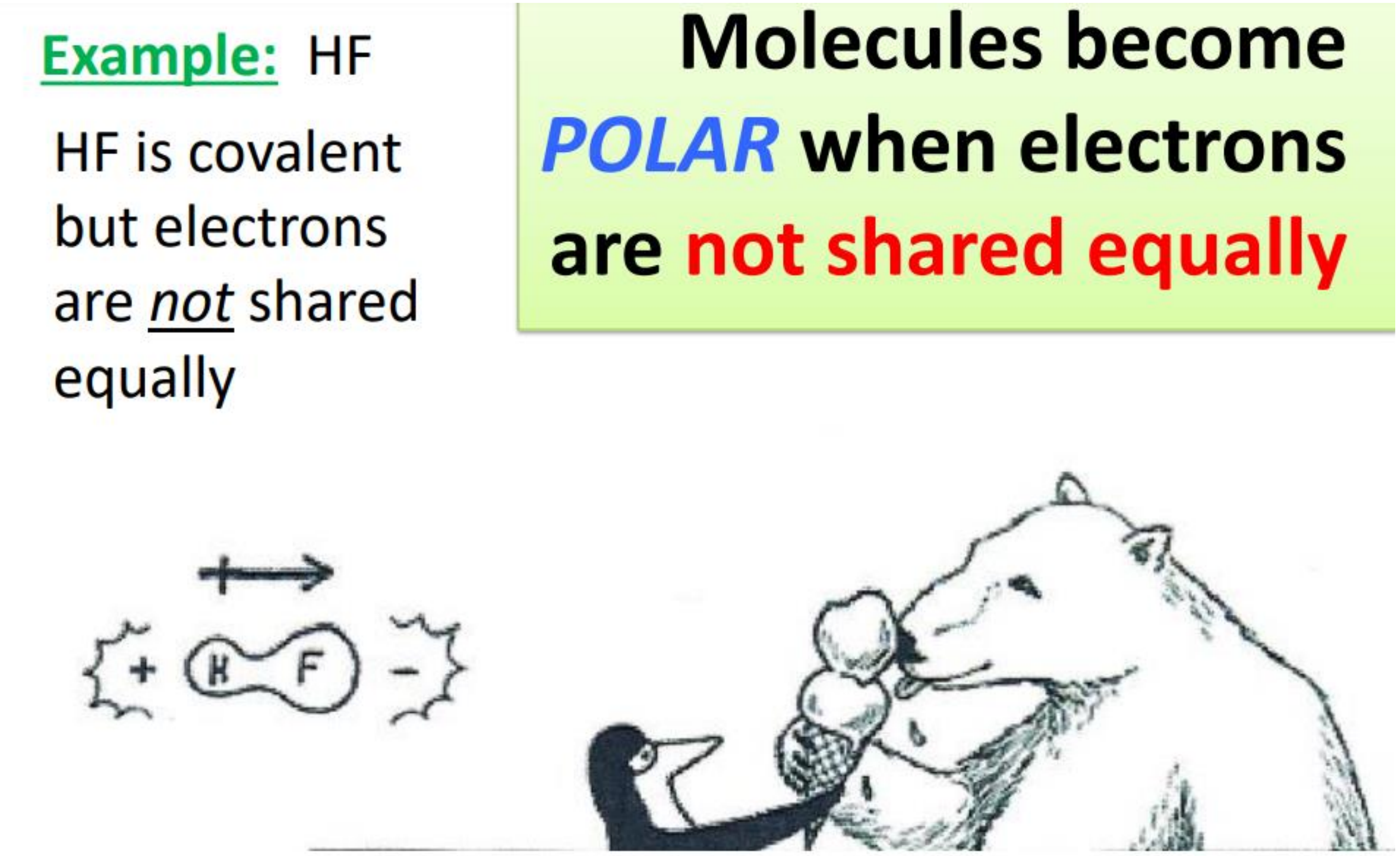
What’s happening inside covalent molecules like O_2 or H_2?

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

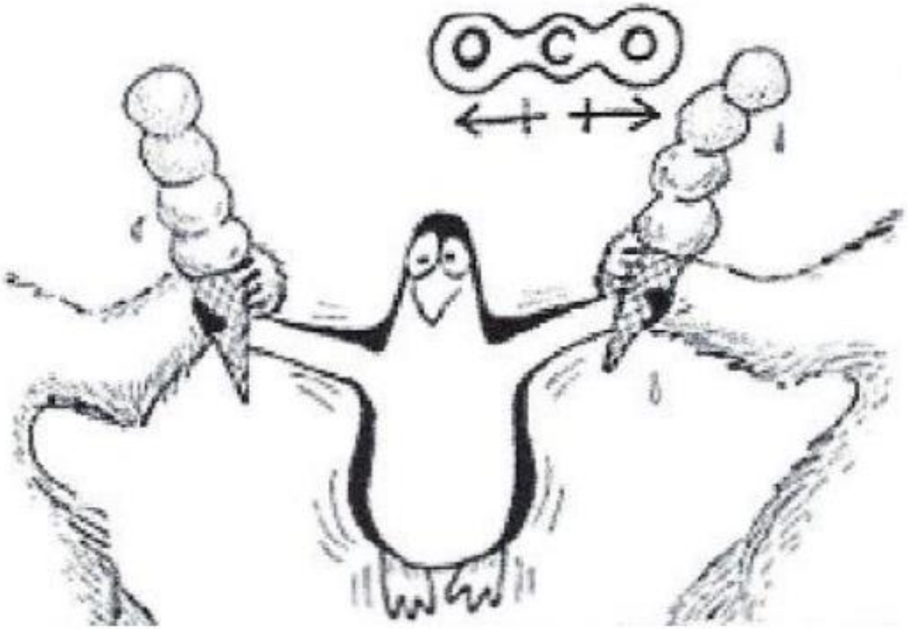
Polarity

[Jump back to title slide]

Symmetry…the pole destroyer!

CO_2

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



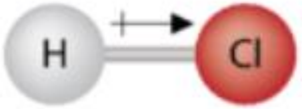
Electron density is still SYMETRICAL which makes it non-polar

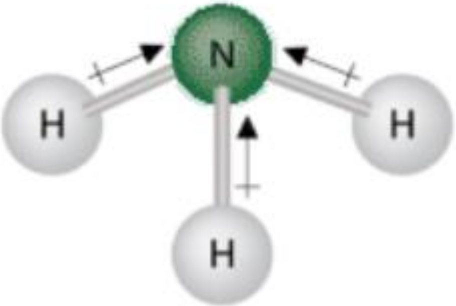
Polarity

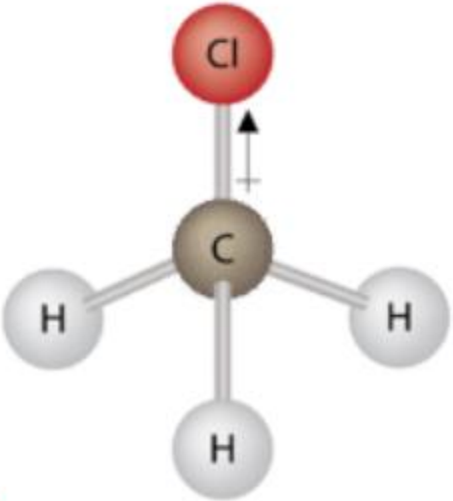
[Jump back to title slide]

Careful about polar BOND versus polar MOLECULE

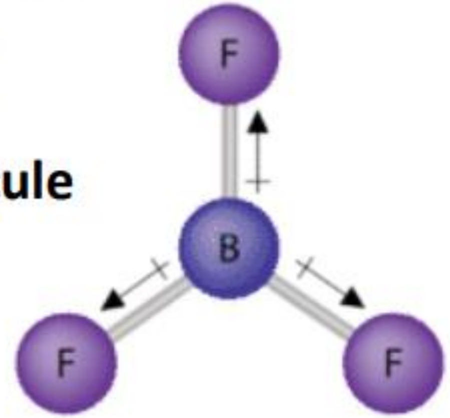
Polar bond AND Polar molecule

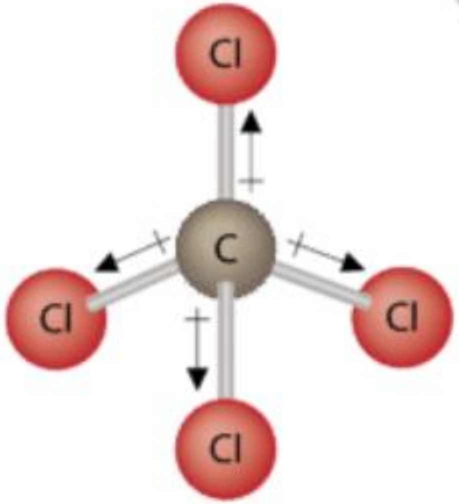






Polar bond AND NON-polar molecule

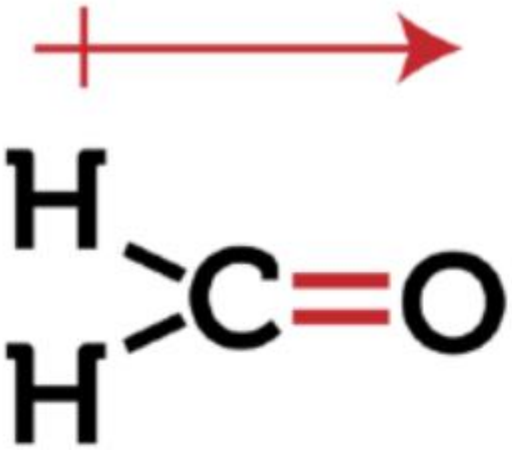


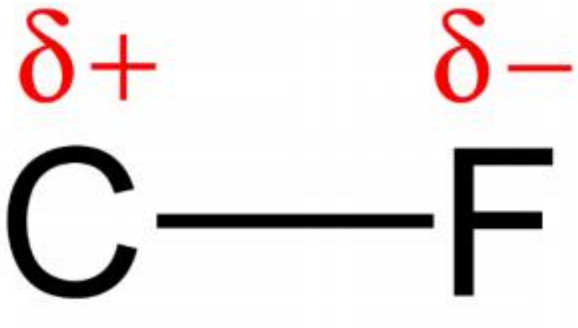


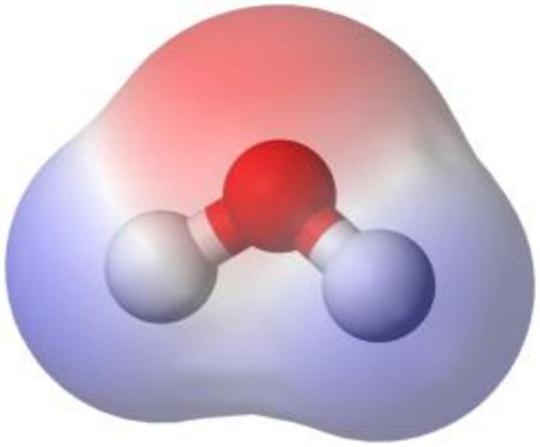
Polarity

Jump back to title slide

Three ways to diagram “dipoles”







IMFs

Jump back to title slide

Vocabulary

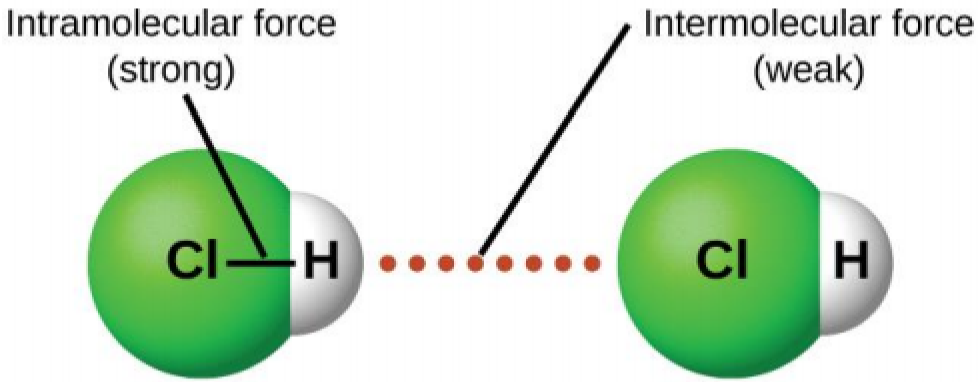
INTRAmolecular Forces

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**



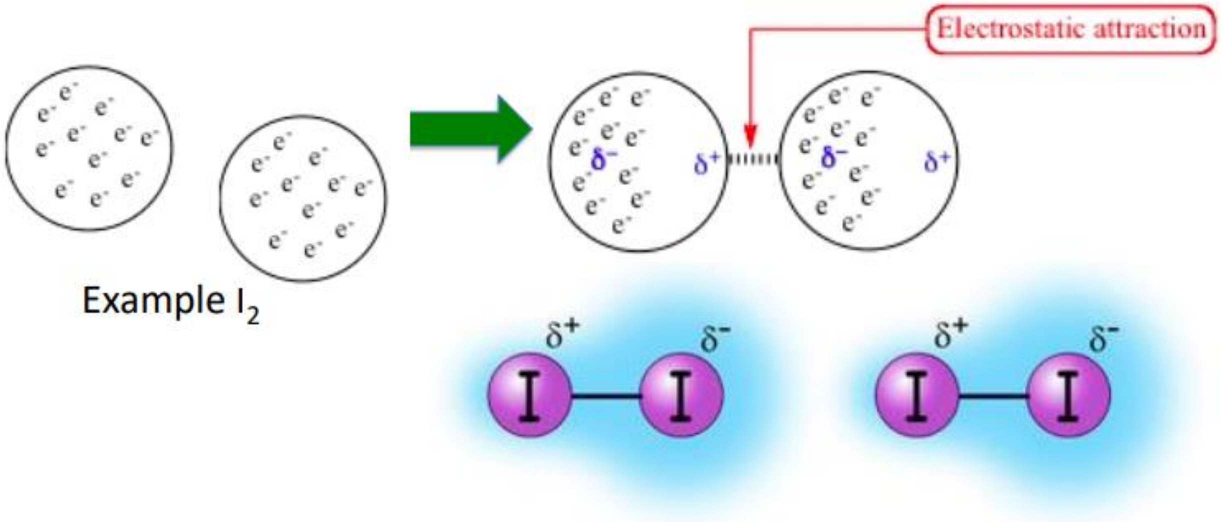
IMFs

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…

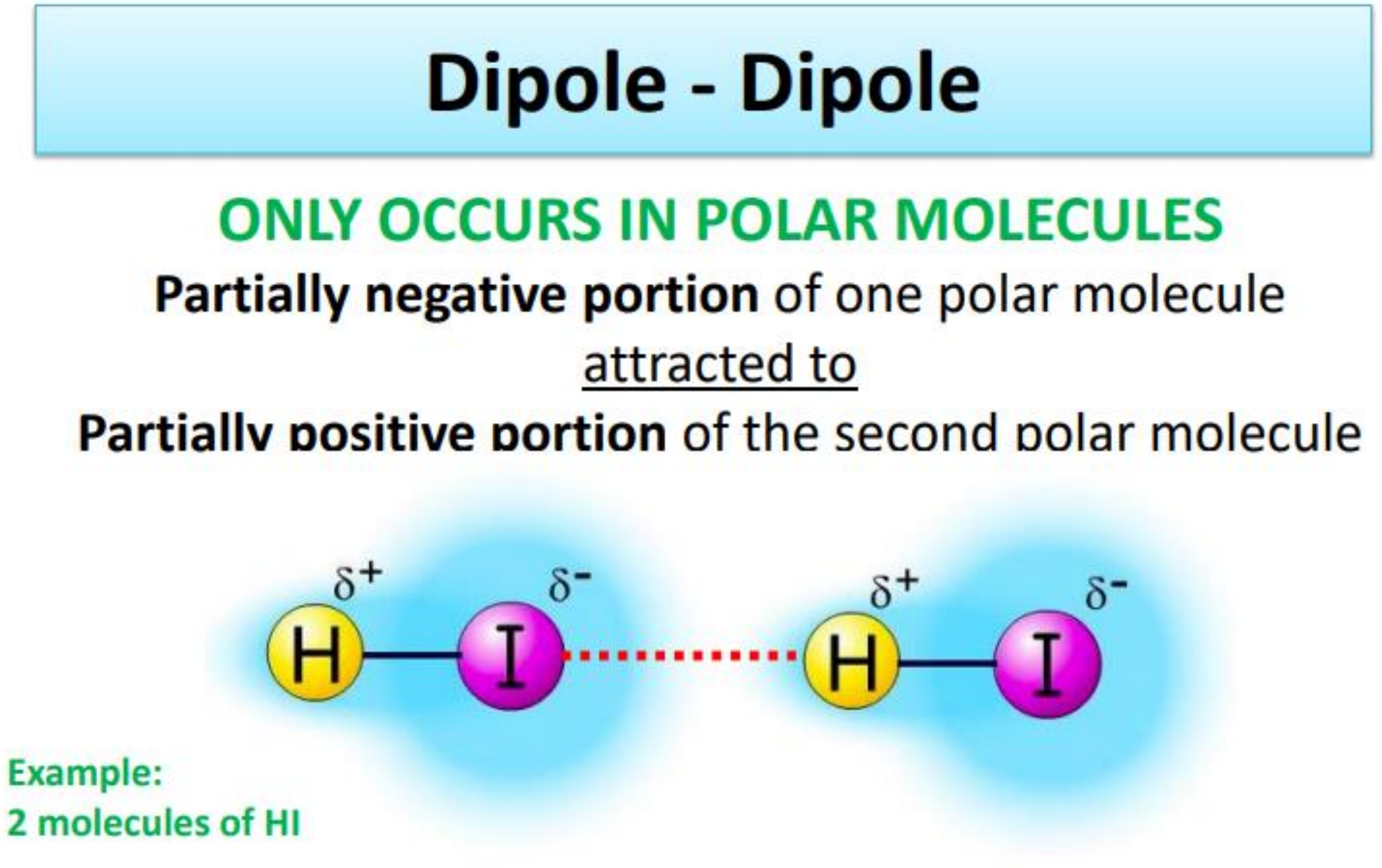
EVERYTHING HAS LONDON DISPERSION FORCES BECAUSE EVERYTHING HAS ELECTRONS!

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

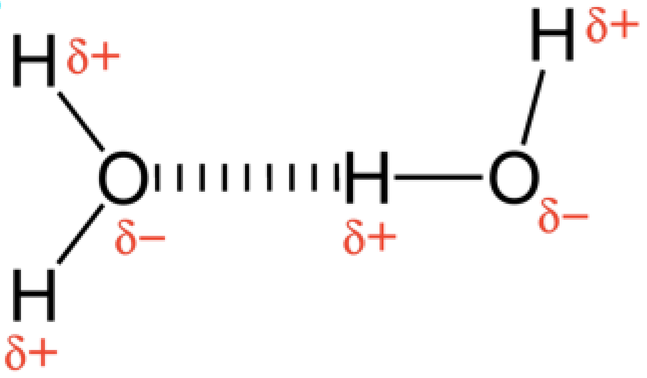
Jump back to title slide

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

<table>
<tr><td>Boiling point
Melting point
Viscosity
Surface tension</td><td colspan="2">When you increase IMFs
Properties increase too!
More forces=higher props</td></tr>
<tr><td rowspan="2">Miscibility (Mixing)</td><td colspan="2">“Like dissolves like”</td></tr>
<tr><td>Polar with polar</td><td>Non-polar with non-polar</td></tr>
</table>

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

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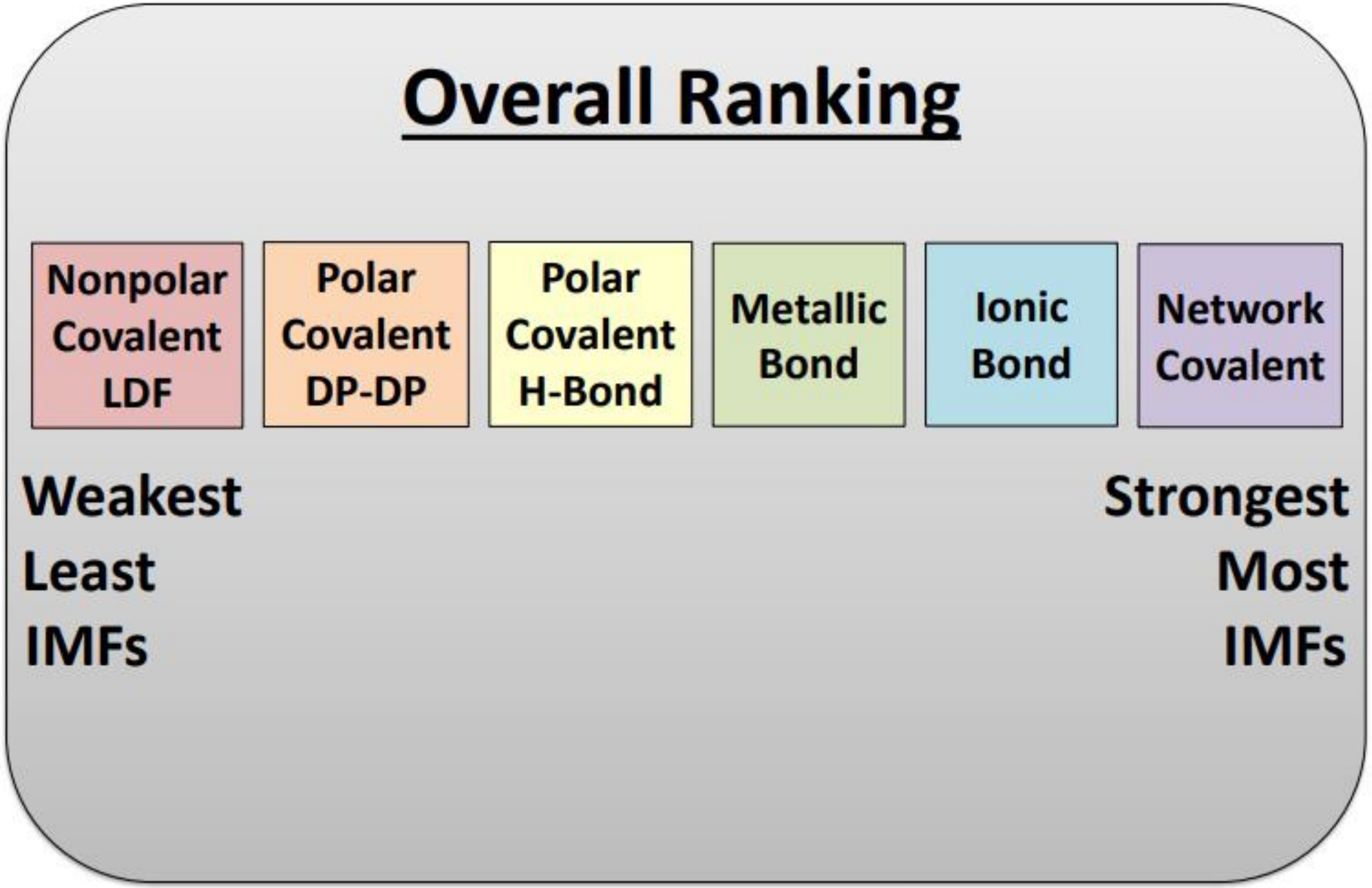

Overall Ranking

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

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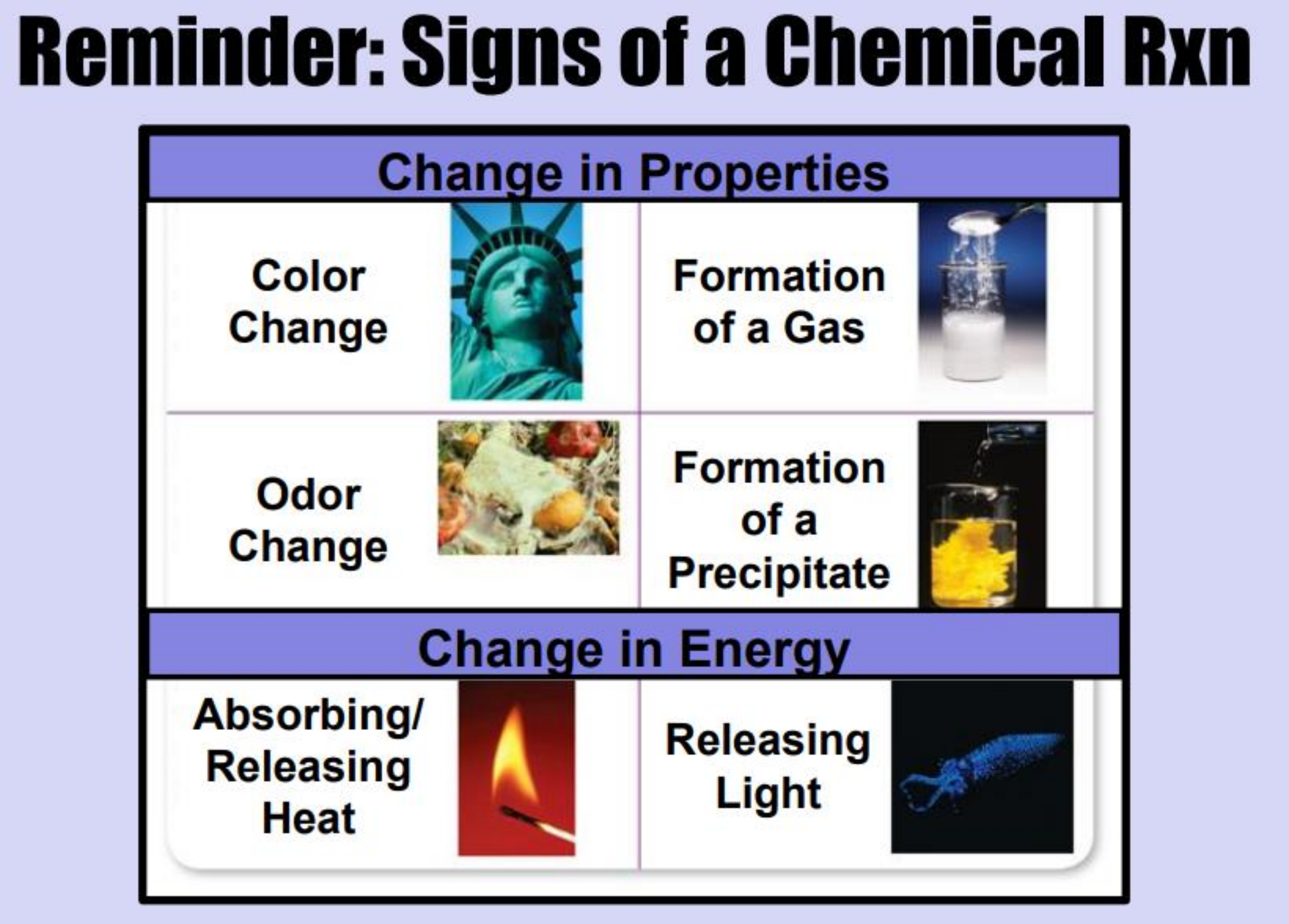


Reminder: Signs of a Chemical Rxn

Change in Properties

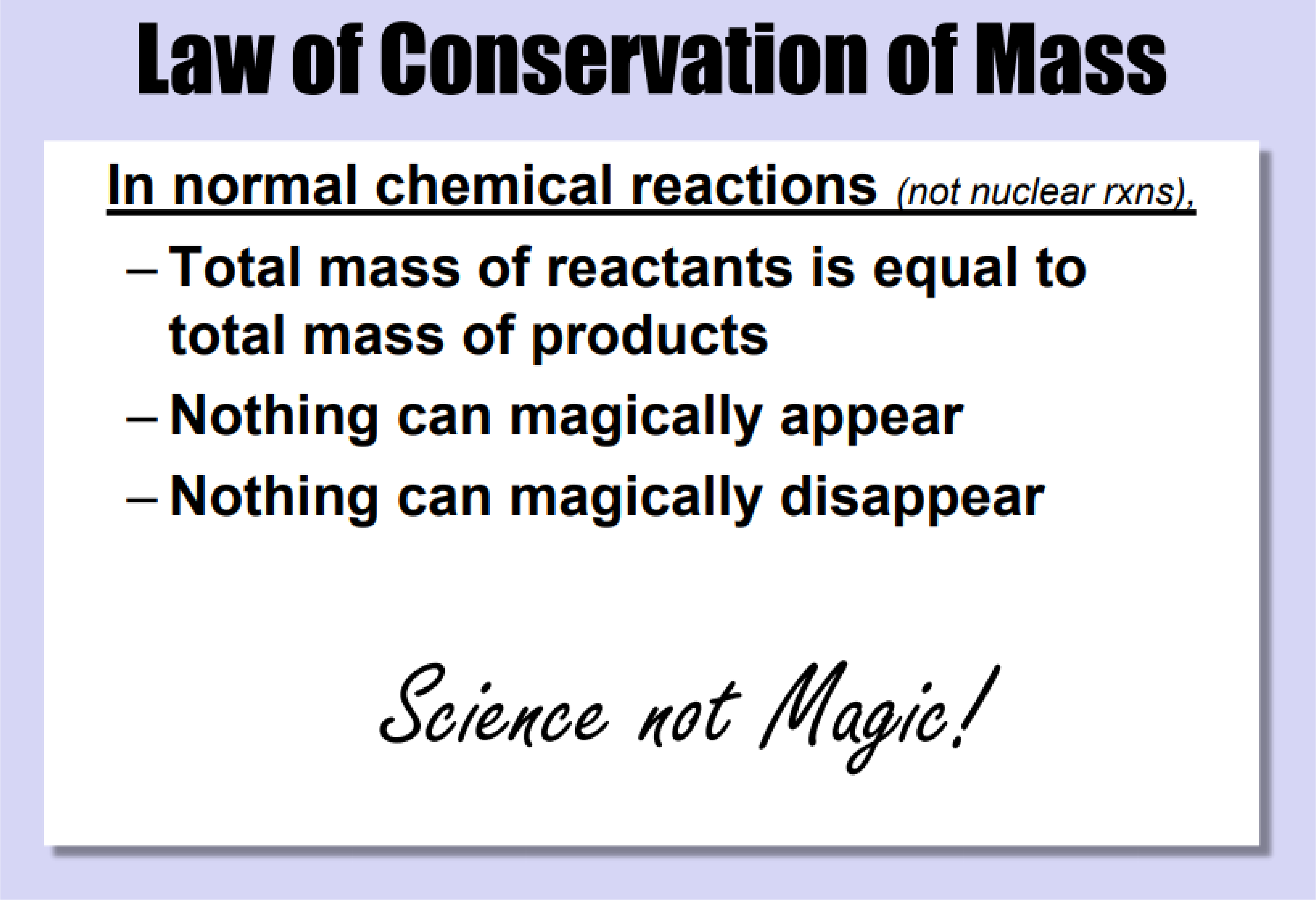
Color Change	Formation of a Gas
Odor Change	Formation of a Precipitate

Change in Energy

Absorbing/ Releasing Heat	Releasing Light

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

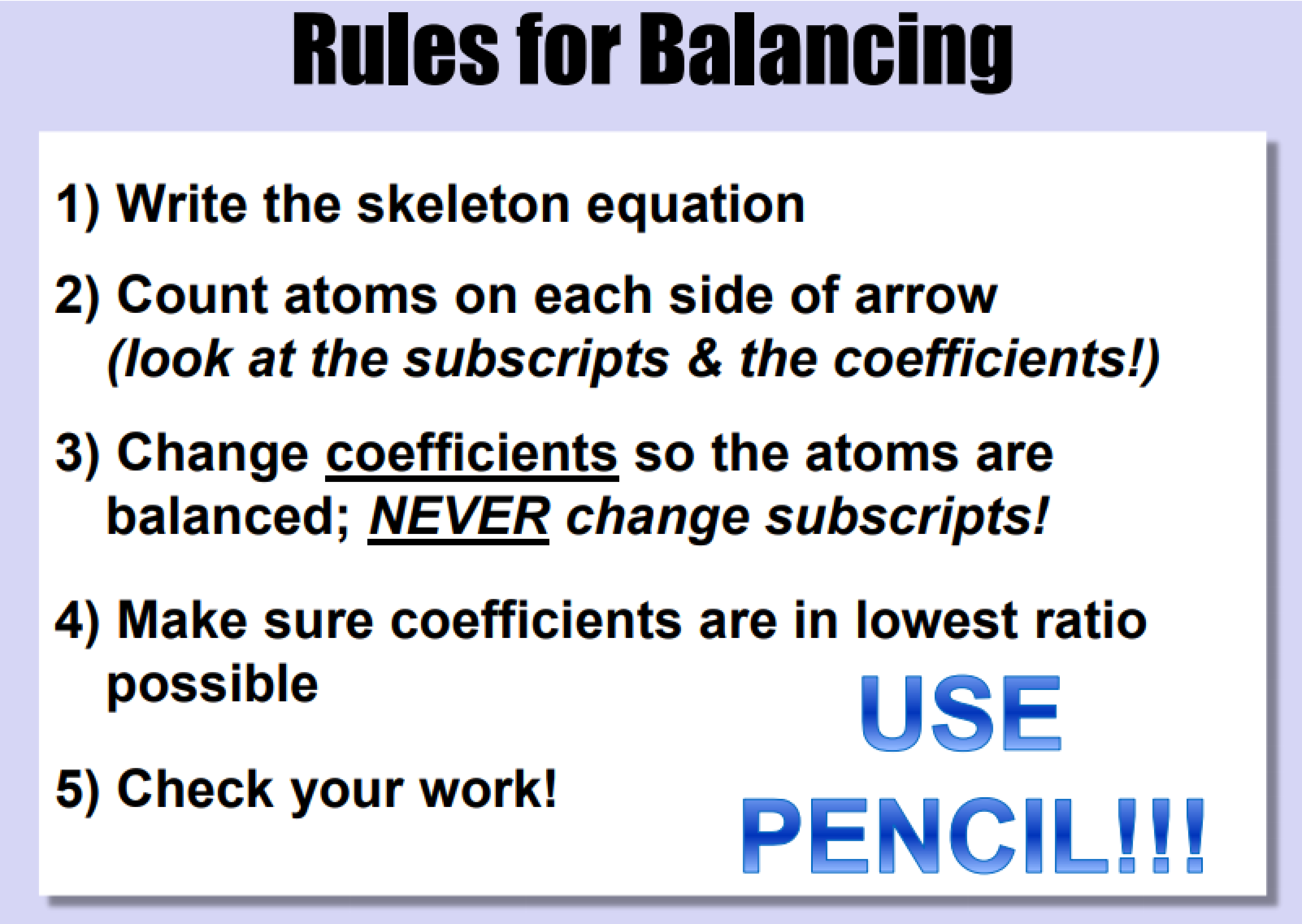
O_2 I_2

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!**

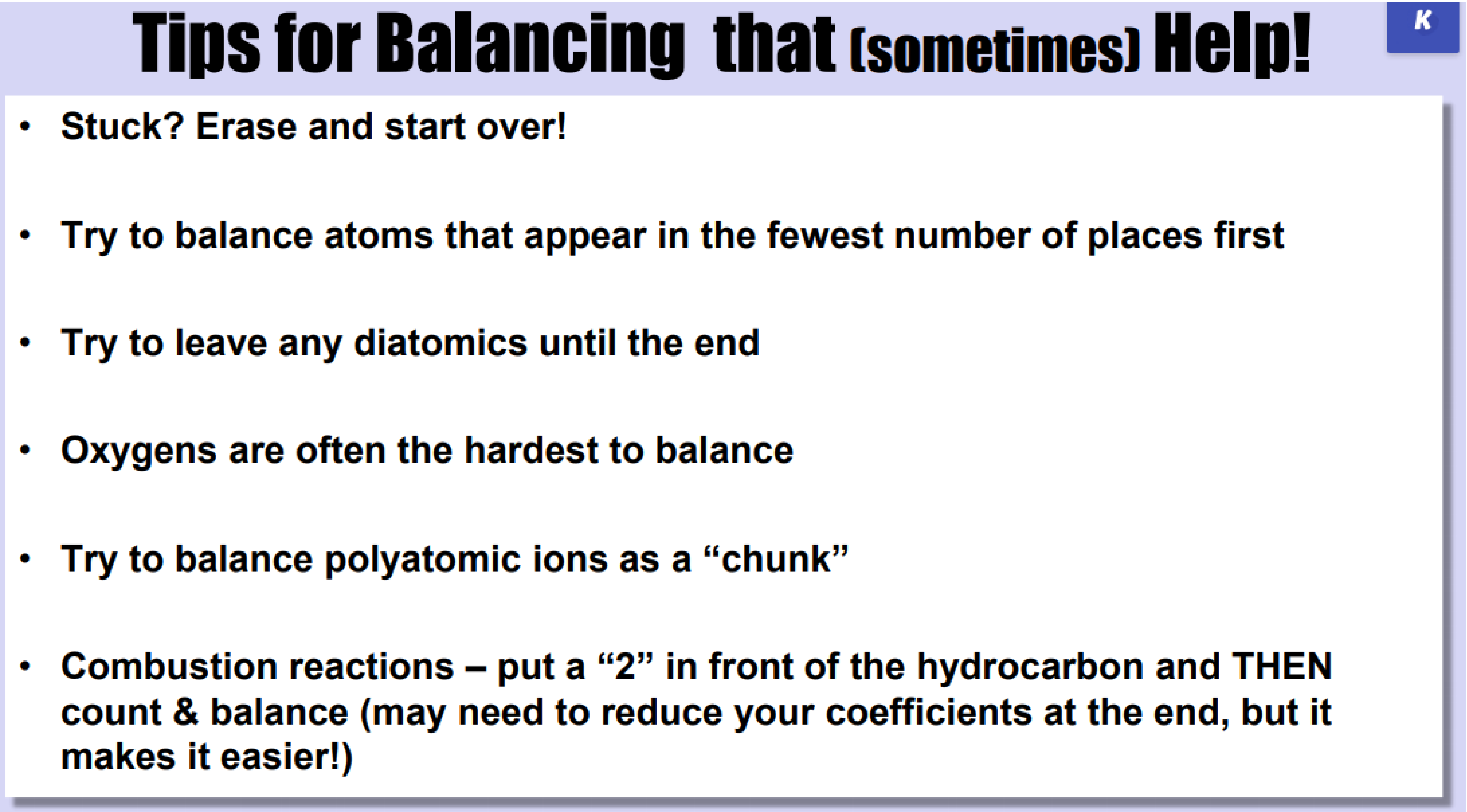
4) Make sure coefficients are in lowest ratio possible

5) Check your work!

USE PENCIL!!!

Balancing

[Jump back to title slide]



Tips for Balancing that (sometimes) Help!

- 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!

$$\underline{\quad 2 \quad}\ \mathrm{ZnS}\ (aq) + \underline{\qquad\quad}\ \mathrm{O_2}\ (g) \rightarrow \underline{\quad 2 \quad}\ \mathrm{ZnO}\ (aq) + \underline{\quad 2 \quad}\ \mathrm{S}\ (s)$$

Zn:	$\cancel{1}$	2	2
S:	$\cancel{1}$	2	2
O:	2		2

Zn:	$\cancel{1}$	2	2
S:	$\cancel{1}$	2	2
O:	$\cancel{1}$	2	2

Types of Reactions

Jump back to title slide

Synthesis

Combustion

Decomposition

Double Replacement

Single Replacement

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 + $O_2 \rightarrow CO_2 + H_2O$

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

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

Reactants = Hydrocarbon and O_2

Products = CO_2 and H_2O

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:

$AB + CD \rightarrow AD + CB$

$AgNO_3 + KCl \rightarrow AgCl + KNO_3$

What to look for:

Reactants = 2 Compounds

Products = 2 Compounds but different ones

Jump back to title slide

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*

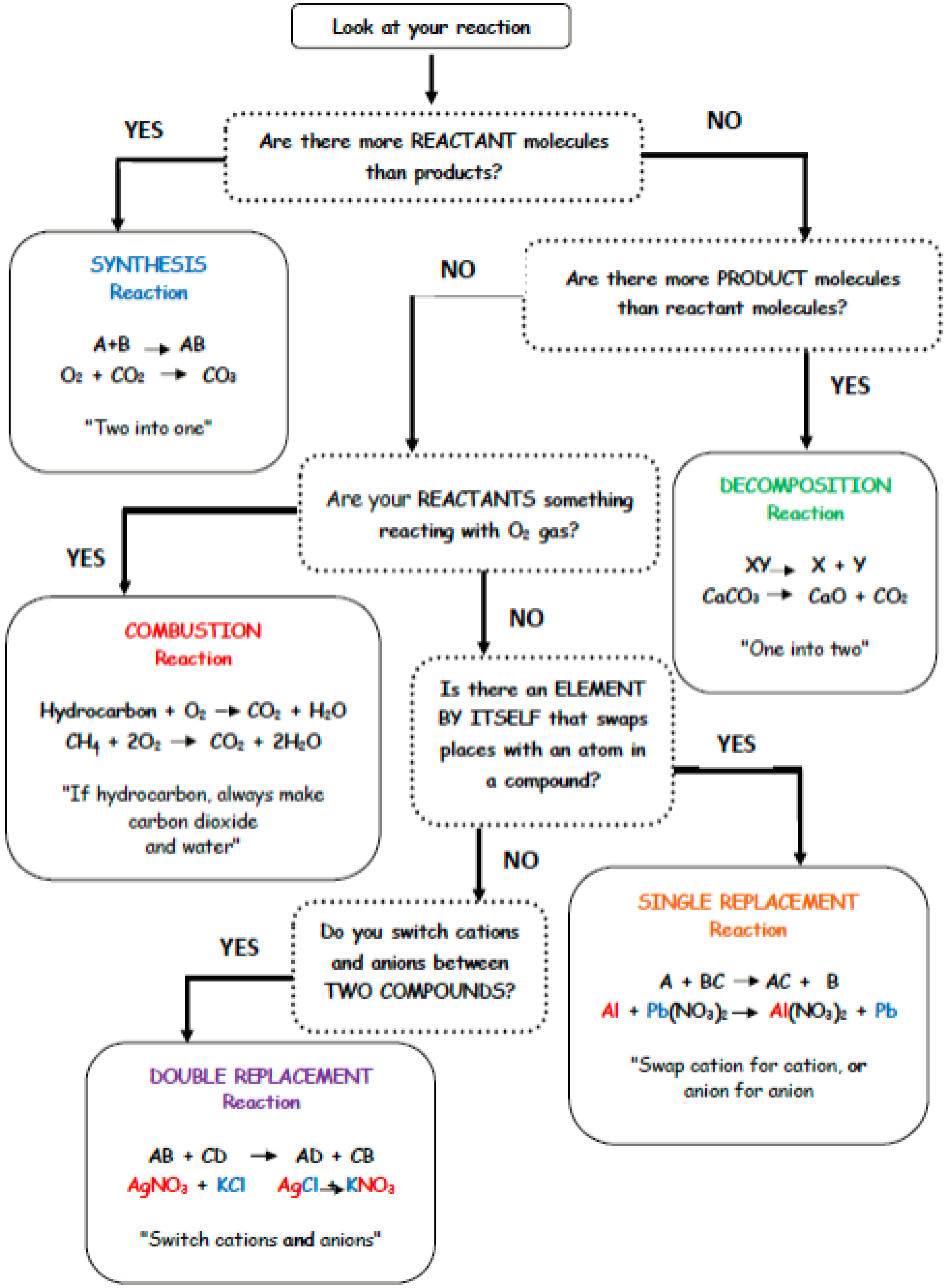
- *All neutral compounds need to have a cation and anion when finished (IN THAT ORDER)*

- *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



Look at your reaction

Are there more REACTANT molecules than products?

YES

SYNTHESIS Reaction

A+B → AB

O_2 + CO_2 → CO_3

"Two into one"

NO

Are there more PRODUCT molecules than reactant molecules?

YES

DECOMPOSITION Reaction

XY → X + Y

$CaCO_3$ → CaO + CO_2

"One into two"

NO

Are your REACTANTS something reacting with O_2 gas?

YES

COMBUSTION Reaction

Hydrocarbon + O_2 → CO_2 + H_2O

CH_4 + $2O_2$ → CO_2 + $2H_2O$

"If hydrocarbon, always make carbon dioxide and water"

NO

Is there an ELEMENT BY ITSELF that swaps places with an atom in a compound?

YES

SINGLE REPLACEMENT Reaction

A + BC → AC + B

Al + $Pb(NO_3)_2$ → $Al(NO_3)_2$ + Pb

"Swap cation for cation, or anion for anion

NO

Do you switch cations and anions between TWO COMPOUNDS?

YES

DOUBLE REPLACEMENT Reaction

AB + CD → AD + CB

$AgNO_3$ + KCl   AgCl → KNO_3

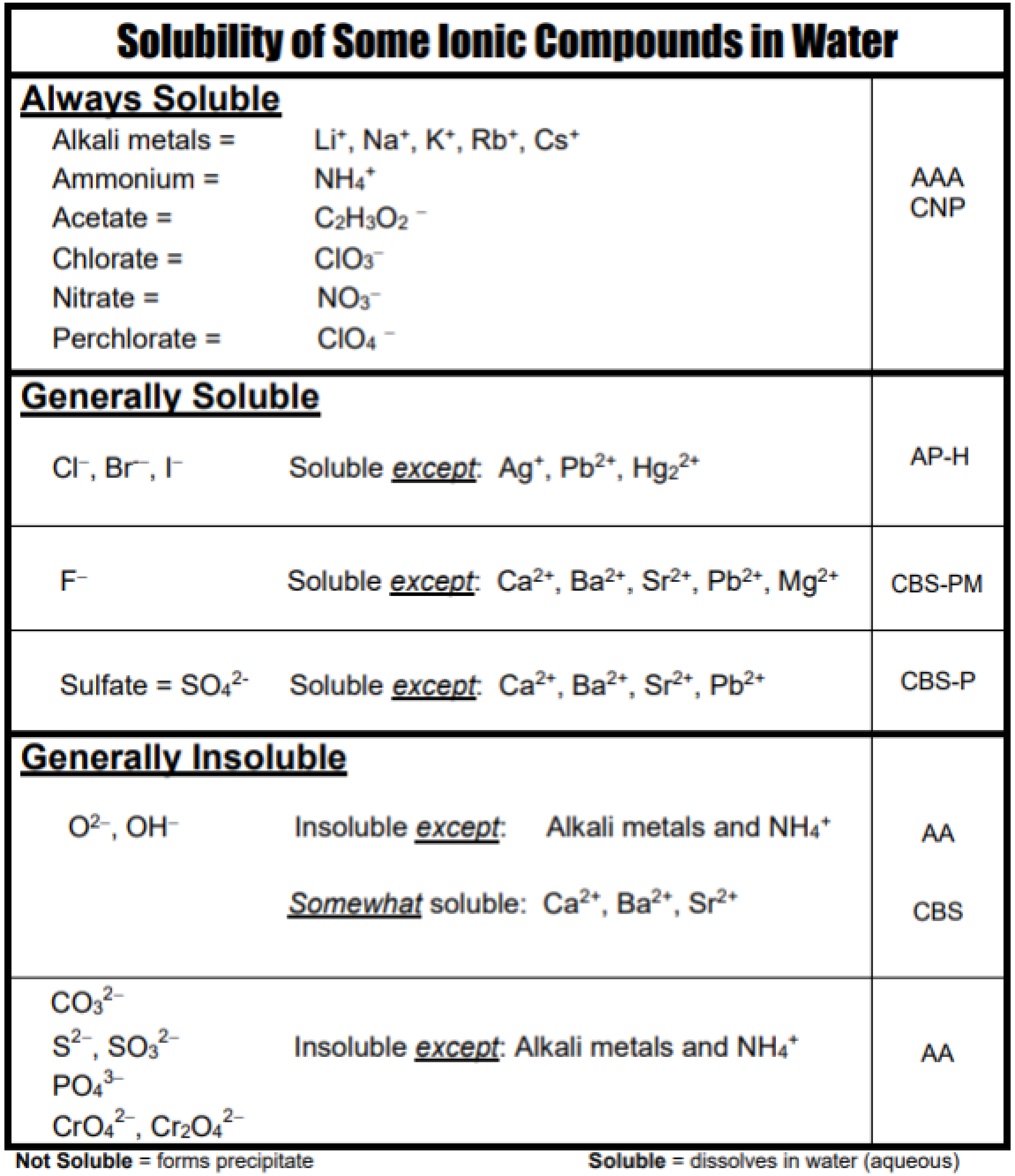
"Switch cations and anions"

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		AAA CNP
Alkali metals =	Li^+, Na^+, K^+, Rb^+, Cs^+	
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

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

Spectator Ions

The Net Ionic Equation

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

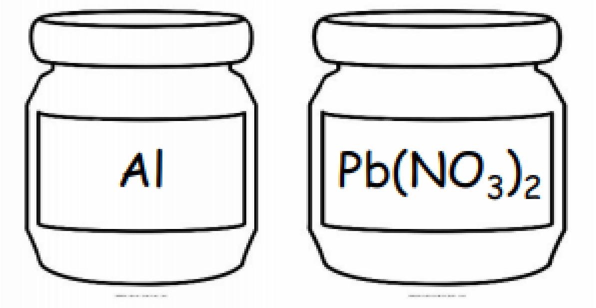
Net Ionic

Jump back to title slide

Particulate Diagrams help our brains!

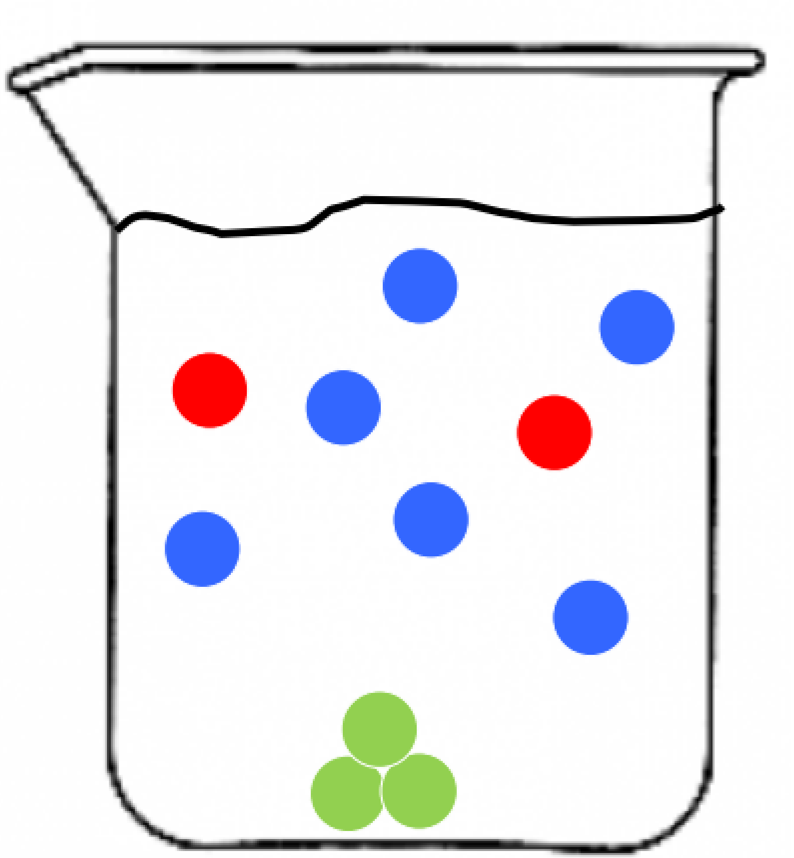
The Balanced Equation

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



Jars of chemicals in stock room

Dump into beaker…



<u>Unit #7</u>
Stoichiometry

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

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

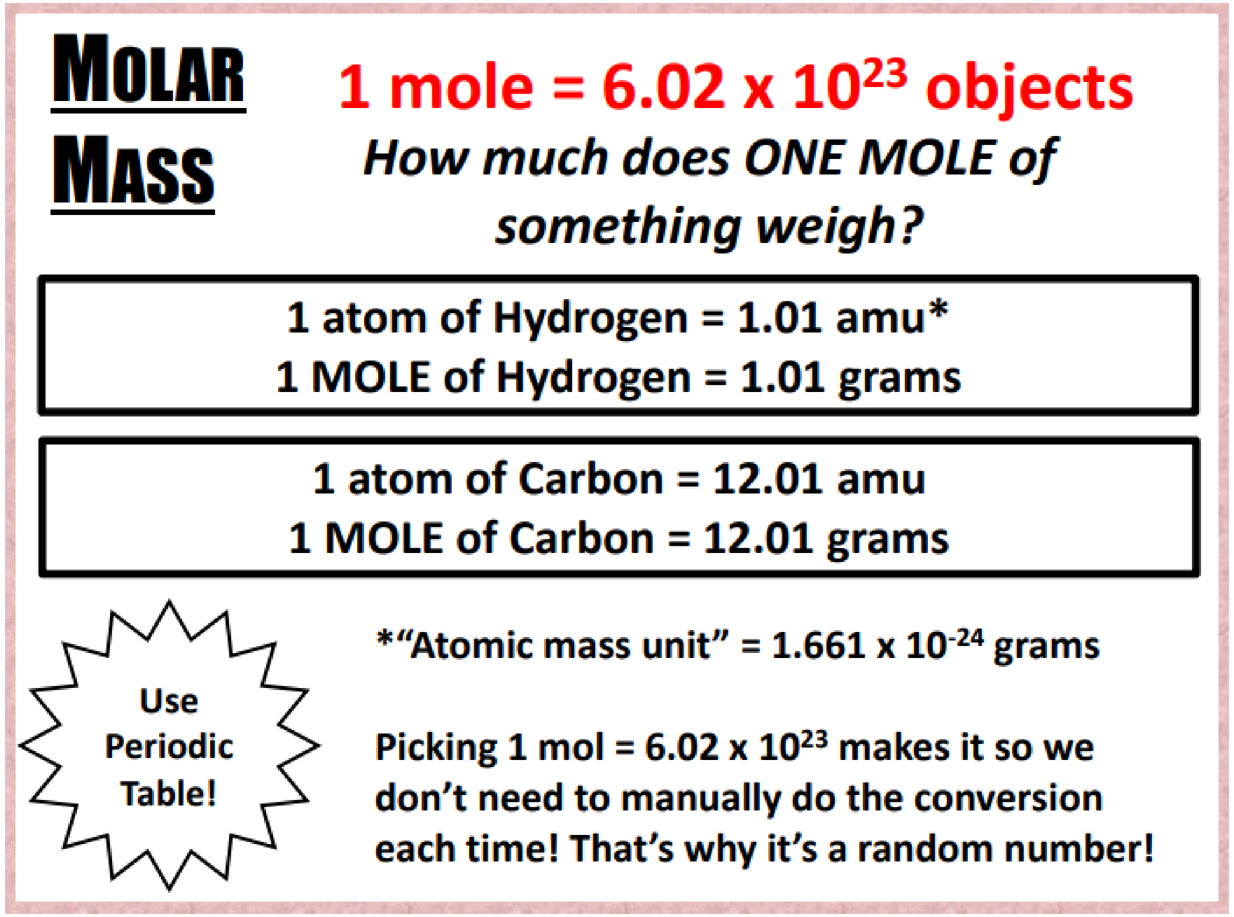
Amedeo Avogadro 1776 – 1856

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

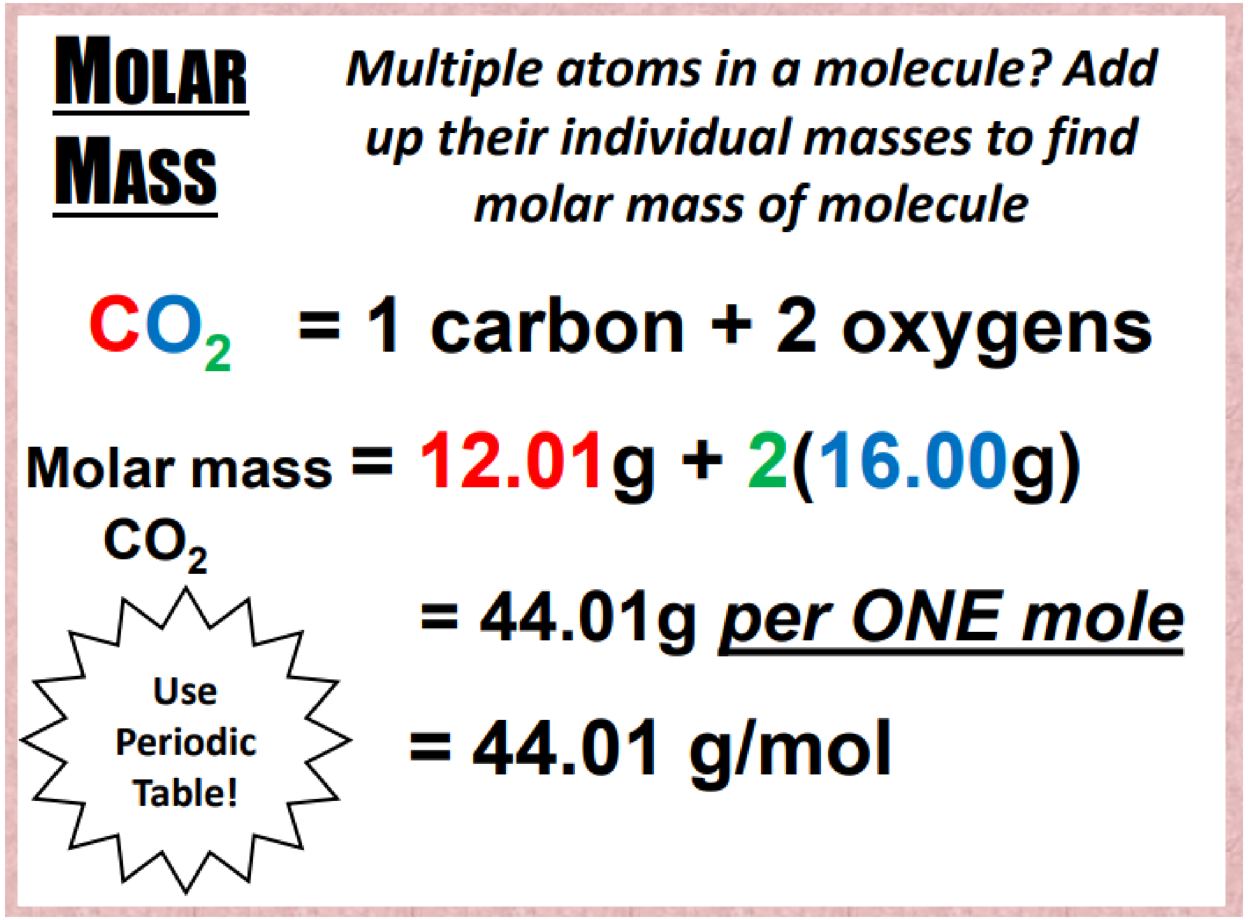
Use Periodic Table!

*"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

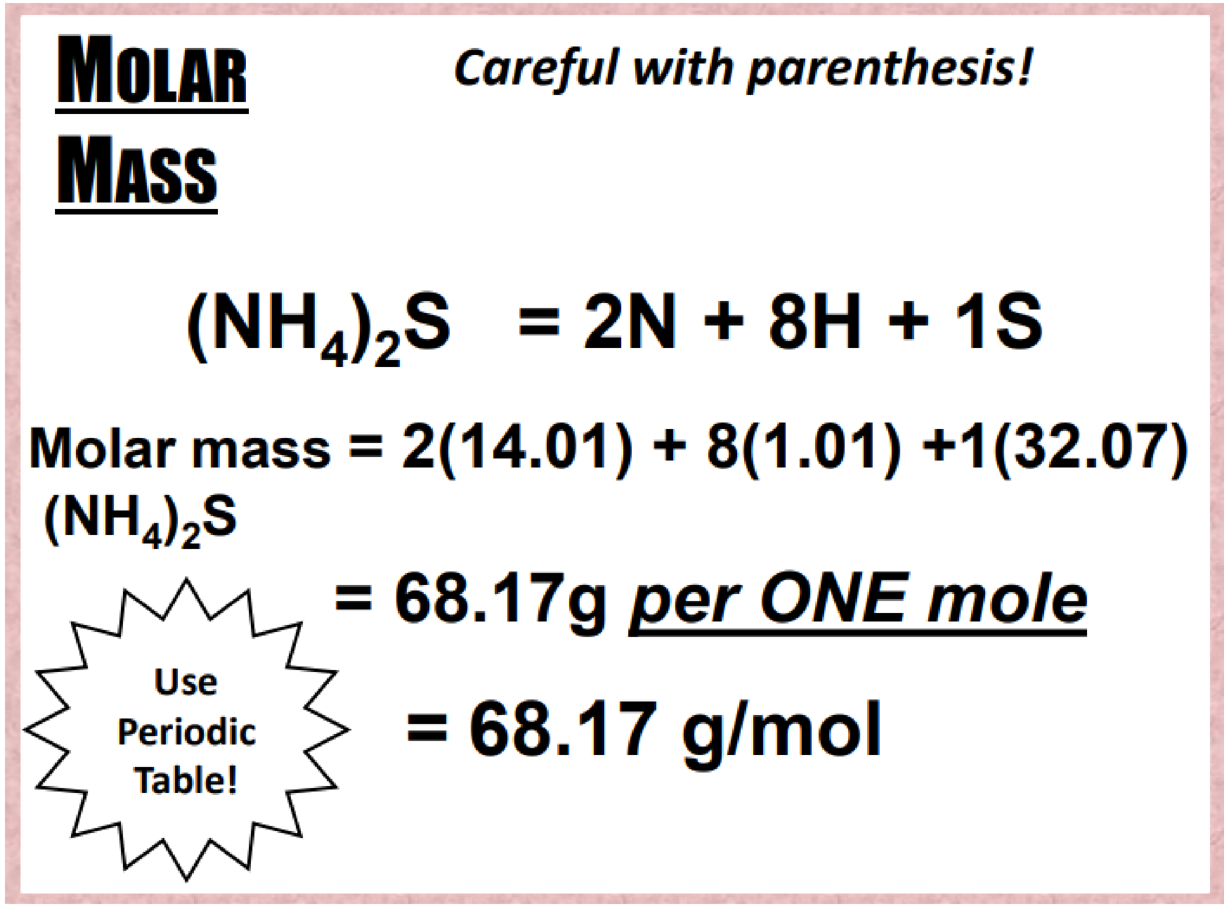
CO_2 = 1 carbon + 2 oxygens

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)

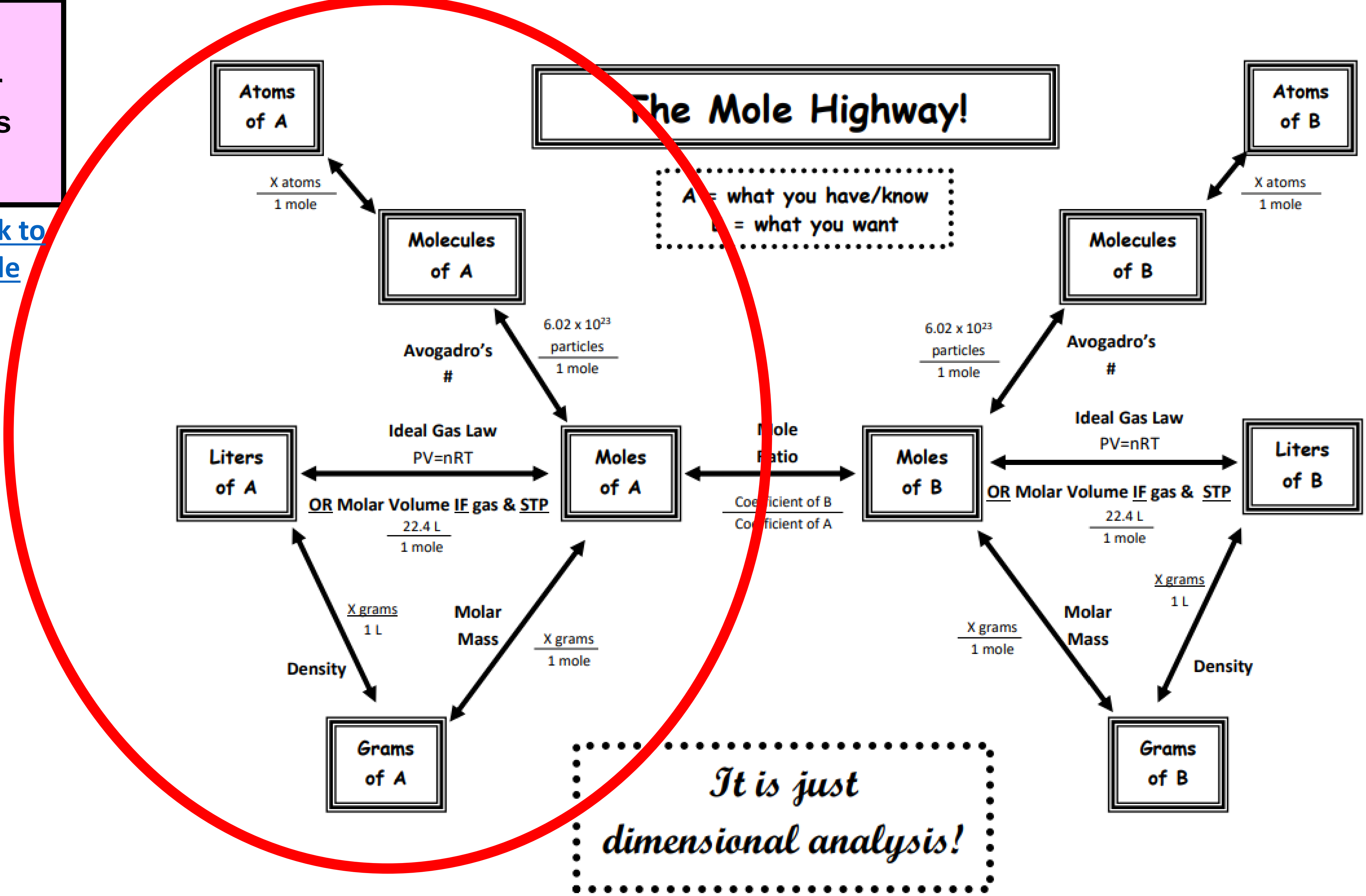
= 68.17g ***per ONE mole***

= 68.17 g/mol

Use Periodic Table!

Molar Conv.s

Jump back to title slide



The Mole Highway!

A = what you have/know
B = what you want

Atoms of A

$\frac{\text{X atoms}}{\text{1 mole}}$

Molecules of A

Avogadro's #

$\frac{6.02 \times 10^{23}\text{ particles}}{\text{1 mole}}$

Liters of A

Ideal Gas Law

PV=nRT

OR Molar Volume IF gas & STP

$\frac{\text{22.4 L}}{\text{1 mole}}$

Moles of A

Mole Ratio

$\frac{\text{Coefficient of B}}{\text{Coefficient of A}}$

Density

$\frac{\text{X grams}}{\text{1 L}}$

Molar Mass

$\frac{\text{X grams}}{\text{1 mole}}$

Grams of A

Atoms of B

$\frac{\text{X atoms}}{\text{1 mole}}$

Molecules of B

Avogadro's #

$\frac{6.02 \times 10^{23}\text{ particles}}{\text{1 mole}}$

Moles of B

Ideal Gas Law

PV=nRT

OR Molar Volume IF gas & STP

$\frac{\text{22.4 L}}{\text{1 mole}}$

Liters of B

Molar Mass

$\frac{\text{X grams}}{\text{1 mole}}$

Density

$\frac{\text{X grams}}{\text{1 L}}$

Grams of B

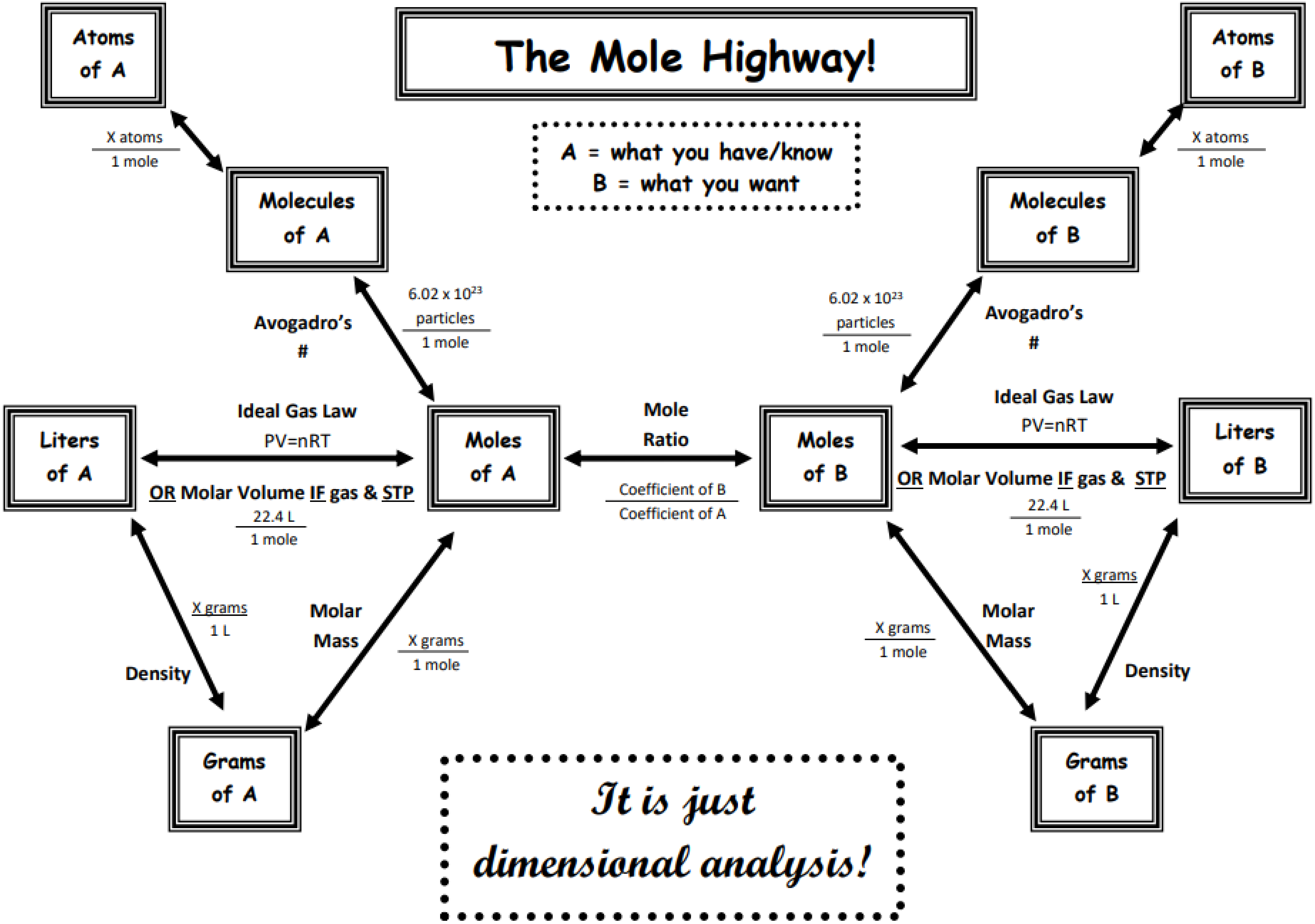
It is just dimensional analysis!

Stoich.

Jump back to title slide

The Mole Highway!

A = what you have/know
B = what you want



Atoms of A

$\frac{\text{X atoms}}{\text{1 mole}}$

Molecules of A

Avogadro's #

$\frac{6.02 \times 10^{23}\ \text{particles}}{\text{1 mole}}$

Liters of A

Ideal Gas Law PV=nRT

OR Molar Volume **IF** gas & **STP**

$\frac{\text{22.4 L}}{\text{1 mole}}$

Moles of A

Mole Ratio

$\frac{\text{Coefficient of B}}{\text{Coefficient of A}}$

Moles of B

Density

$\frac{\text{X grams}}{\text{1 L}}$

Molar Mass

$\frac{\text{X grams}}{\text{1 mole}}$

Grams of A

Atoms of B

$\frac{\text{X atoms}}{\text{1 mole}}$

Molecules of B

Avogadro's #

$\frac{6.02 \times 10^{23}\ \text{particles}}{\text{1 mole}}$

Ideal Gas Law PV=nRT

OR Molar Volume **IF** gas & **STP**

$\frac{\text{22.4 L}}{\text{1 mole}}$

Liters of B

$\frac{\text{X grams}}{\text{1 mole}}$

Molar Mass

$\frac{\text{X grams}}{\text{1 L}}$

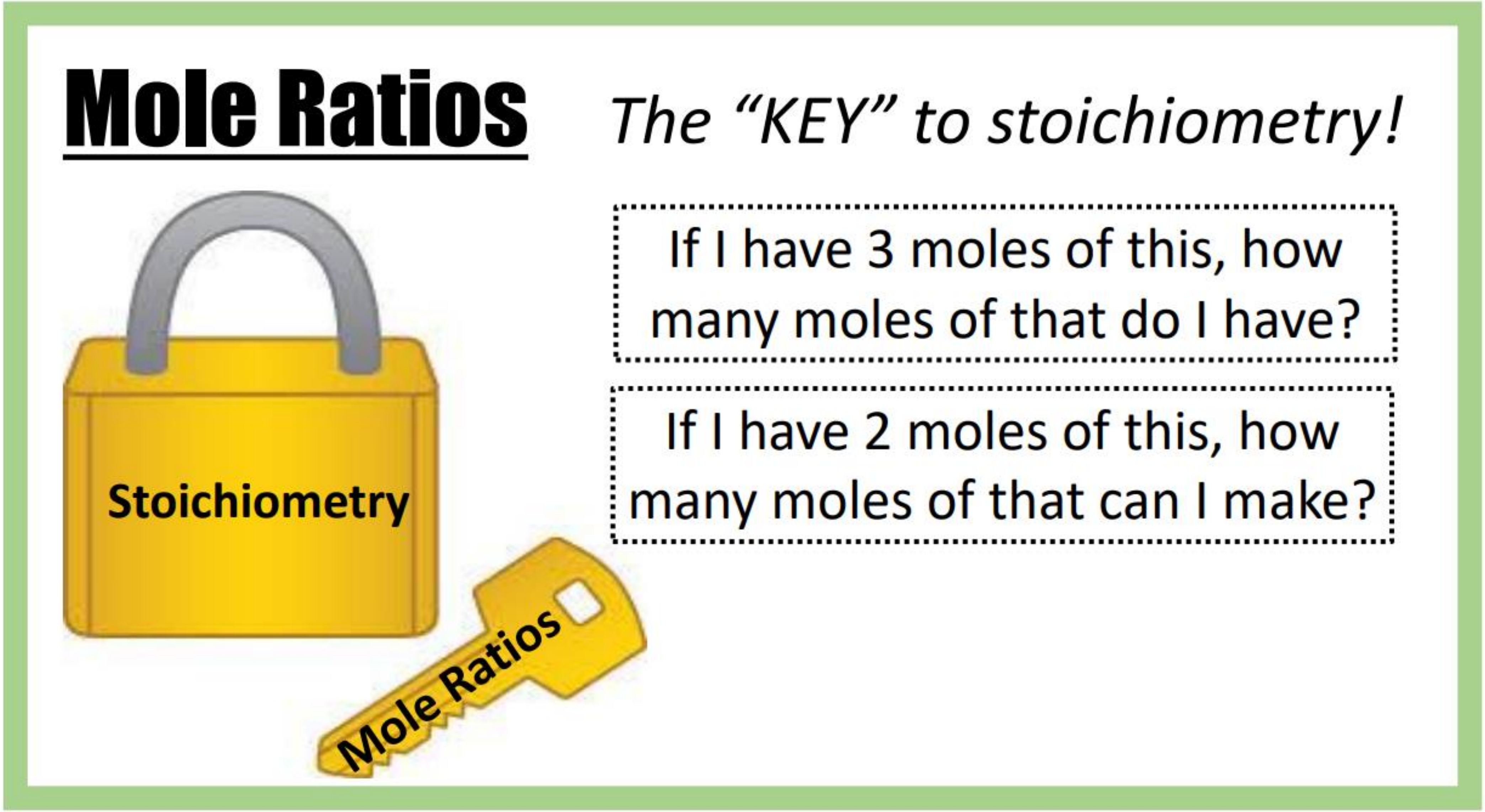
Density

Grams of B

It is just dimensional analysis!

Mole Ratio

Jump back to title slide



Mole Ratios

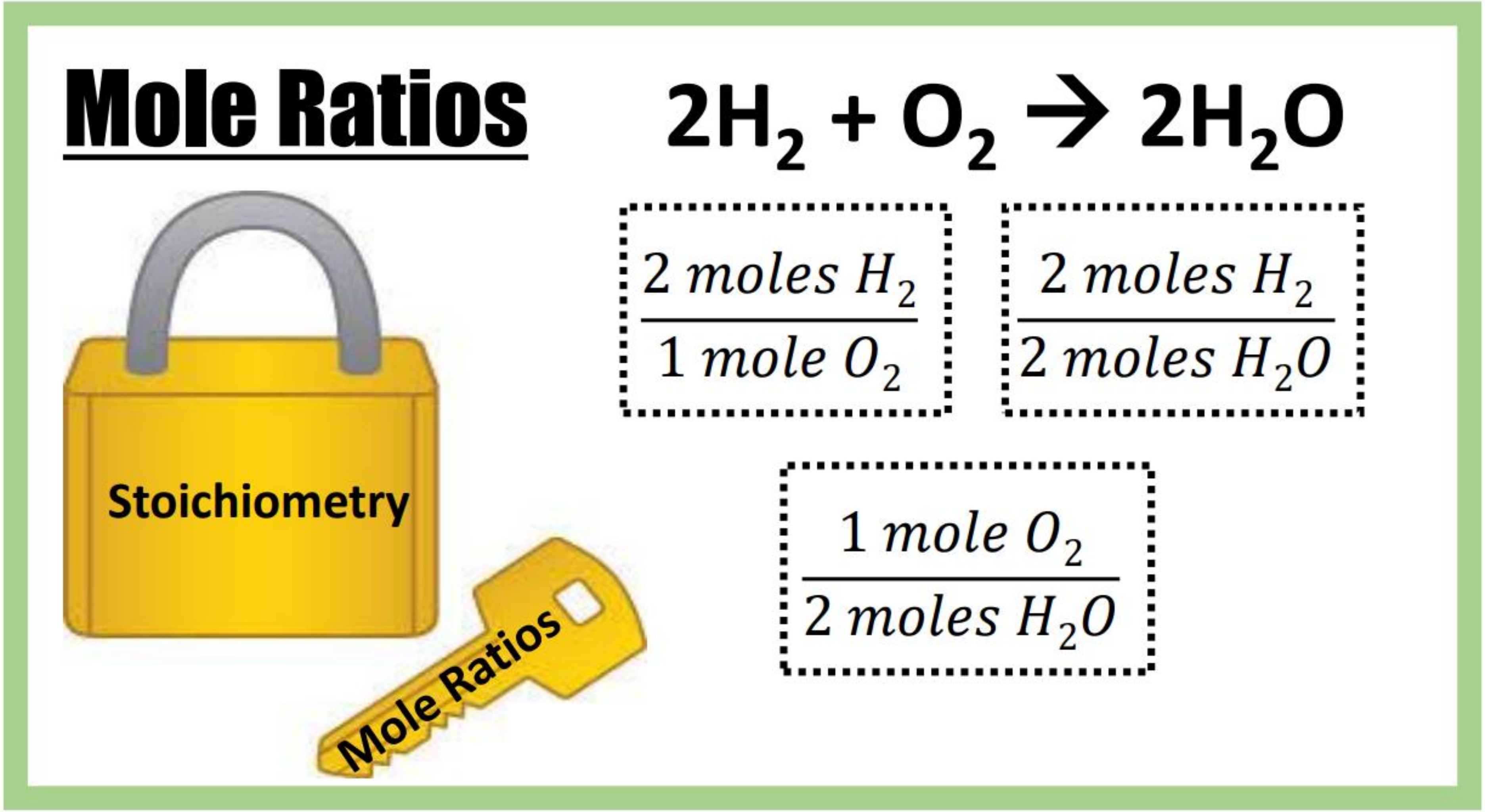
The “KEY” to stoichiometry!

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

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

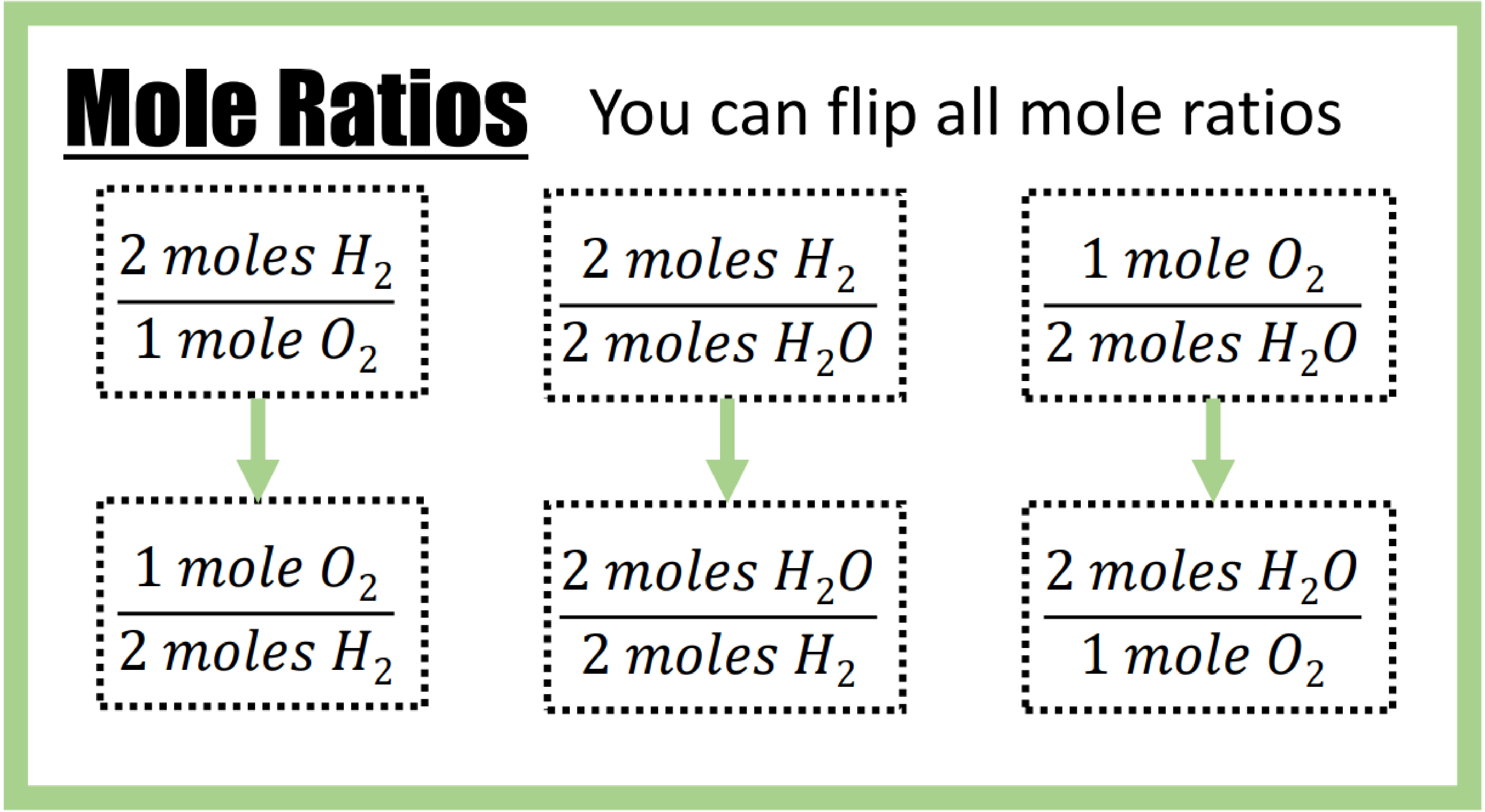
$$\frac{2\ moles\ H_2}{1\ mole\ O_2}$$

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

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

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***
$\frac{X\ g\ A}{1\ mole\ A}$	$\frac{moles\ B}{moles\ A}$	$\frac{X\ g\ B}{1\ mole\ B}$

Stoich.

Jump back to title slide

Q #2

$N_2 + 3H_2 \rightarrow 2NH_3$

75 grams NH_3 → ? g H_2

$$\begin{array}{c|c|c|c} 75\ \text{g}\ \cancel{\text{NH}_3} & 1\ \cancel{\text{mole NH}_3} & 3\ \cancel{\text{mole H}_2} & 2.02\ \boxed{\text{g H}_2} \\ \hline & 17.03\ \cancel{\text{g NH}_3} & 2\ \cancel{\text{mole NH}_3} & 1\ \cancel{\text{mole H}_2} \end{array}$$

= 13.34 g H_2

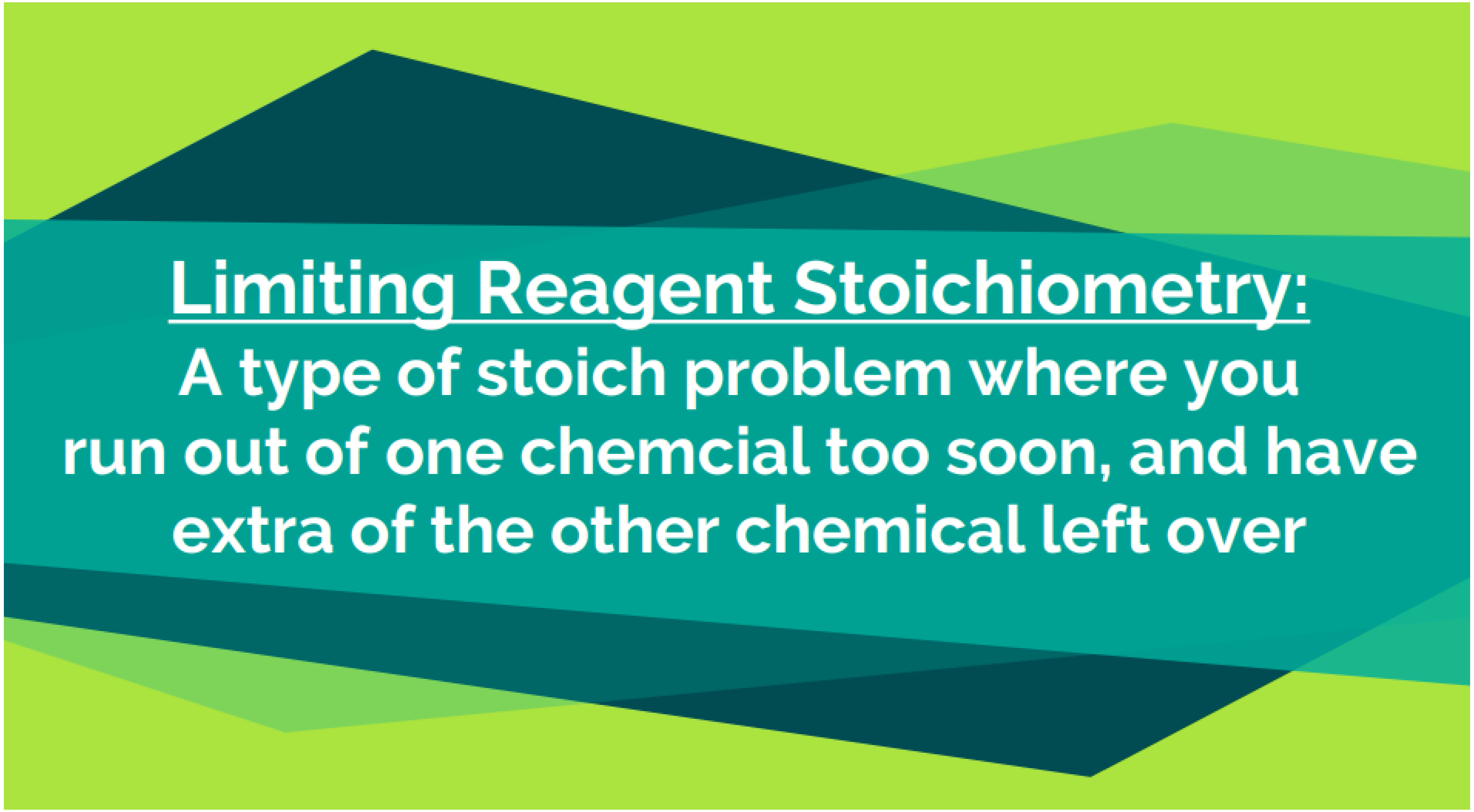
Unit #8

Advanced Chemical Ratios

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

Limiting Reagent Stoich.

Jump back to title slide

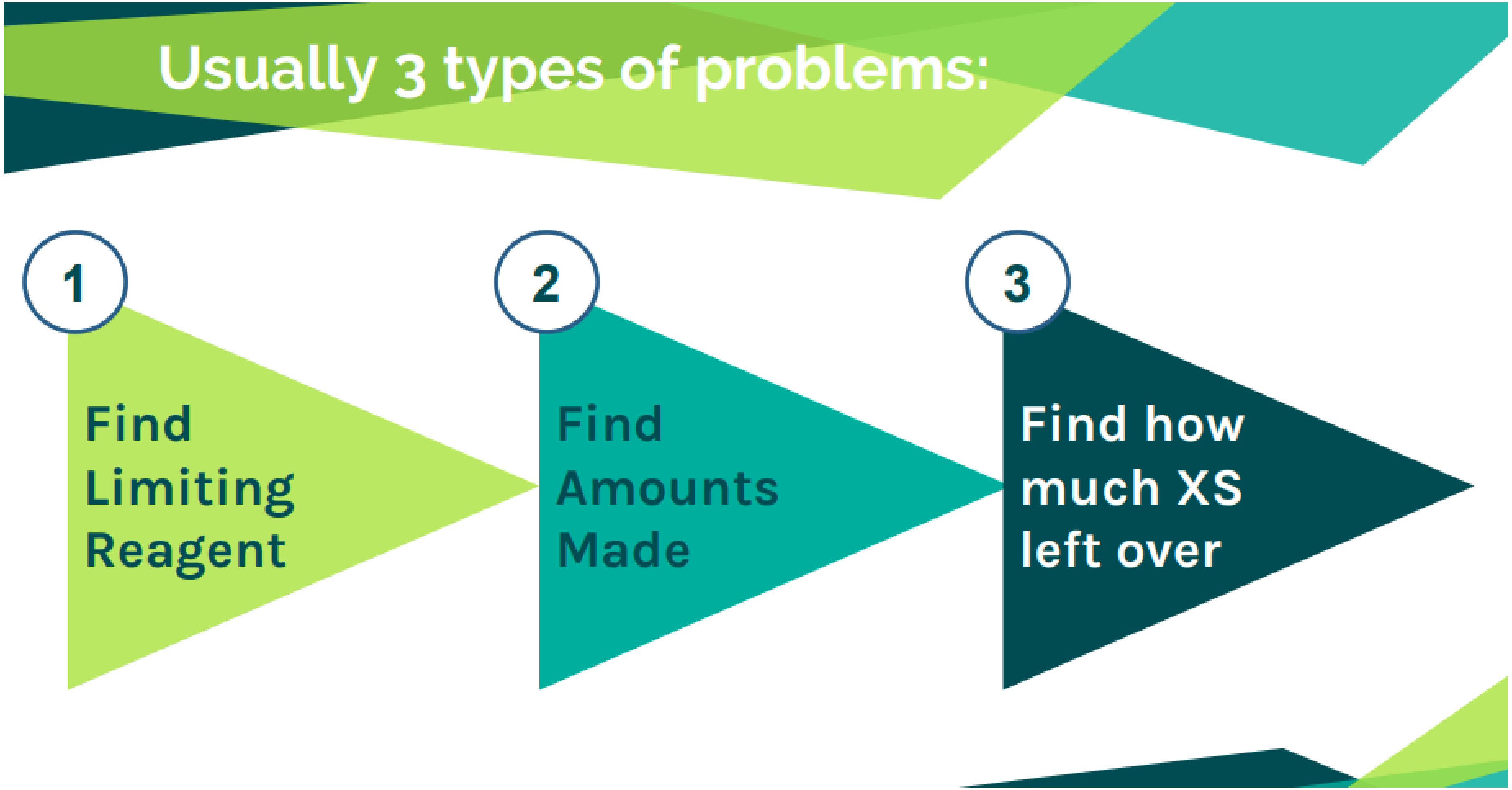


Limiting Reagent Stoichiometry:

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.

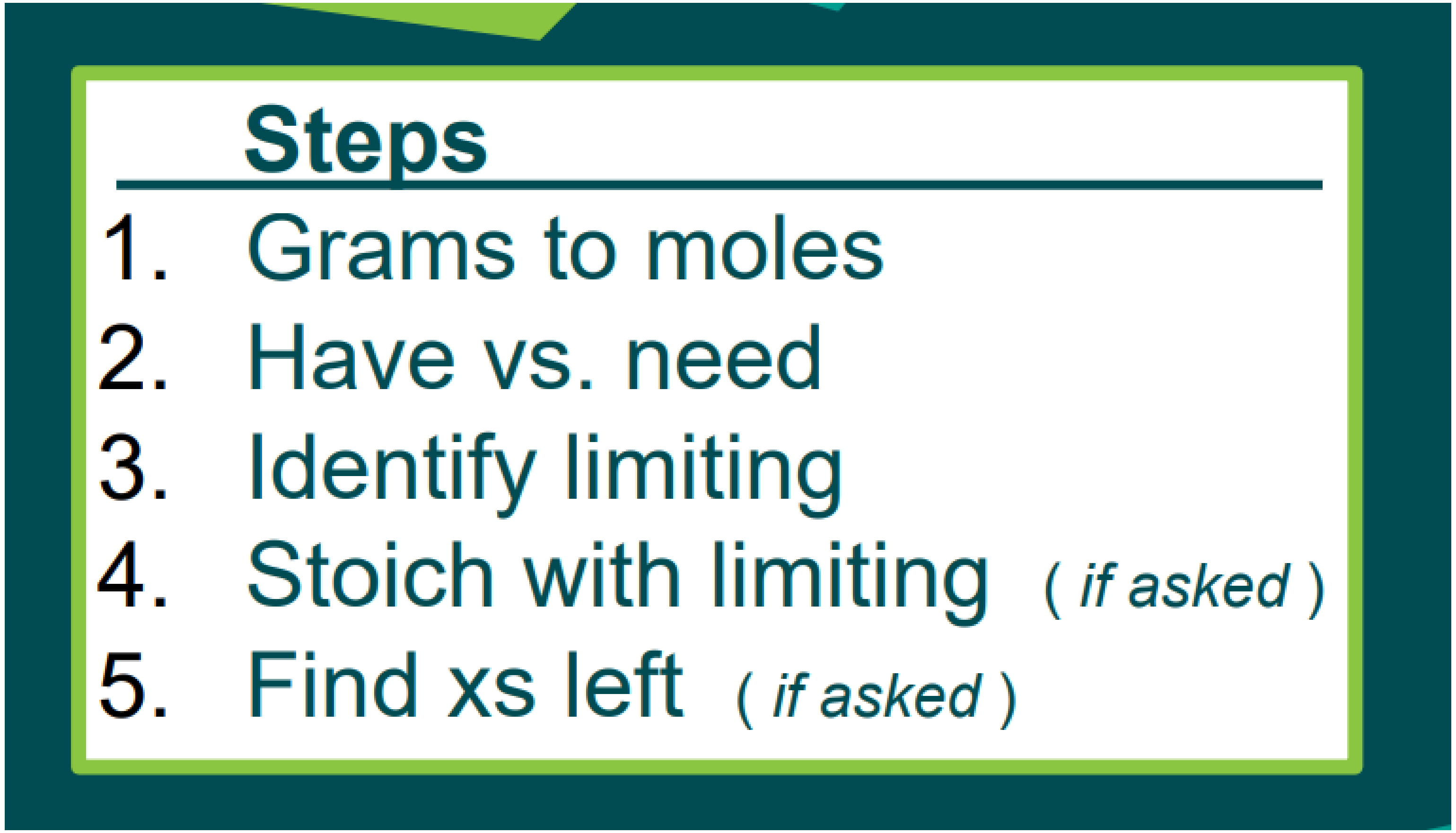
[Jump back to title slide]

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?

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

$$\begin{array}{c|c} 150.0\text{ g K} & 1\text{ mol K} \\ \hline & 39.10\text{ g K} \end{array} = 3.836\text{ mol K}$$

$$\begin{array}{c|c} 225\text{ g }Br_2 & 1\text{ mol }Br_2 \\ \hline & 159.8\text{ g }Br_2 \end{array} = 1.408\text{ mol }Br_2$$

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?

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

HAVE:	**3.836** mol	**1.408** mol
NEED:		**1.918** mol

$$\frac{3.836 \text{ mol K}}{} \left| \frac{1 \text{ mol Br}_2}{2 \text{ mol K}} \right.$$

= 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

***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**

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:	**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**

$$\begin{array}{c|c} 1.408 \text{ mol } Br_2 & 2 \text{ mol K} \\ \hline & 1 \text{ mol } Br_2 \end{array}$$

= 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?

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

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

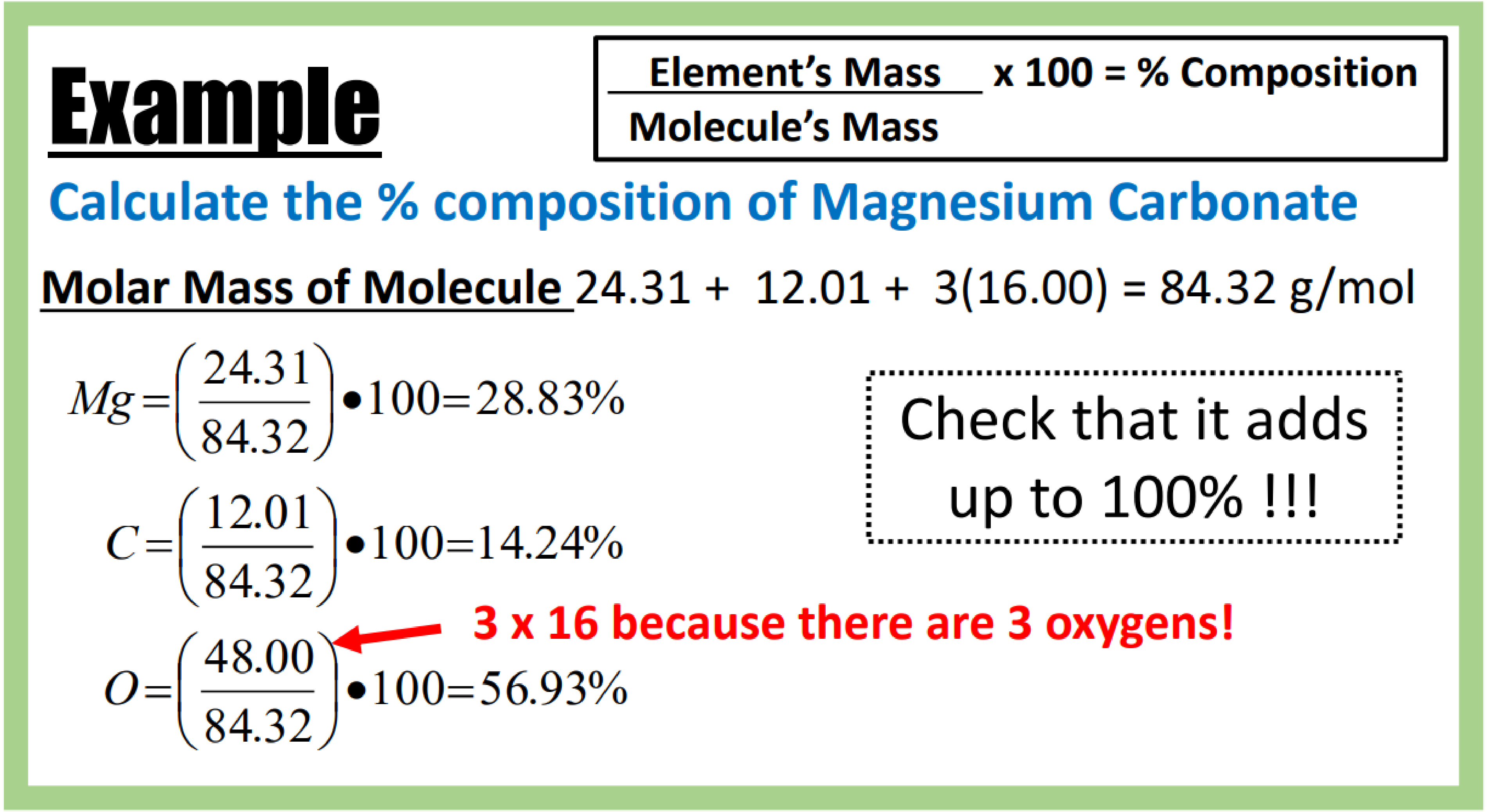
Determining how much of a molecule's mass is from each element

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

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

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% !!!

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.

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?

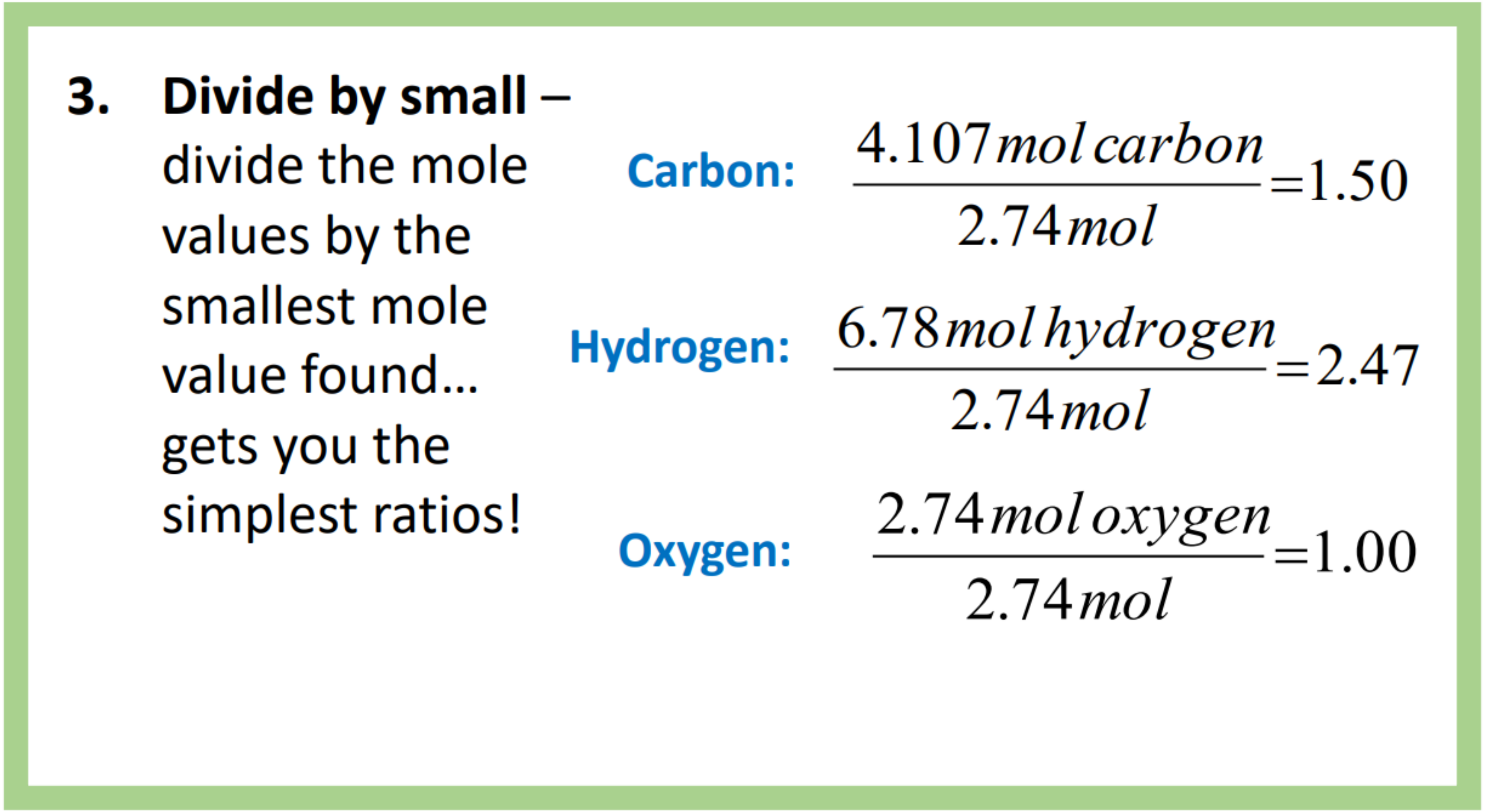
1. **Percent to mass** – 49.32g C, 43.84g O, 6.85g H
2. **Mass to mole**

$$\frac{49.32\,g\ carbon}{}\left|\frac{1\,mol\ carbon}{12.01\,g\ carbon}\right.=4.107\,mol\ carbon$$

$$\frac{6.85\,g\ hydrogen}{}\left|\frac{1\,mol\ hydrogen}{1.01\,g\ hydrogen}\right.=6.78\,mol\ hydrogen$$

$$\frac{43.84\,g\ oxygen}{}\left|\frac{1\,mol\ oxygen}{16.00\,g\ oxygen}\right.=2.74\,mol\ oxygen$$

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 →

Carbon: 1.50
x 2
3

2.50
x 2
5

Oxygen: 1.00
x 2
2

Empirical formula: $C_3H_5O_2$

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! ☺

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**

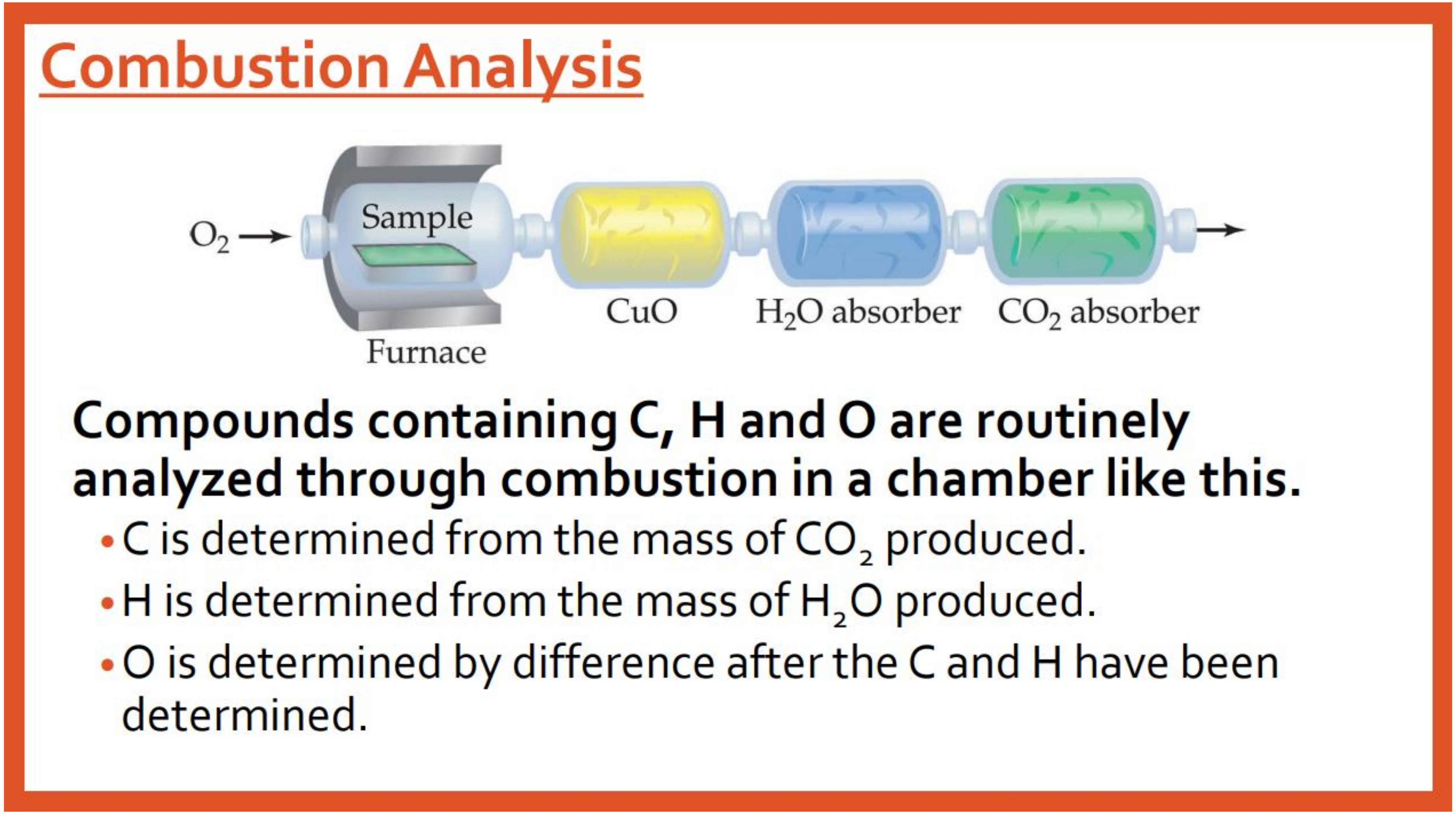
   $\frac{146}{73.08} = 1.997 \rightarrow 2$ **you will usually have to round a bit**

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

$$(C_3H_5O_2) \text{ x } 2 = C_6H_{10}O_4$$

Combust. Analysis

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.

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

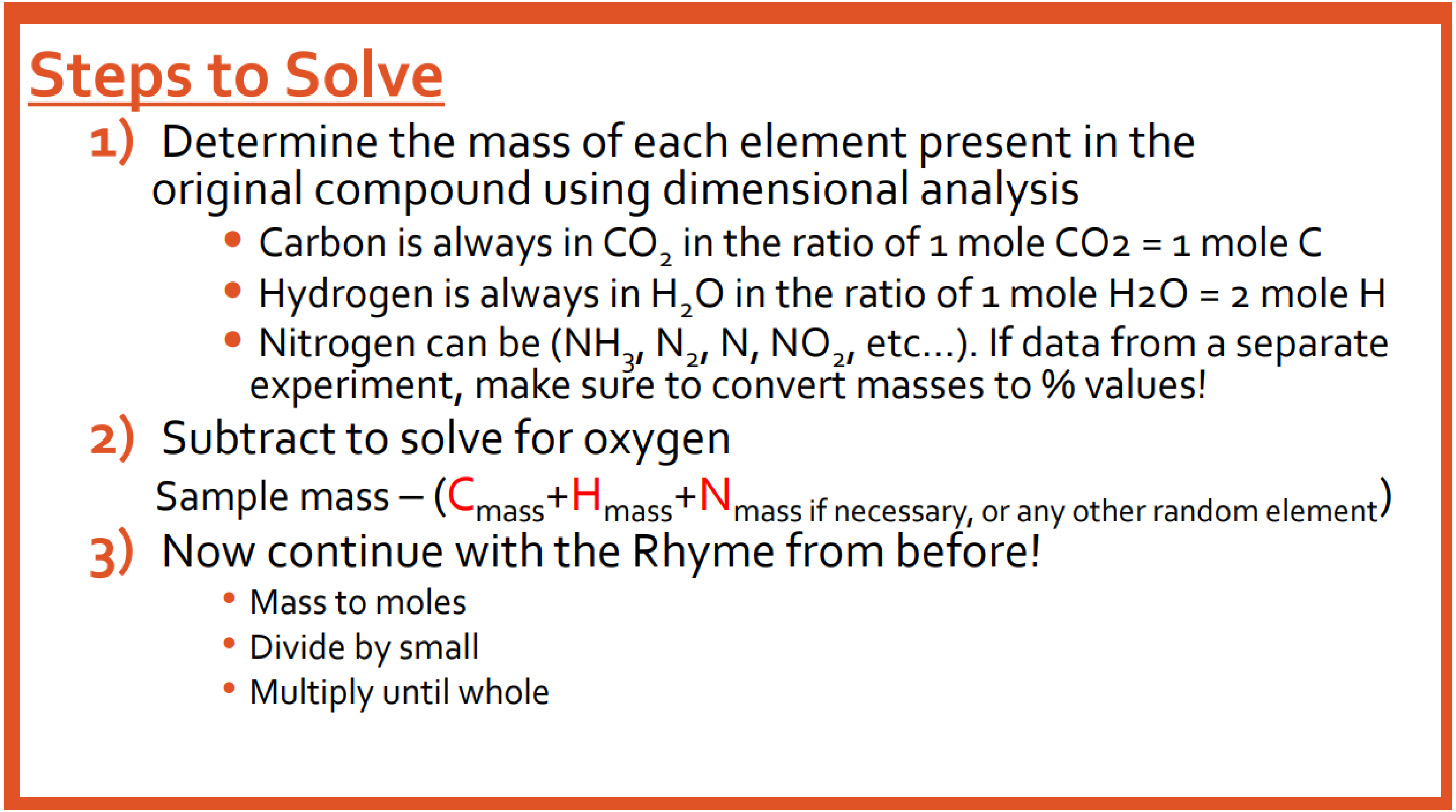
Jump back to title slide

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 $CO2$ and $H2O$. Might have extra products if other elements are present!
- Nitrogen product can come in different forms. $N2$, $NH3$, 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

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Example #1

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

Moles of Carbon

$$\frac{16.0\ \text{g}\ CO_2}{} \left|\ \frac{1\ \text{mole}\ CO_2}{44.0\ \text{g}\ CO_2}\ \right|\ \frac{1\ \text{mole C}}{1\ \text{mole}\ CO_2} = 0.364\ \text{mole C}$$

Moles of Hydrogen

$$\frac{9.80\ \text{g}\ H_2O}{} \left|\ \frac{1\ \text{mole}\ H_2O}{18.0\ \text{g}\ H_2O}\ \right|\ \frac{2\ \text{mole H}}{1\ \text{mole}\ H_2O} = 1.09\ \text{mole H}$$

Combust. Analysis

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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

$$\begin{array}{l|l} 0.364\text{ mole C} & 12.0\text{ g C} \\ \hline & 1\text{ mole C} \end{array} = 4.37\text{ g C}$$

$$\begin{array}{l|l} 1.09\text{ mole H} & 1.01\text{ g H} \\ \hline & 1\text{ mole H} \end{array} = 1.10\text{ g H}$$

Grams of Oxygen

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

Combust. Analysis

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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!*

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

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

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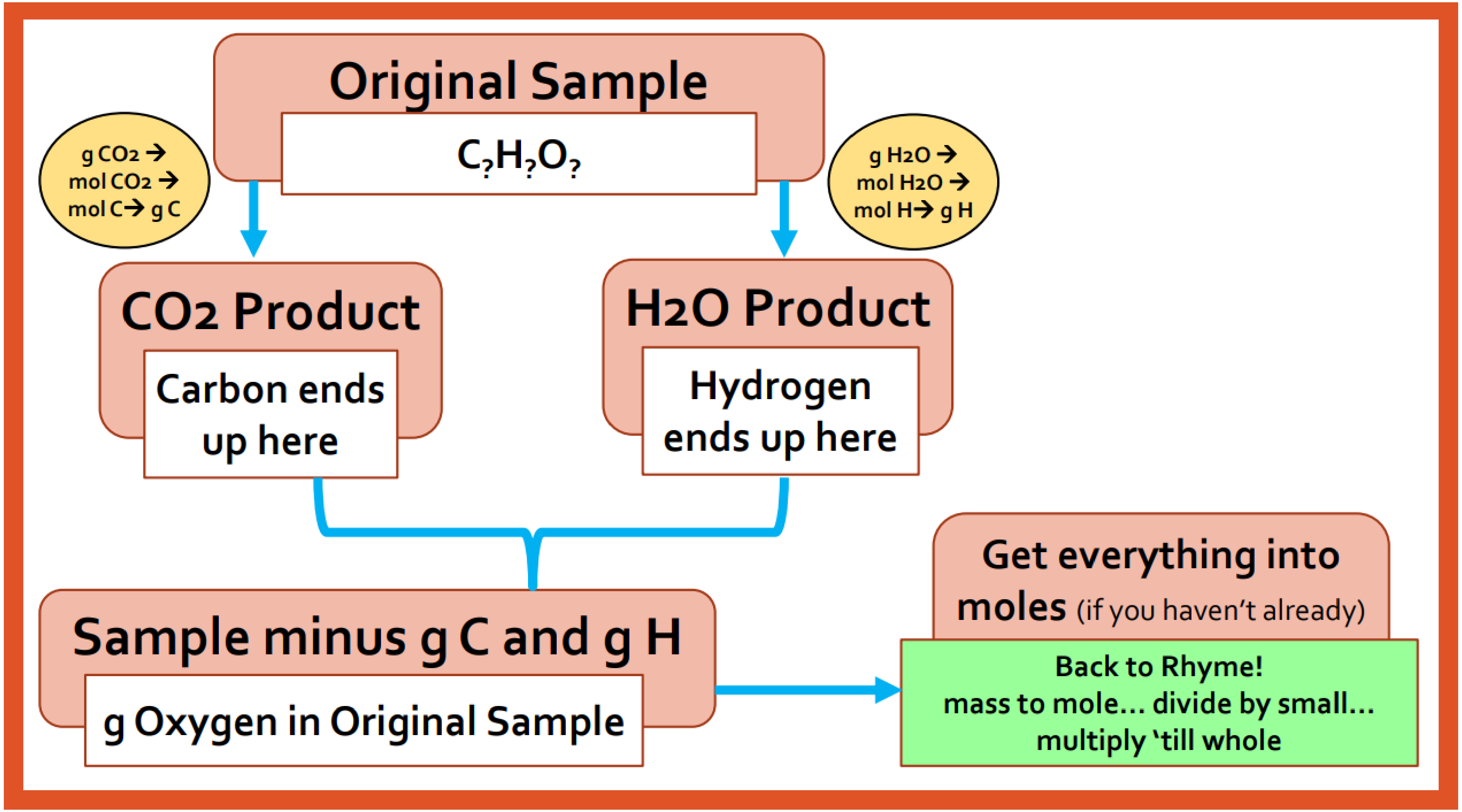


Original Sample

$C_?H_?O_?$

g CO_2 →
mol CO_2 →
mol C→ g C

g H_2O →
mol H_2O →
mol H→ g H

CO_2 Product

Carbon ends up here

H_2O Product

Hydrogen ends up here

Sample minus g C and g H

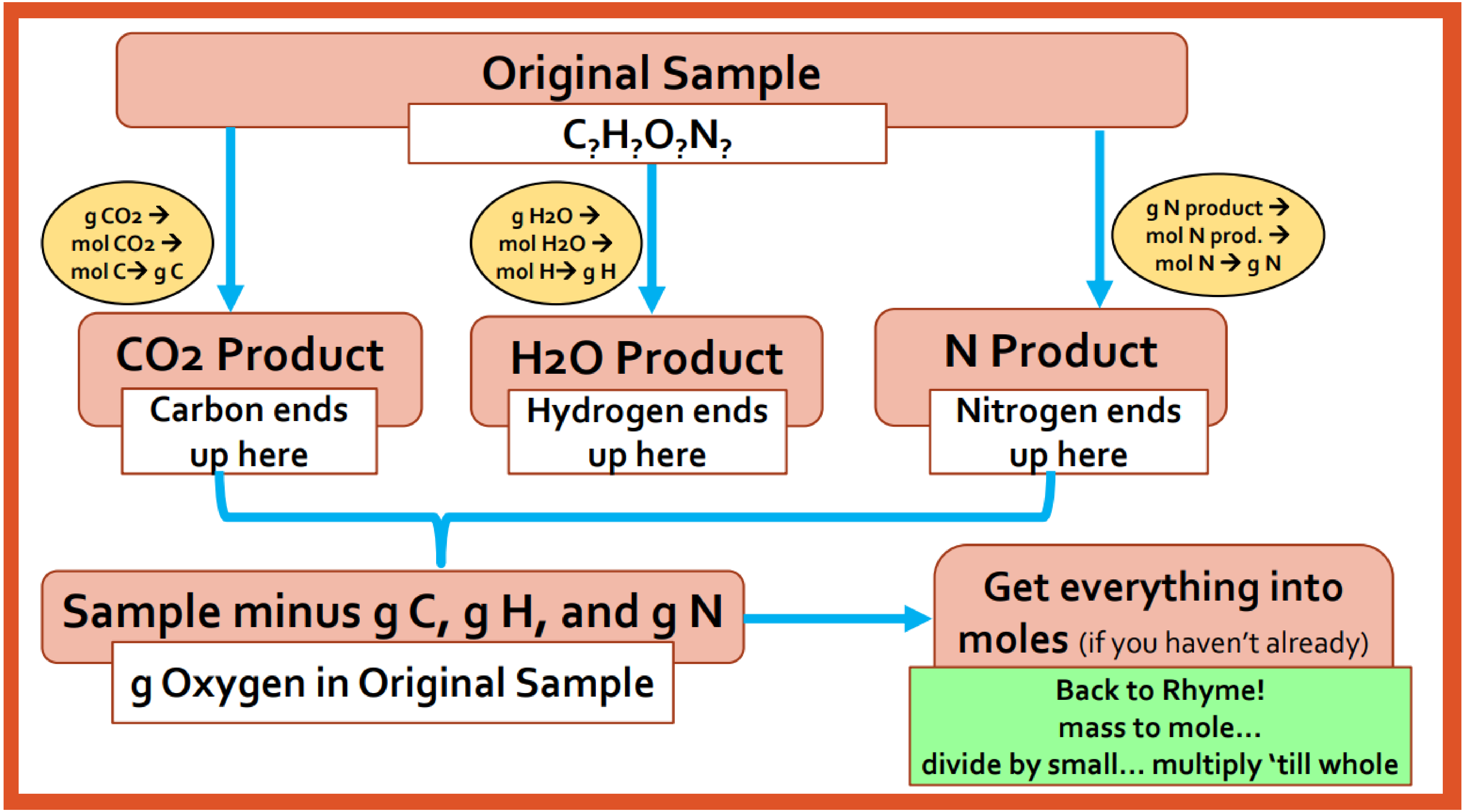
g Oxygen in Original Sample

Get everything into moles (if you haven't already)

Back to Rhyme!
mass to mole… divide by small…
multiply 'till whole

Combust. Analysis

Jump back to title slide



Original Sample

$C_?H_?O_?N_?$

g CO_2 → mol CO_2 → mol C → g C

g H_2O → mol H_2O → mol H → g H

g N product → mol N prod. → mol N → g N

CO_2 Product

Carbon ends up here

H_2O Product

Hydrogen ends up here

N Product

Nitrogen ends up here

Sample minus g C, g H, and g N

g Oxygen in Original Sample

Get everything into moles (if you haven't already)

Back to Rhyme!
mass to mole…
divide by small… multiply 'till whole

Combust. Analysis

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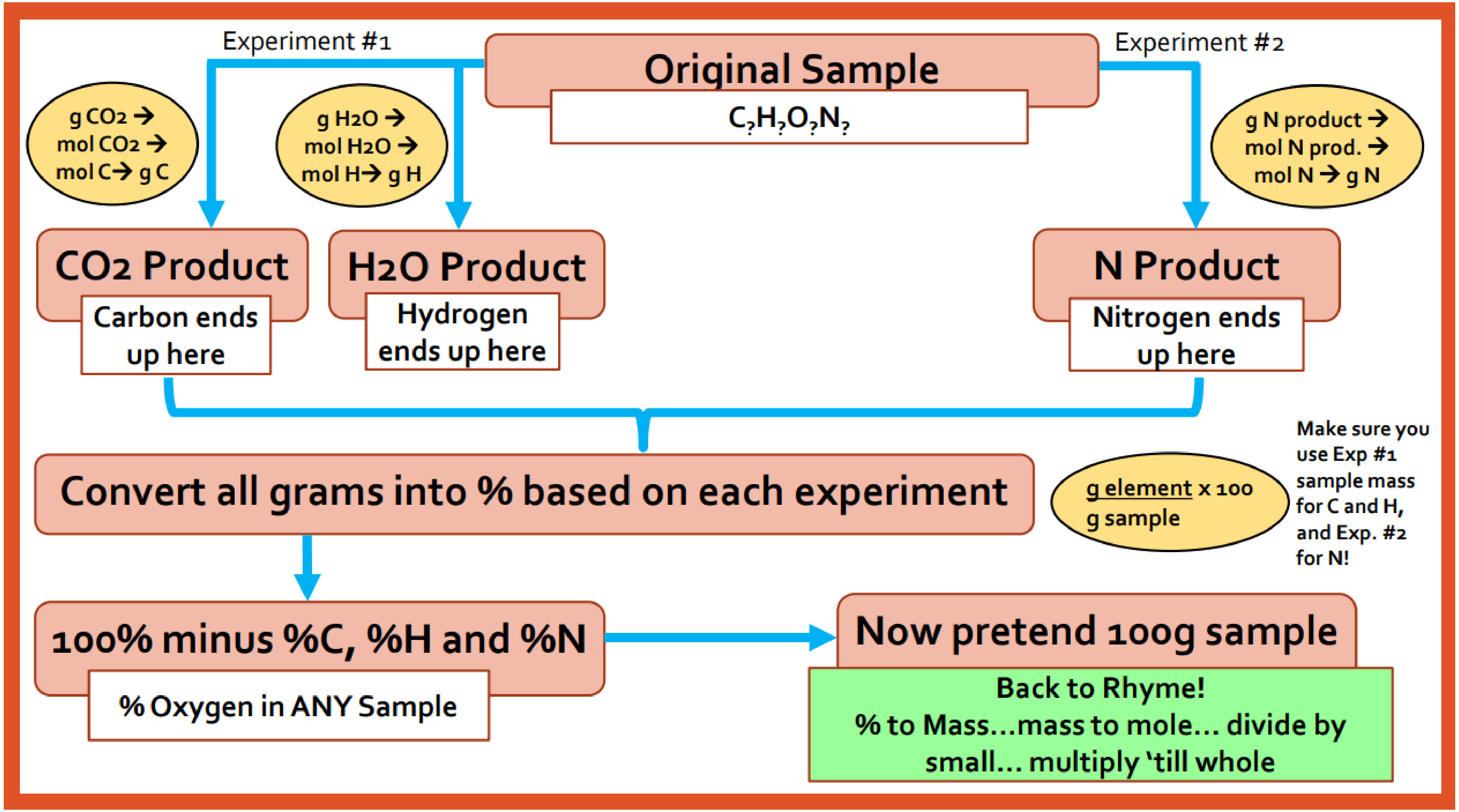

Experiment #1

Experiment #2

Original Sample

$C_?H_?O_?N_?$

g CO_2 → mol CO_2 → mol C → g C

g H_2O → mol H_2O → mol H → g H

g N product → mol N prod. → mol N → g N

CO_2 Product

Carbon ends up here

H_2O Product

Hydrogen ends up here

N Product

Nitrogen ends up here

Convert all grams into % based on each experiment

$\frac{\text{g element}}{\text{g sample}} \times 100$

Make sure you use Exp #1 sample mass for C and H, and Exp. #2 for N!

100% minus %C, %H and %N

% Oxygen in ANY Sample

Now pretend 100g sample

Back to Rhyme!
% to Mass…mass to mole… divide by small… multiply 'till whole

Unit #9

Gas Laws

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

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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

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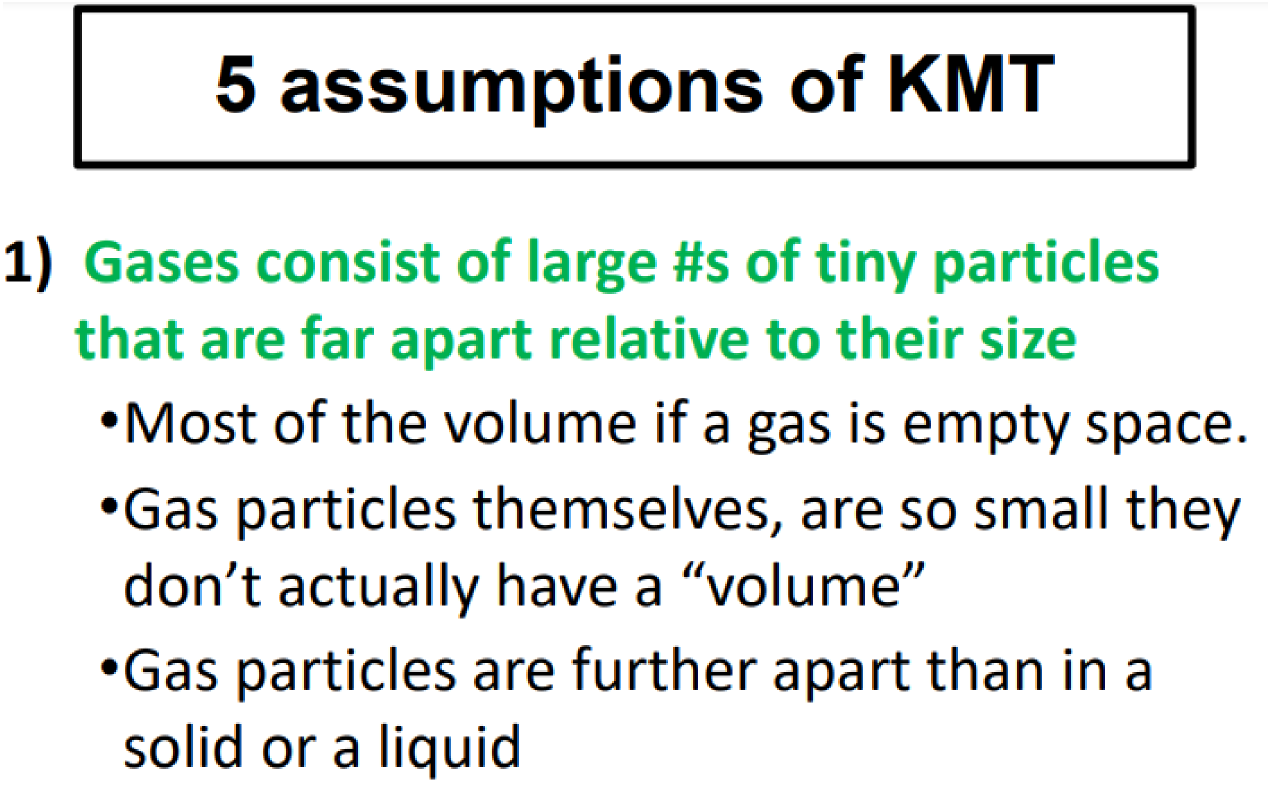

5 assumptions of KMT

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

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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

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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

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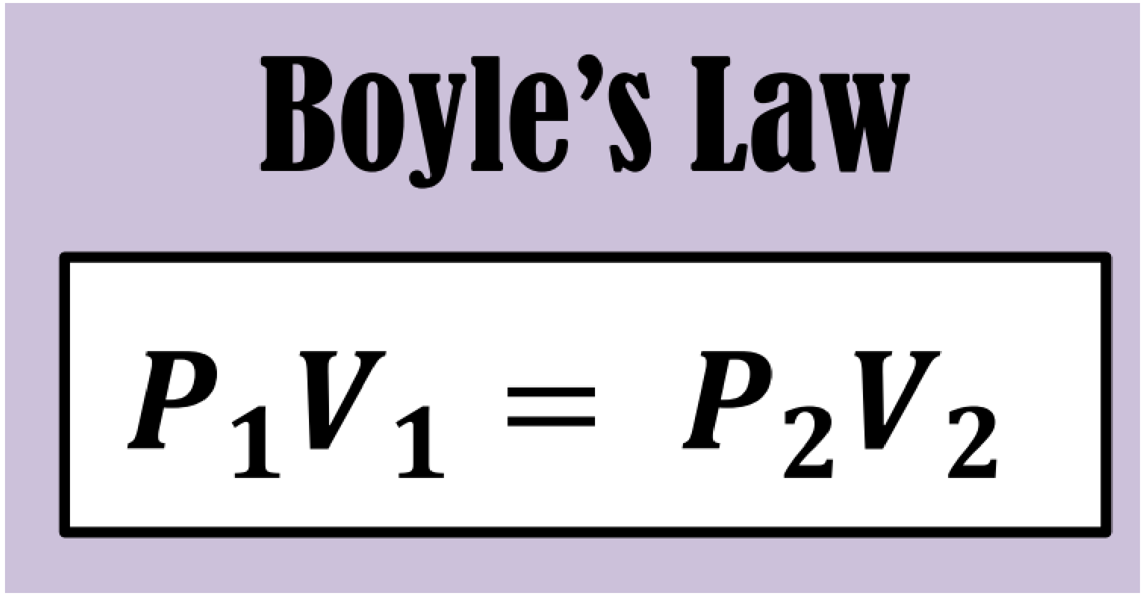
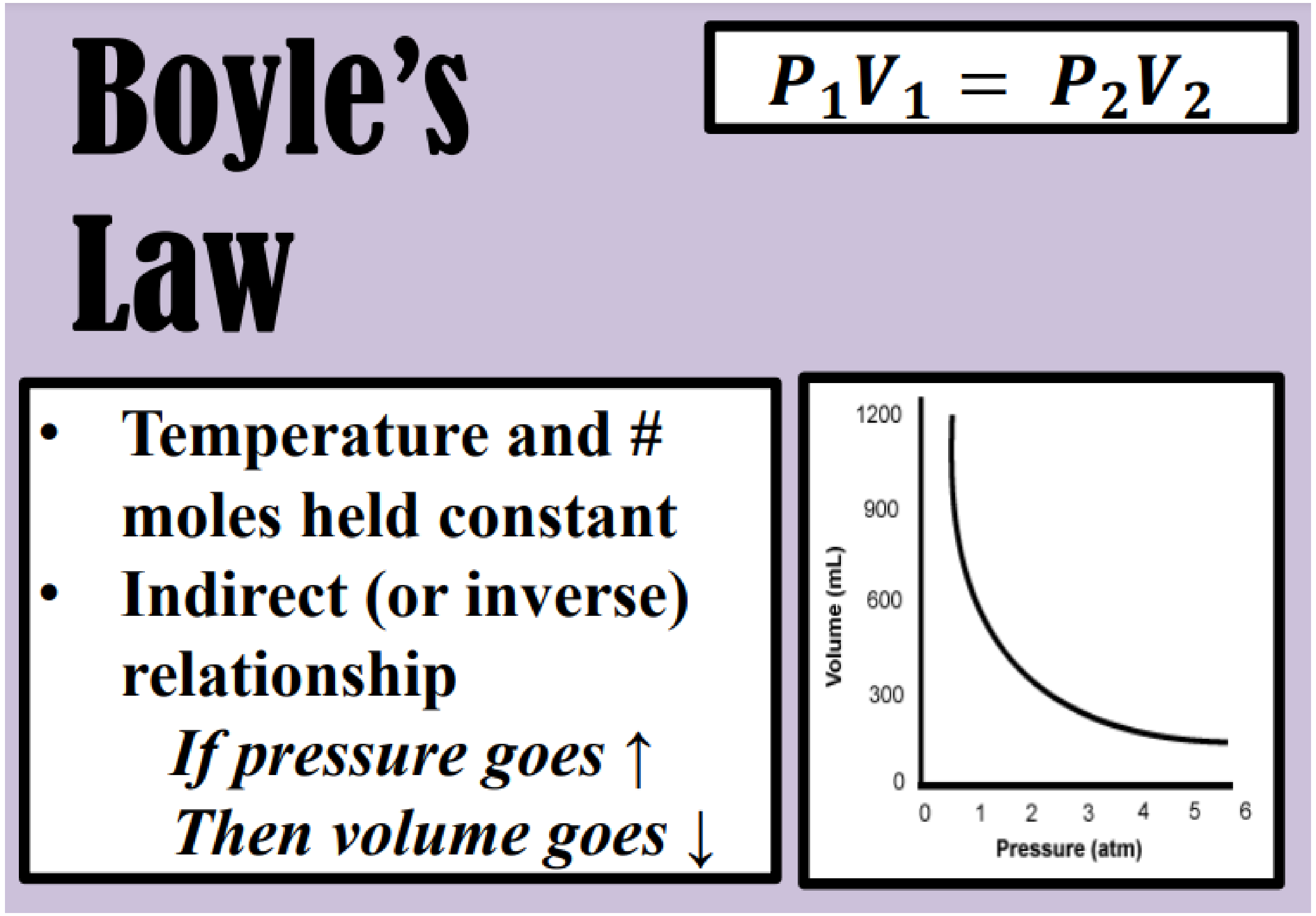


Boyle's Law

$$P_1V_1 = P_2V_2$$



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

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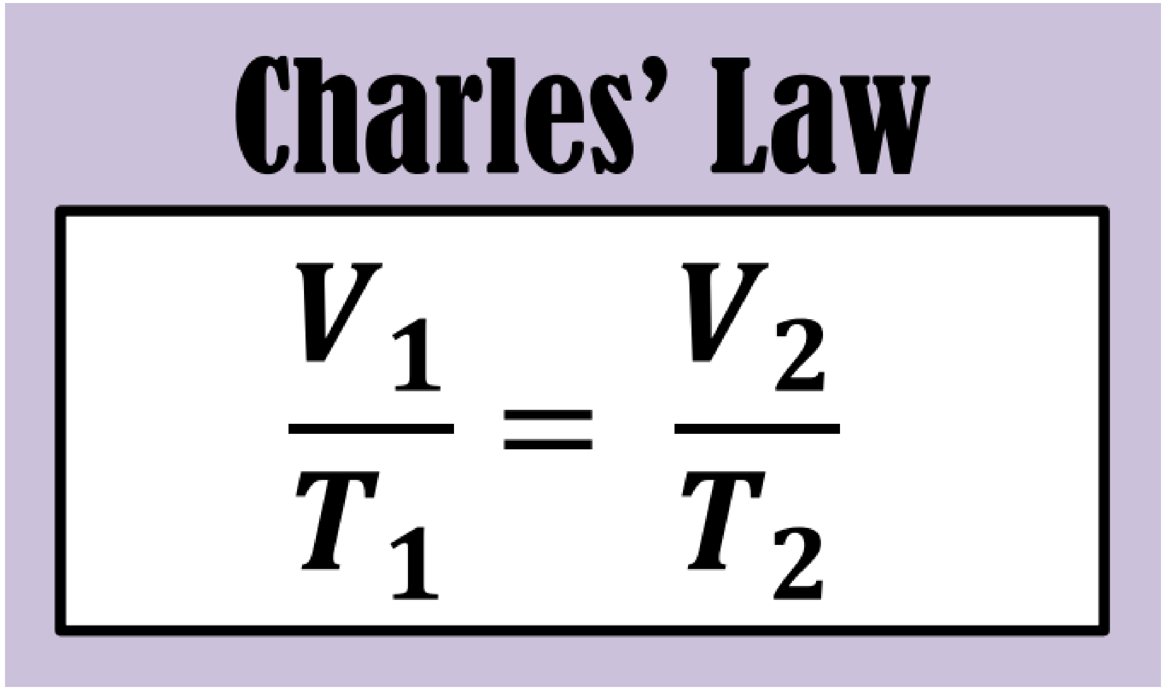
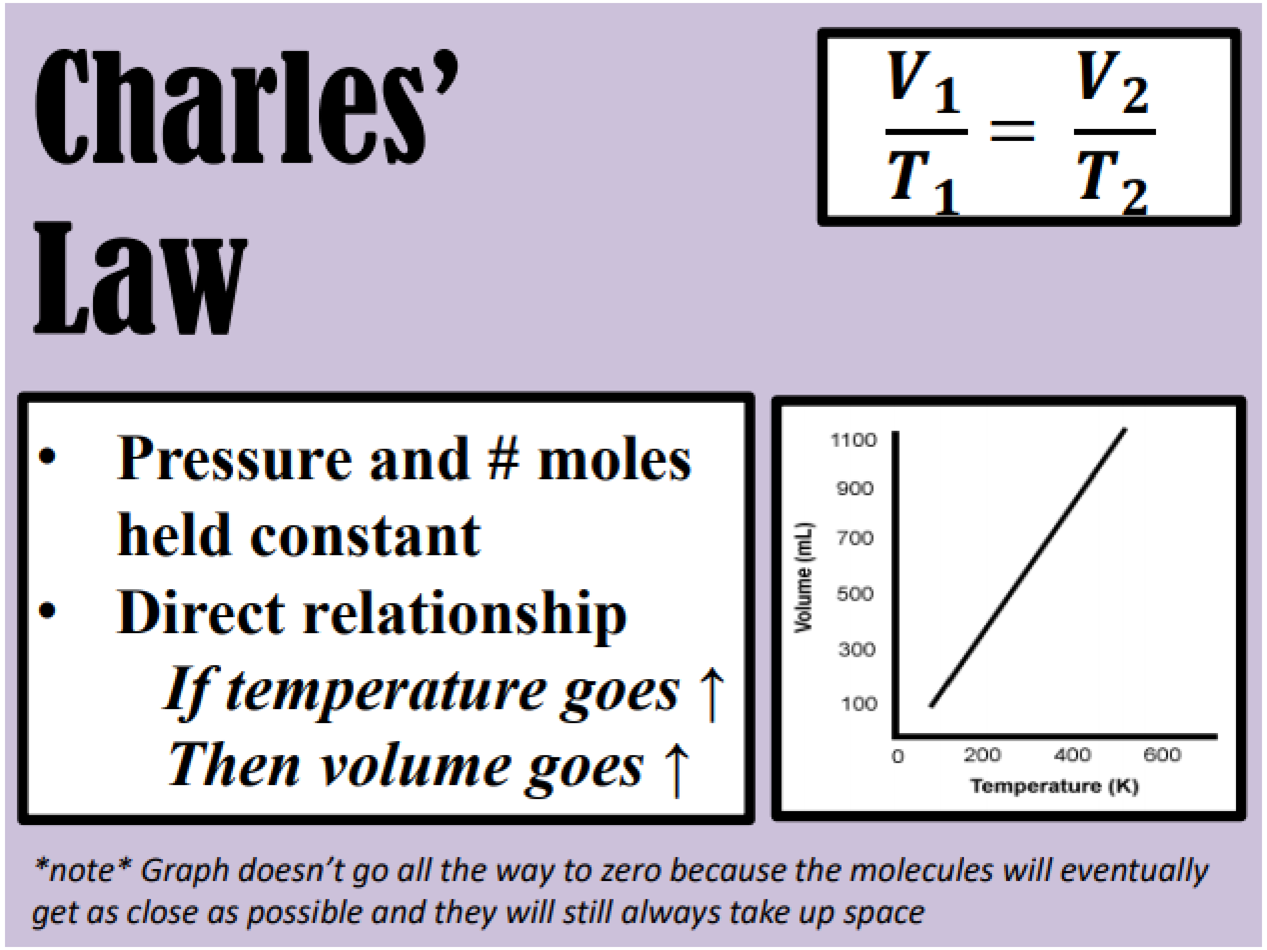


Charles' Law

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



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 ↑

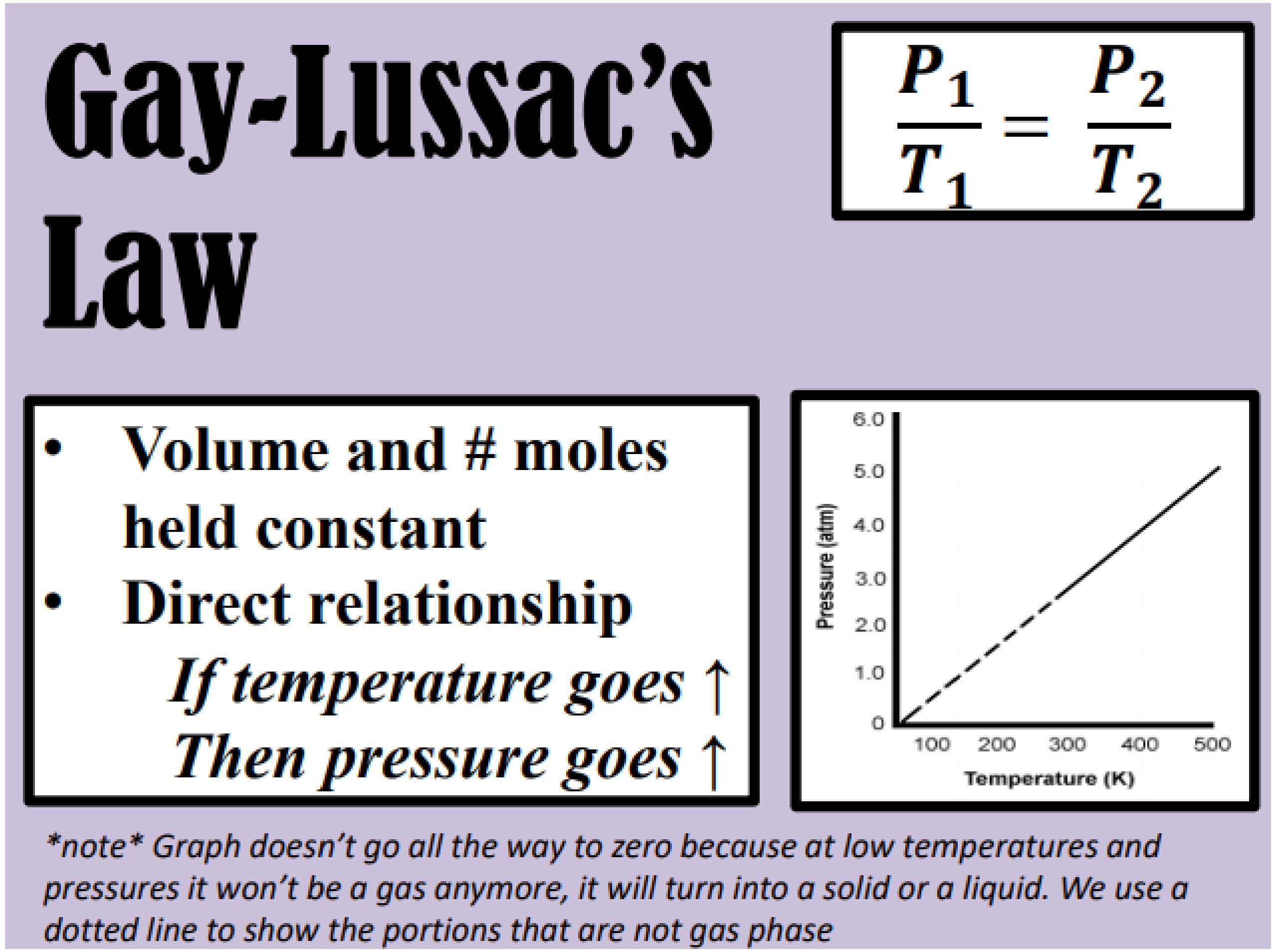
**note* Graph doesn't go all the way to zero because the molecules will eventually get as close as possible and they will still always take up space*

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

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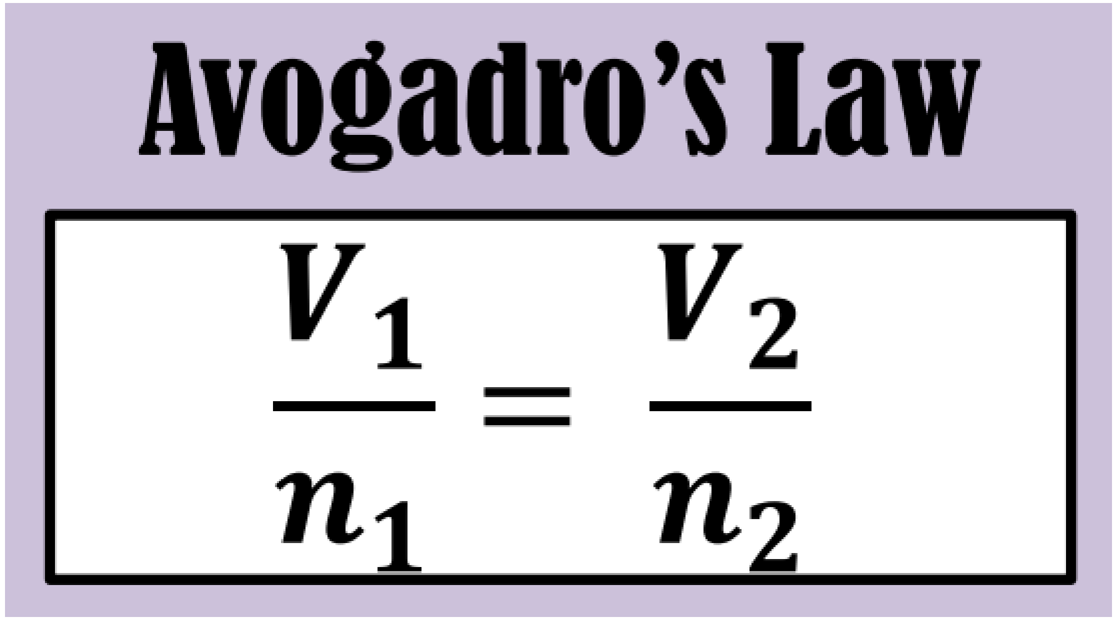
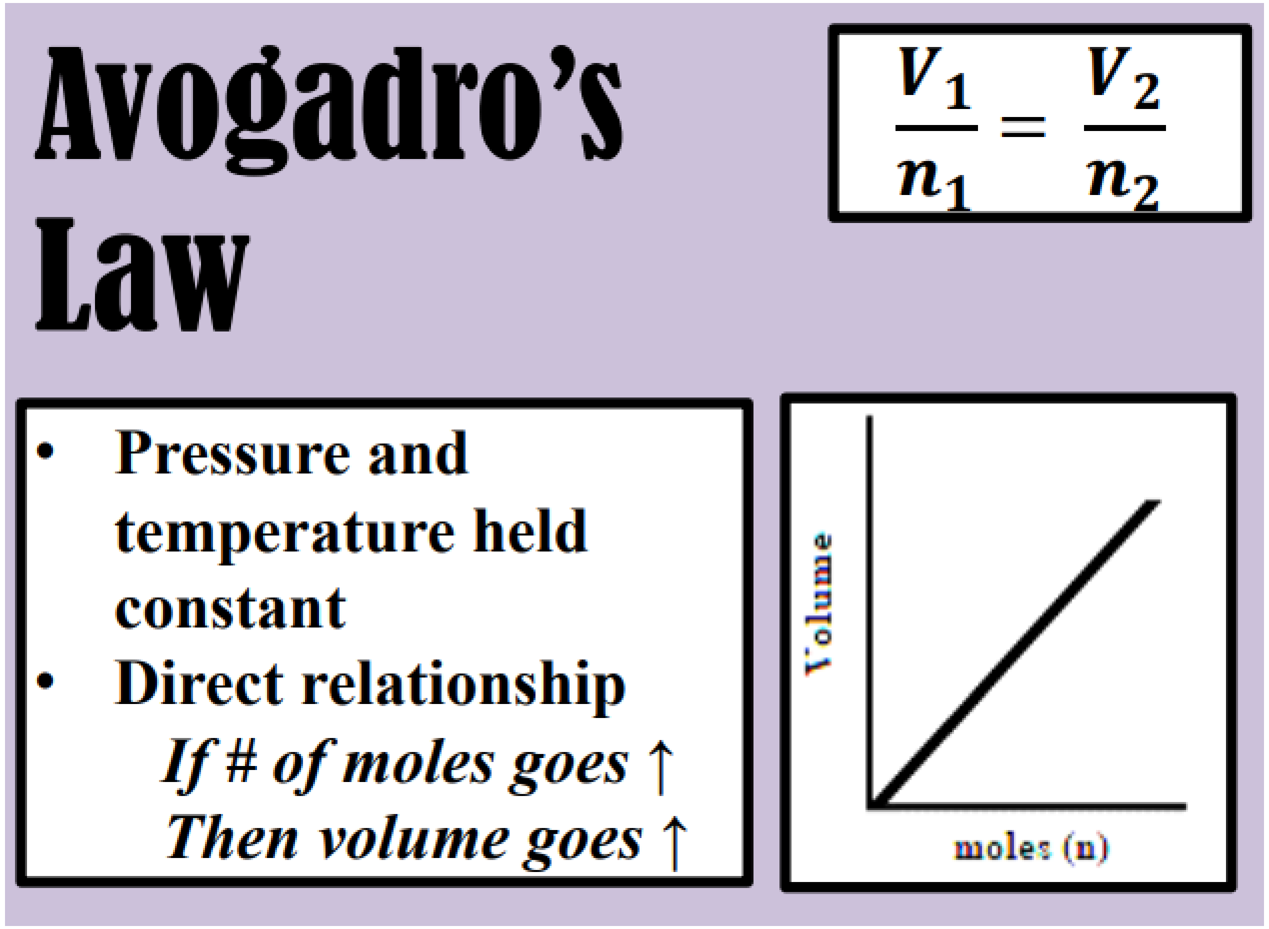


Avogadro's Law

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



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

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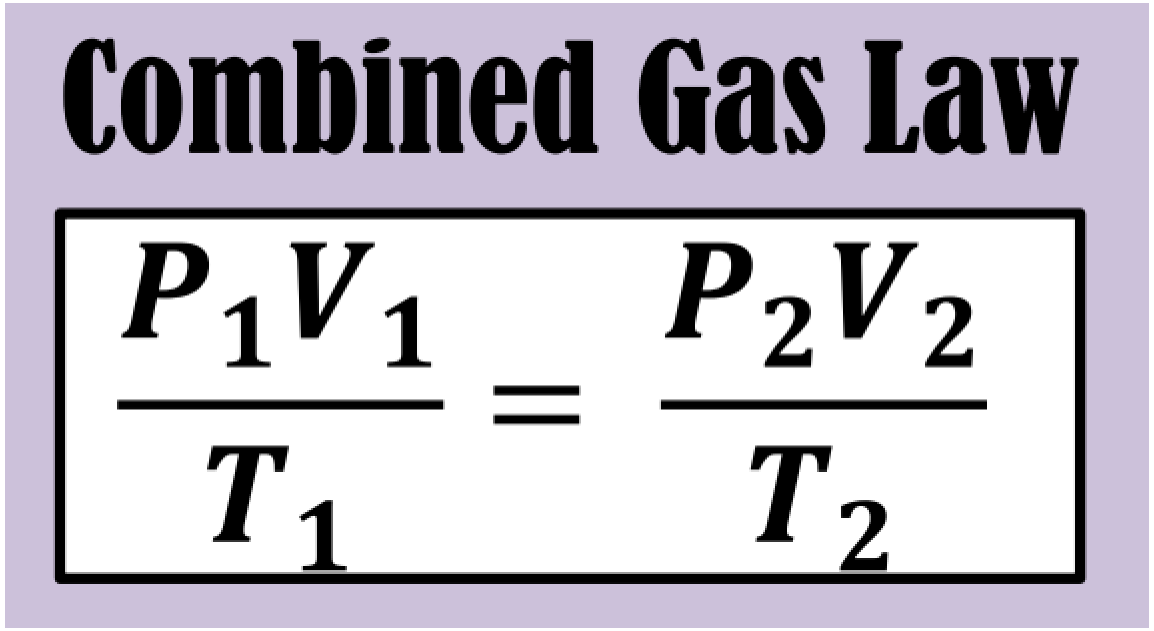
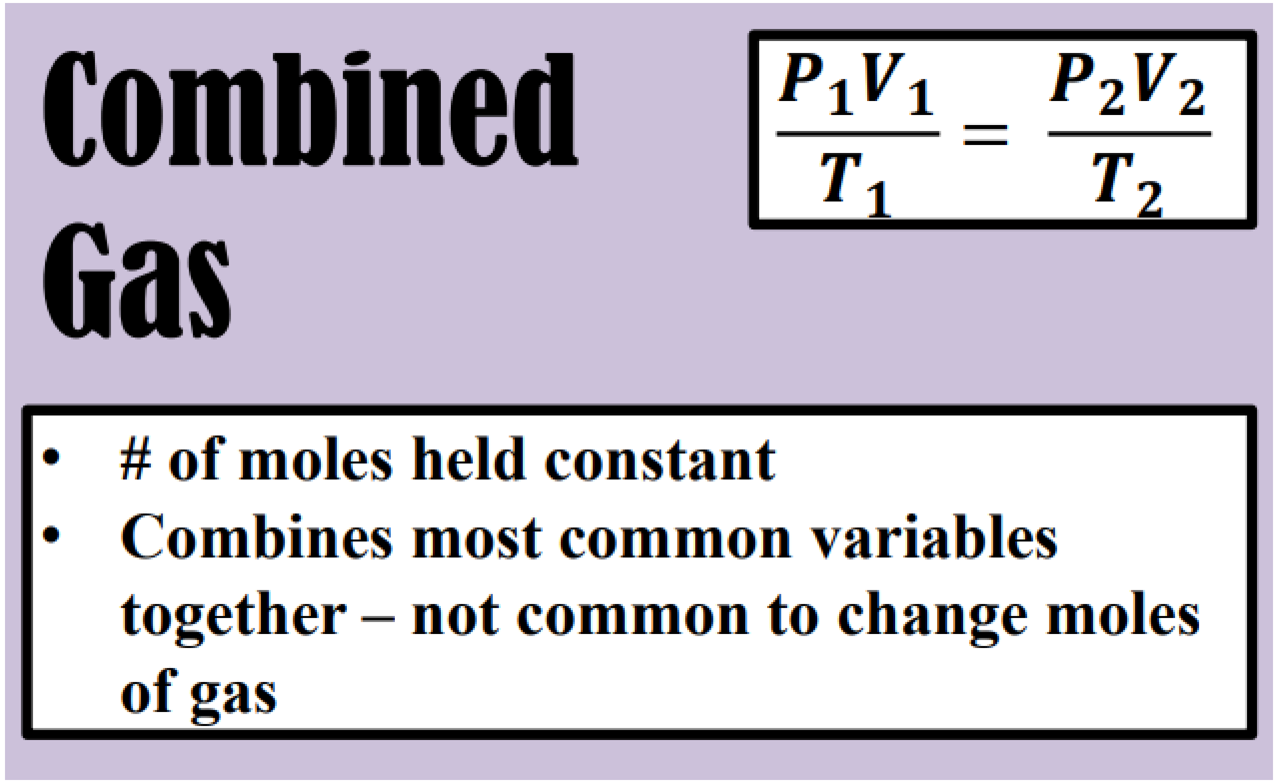


Combined Gas Law

$$\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$$



Combined Gas

$$\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$$

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

Ideal Gas Law

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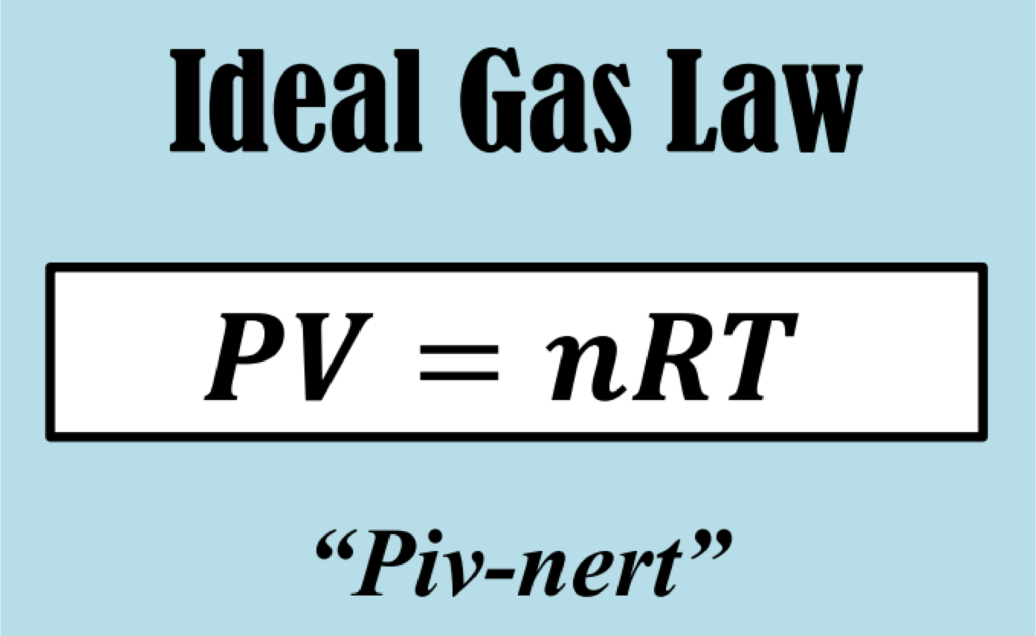
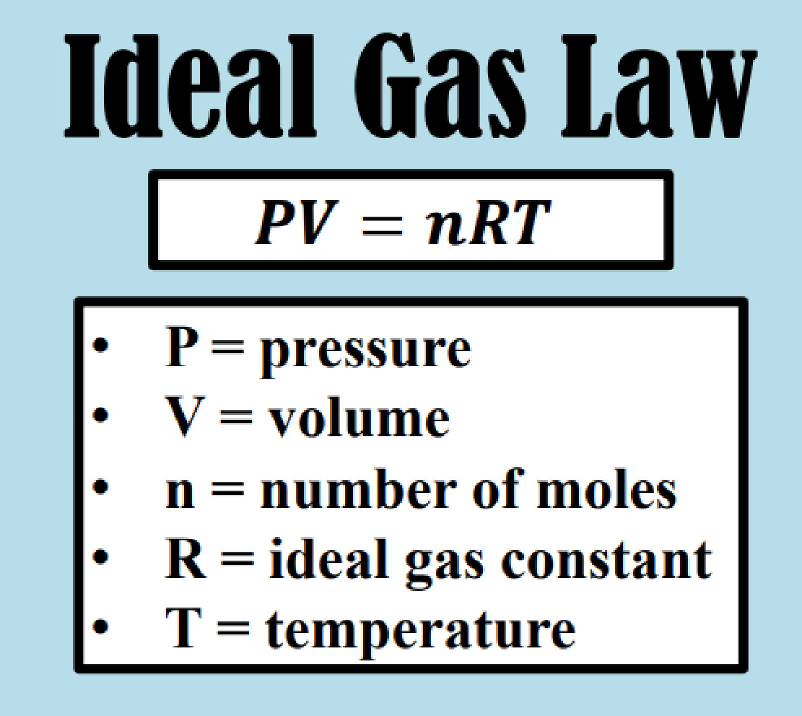


Ideal Gas Law

$$PV = nRT$$

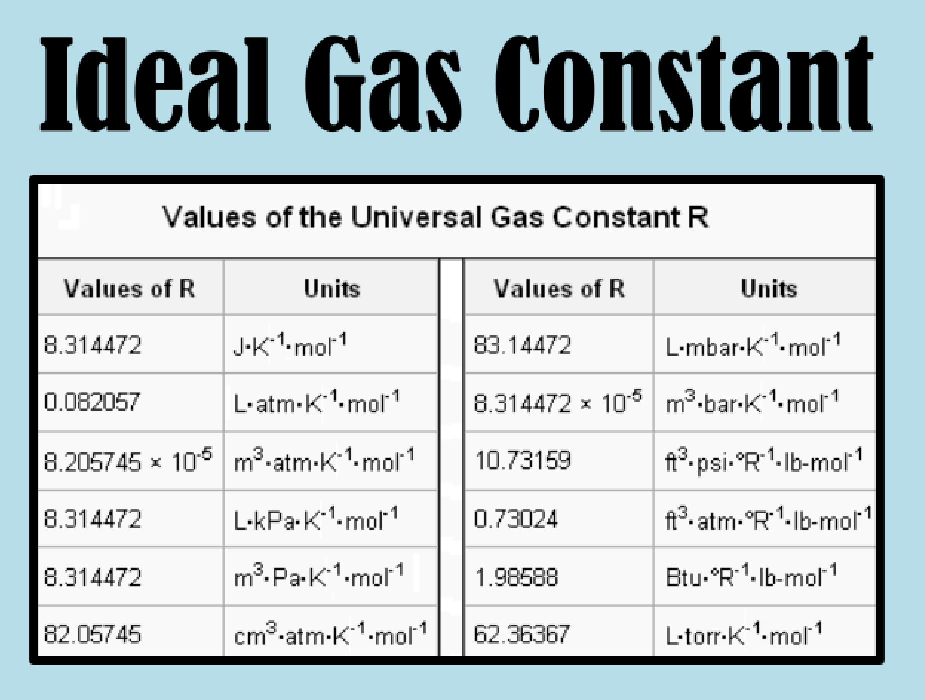
“Piv-nert”



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	$ft^3 \cdot psi \cdot °R^{-1} \cdot lb\text{-}mol^{-1}$
8.314472	$L \cdot kPa \cdot K^{-1} \cdot mol^{-1}$	0.73024	$ft^3 \cdot atm \cdot °R^{-1} \cdot lb\text{-}mol^{-1}$
8.314472	$m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}$	1.98588	$Btu \cdot °R^{-1} \cdot lb\text{-}mol^{-1}$
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

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

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

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

Molar Mass Kitty always puts DIRT over its PEE

Dalton's Law

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Dalton's Law

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

Dalton's Law

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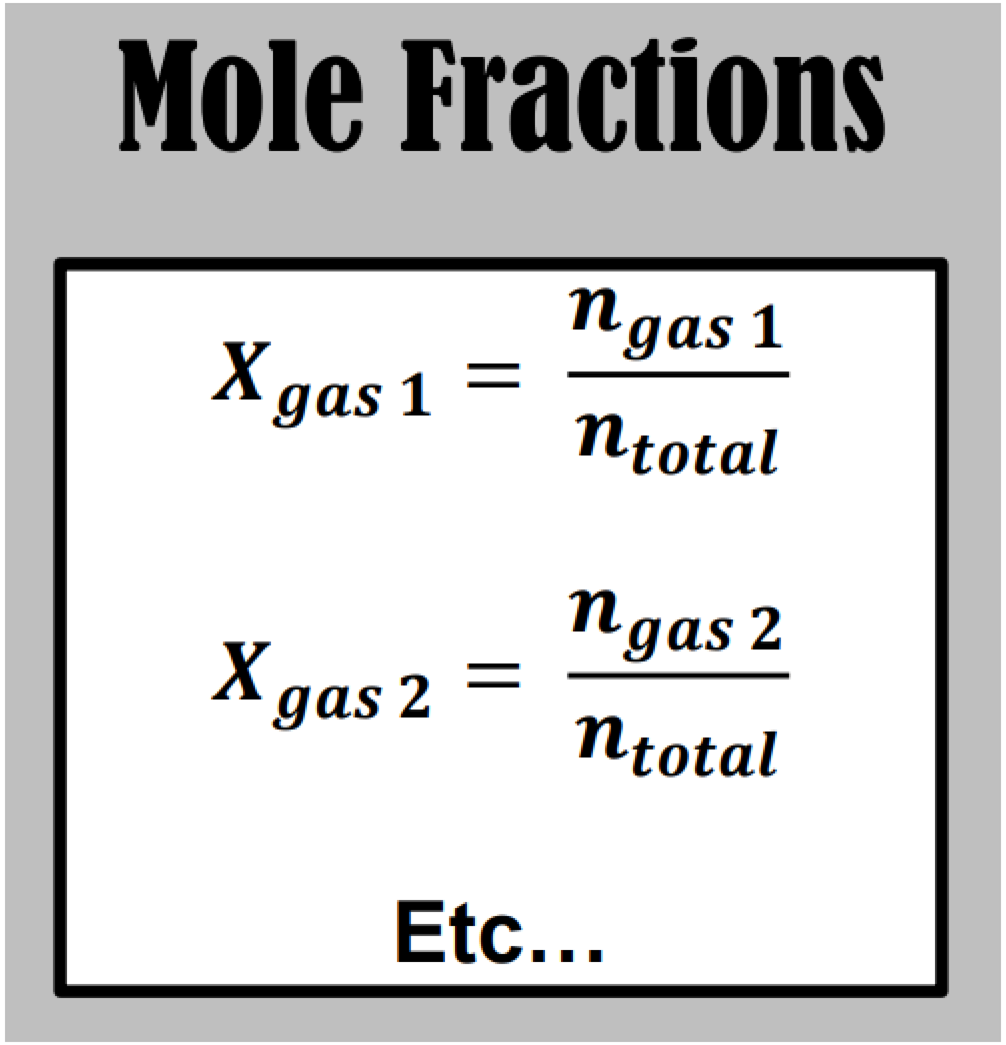


Mole Fractions

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

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

Etc…

Jump back to title slide

Partial Pressure

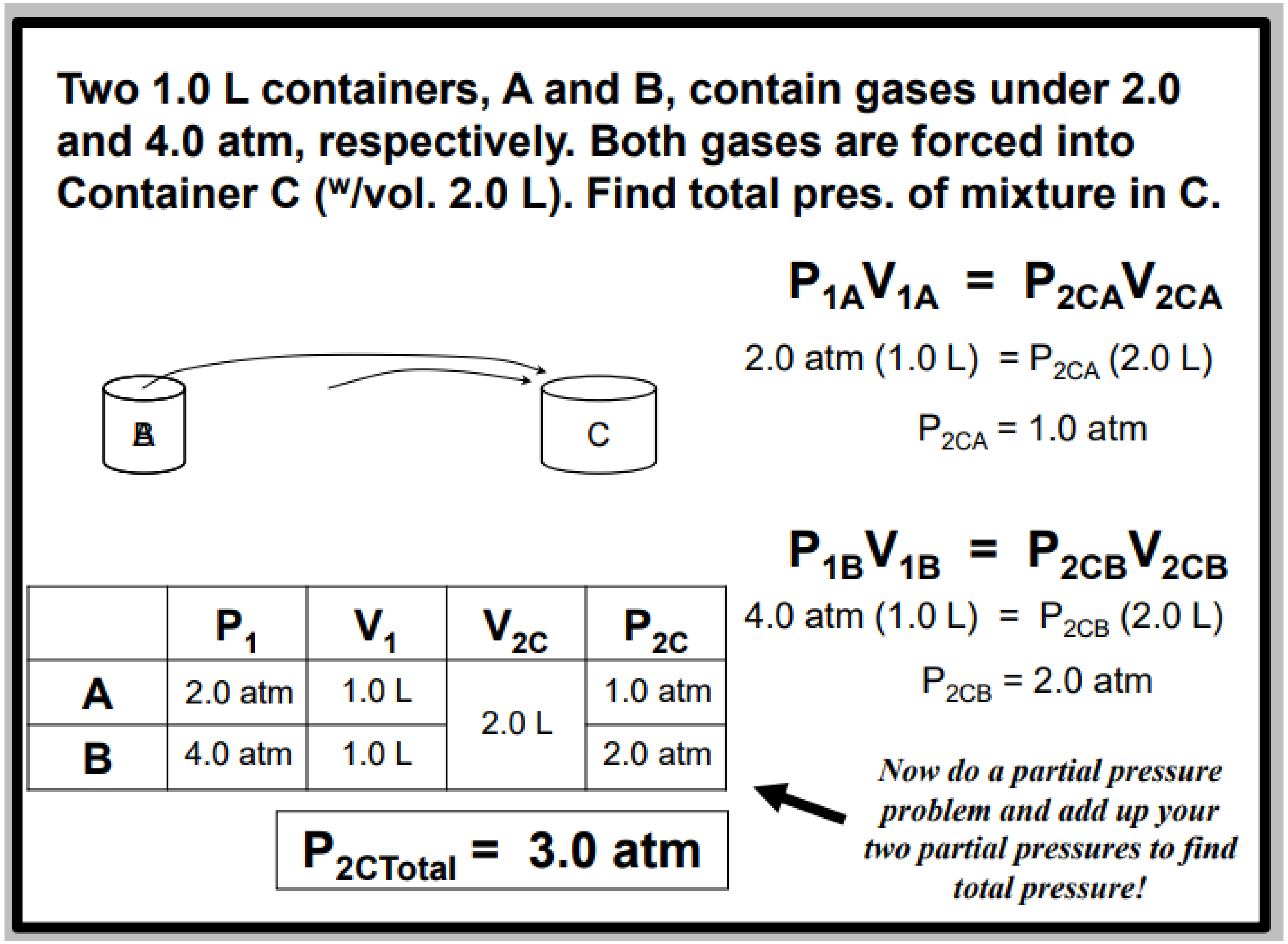
$$P_{gas\ 1} = (X_{gas\ 1}) \bullet (P_{total})$$

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

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

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

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

Dalton’s Law

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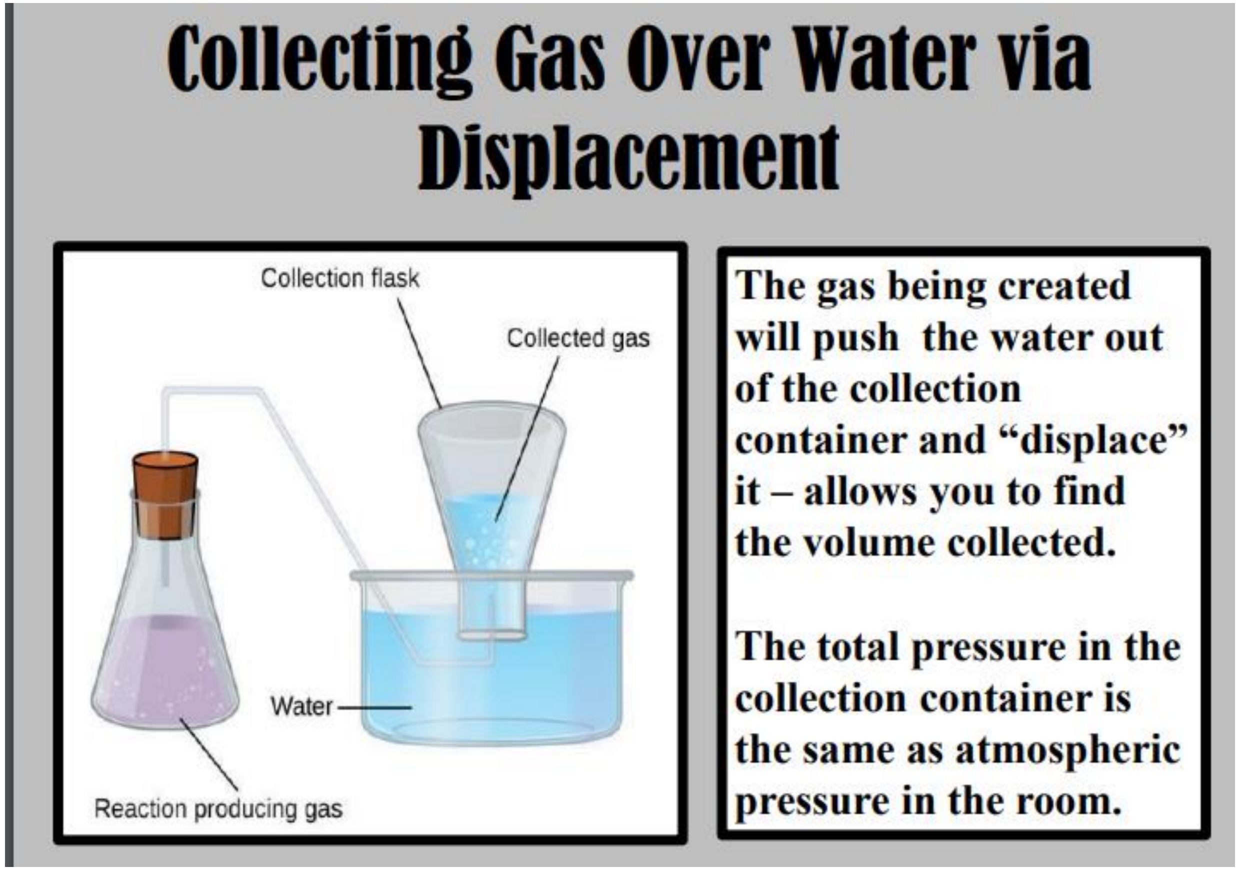
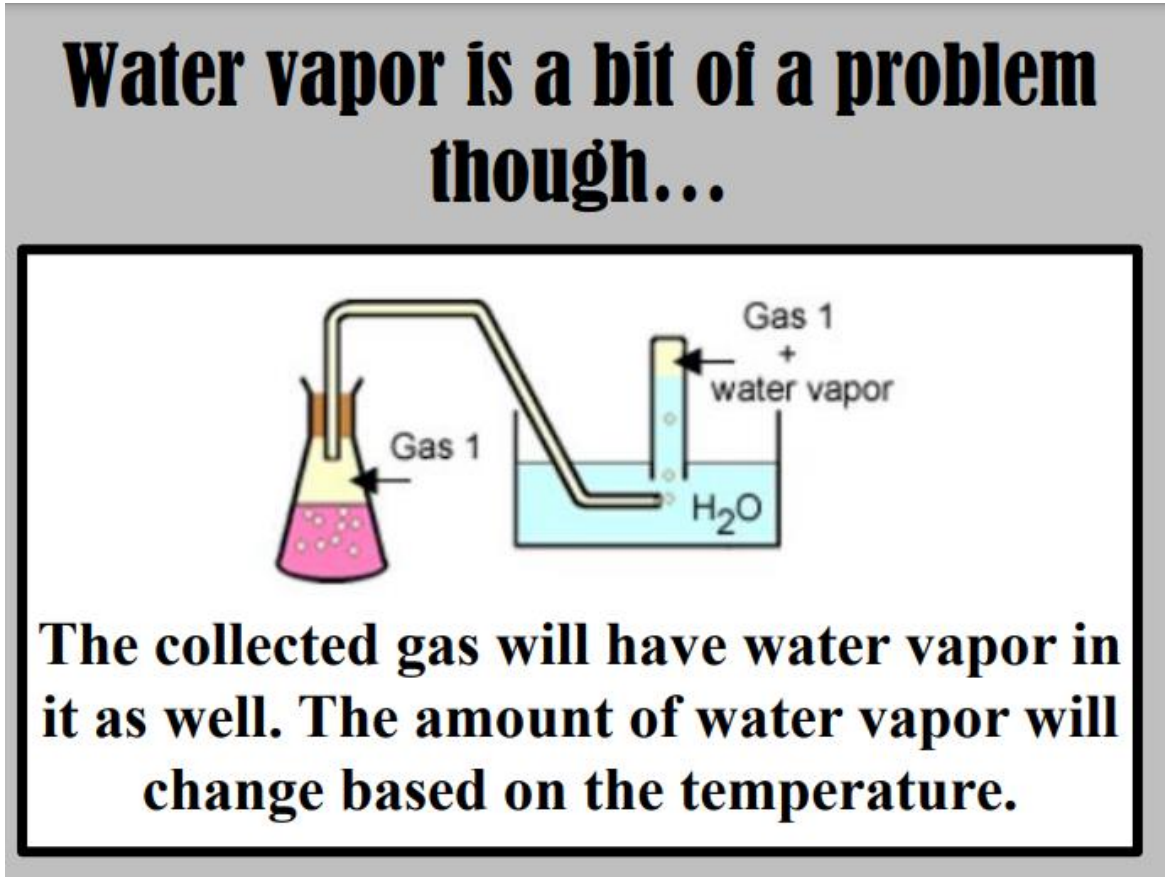


Collecting Gas Over Water via Displacement

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

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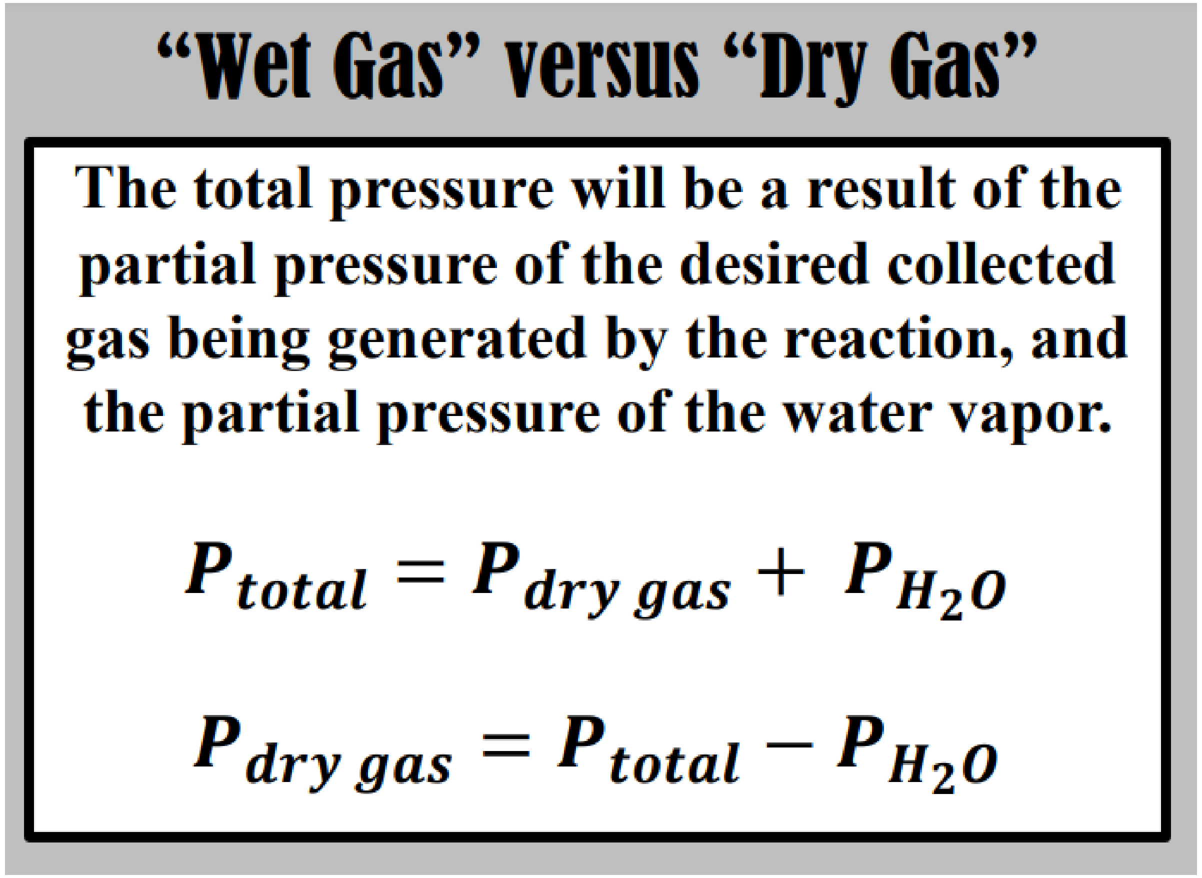
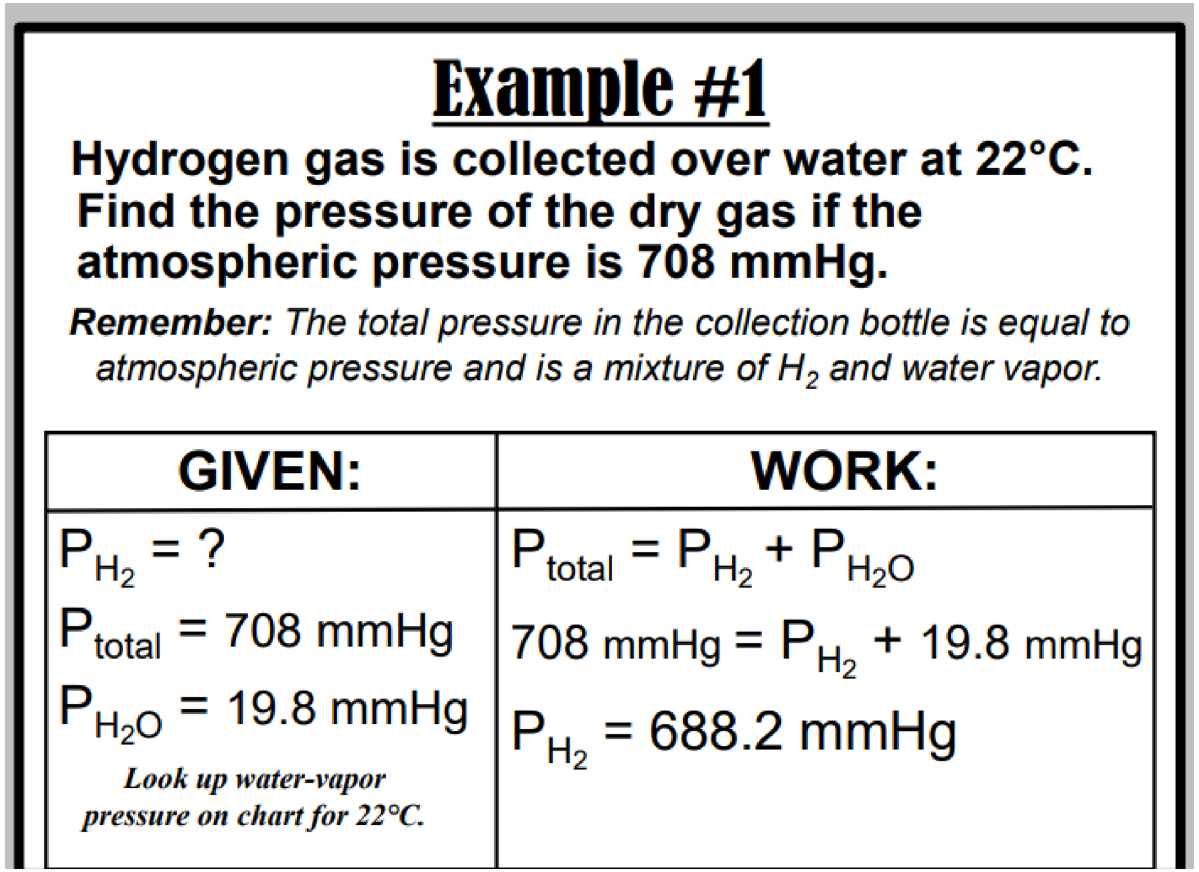


"Wet Gas" versus "Dry Gas"

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

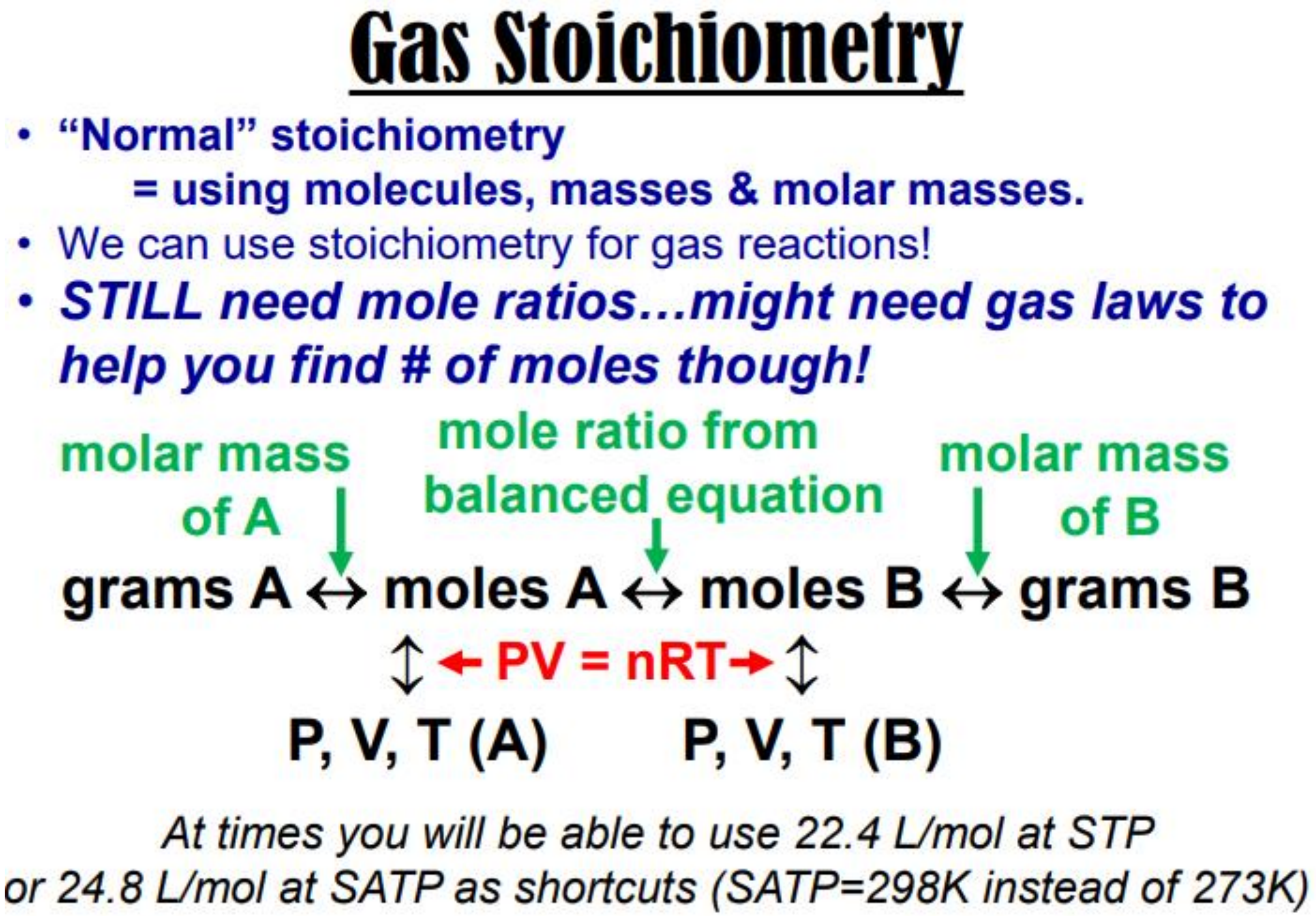
Hydrogen gas is collected over water at 22°C. Find the pressure of the dry gas if the atmospheric pressure is 708 mmHg.

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

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

Mole Ratio

mol CH_4 → mol O_2 :

$$\frac{0.167\ \cancel{\text{mol CH}_4}}{} \left| \frac{2\ \text{mol O}_2}{1\ \cancel{\text{mol CH}_4}} \right. = \mathbf{0.334\ mol\ O_2}$$

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

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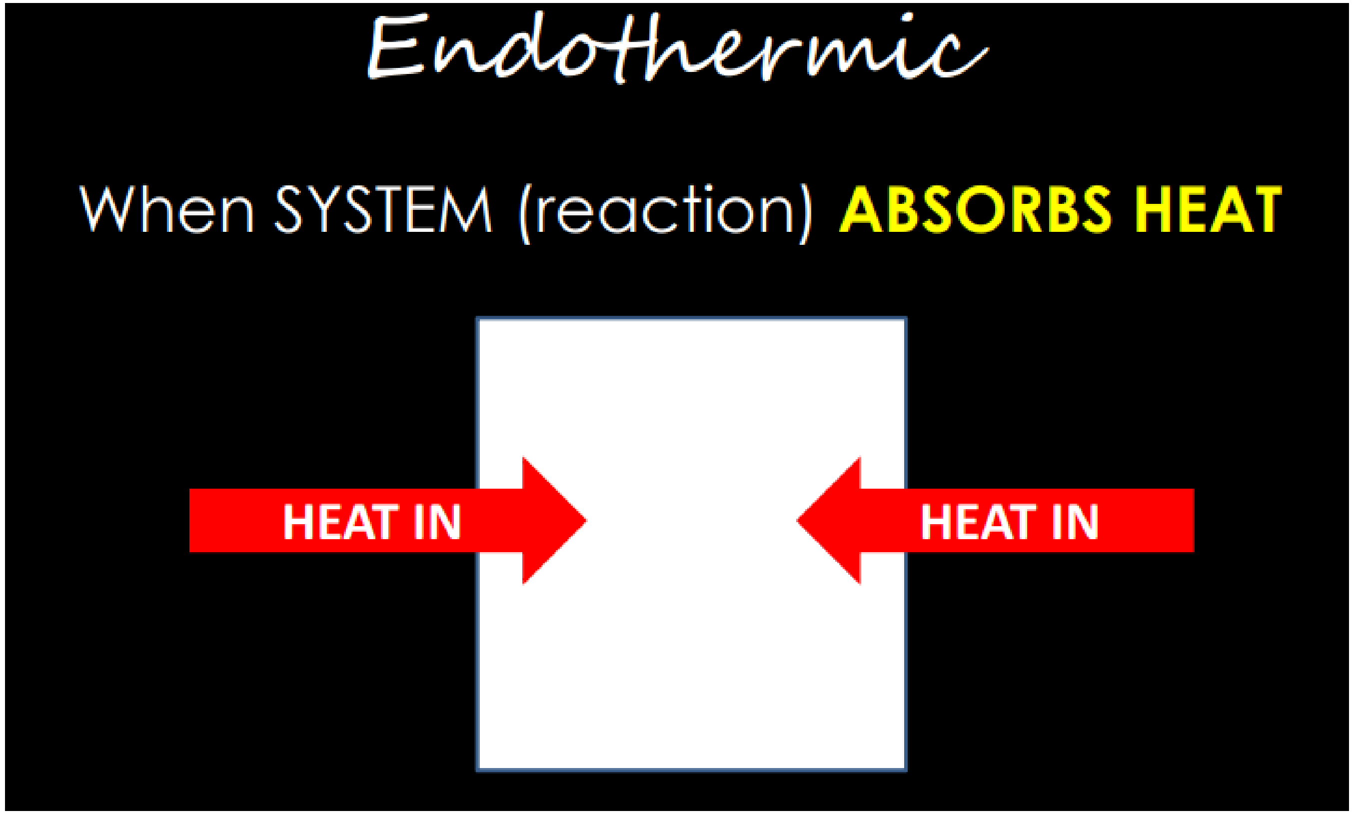
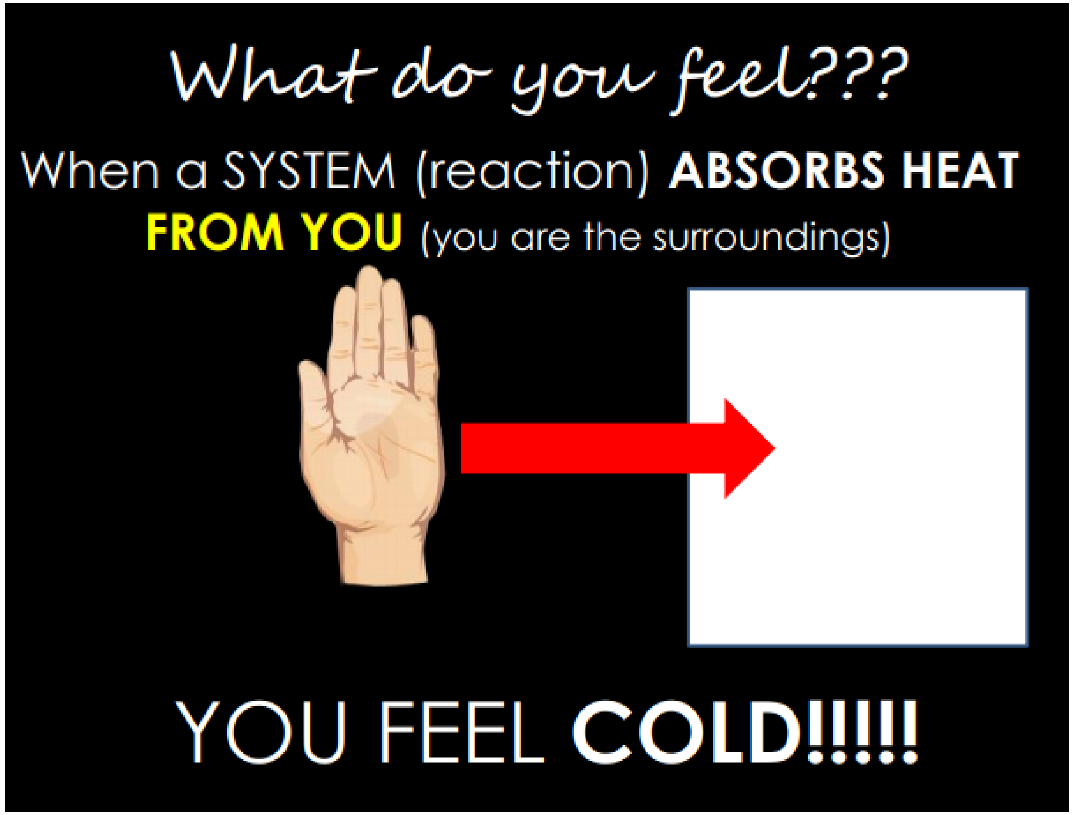


Endothermic

When SYSTEM (reaction) **ABSORBS HEAT**



What do you feel???

When a SYSTEM (reaction) **ABSORBS HEAT FROM YOU** (you are the surroundings)

YOU FEEL **COLD!!!!!**

Endo vs. Exo

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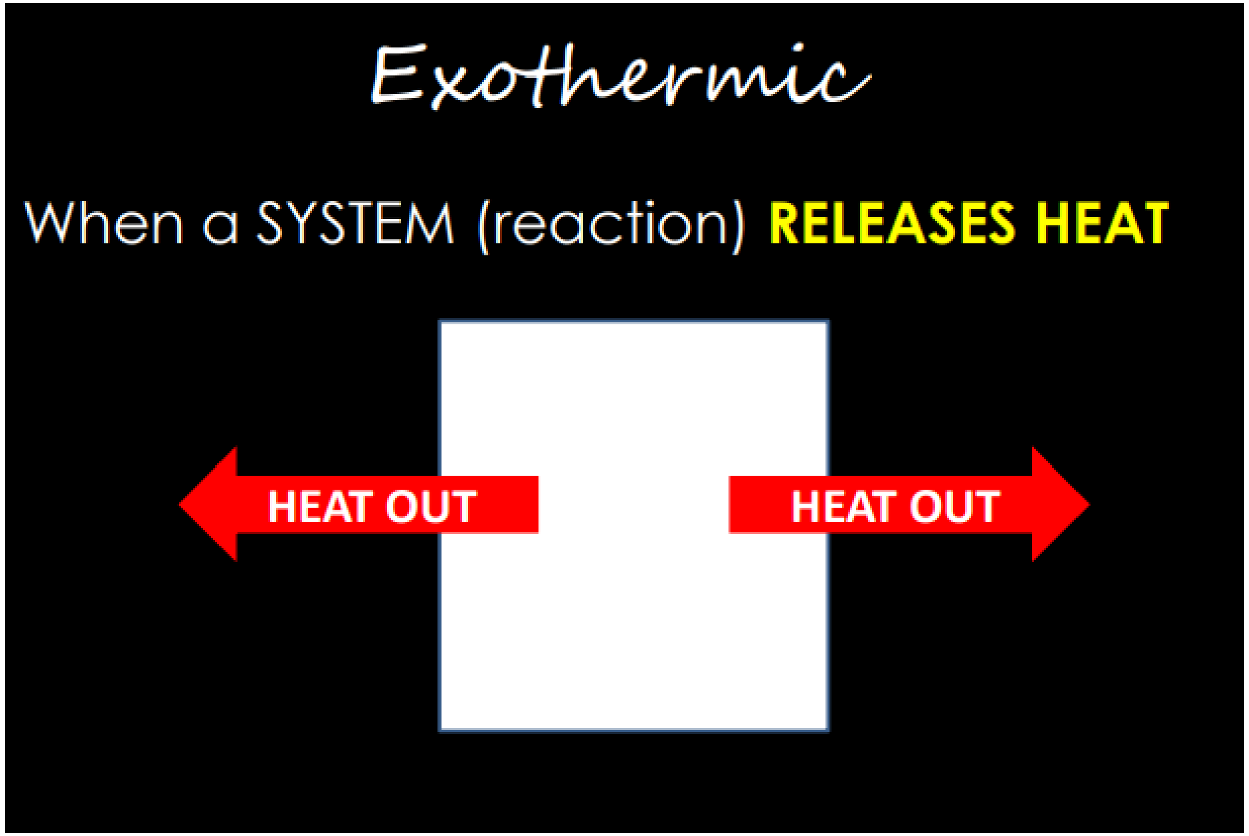
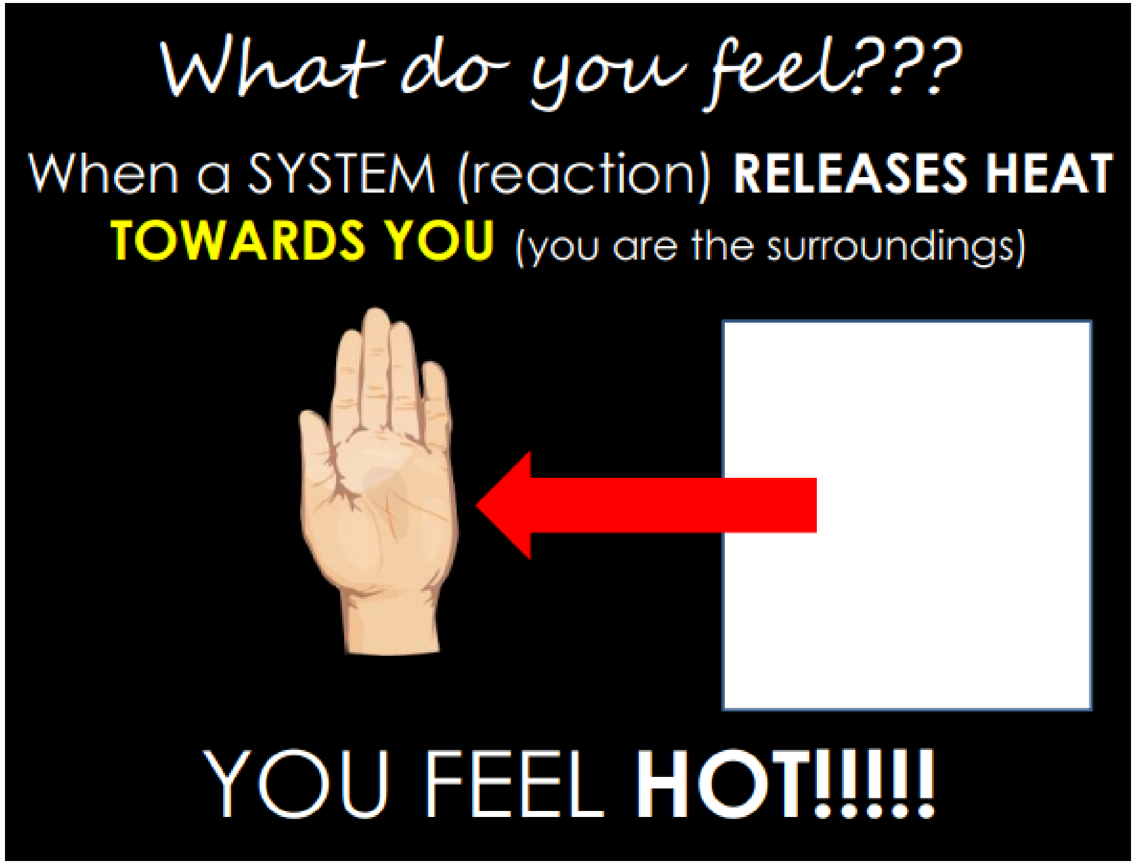


Exothermic

When a SYSTEM (reaction) **RELEASES HEAT**



What do you feel???

When a SYSTEM (reaction) **RELEASES HEAT TOWARDS YOU** (you are the surroundings)

YOU FEEL **HOT!!!!!**

Endo vs. Exo

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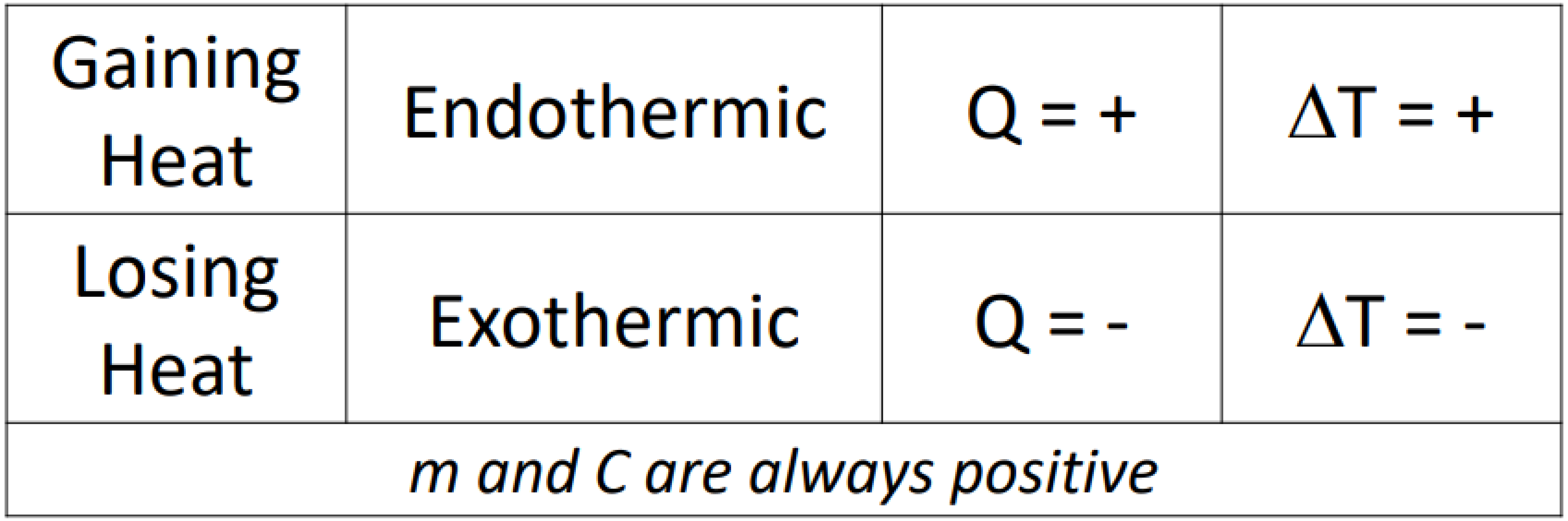
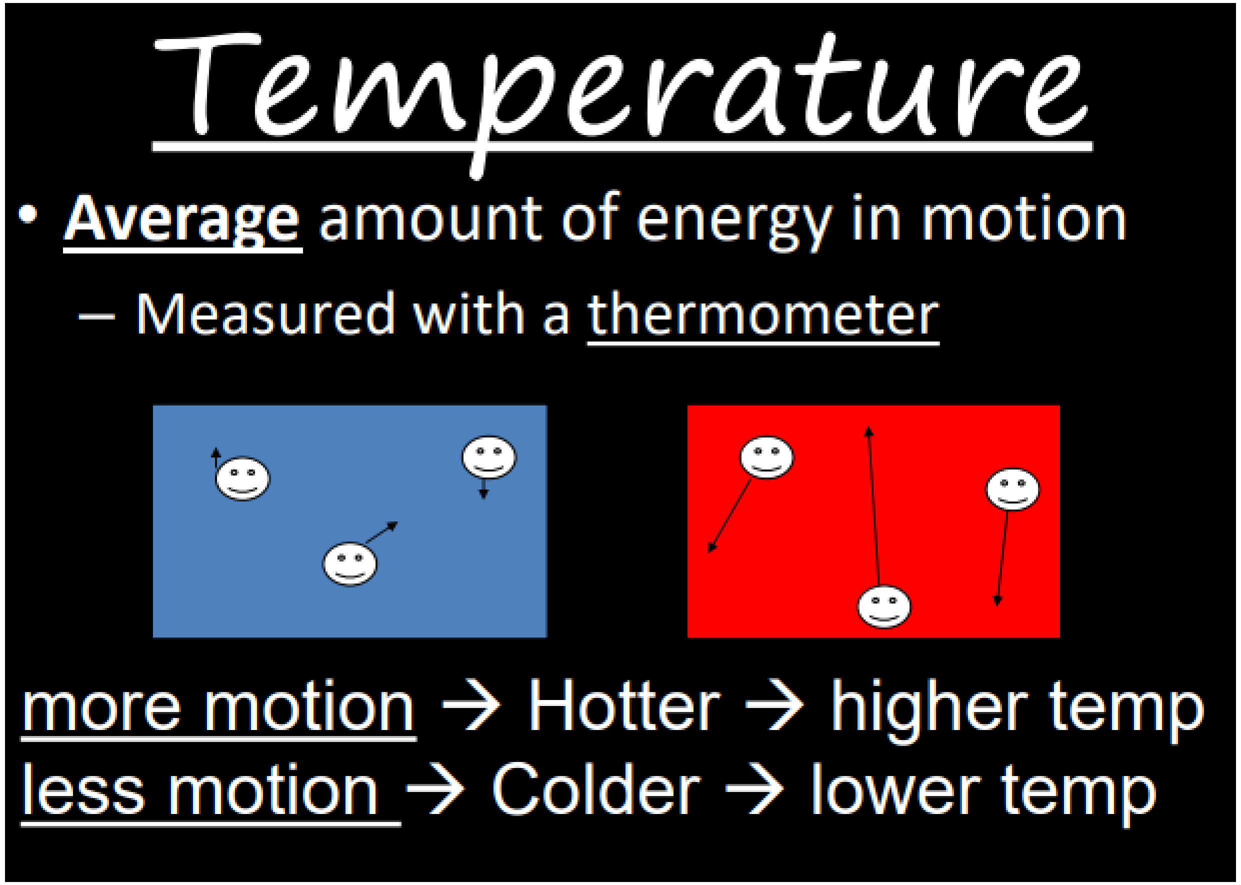


Gaining Heat	Endothermic	Q = +	ΔT = +
Losing Heat	Exothermic	Q = -	ΔT = -
m and C are always positive			

Thermo

Jump back to title slide



Temperature

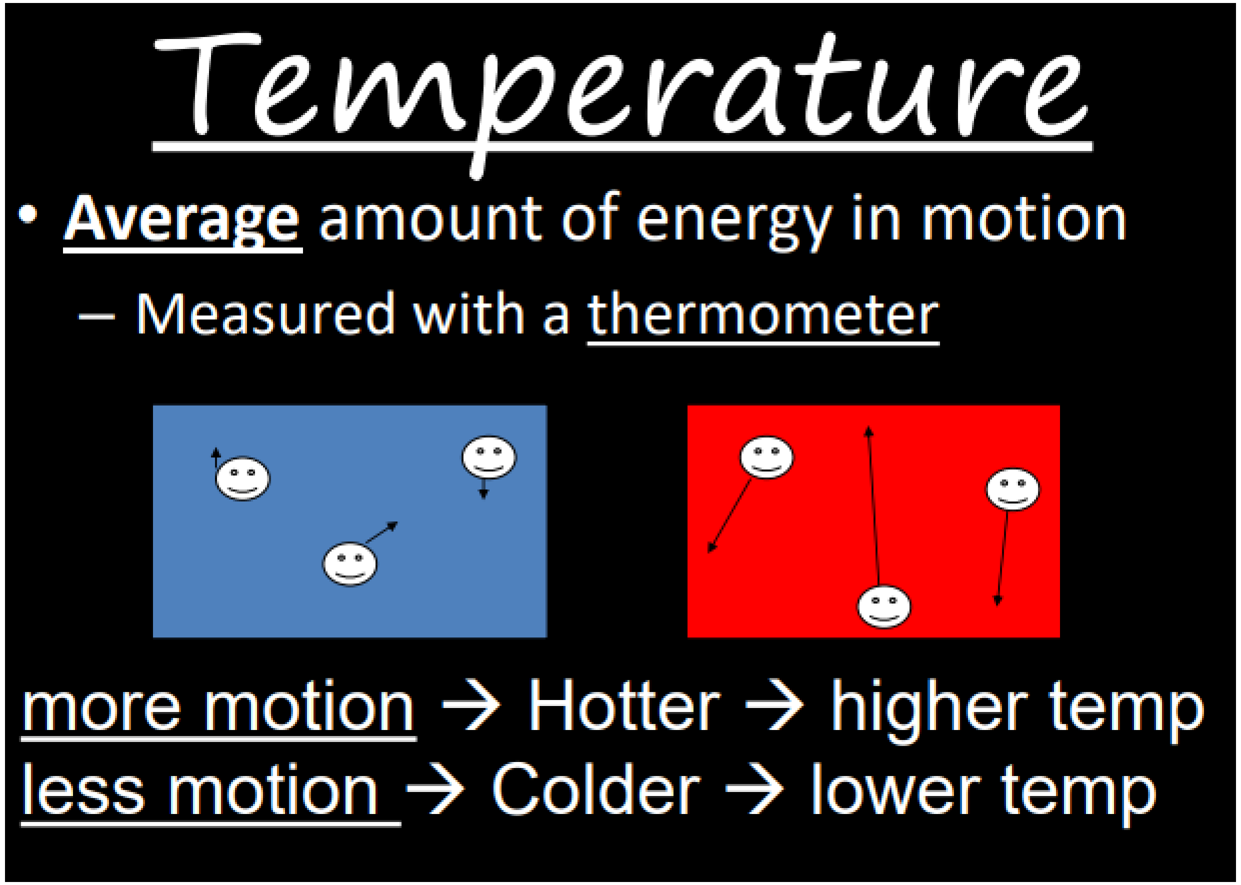
- **Average** amount of energy in motion
  - Measured with a thermometer

more motion → Hotter → higher temp

less motion → Colder → lower temp

Thermo

Jump back to title slide



Temperature

- **Average** amount of energy in motion
  - Measured with a thermometer

more motion → Hotter → higher temp

less motion → Colder → lower temp

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:

$$\frac{J}{g\ {}^{\circ}C}$$

$$Q = mC\Delta T$$

C = specific heat

Q = energy lost or gained

m = mass

ΔT = "delta" T or change in temp

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

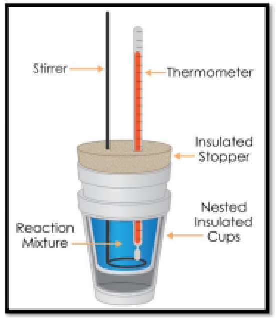
Calorimetry

Jump back to title slide

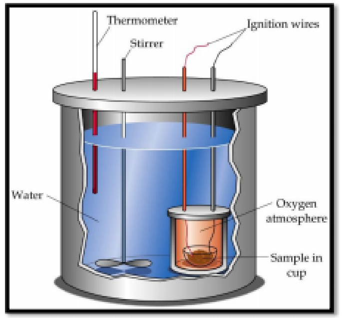
Purpose of Calorimetry

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

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

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

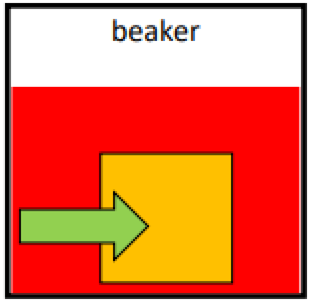
Calorimetry

Jump back to title slide

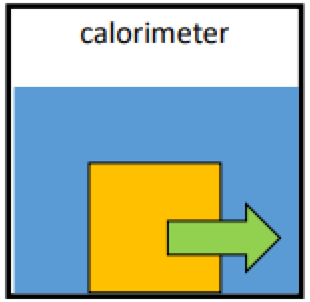
ENERGY IN = ENERGY OUT

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} = ?

m_{water} = From the water you put in the calorimeter

1mL = 1g

C_{water} = 4.184 J/g°C

ΔT_{water} = Tf – Ti

(From your thermometer readings)

Q_{metal} = $-Q_{water}$

Energy IN must = energy OUT!

(opposite sign, not necessarily negative)

m_{metal} = From your scale

C_{metal} = ?

ΔT_{metal} = Tf – Ti

Tf − 100°C

From water

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

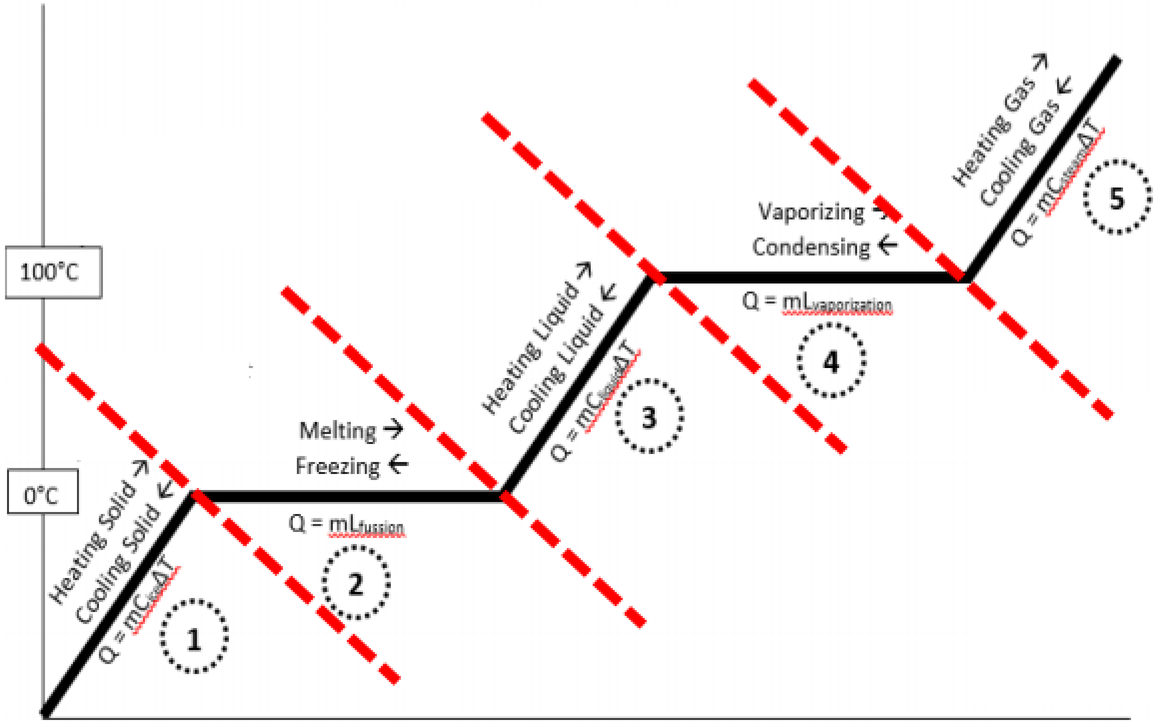
Jump back to title slide

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



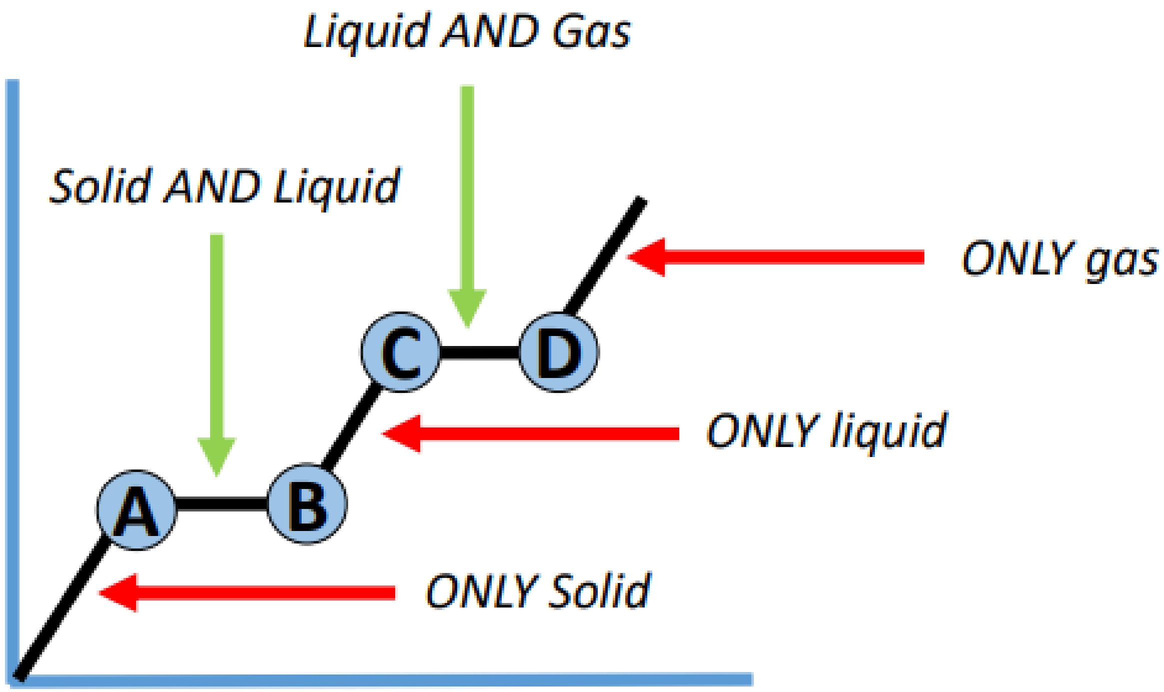
Calculate everything separately and then add up your answers. You could have up to five Q values to add up!

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

Heating Curves

Jump back to title slide

- **A** *ONLY Solid at 0°C*
- **B** *ONLY Liquid at 0°C*
- **C** *ONLY Liquid at 100°C*
- **D** *ONLY Gas at 100°C*



Liquid AND Gas

Solid AND Liquid

ONLY gas

ONLY liquid

ONLY Solid

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**

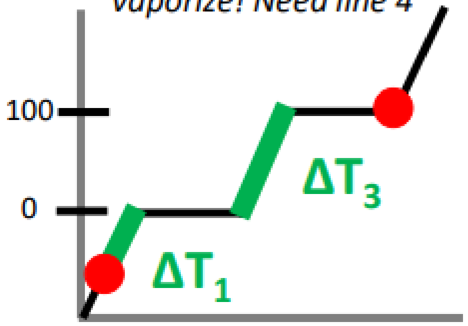
① Heat ice

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*

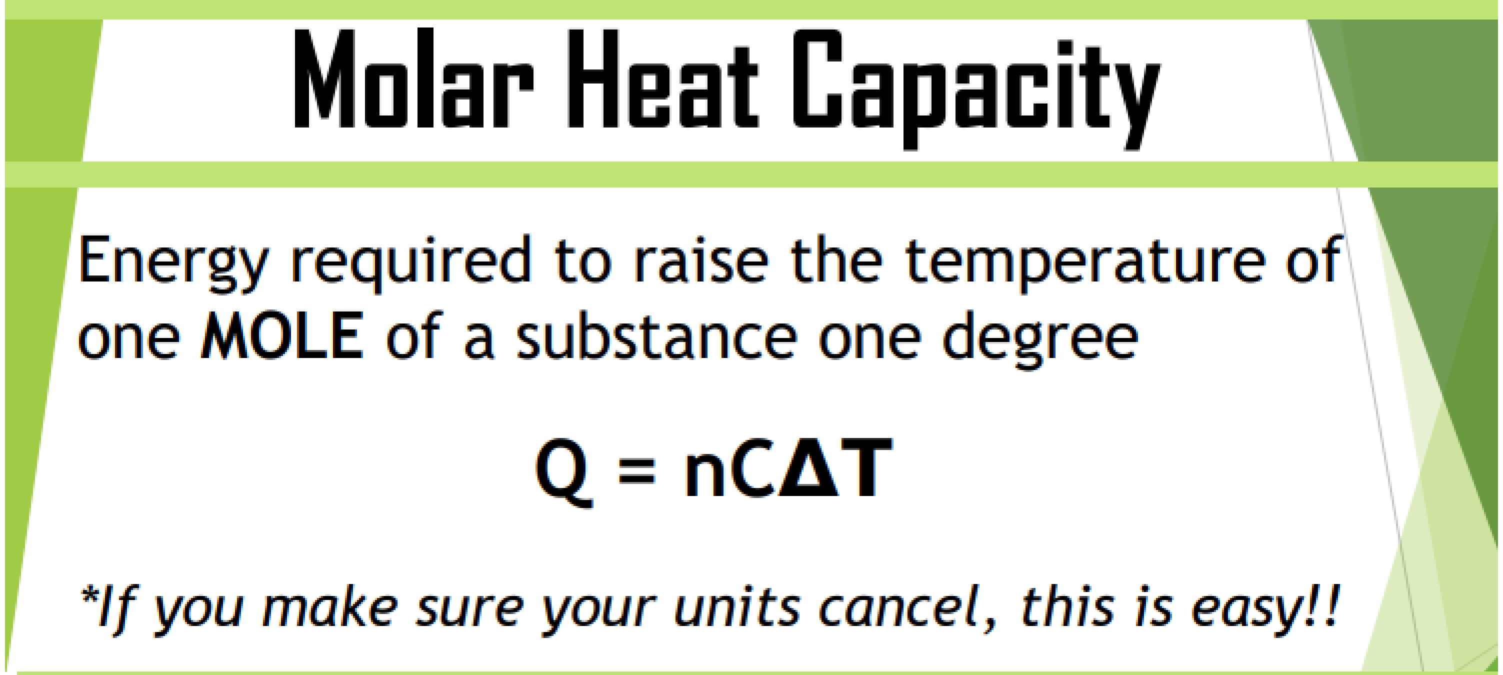
$Q_4 = mL = (21.1g)(2260\ J/g) =$ *47686 J*

$Q_T = Q_1 + Q_2 + Q_3 + Q_4$

$\boxed{= 63817.79\ J}$

Heat of Reaction

Jump back to title slide

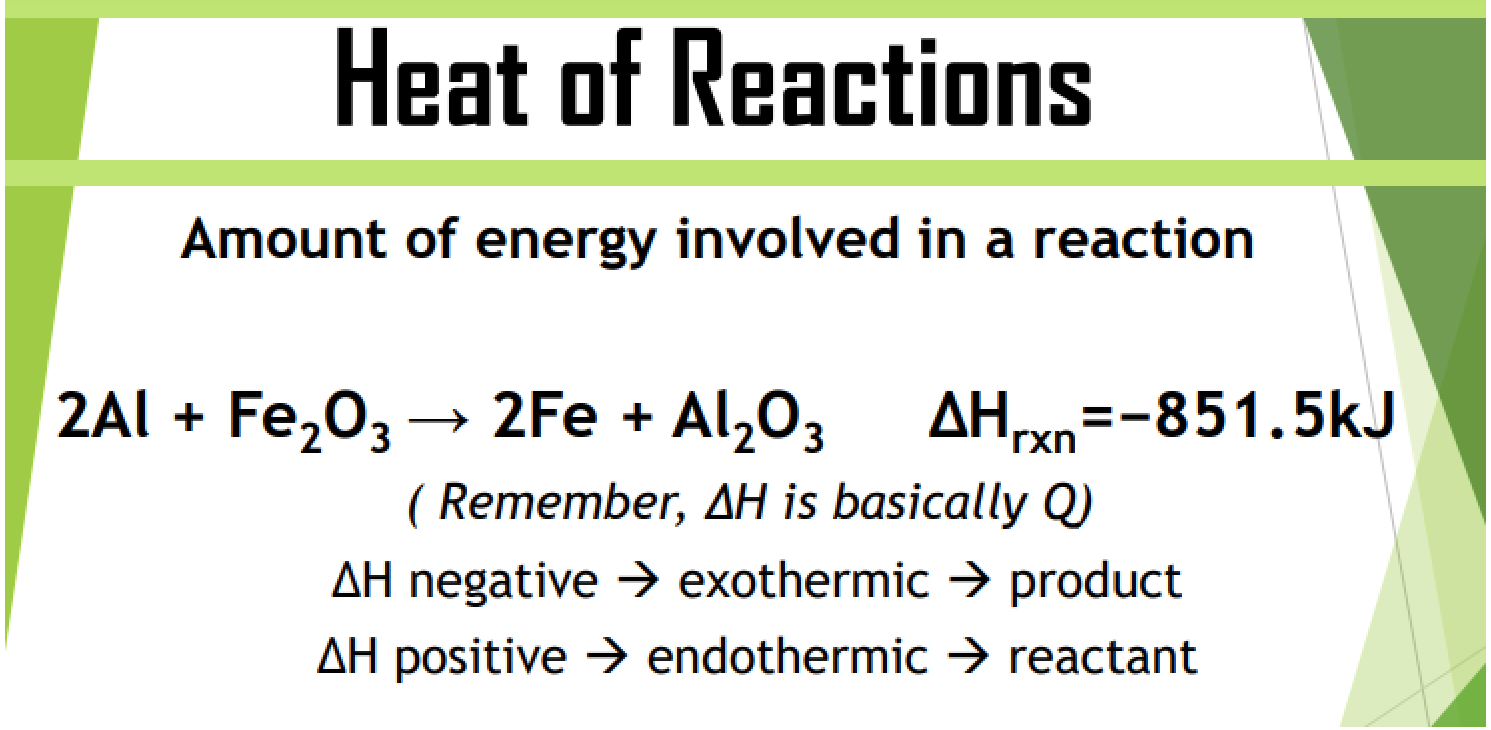


Molar Heat Capacity

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

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

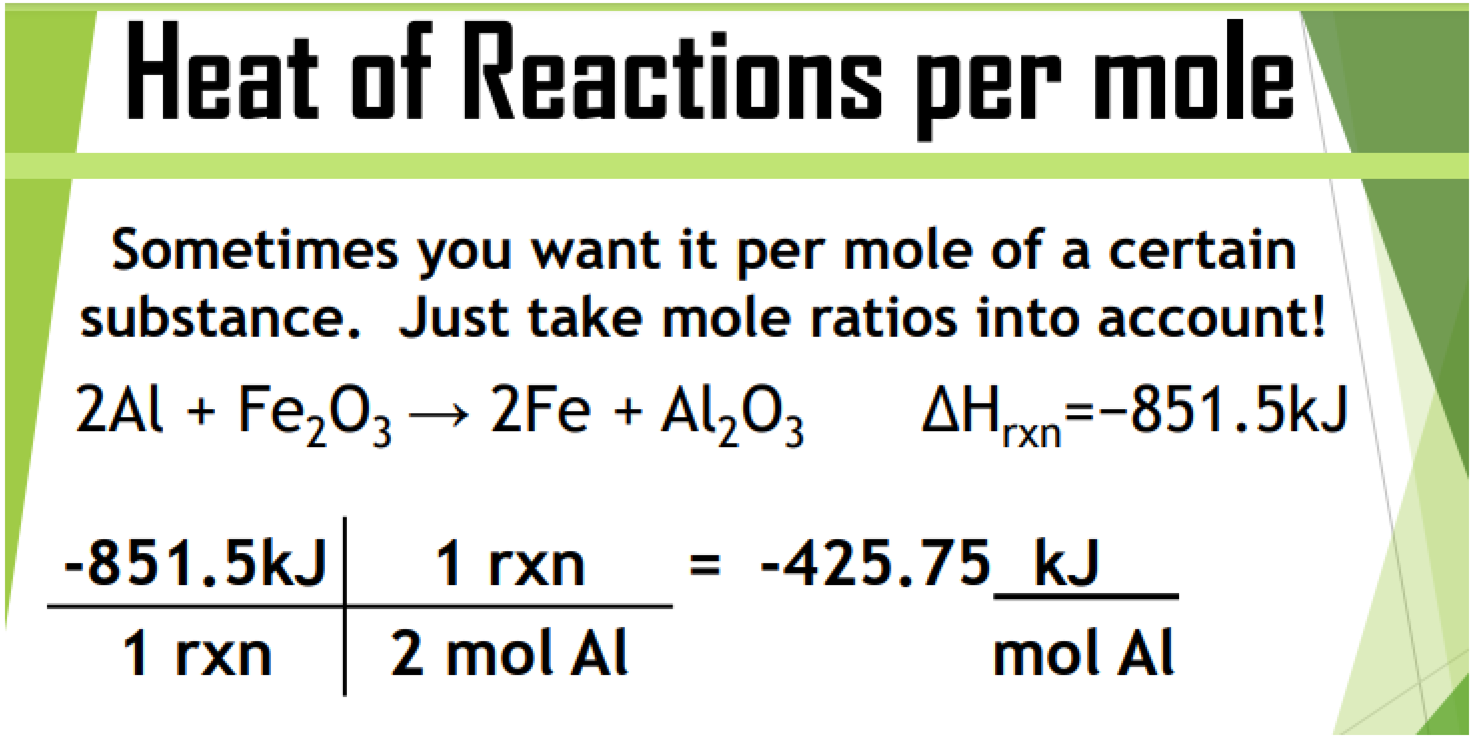
(Remember, ΔH is basically Q)

ΔH negative → exothermic → product

ΔH positive → endothermic → reactant

Heat of Reaction

Jump back to title slide



Heat of Reactions per mole

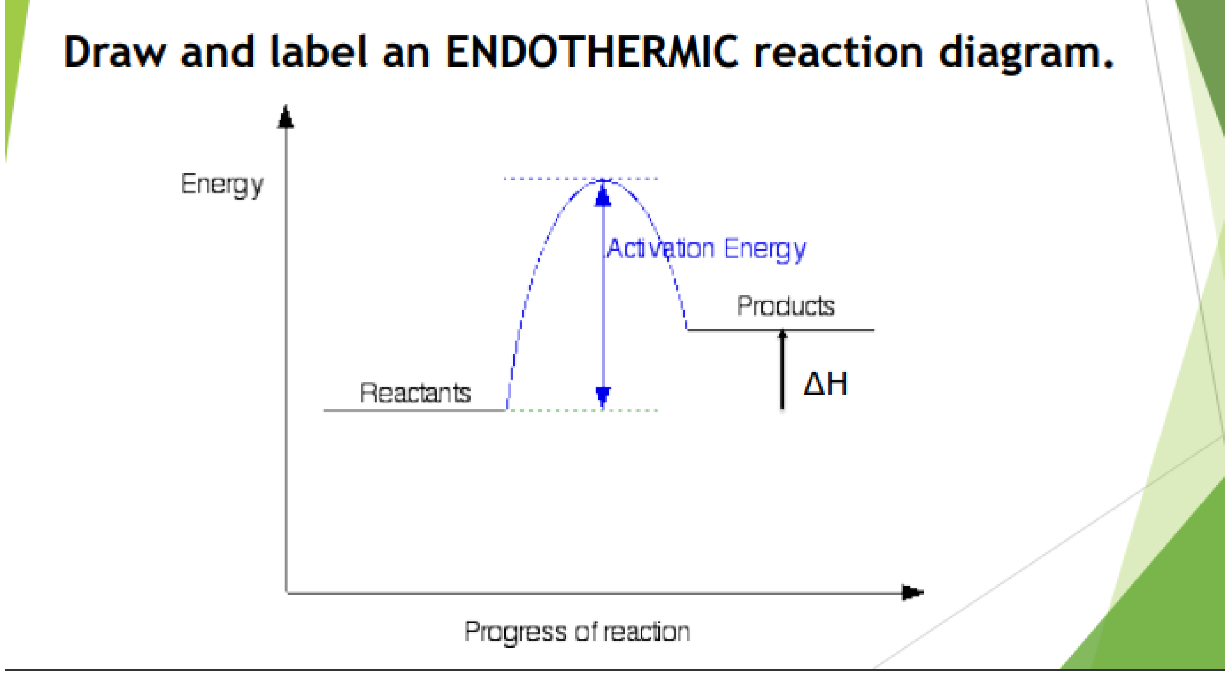
Sometimes you want it per mole of a certain substance. Just take mole ratios into account!

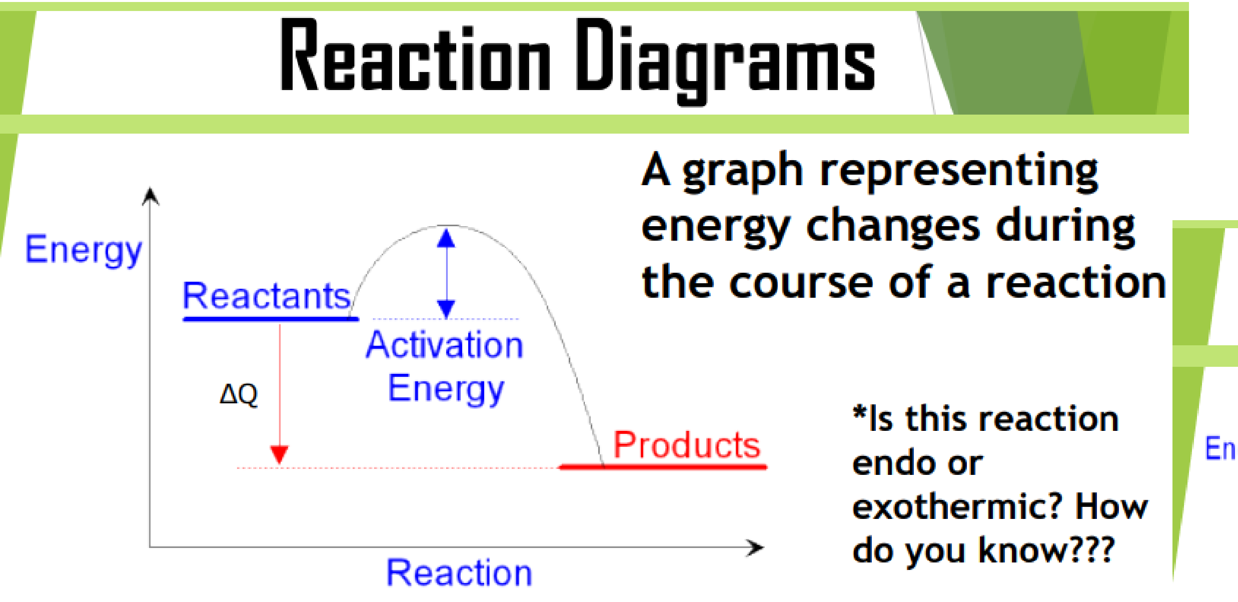
$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3 \qquad \Delta H_{rxn} = -851.5kJ$

$$\begin{array}{c|c} -851.5\text{kJ} & 1\text{ rxn} \\ \hline 1\text{ rxn} & 2\text{ mol Al} \end{array} = -425.75\ \frac{\text{kJ}}{\text{mol Al}}$$

Reaction Diagrams

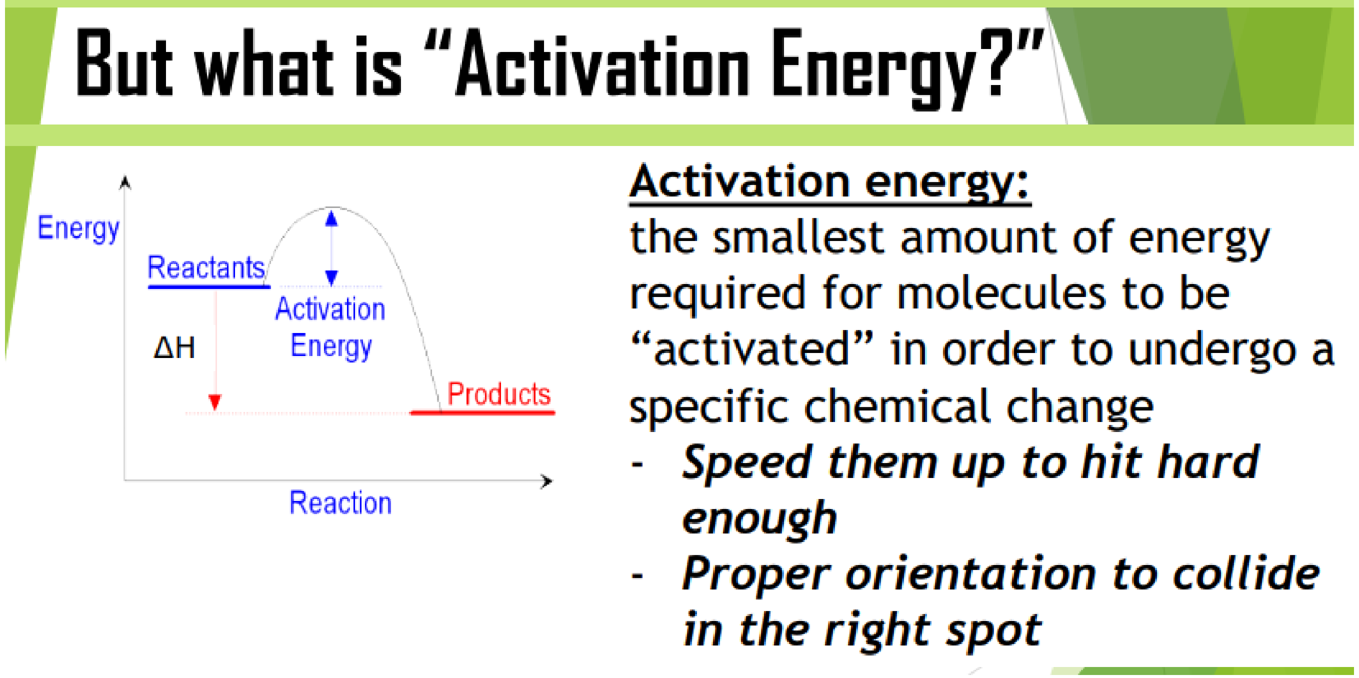
Jump back to title slide


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

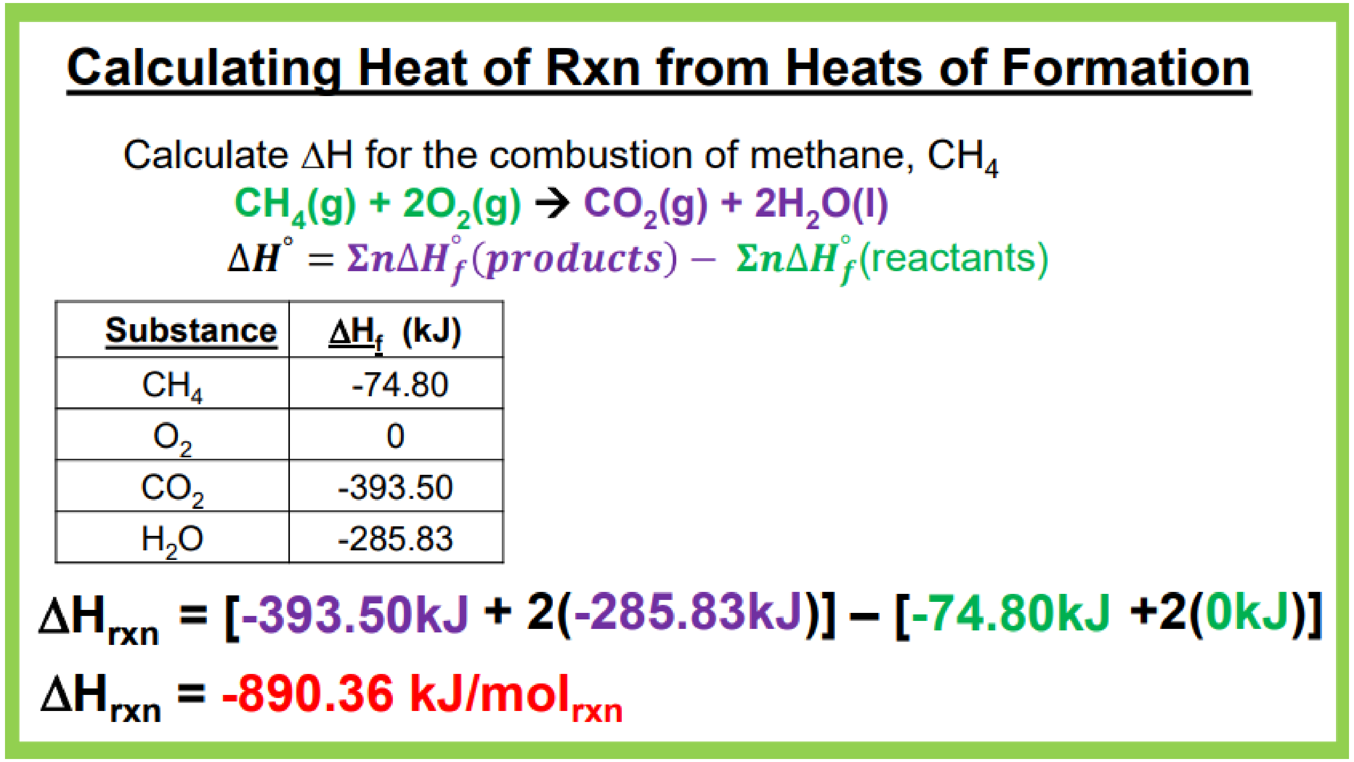
Jump back to title slide

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!

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

- 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

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

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

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

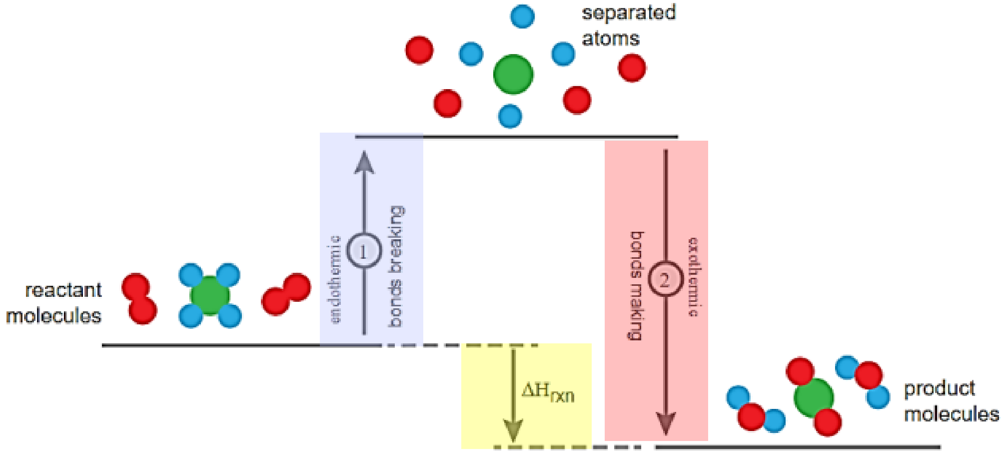
Bond Energy

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!



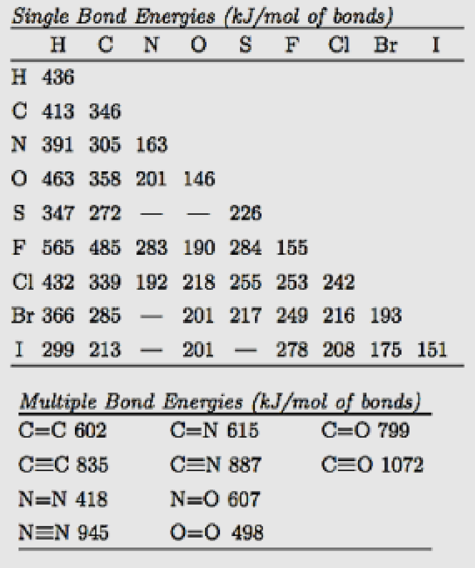
Use Bond Energy Chart

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	

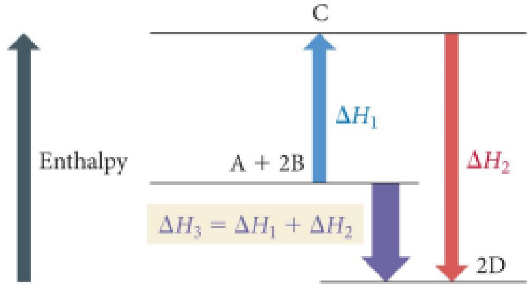
Hess's Law

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."

Hess's Law
The change in enthalpy for a stepwise process is the sum of the enthalpy changes of the 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

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

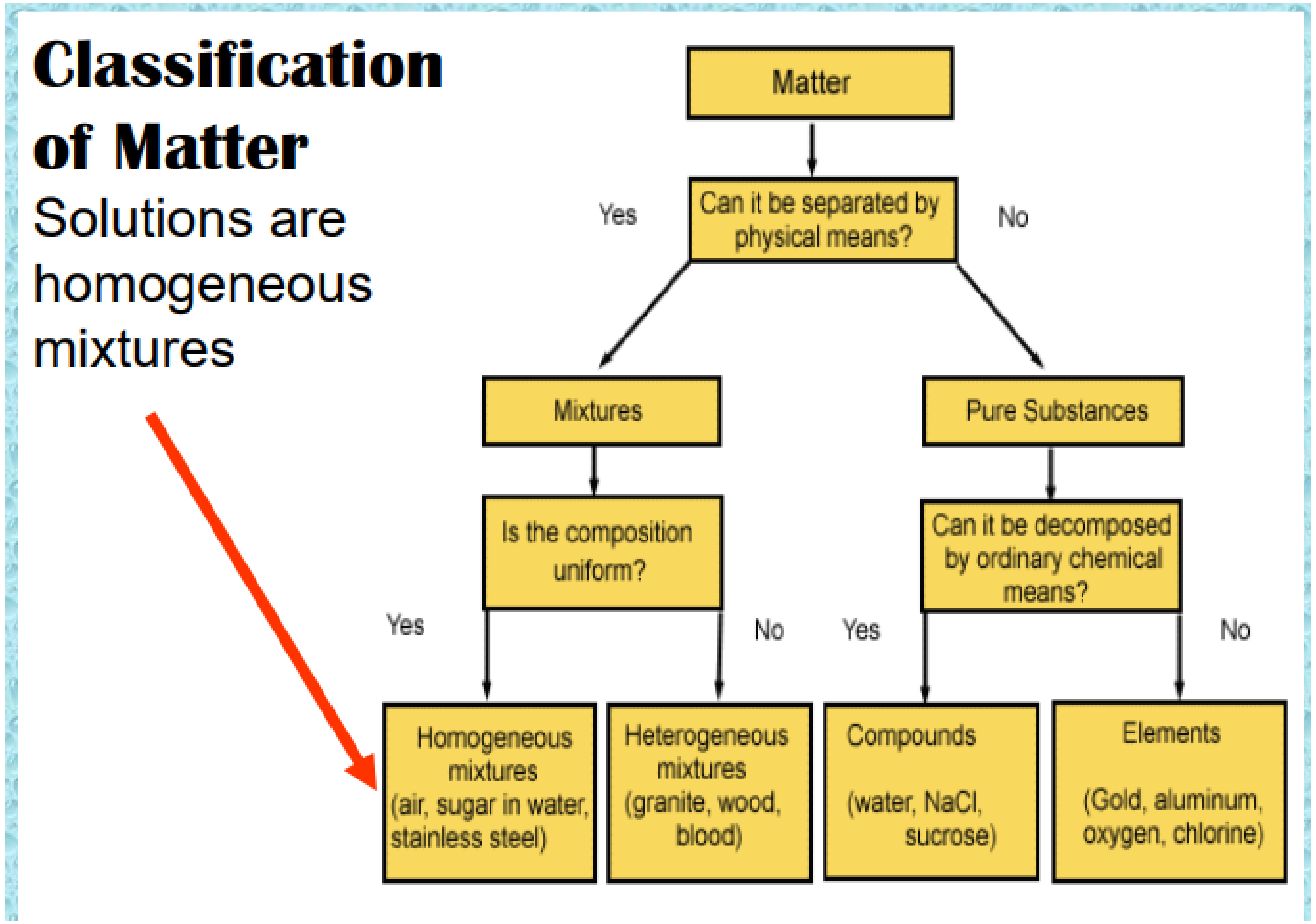
- rxn 1	$CH_4 \rightarrow \cancel{C} + \cancel{2H_2}$	-(-74.80 kJ)
rxn 2	$\cancel{C} + O_2 \rightarrow CO_2$	-393.50 kJ
2 x rxn 3	$\cancel{2H_2} + O_2 \rightarrow 2H_2O$	2 x (-285.83 kJ)
	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	-890.36 kJ

Unit #11
Solutions

- Solution vocabulary
- Solubility
- Solutions calculations

Solutions Vocabulary

Jump back to title slide



Classification of Matter

Solutions are homogeneous mixtures

Matter

Can it be separated by physical means?

Yes

No

Mixtures

Pure Substances

Is the composition uniform?

Yes

No

Can it be decomposed by ordinary chemical means?

Yes

No

Homogeneous mixtures
(air, sugar in water, stainless steel)

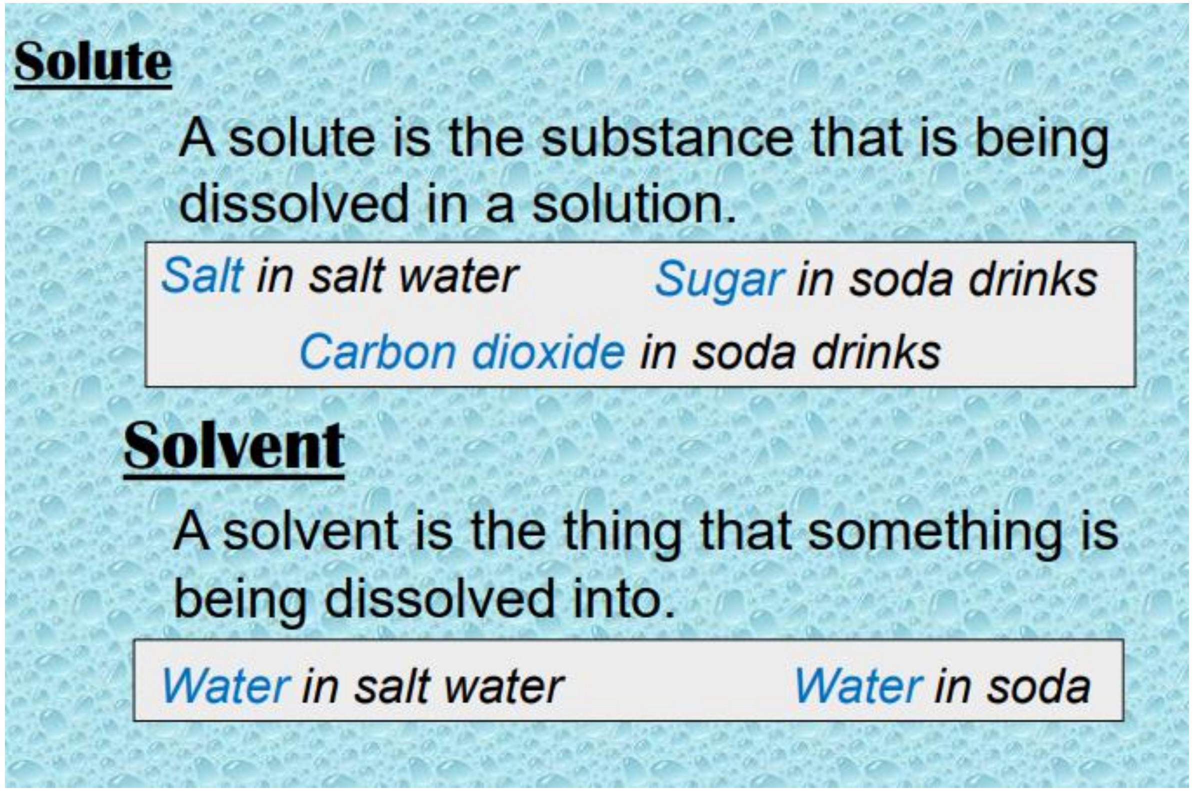
Heterogeneous mixtures
(granite, wood, blood)

Compounds
(water, NaCl, sucrose)

Elements
(Gold, aluminum, oxygen, chlorine)

Solutions Vocabulary

Jump back to title slide



Solute

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

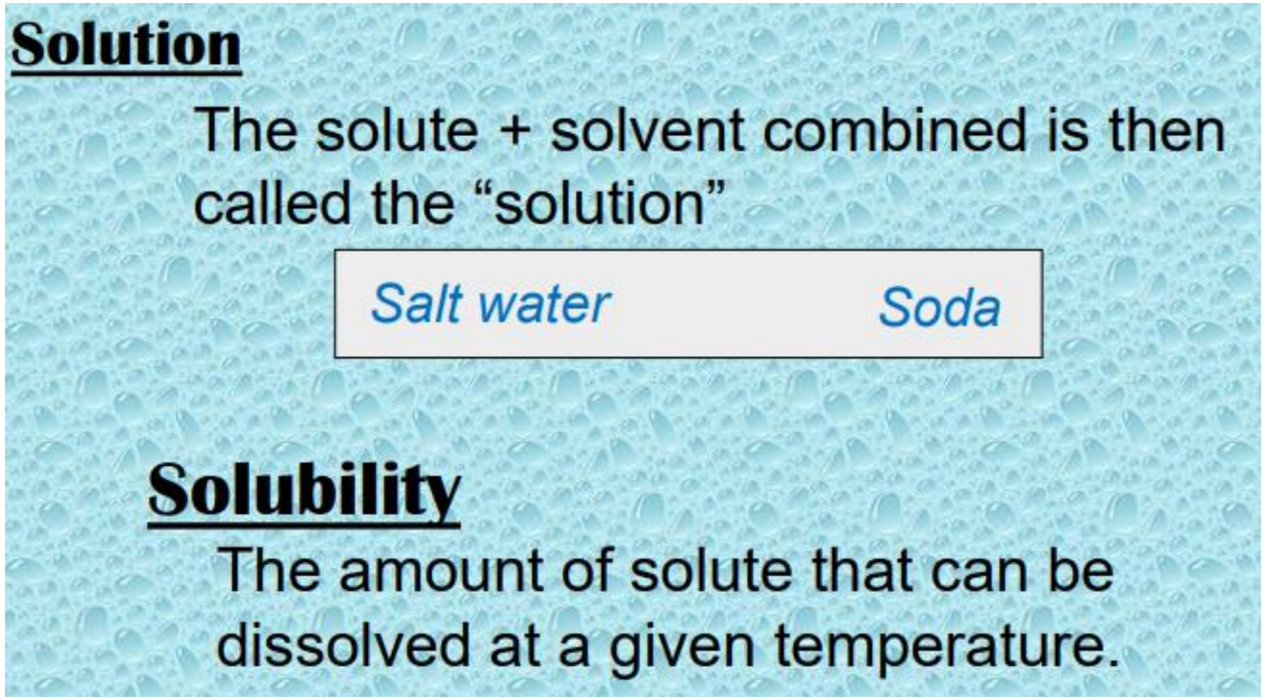
Salt in salt water *Sugar in soda drinks*

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”

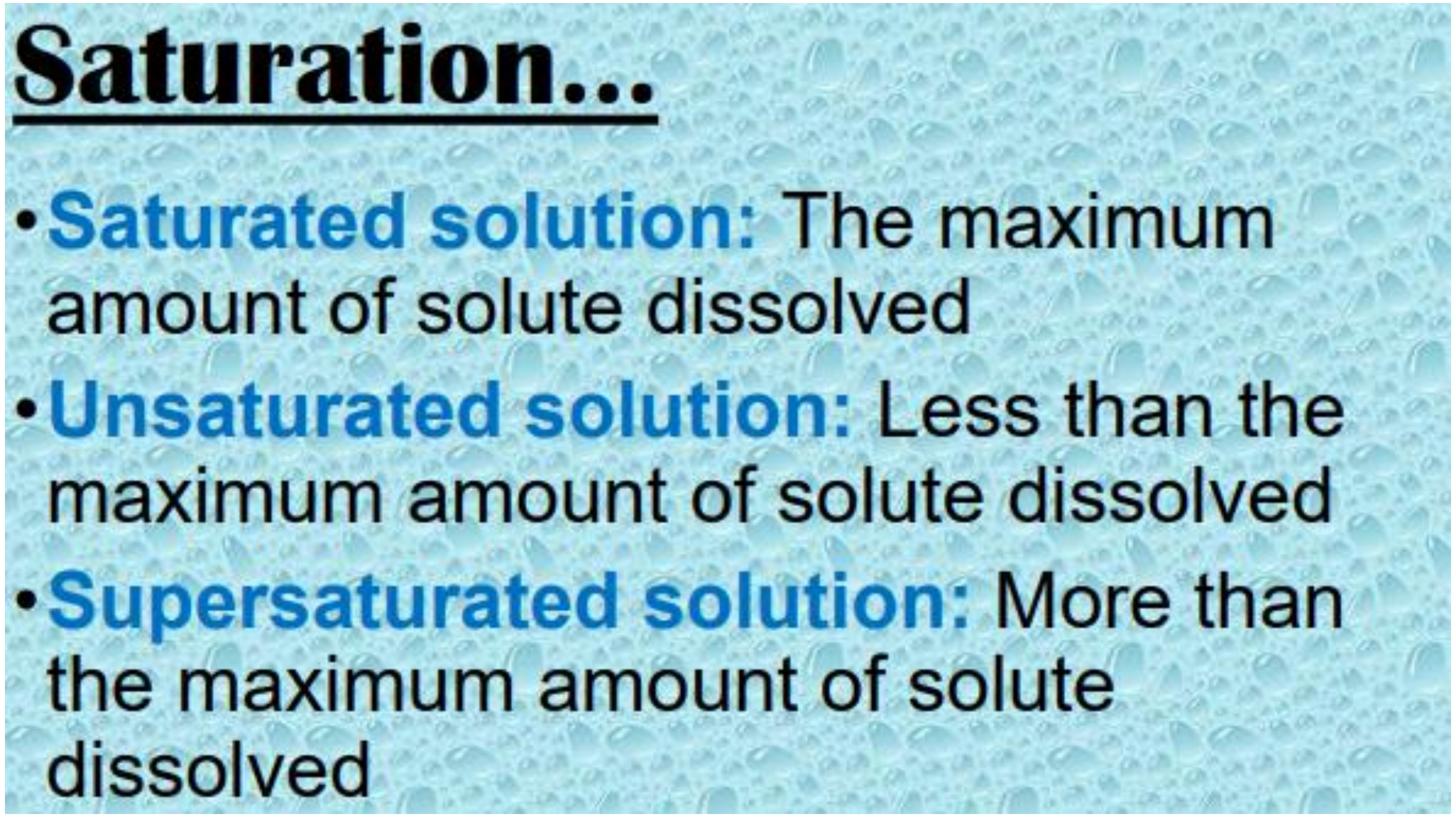
Salt water *Soda*

Solubility

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

Solutions Vocabulary

[Jump back to title slide]

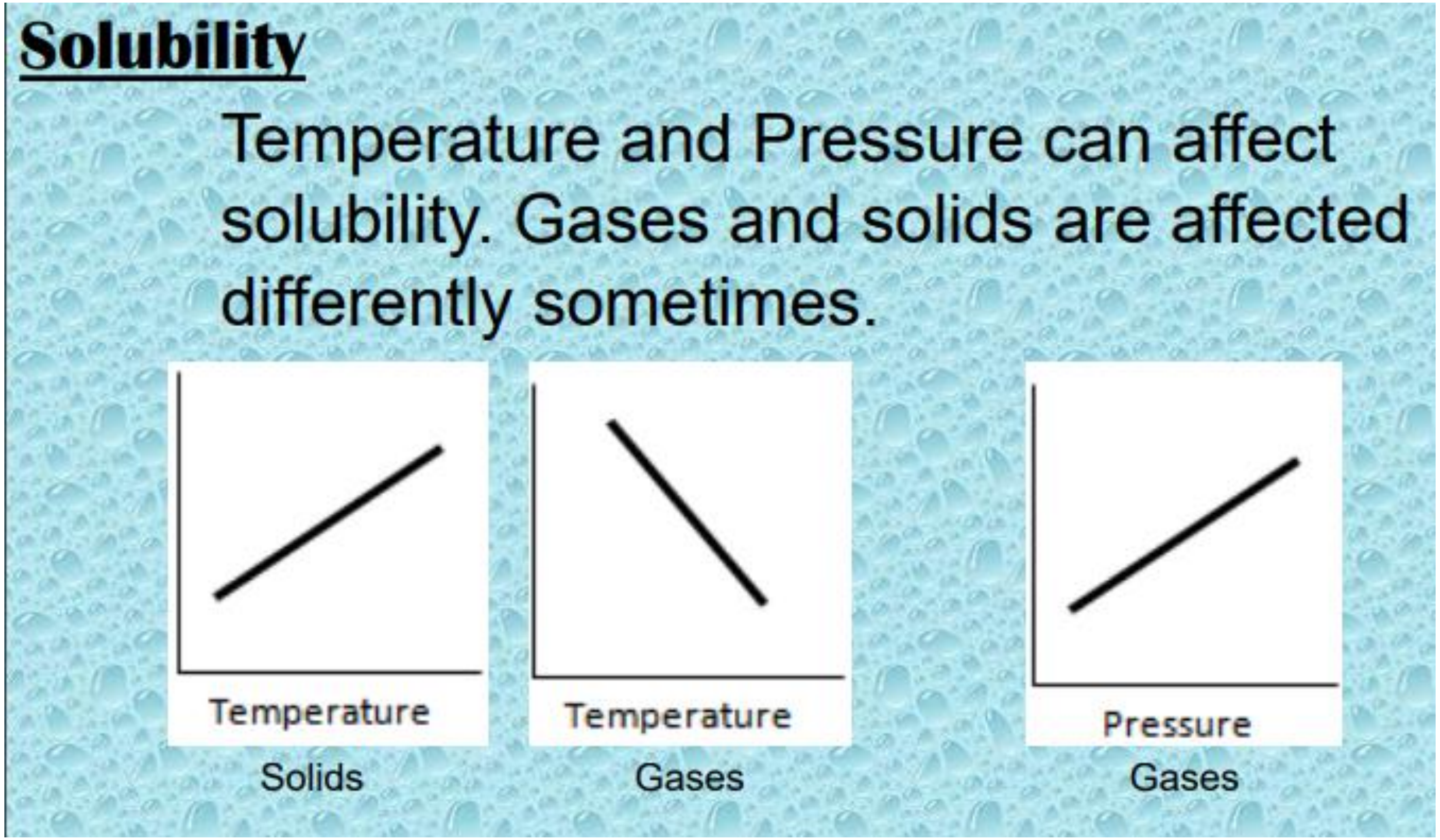


Saturation...

- **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]

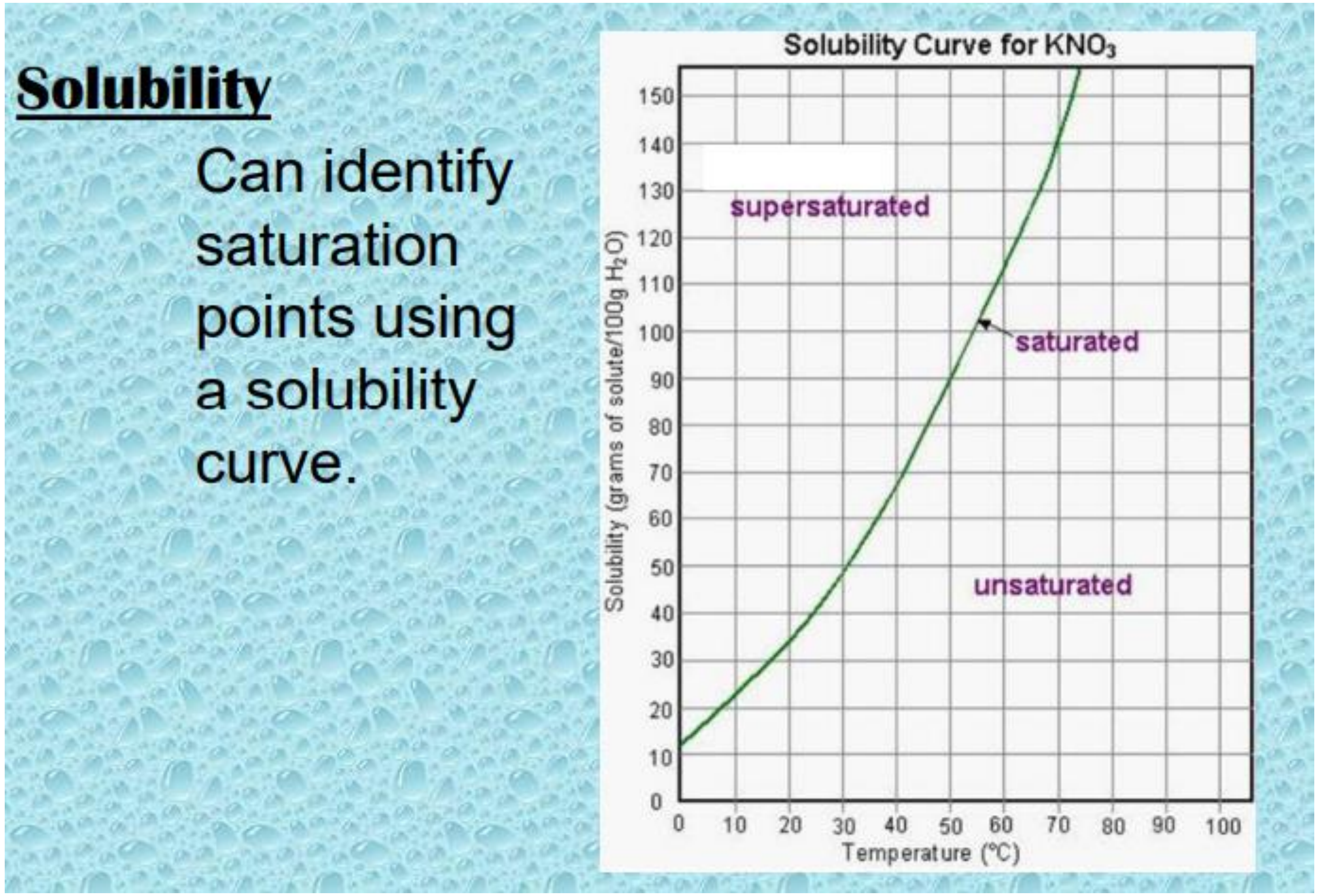


Solubility

Temperature and Pressure can affect solubility. Gases and solids are affected differently sometimes.

Solubility

Jump back to title slide

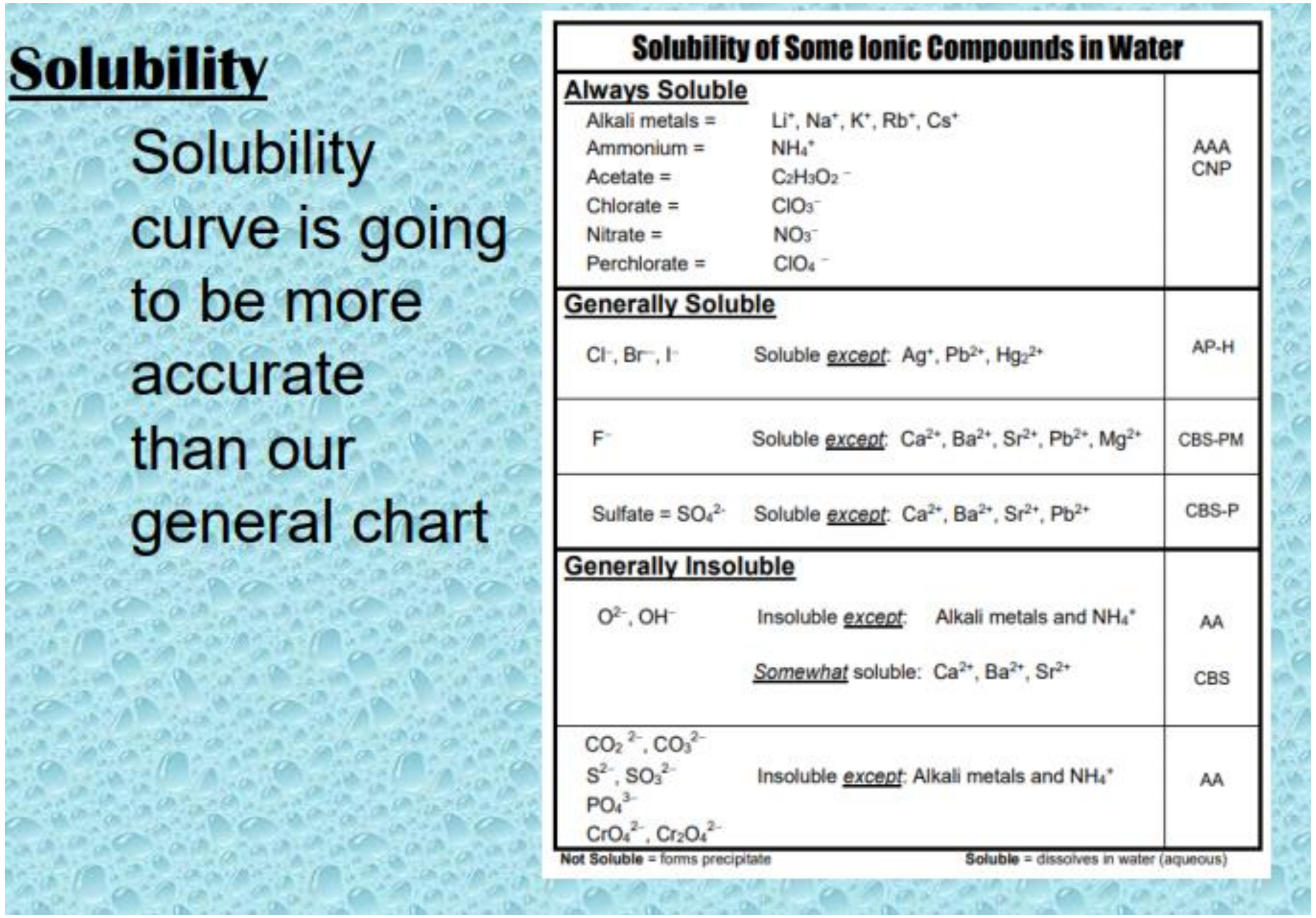


Solubility

Can identify saturation points using a solubility curve.

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

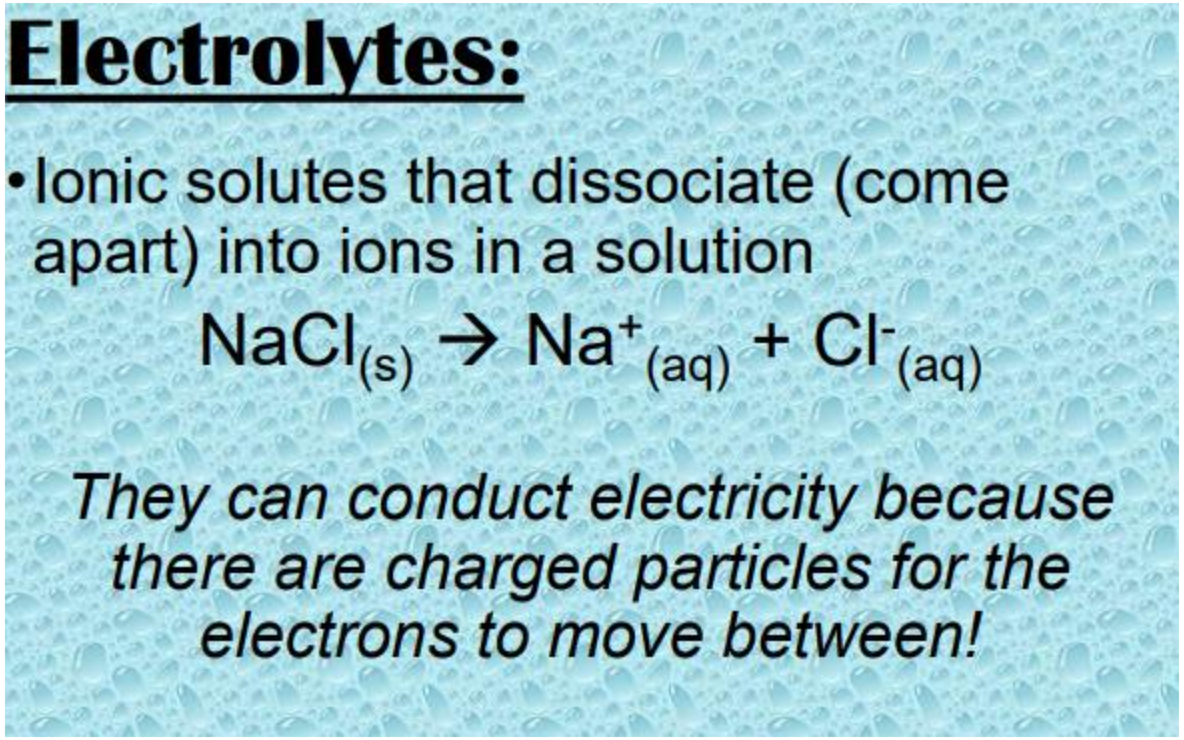
Always Soluble		
Alkali metals =	Li^+, Na^+, K^+, Rb^+, Cs^+	AAA CNP
Ammonium =	NH_4^+	
Acetate =	$C_2H_3O_2^-$	
Chlorate =	ClO_3^-	
Nitrate =	NO_3^-	
Perchlorate =	ClO_4^-	
Generally Soluble		
Cl^-, Br^-, I^-	Soluble *except*: Ag^+, Pb^{2+}, Hg_2^{2+}	AP-H
F^-	Soluble *except*: Ca^{2+}, Ba^{2+}, Sr^{2+}, 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

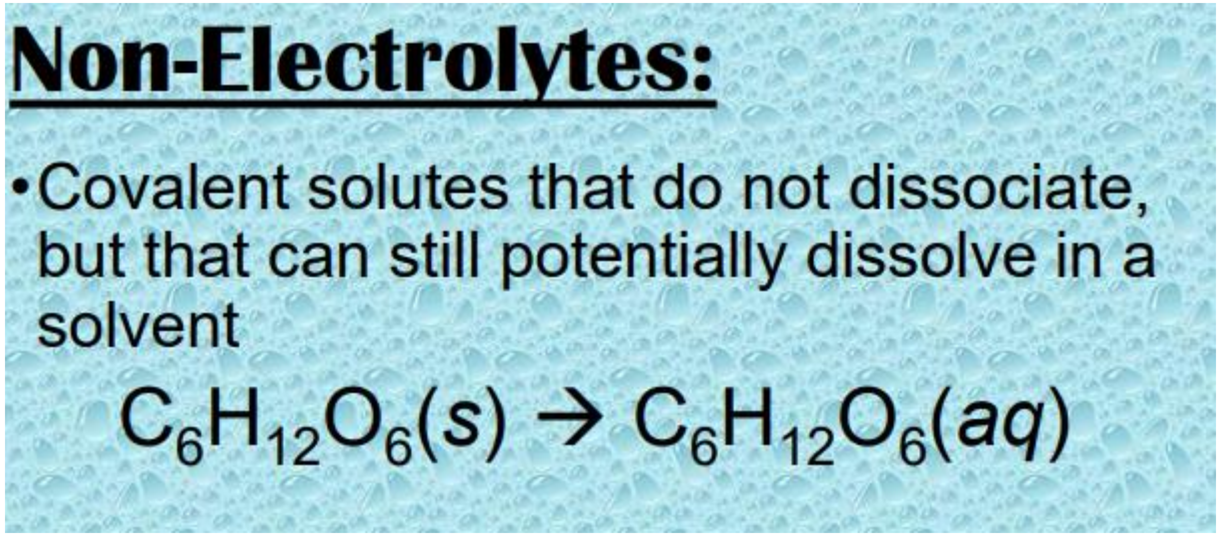


Electrolytes:

- 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!



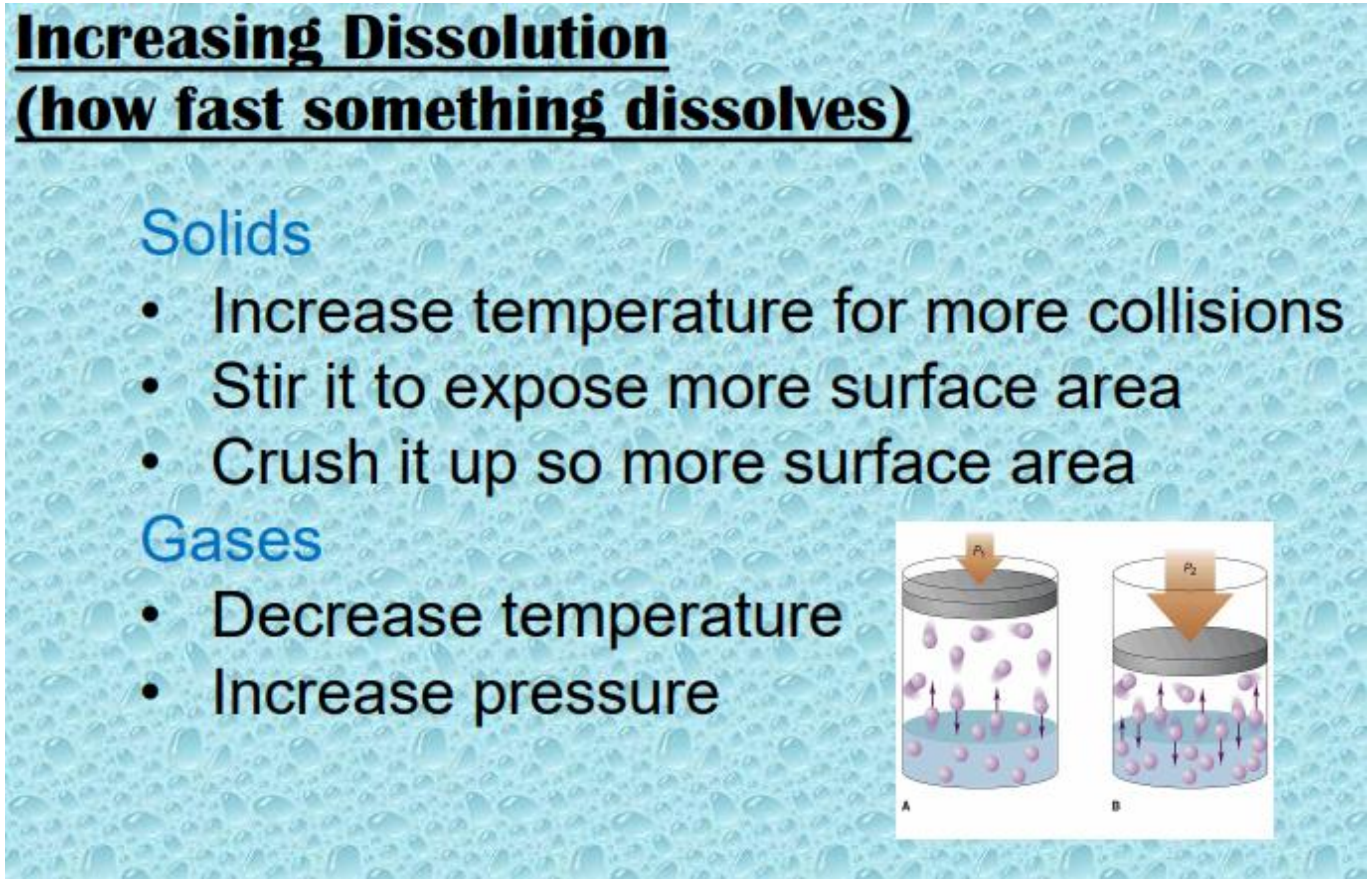
Non-Electrolytes:

- 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

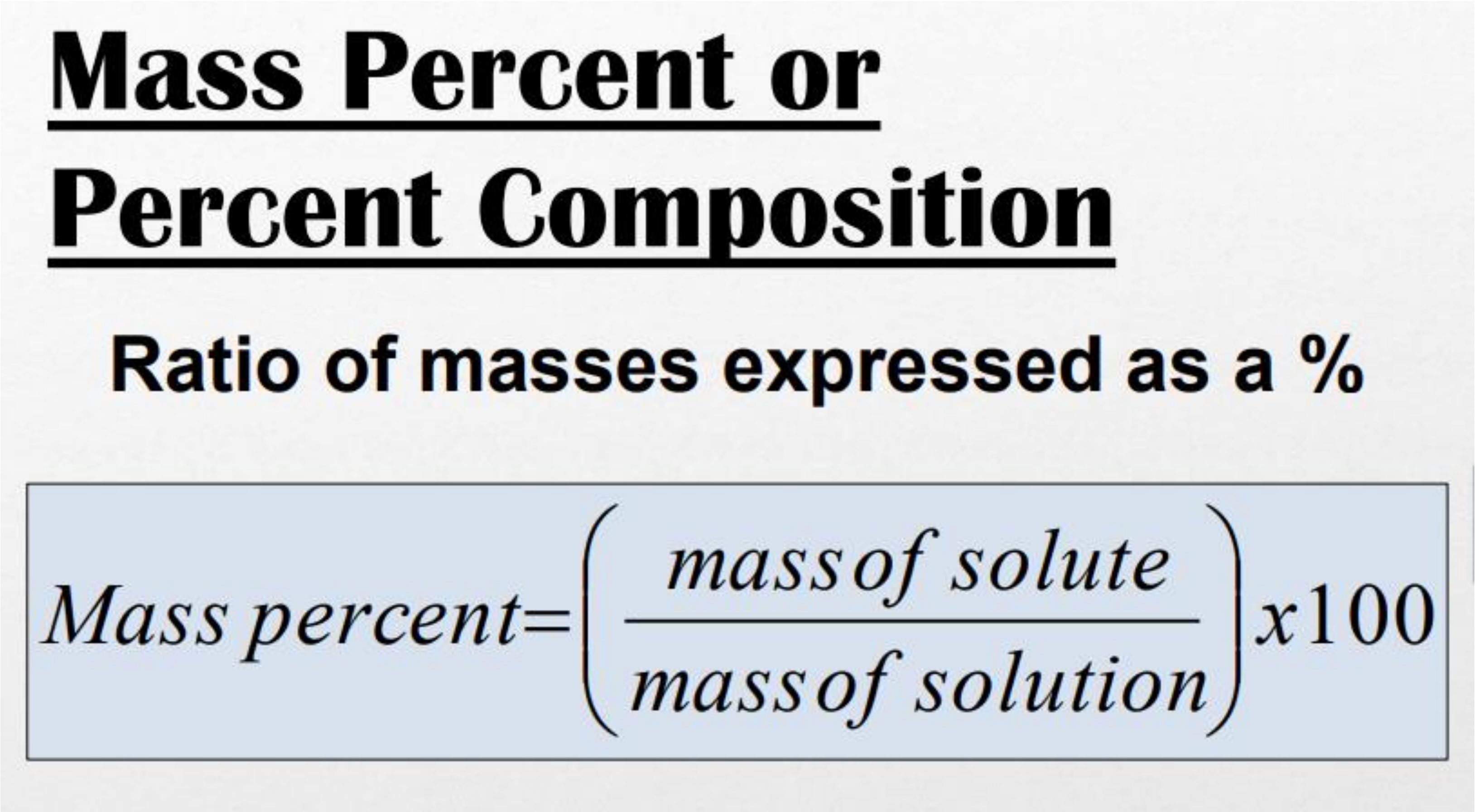
- Increase temperature for more collisions
- Stir it to expose more surface area
- Crush it up so more surface area

Gases

- Decrease temperature
- Increase pressure

Solutions Calcs.

Jump back to title slide



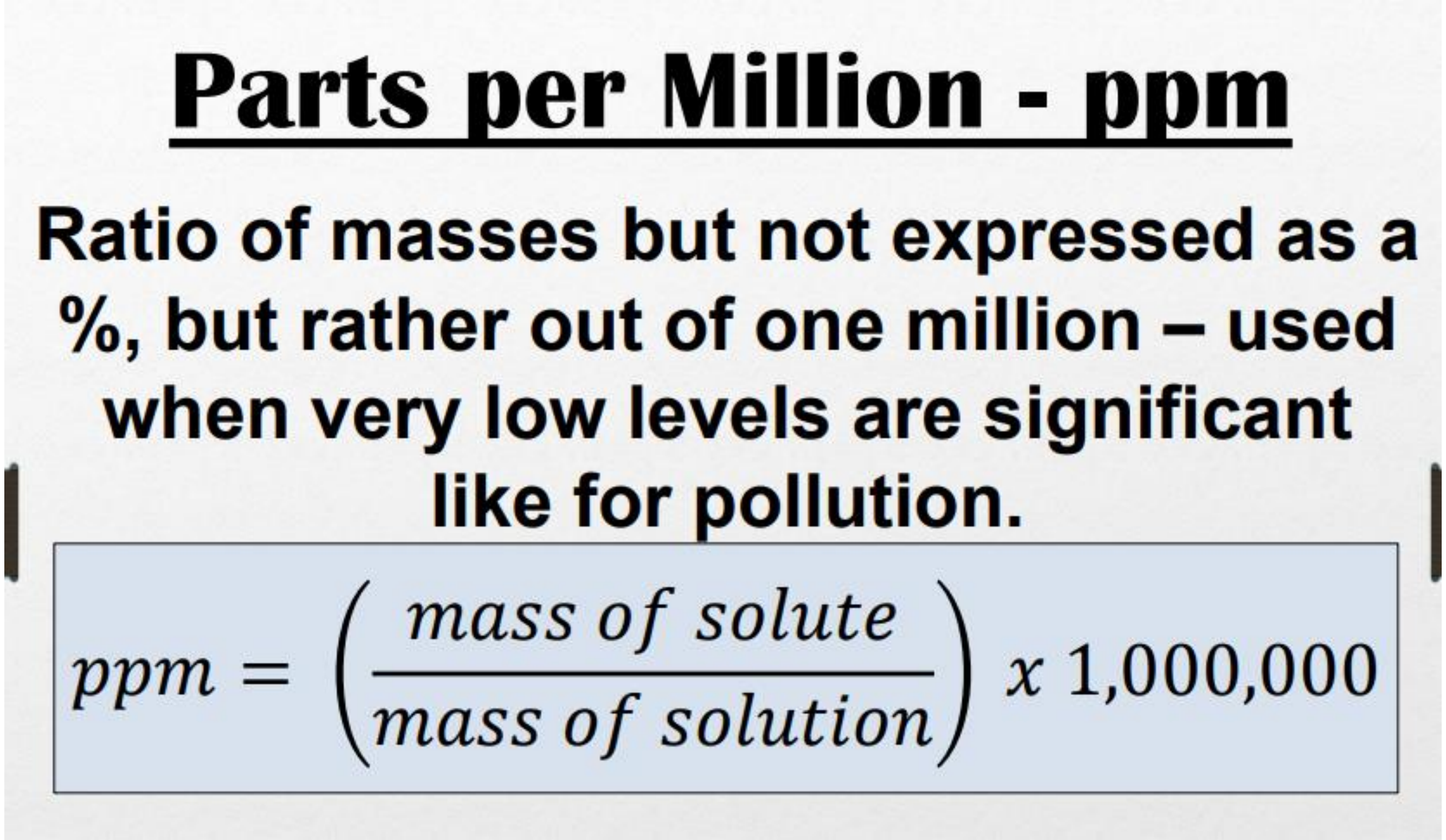
Mass Percent or Percent Composition

Ratio of masses expressed as a %

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

Solutions Calcs.

Jump back to title slide

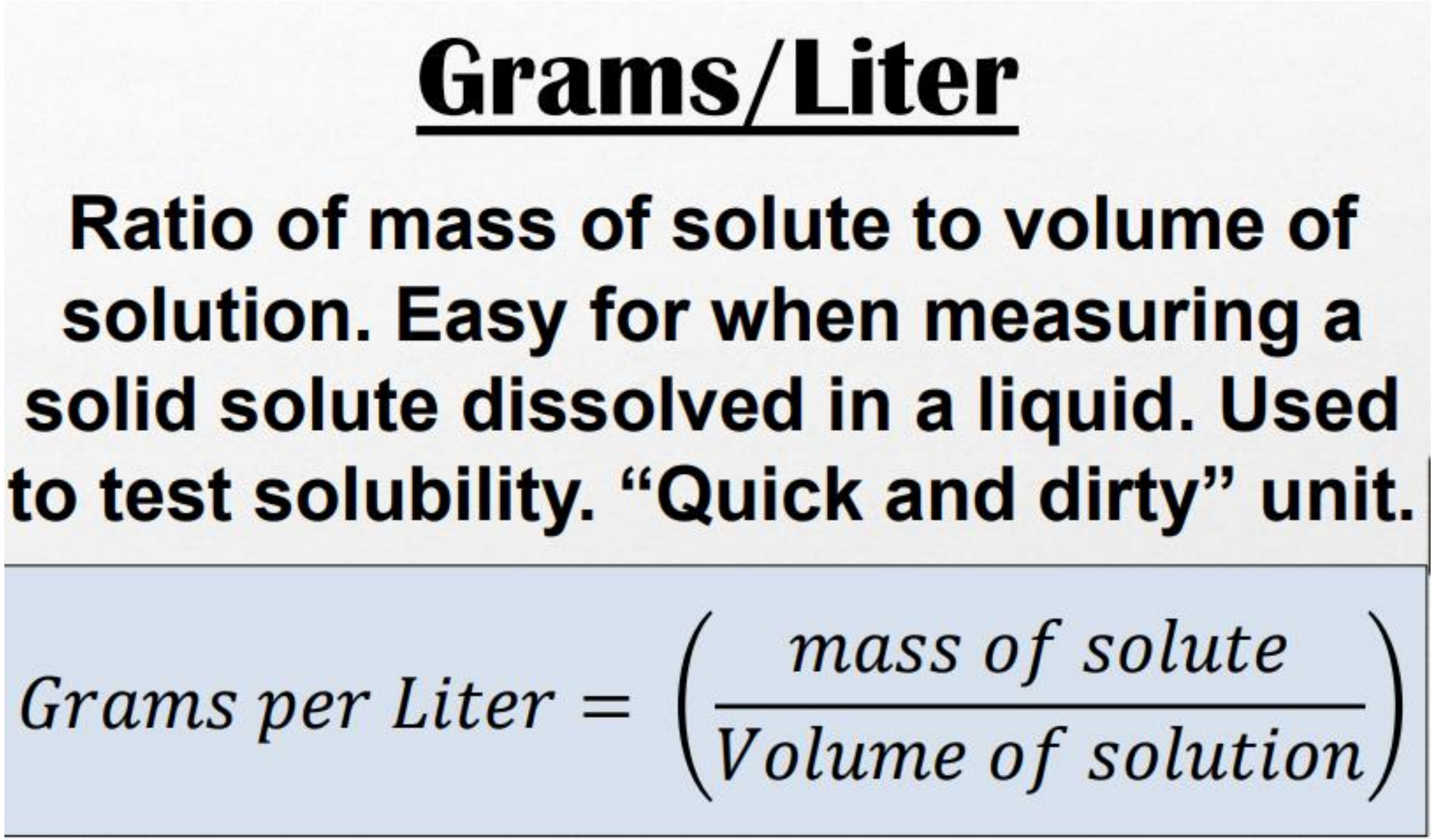


Parts per Million - ppm

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

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

Jump back to title slide



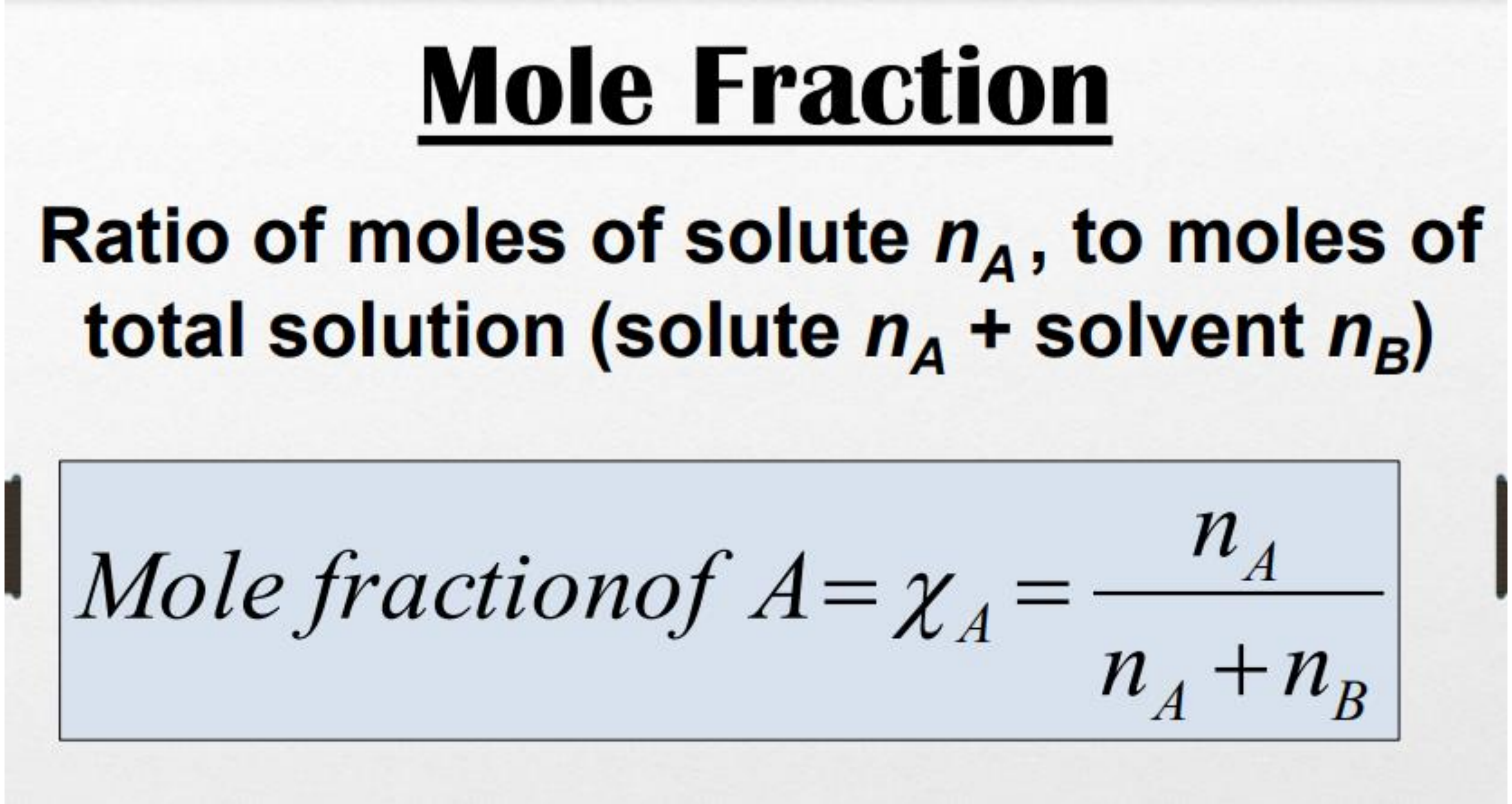
Grams/Liter

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.

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

Solutions Calcs.

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)

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

Solutions Calcs.

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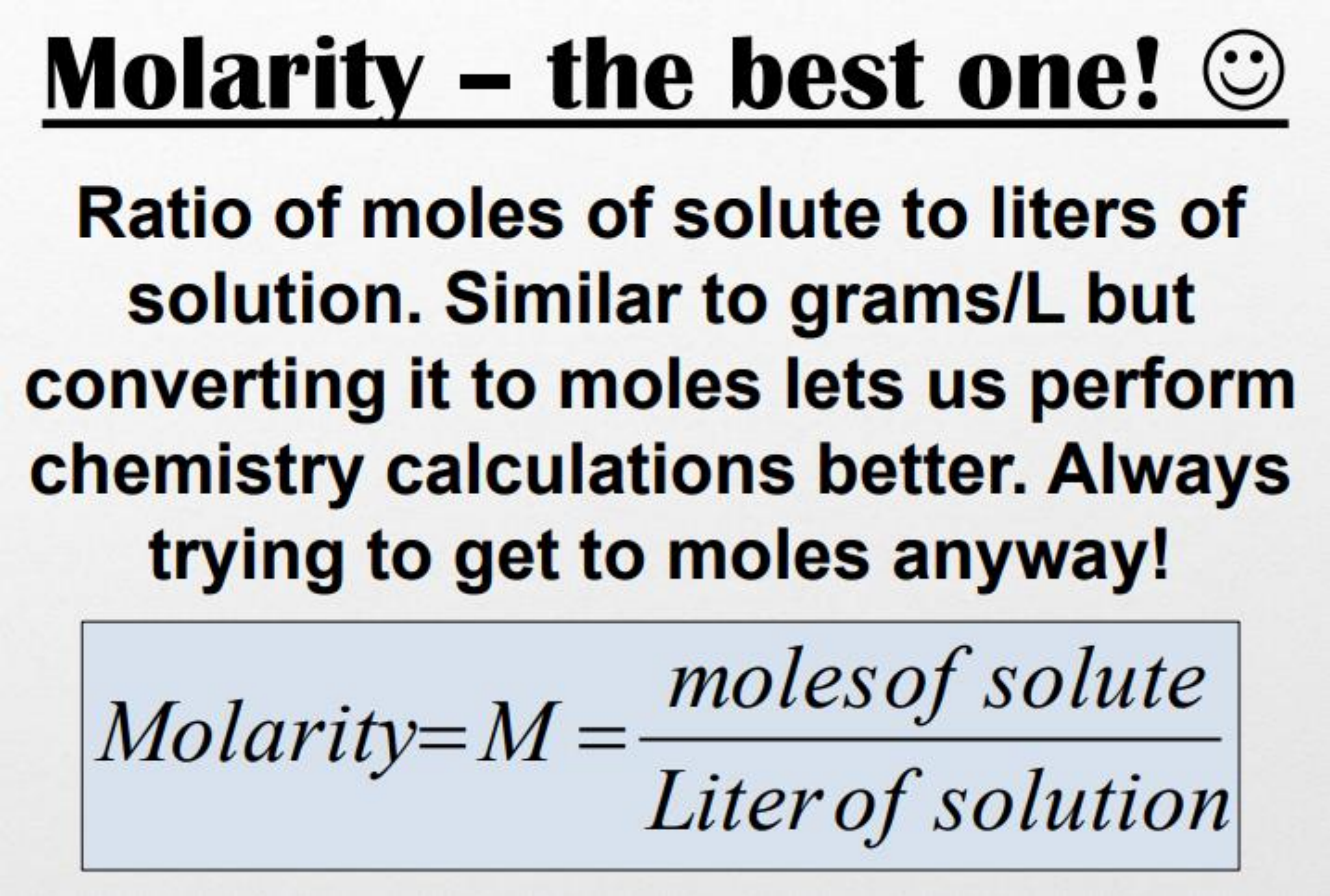

Molarity – the best one! ☺

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!

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

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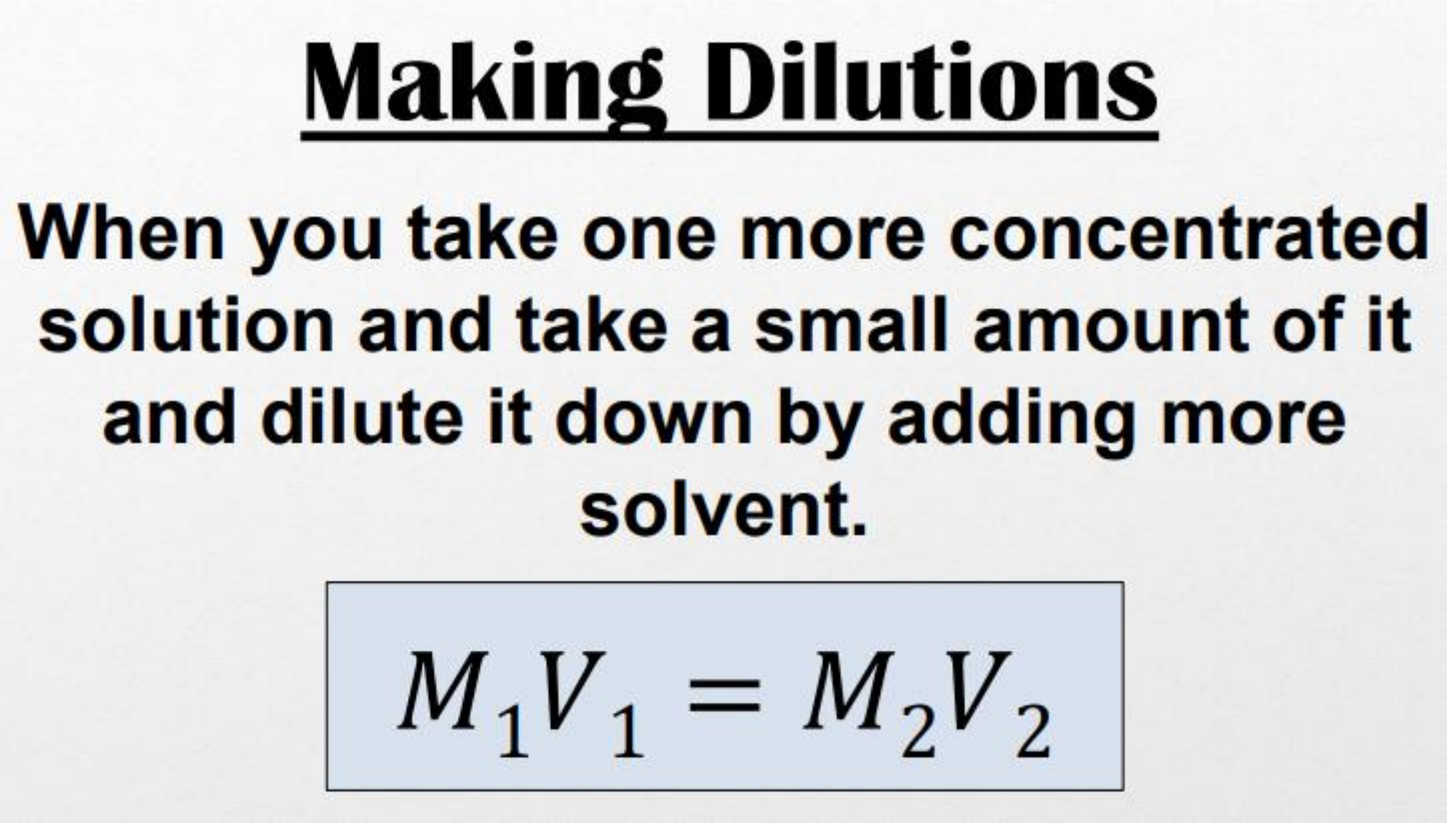


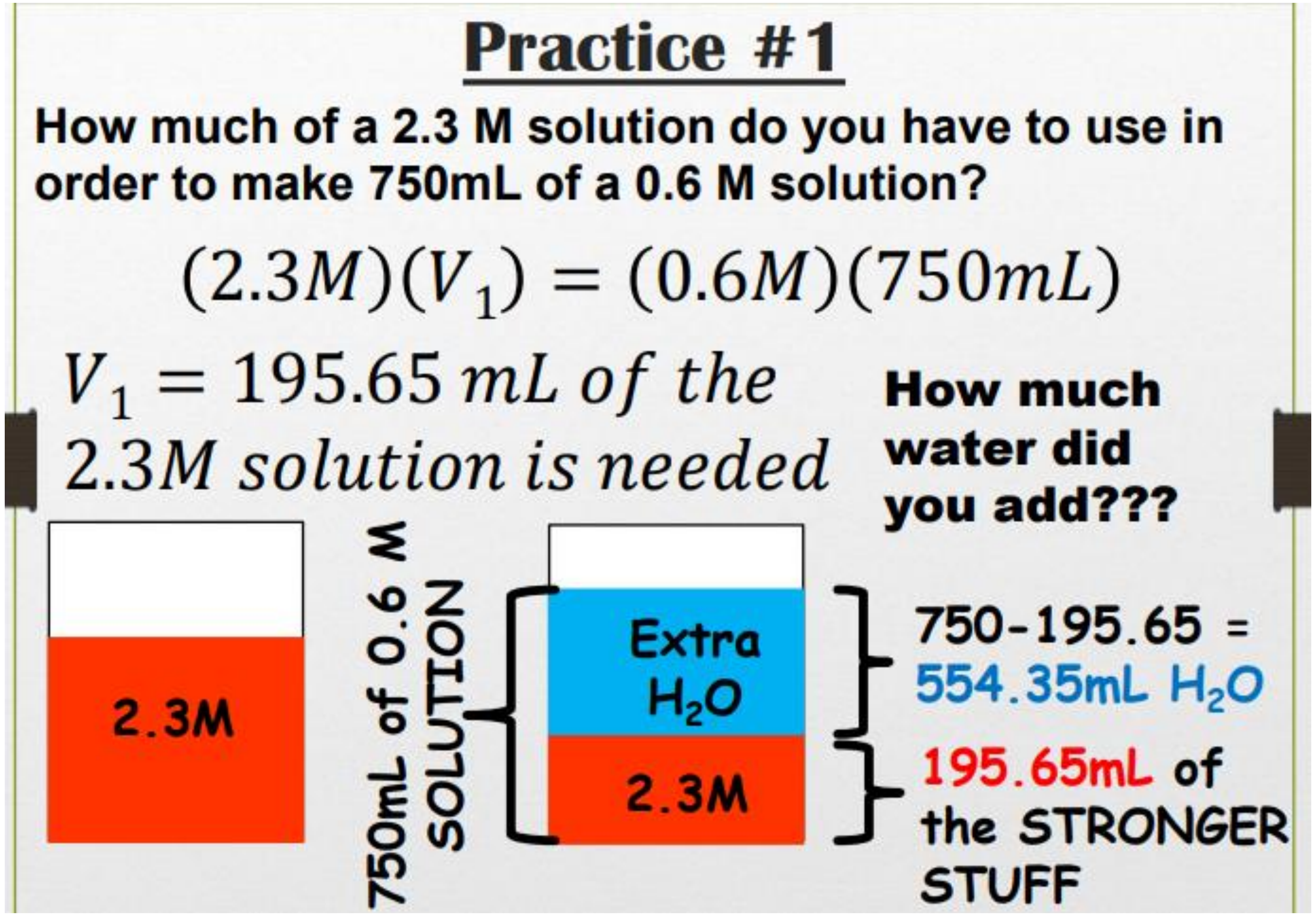
Making Dilutions

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

$$\boxed{M_1V_1 = M_2V_2}$$

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???

2.3M

750mL of 0.6 M SOLUTION

Extra H_2O

2.3M

750-195.65 = 554.35mL H_2O

195.65mL of the STRONGER STUFF

Unit #12
Kinetics

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

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

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

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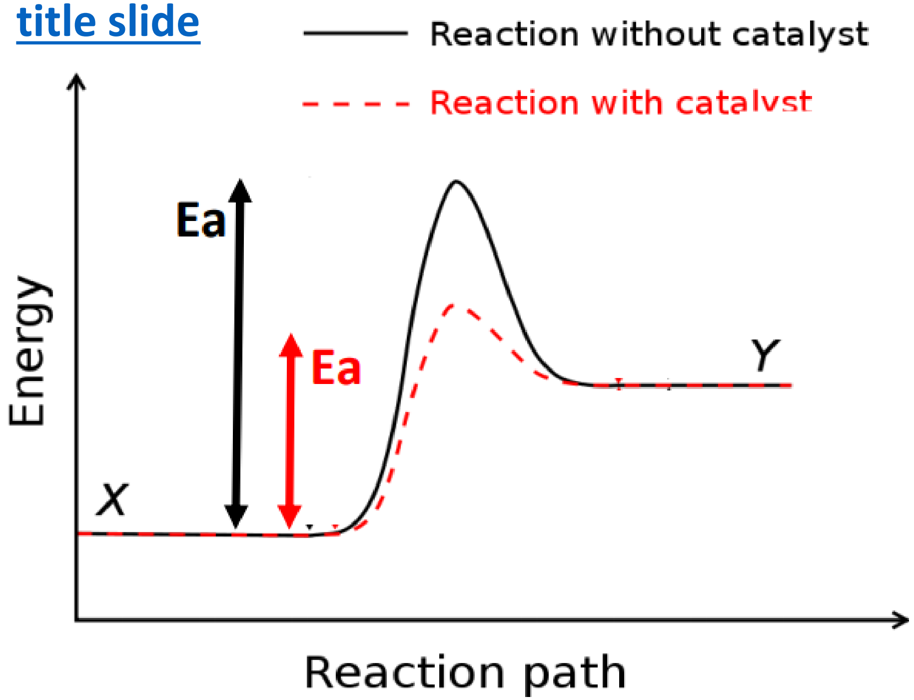

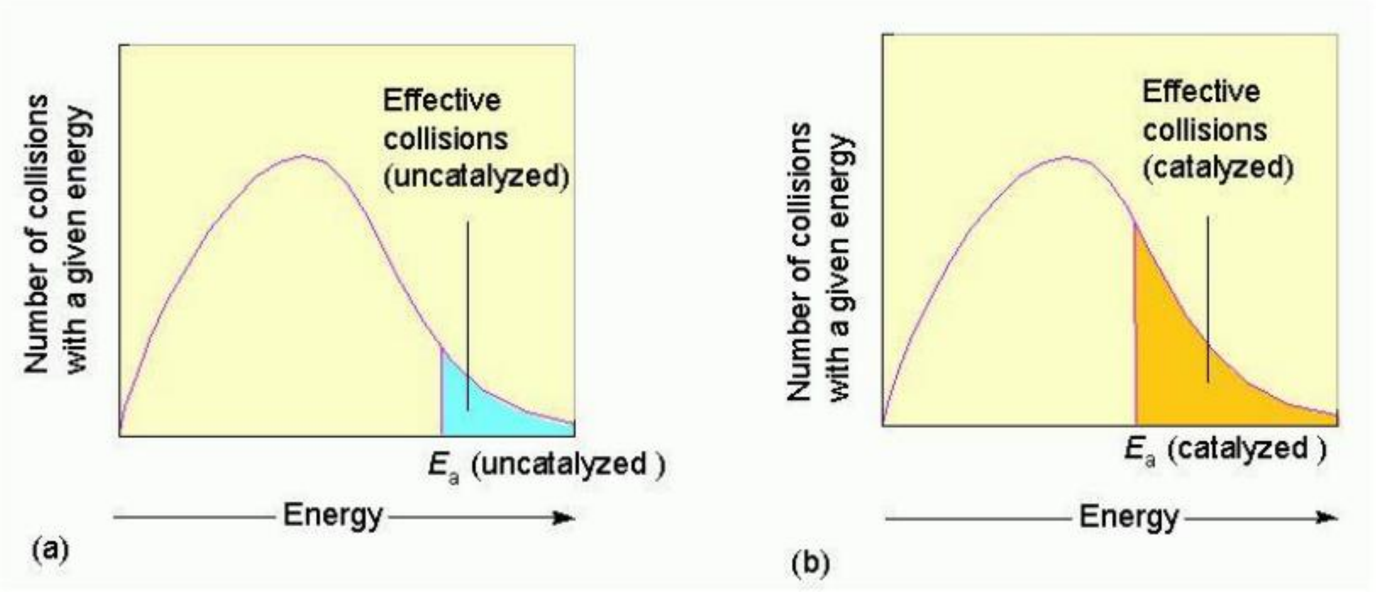

Rate Affecting Factors

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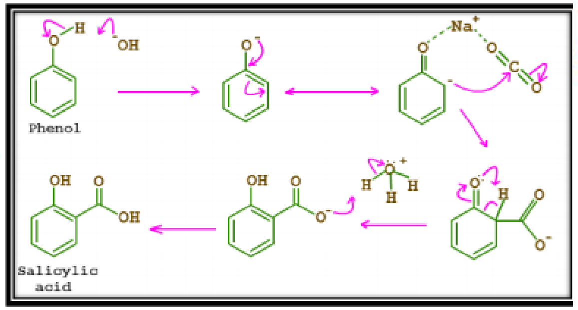
Reaction Mechanism

- A chemical equation does not tell us **HOW** reactants become products; just a summary of the overall process.

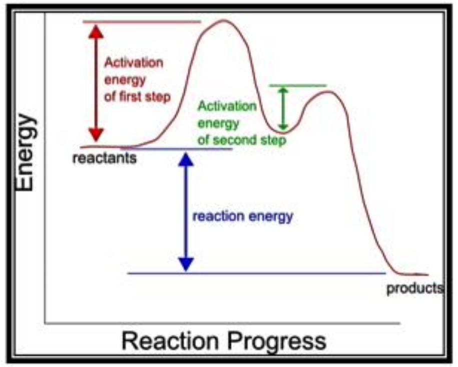


- The reaction mechanism is the series of steps by which a chemical reaction occurs.
- Some reactions take place in one step, two steps, three steps etc.

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

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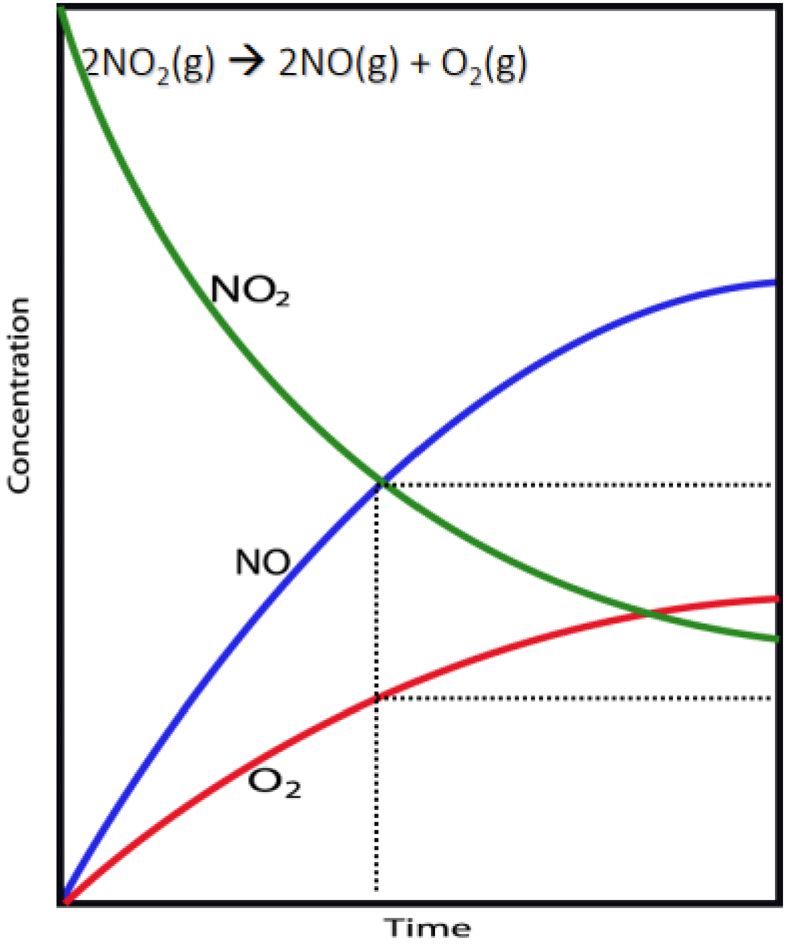

Reaction Rates

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

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

Rate Expression

Jump back to title slide

Reaction Rates and Stoichiometry

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

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

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

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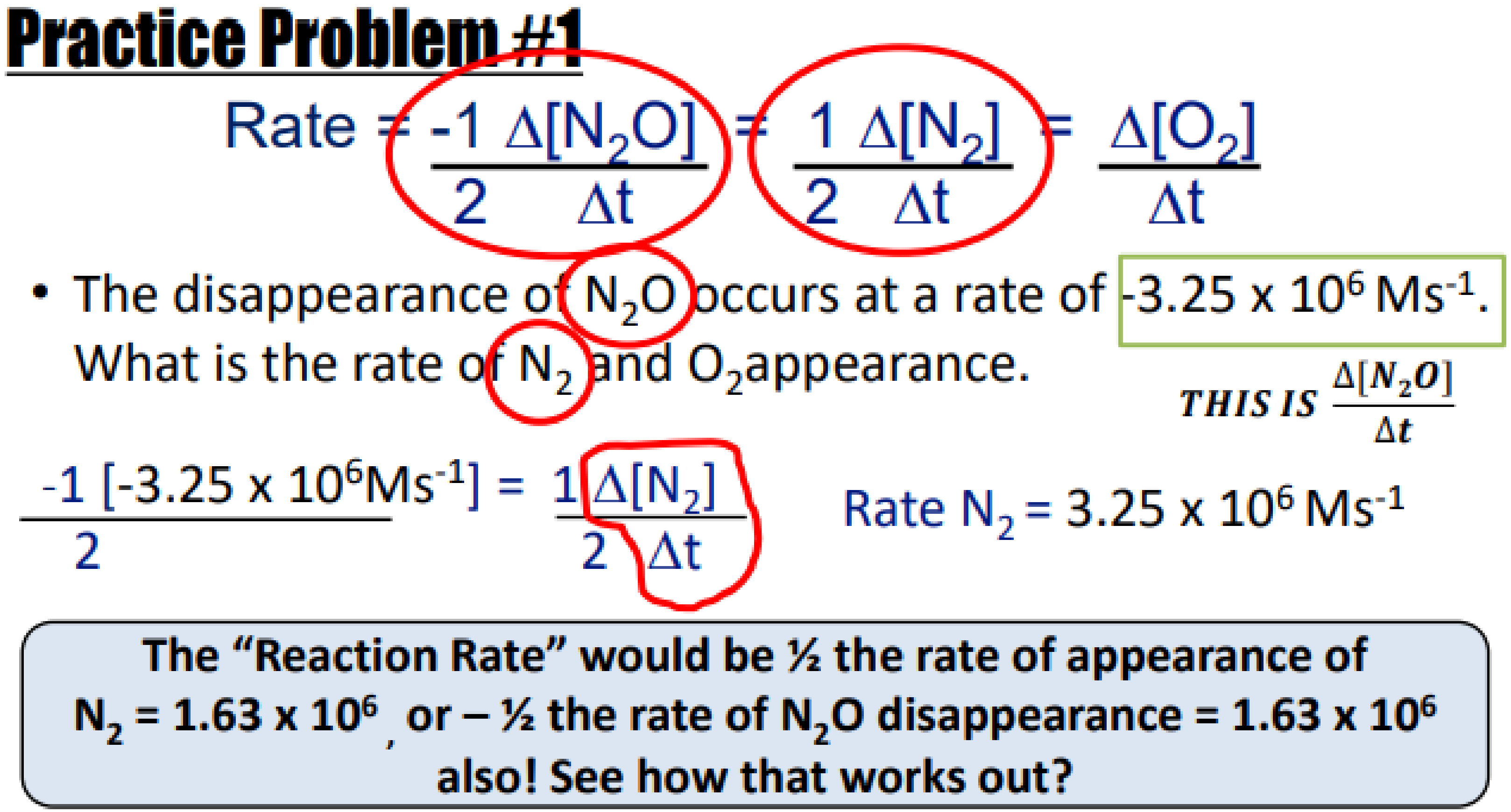


Practice Problem #1

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

- 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***

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

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

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**

Rate Law

Jump back to title slide

What is this “k” thing?

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

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?

Jump back to title slide

Rate Laws

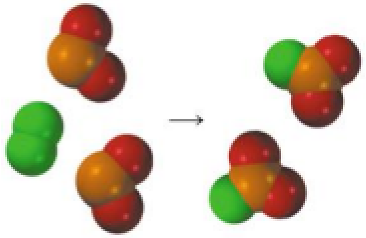
- Rate laws are **always** determined experimentally.
- Reaction order is **always** defined in terms of reactant (not product) concentrations.

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

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

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

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



Rate Law

Jump back to title slide

Rate Laws

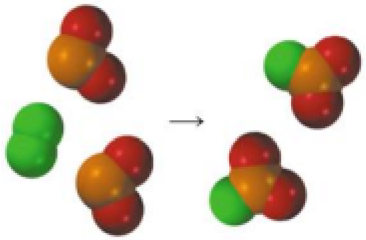
Coefficients from *rate determining step* are the exponents.

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

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

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

↗

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

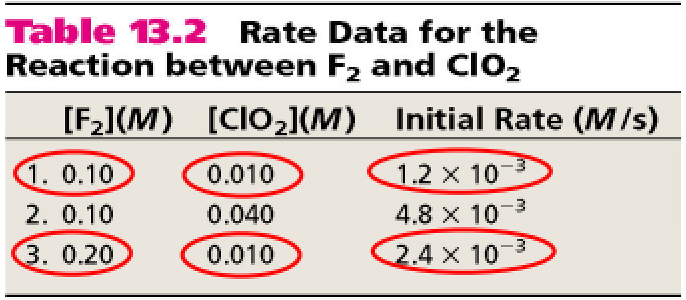


Table 13.2 Rate Data for the Reaction between F_2 and ClO_2

	$[F_2]$ (*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}

$[ClO_2]$ 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

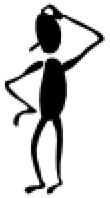
Jump back to title slide

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}



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

$$x = 1 \qquad y = 1$$

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

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)

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

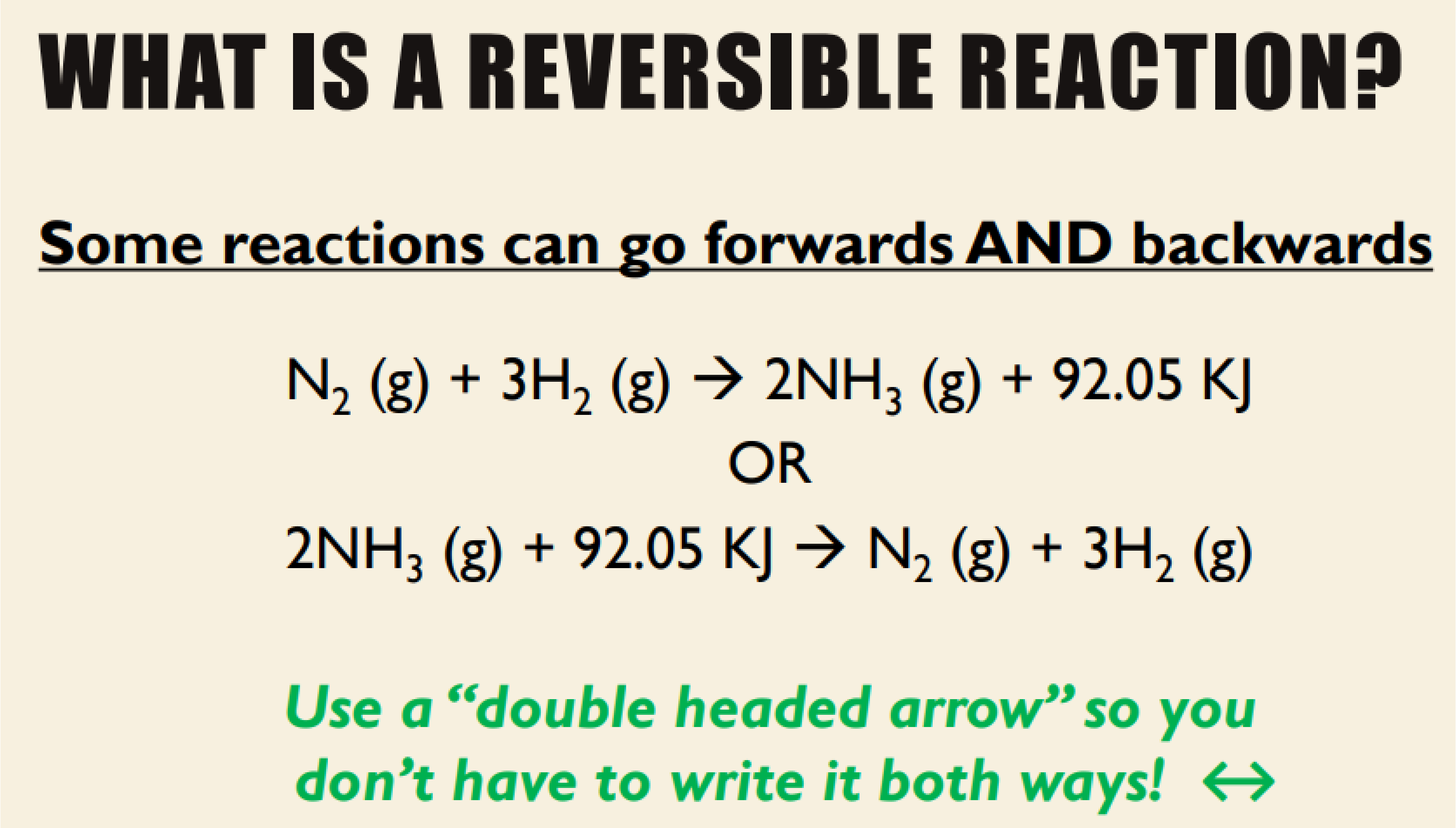
$$\boxed{= 0.08/M \cdot \text{s}}$$

Careful with units for k! They depend on order!

Unit #13
Equilibrium

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

Jump back to title slide



WHAT IS A REVERSIBLE REACTION?

Some reactions can go forwards AND backwards

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

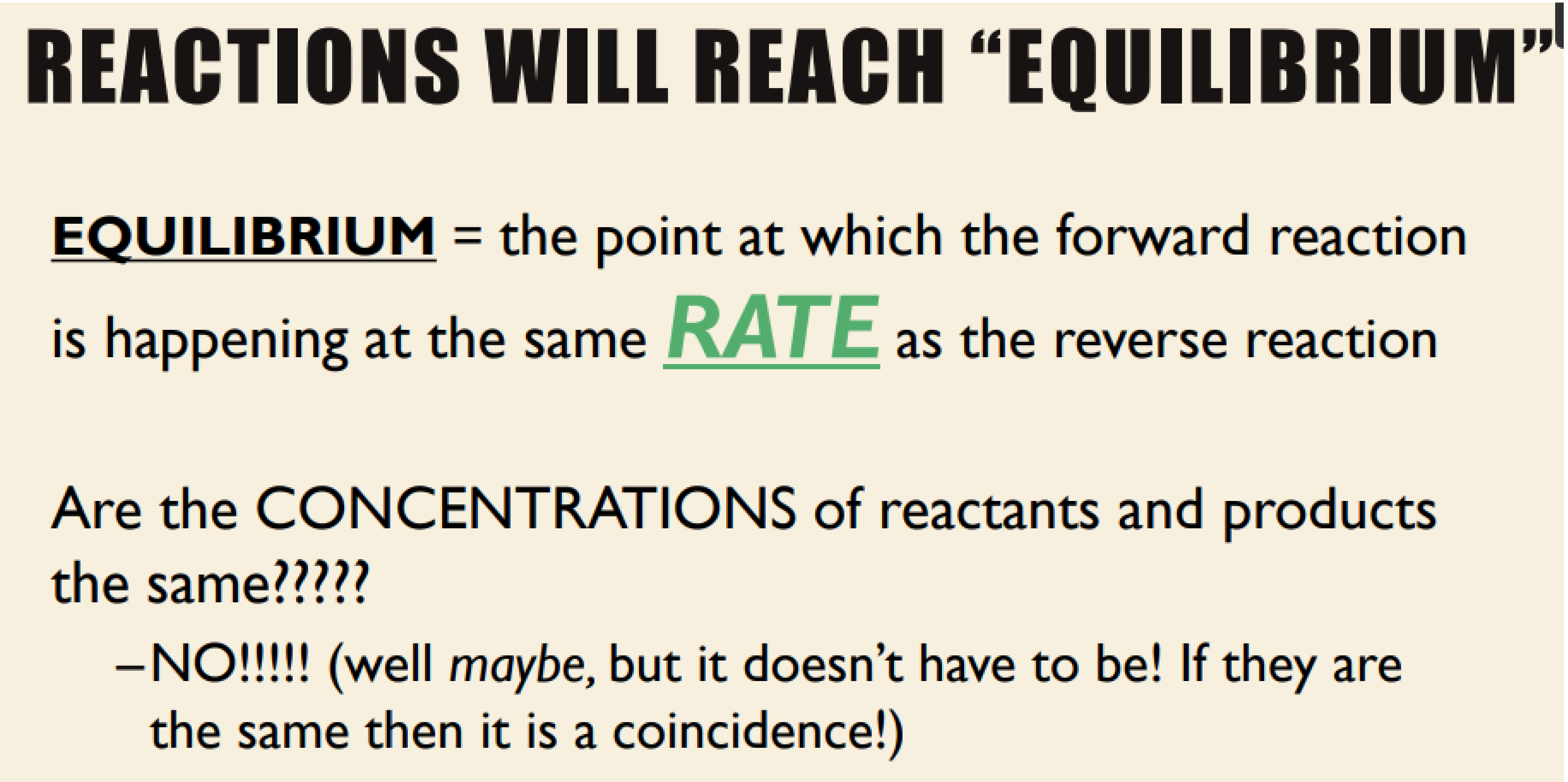
OR

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

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"

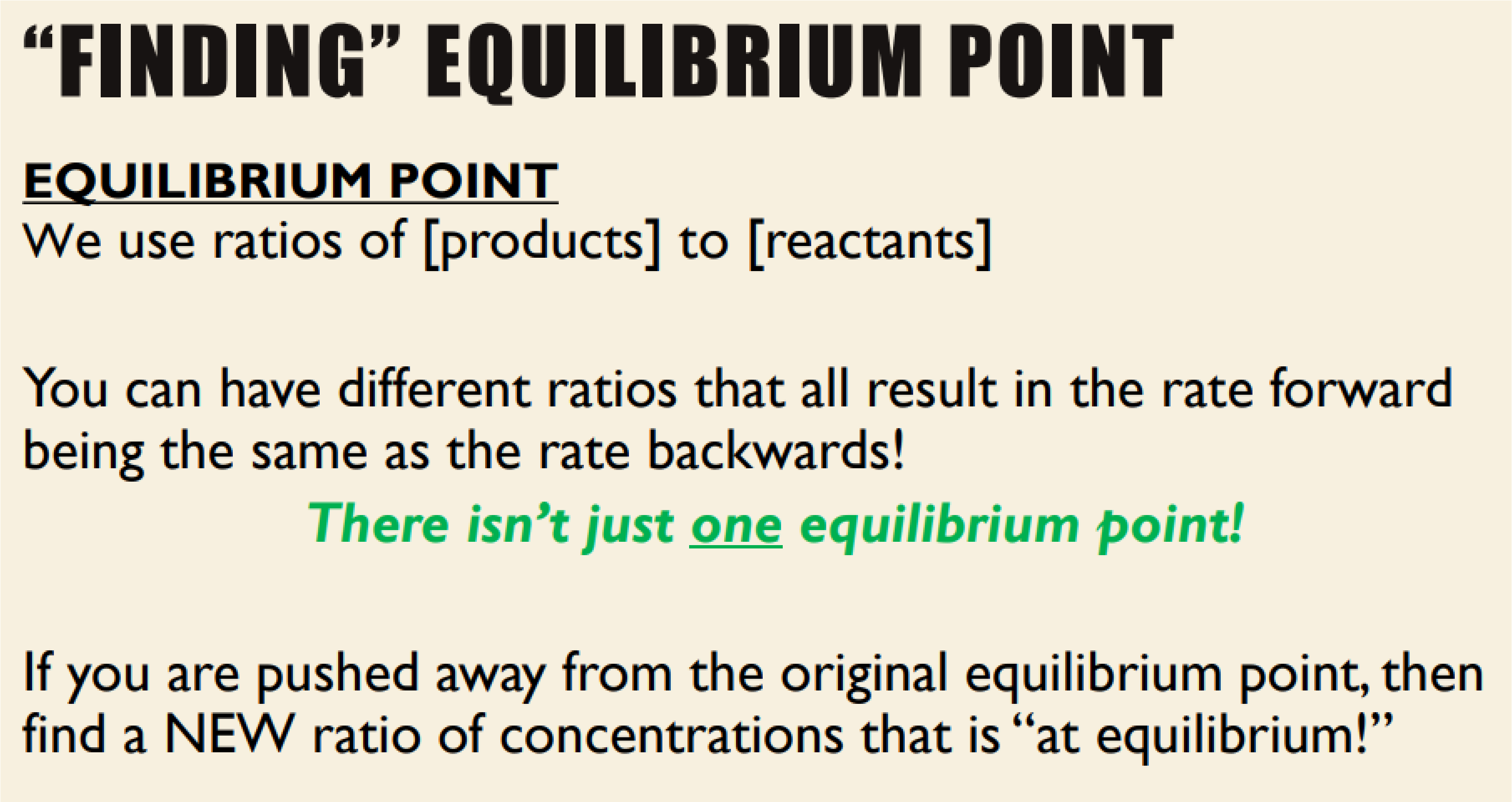
EQUILIBRIUM = the point at which the forward reaction is happening at the same ***RATE*** as the reverse reaction

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

EQUILIBRIUM POINT
We use ratios of [products] to [reactants]

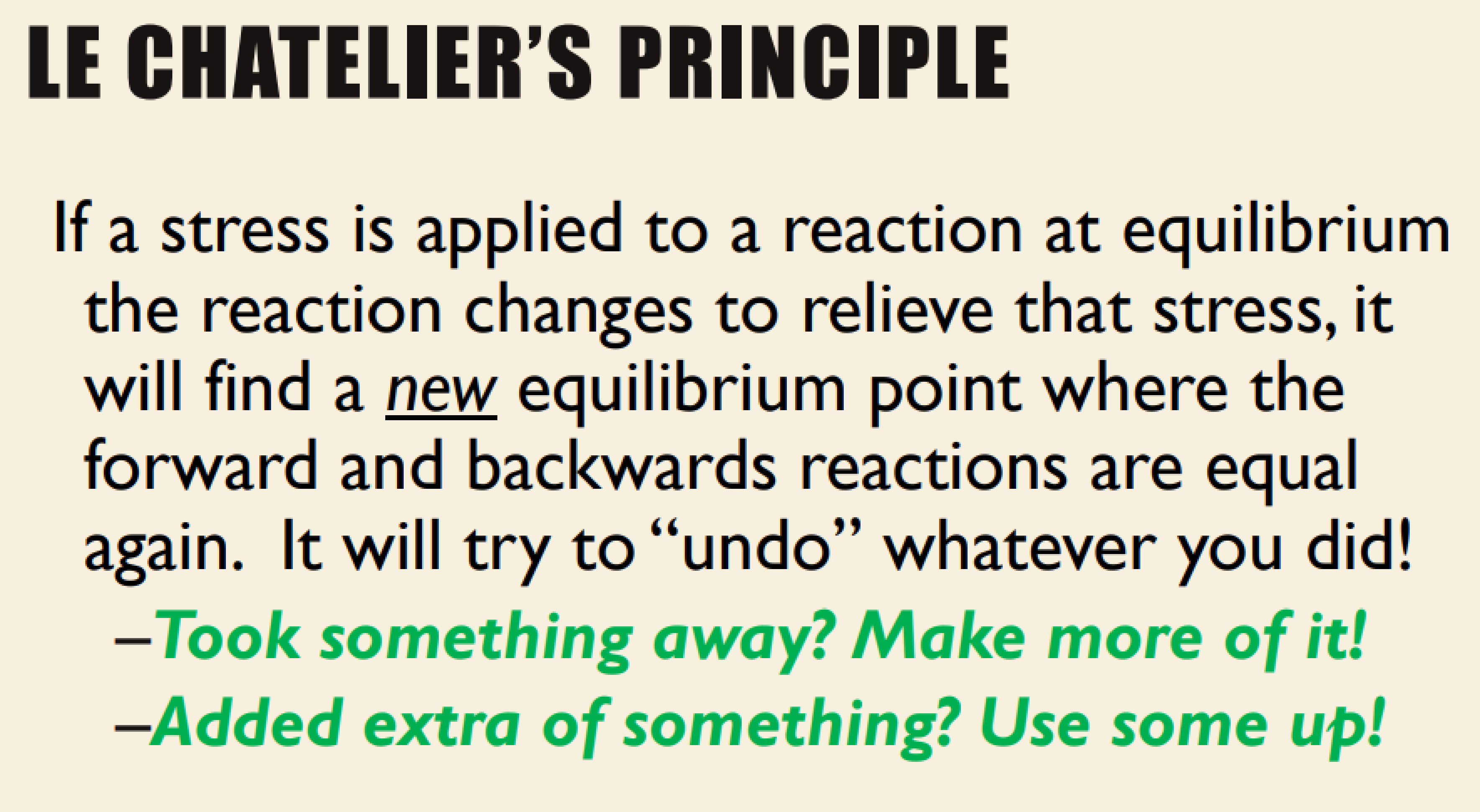
You can have different ratios that all result in the rate forward being the same as the rate backwards!

There isn’t just one 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



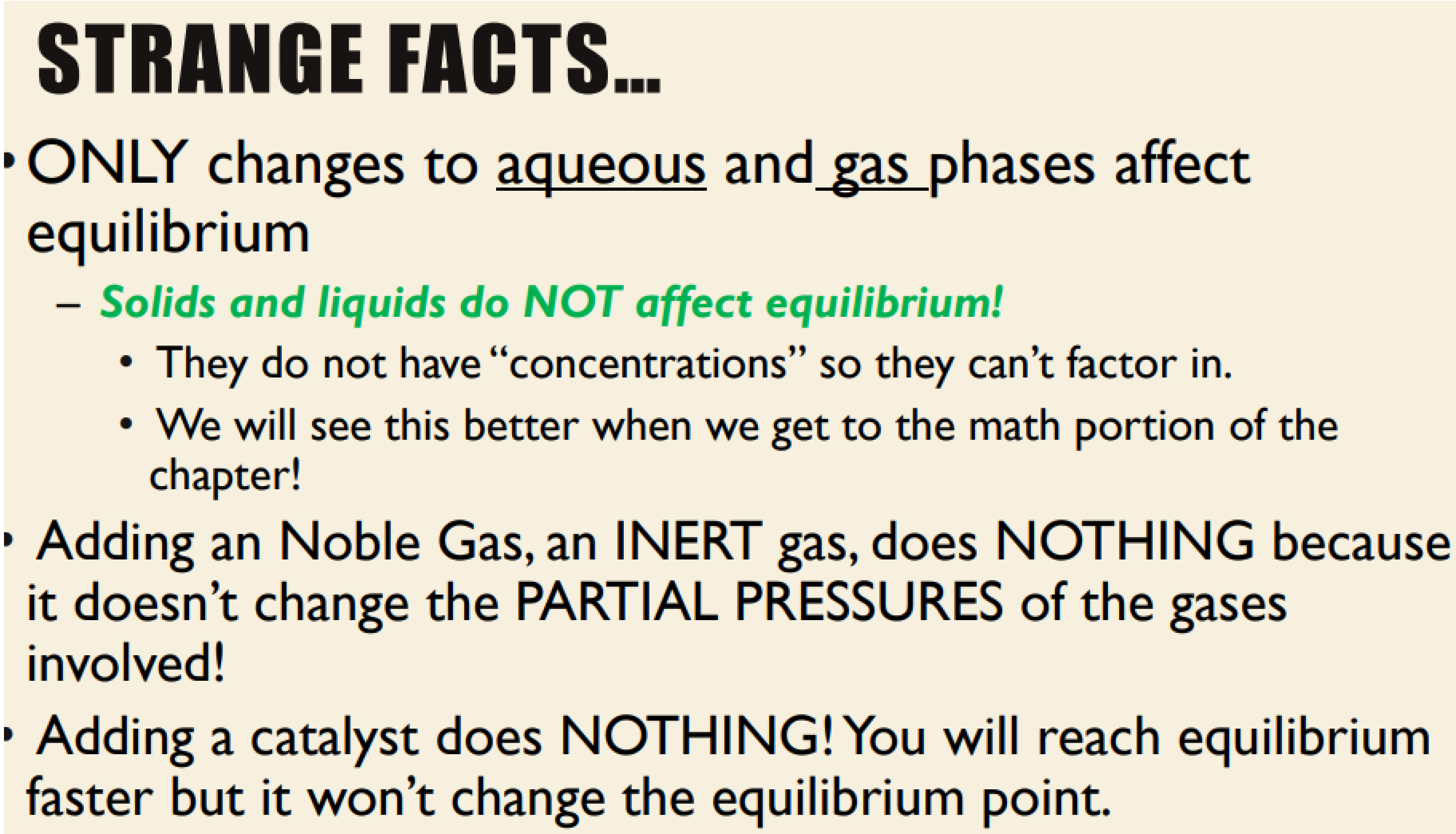
LE CHATELIER'S PRINCIPLE

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

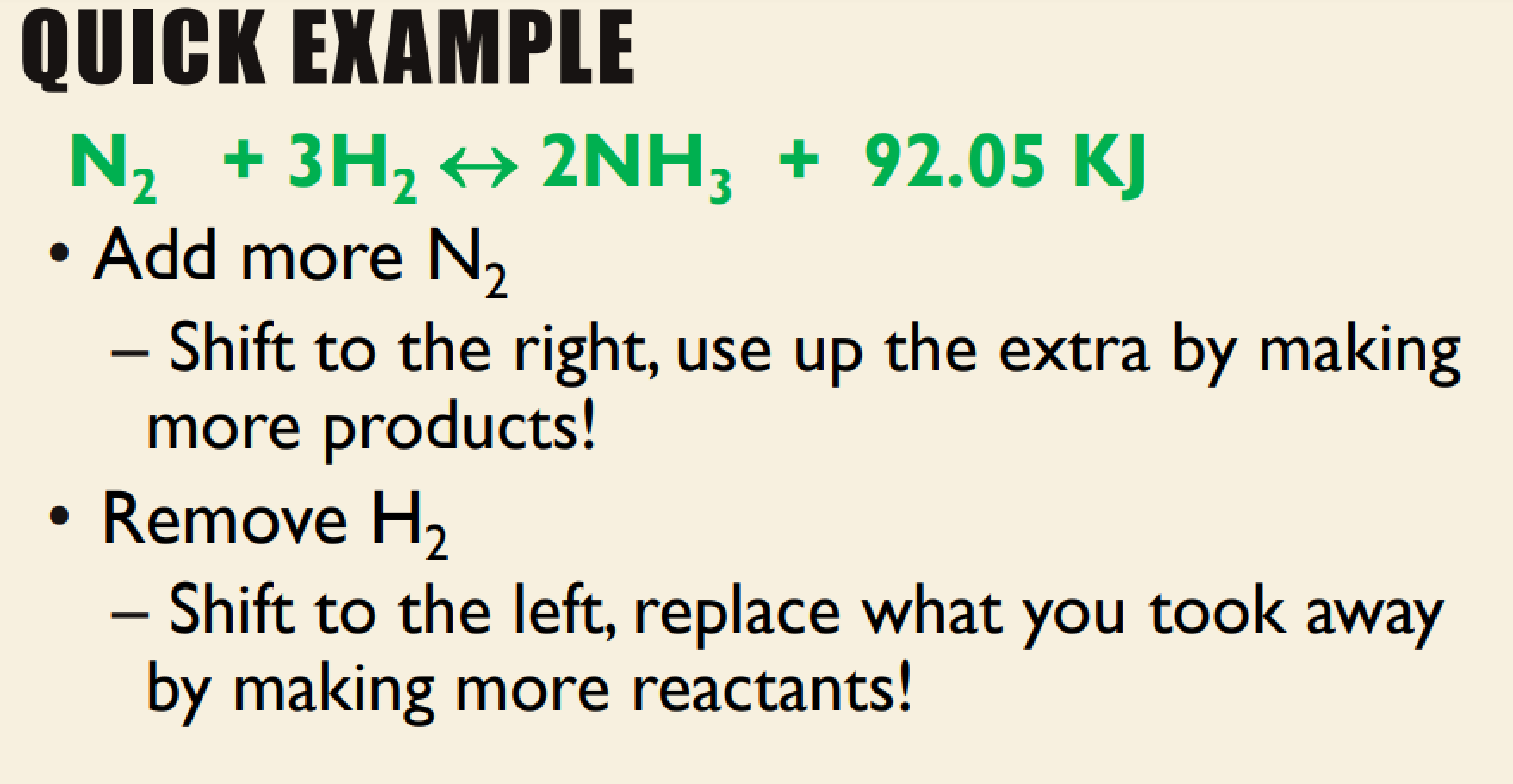


STRANGE FACTS…

- 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



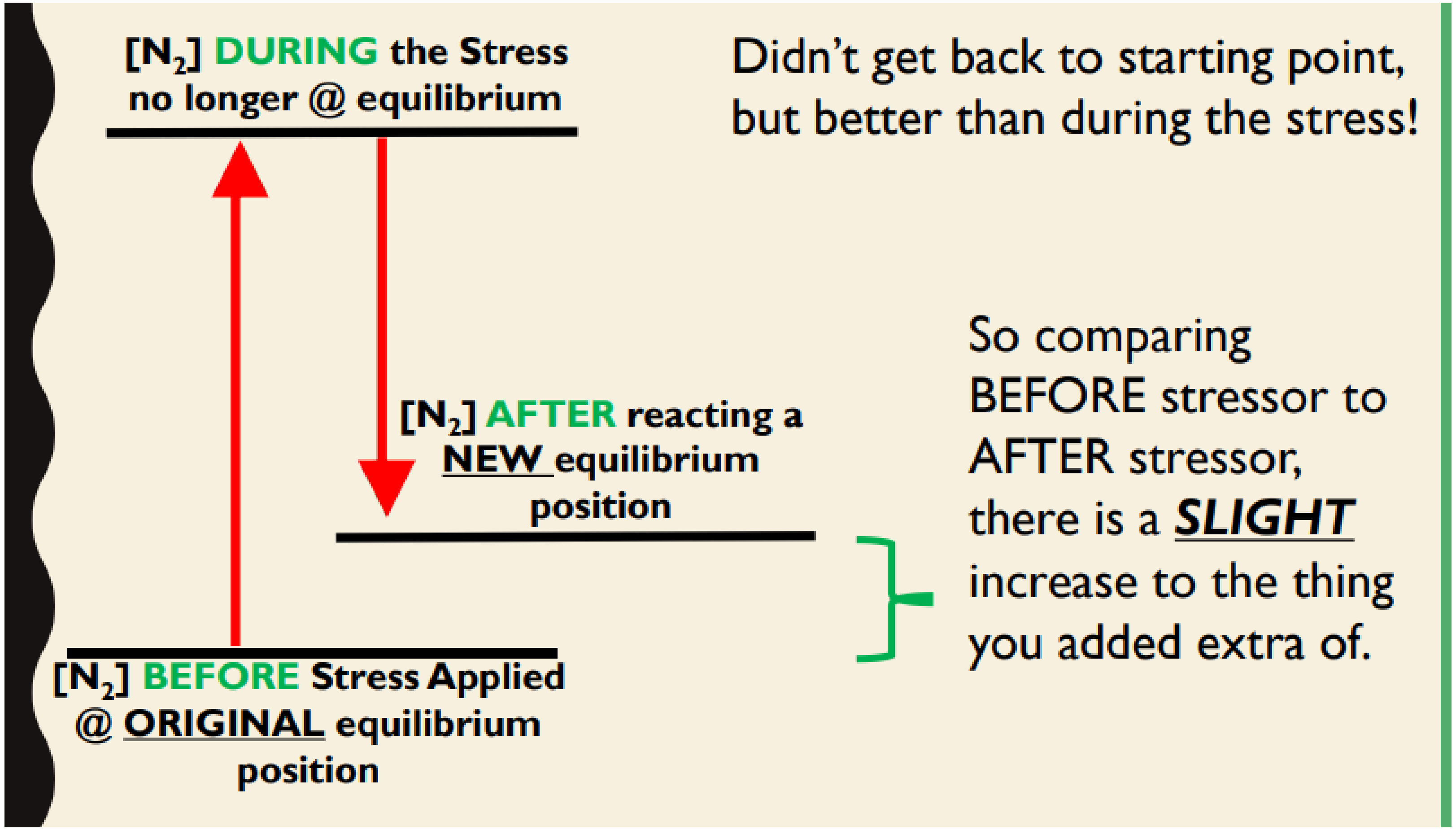
QUICK EXAMPLE

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



$[N_2]$ DURING the Stress
no longer @ equilibrium

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

$[N_2]$ AFTER reacting a
<u>NEW</u> equilibrium
position

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

$[N_2]$ BEFORE Stress Applied
@ <u>ORIGINAL</u> equilibrium
position

Le Chatelier

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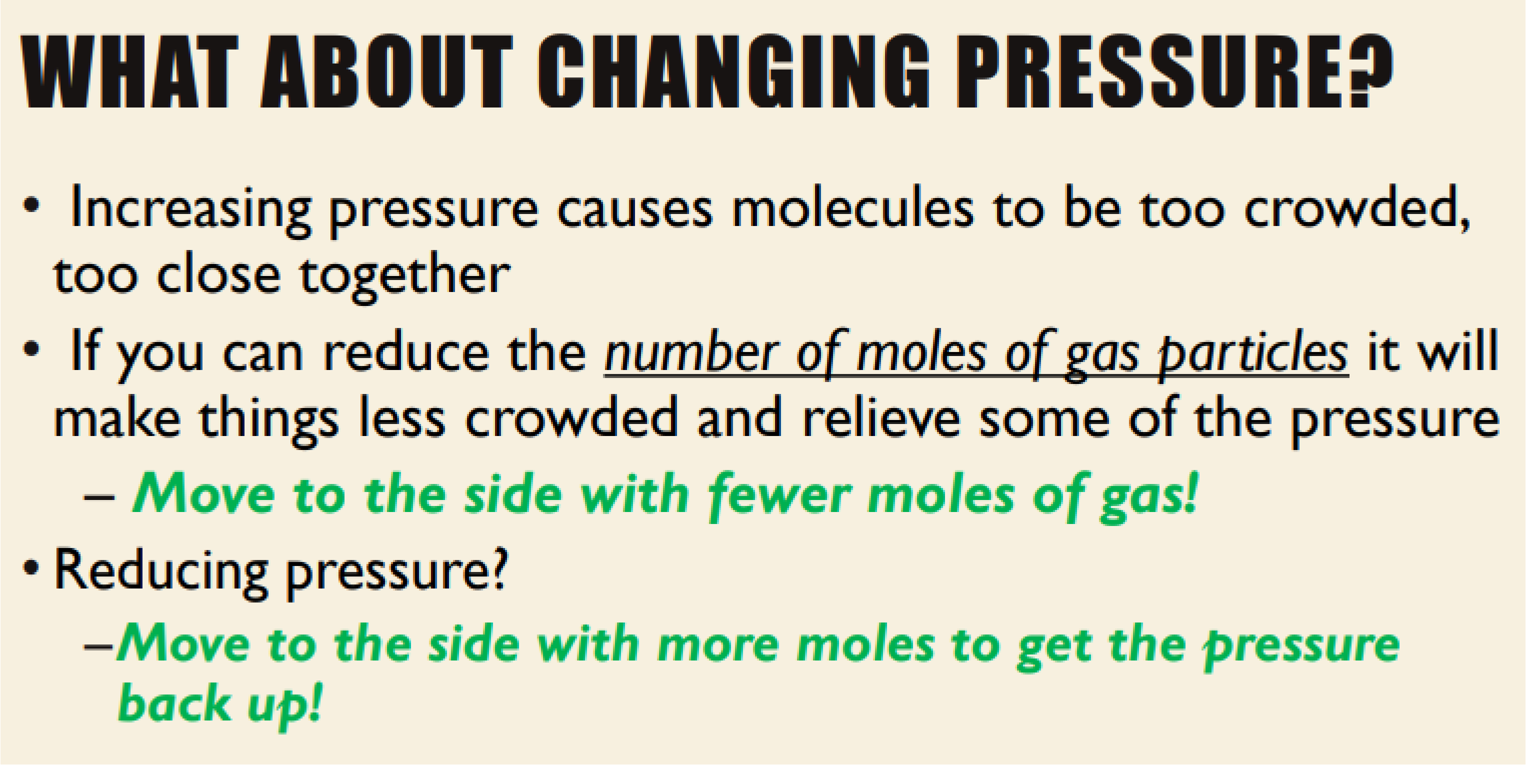
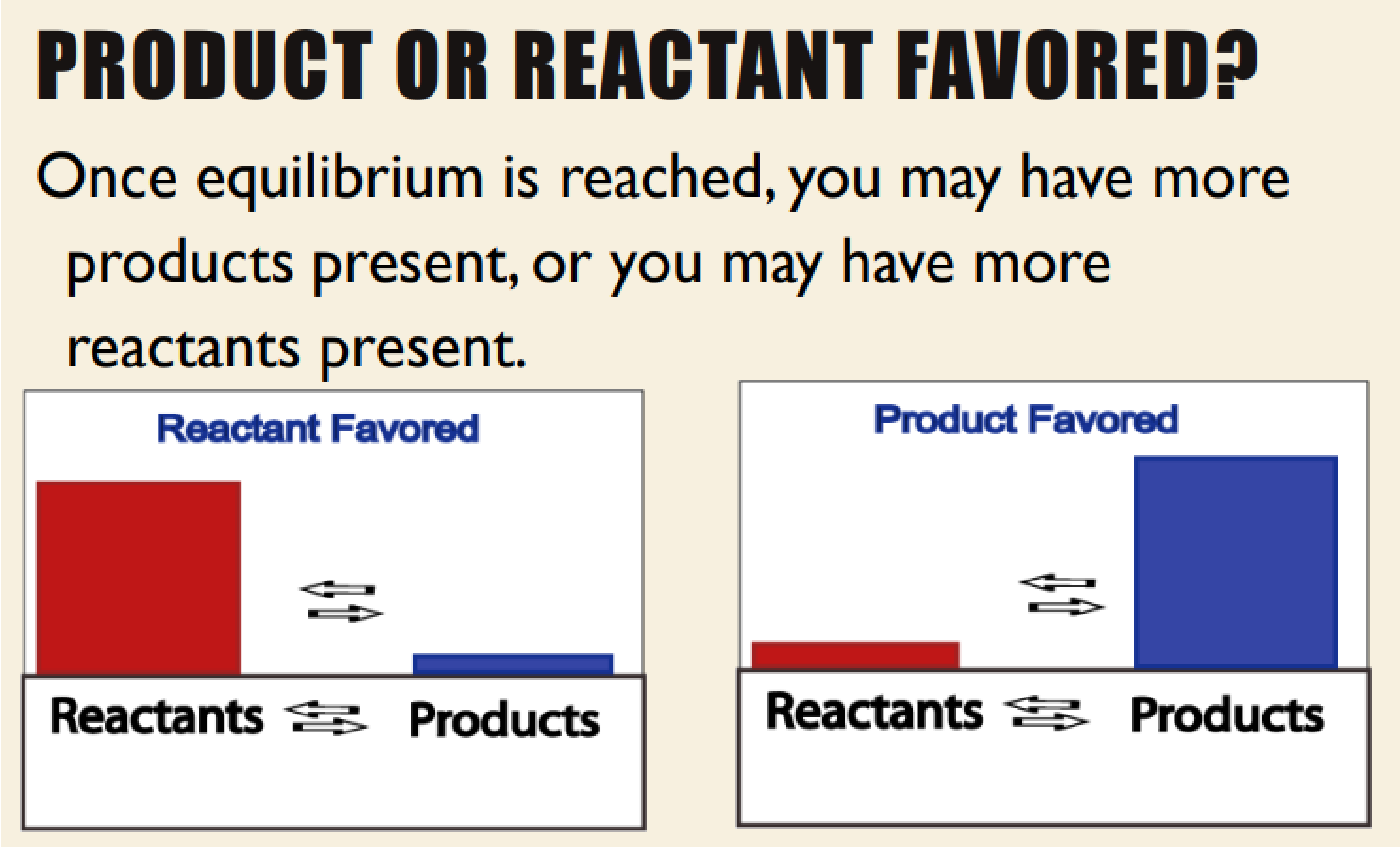


WHAT ABOUT CHANGING PRESSURE?

- 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.

Reactant Favored

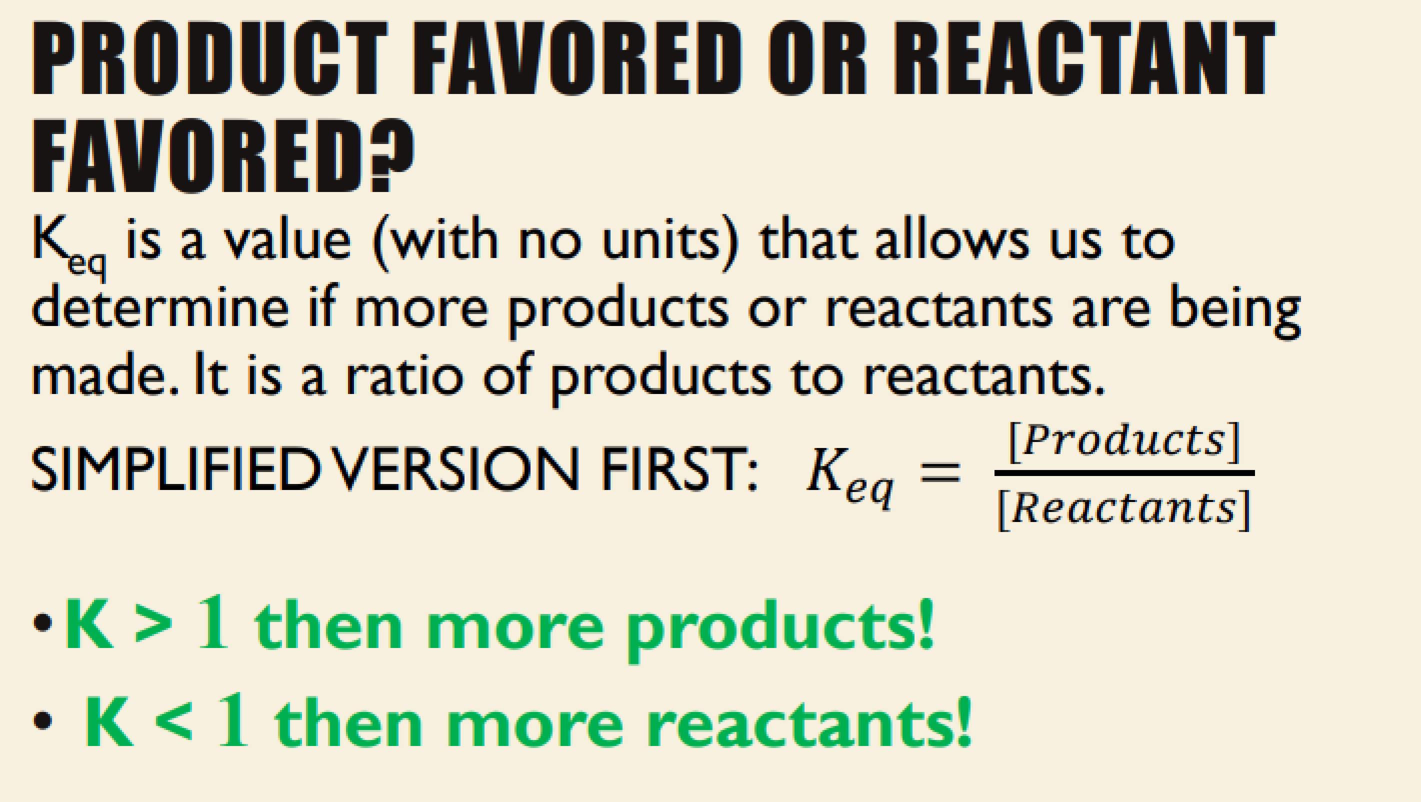
Reactants $\rightleftarrows$ Products

Product Favored

Reactants $\rightleftarrows$ Products

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.

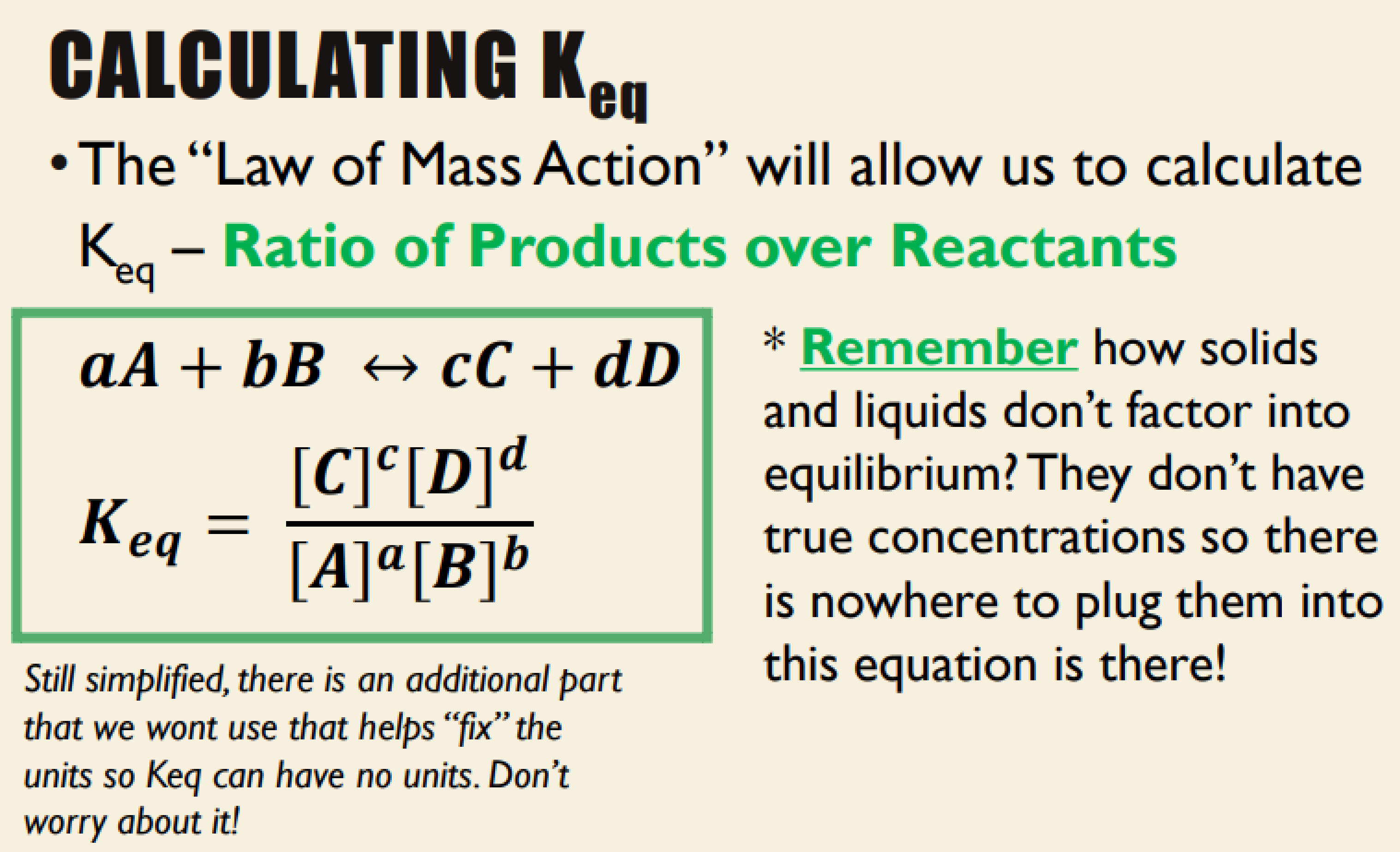
SIMPLIFIED VERSION FIRST: $K_{eq} = \frac{[Products]}{[Reactants]}$

- **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**

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

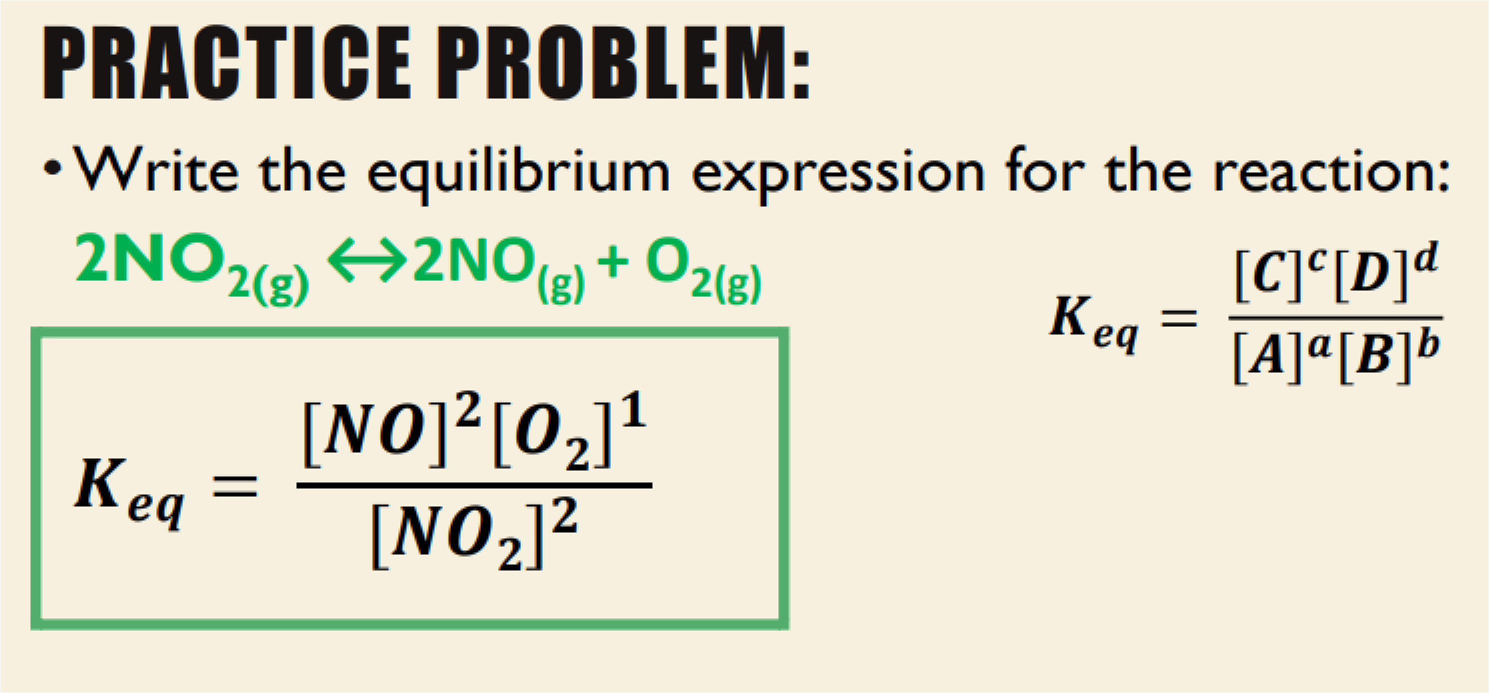
$$K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

* **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!

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!

Equilibrium Constant

Jump back to title slide



PRACTICE PROBLEM:

- Write the equilibrium expression for the reaction:

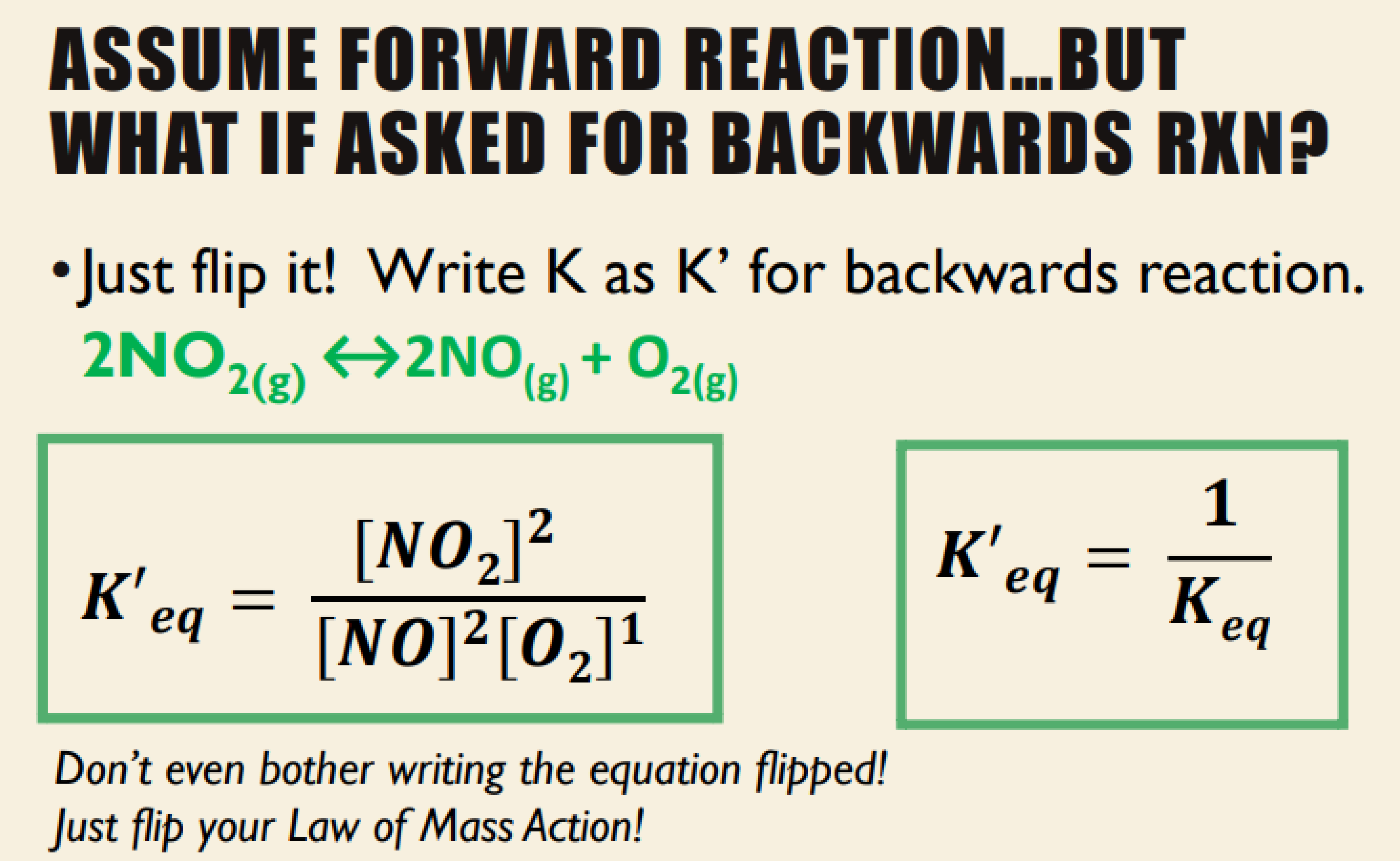
$2NO_{2(g)} \leftrightarrow 2NO_{(g)} + O_{2(g)}$

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

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

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.

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

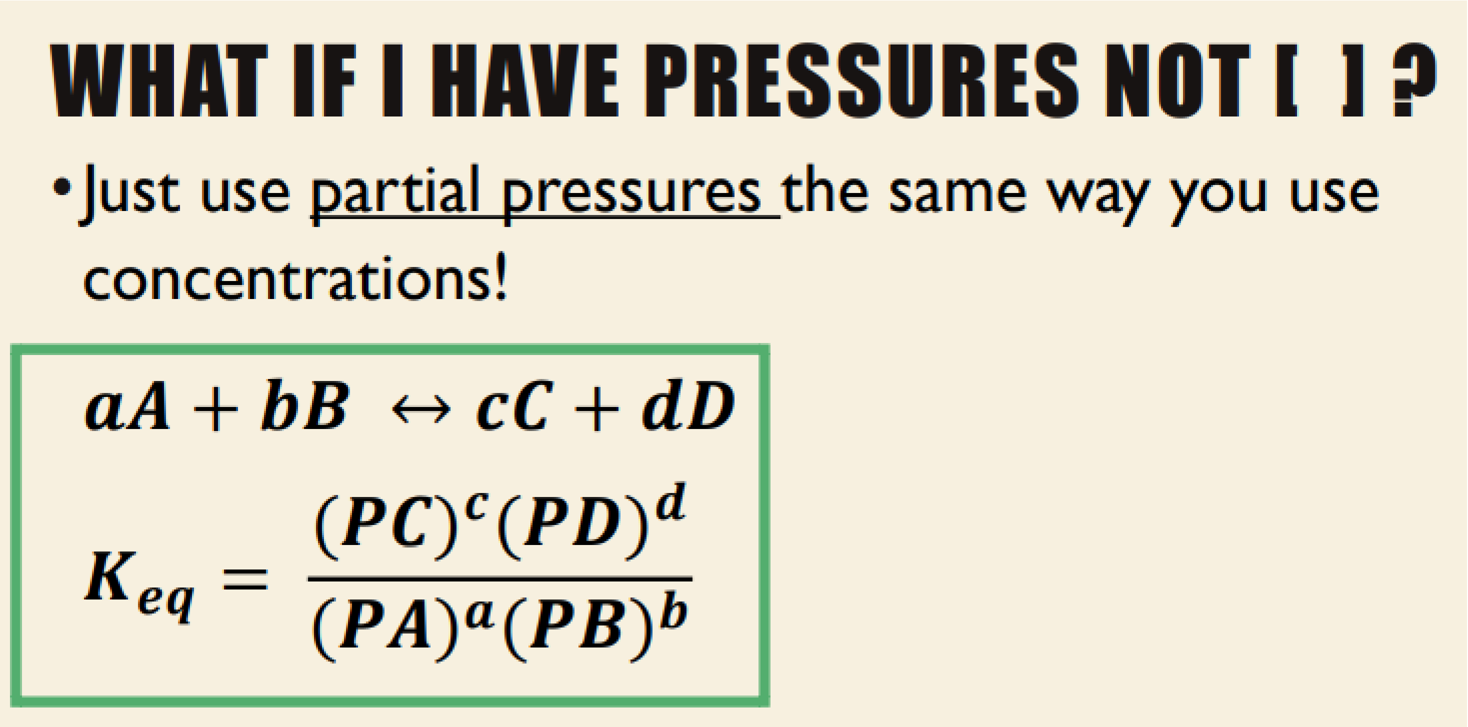
$$\boxed{K'_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]^1}}$$

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

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}

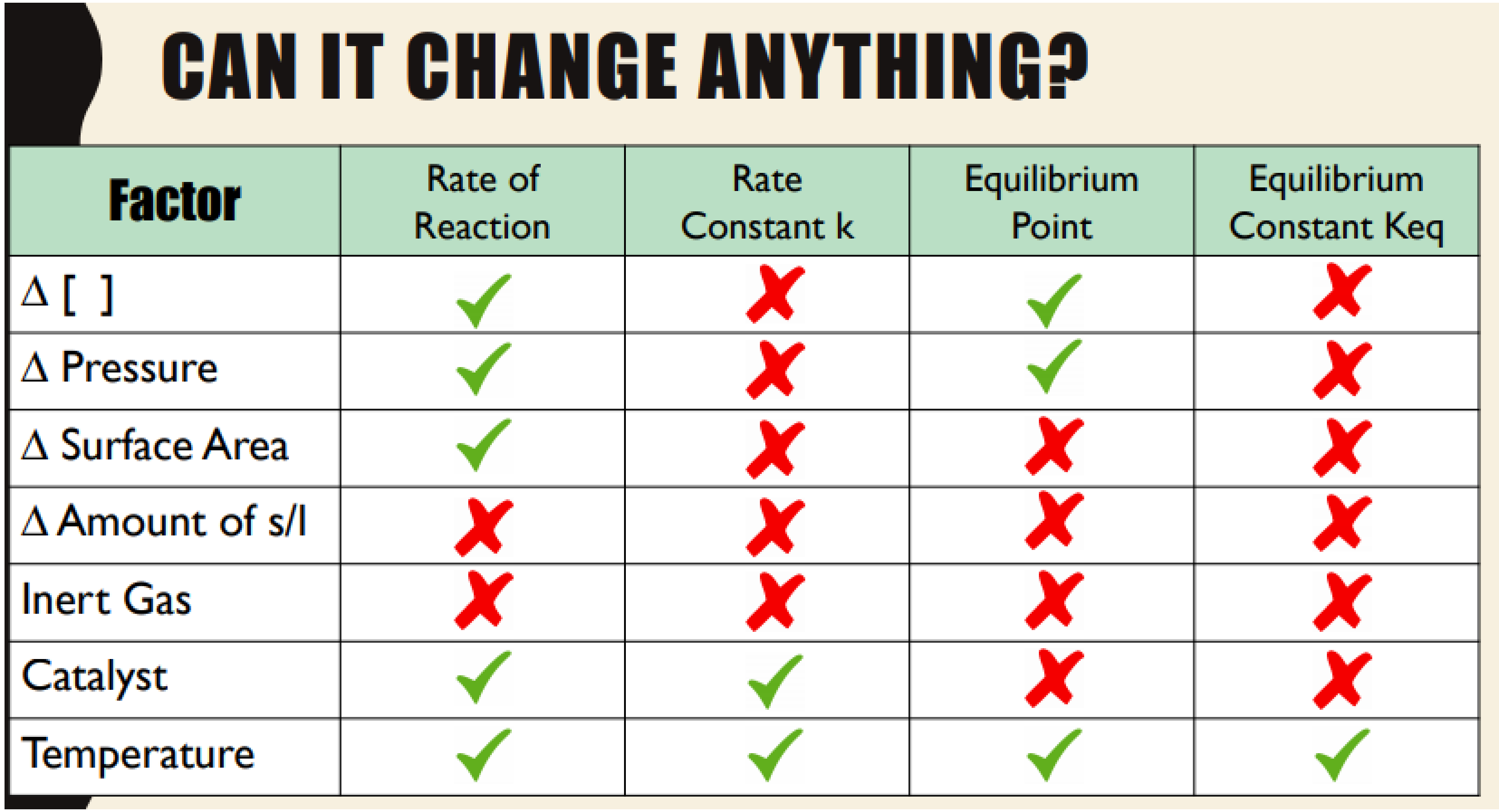
- Changing Concentrations
- Changing Pressures
- Adding Solids or Liquids
- Adding Catalysts

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

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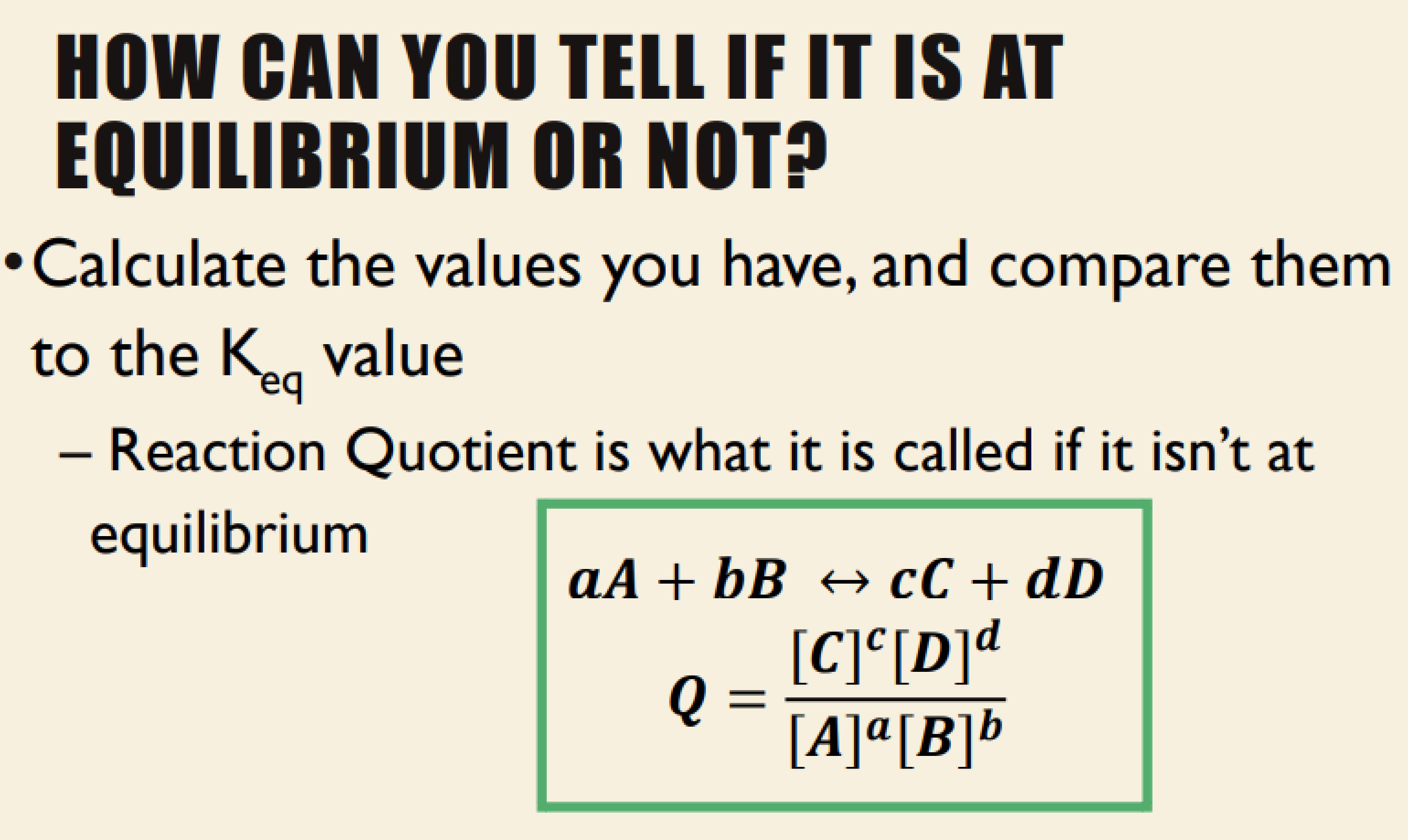


HOW CAN YOU TELL IF IT IS AT EQUILIBRIUM OR NOT?

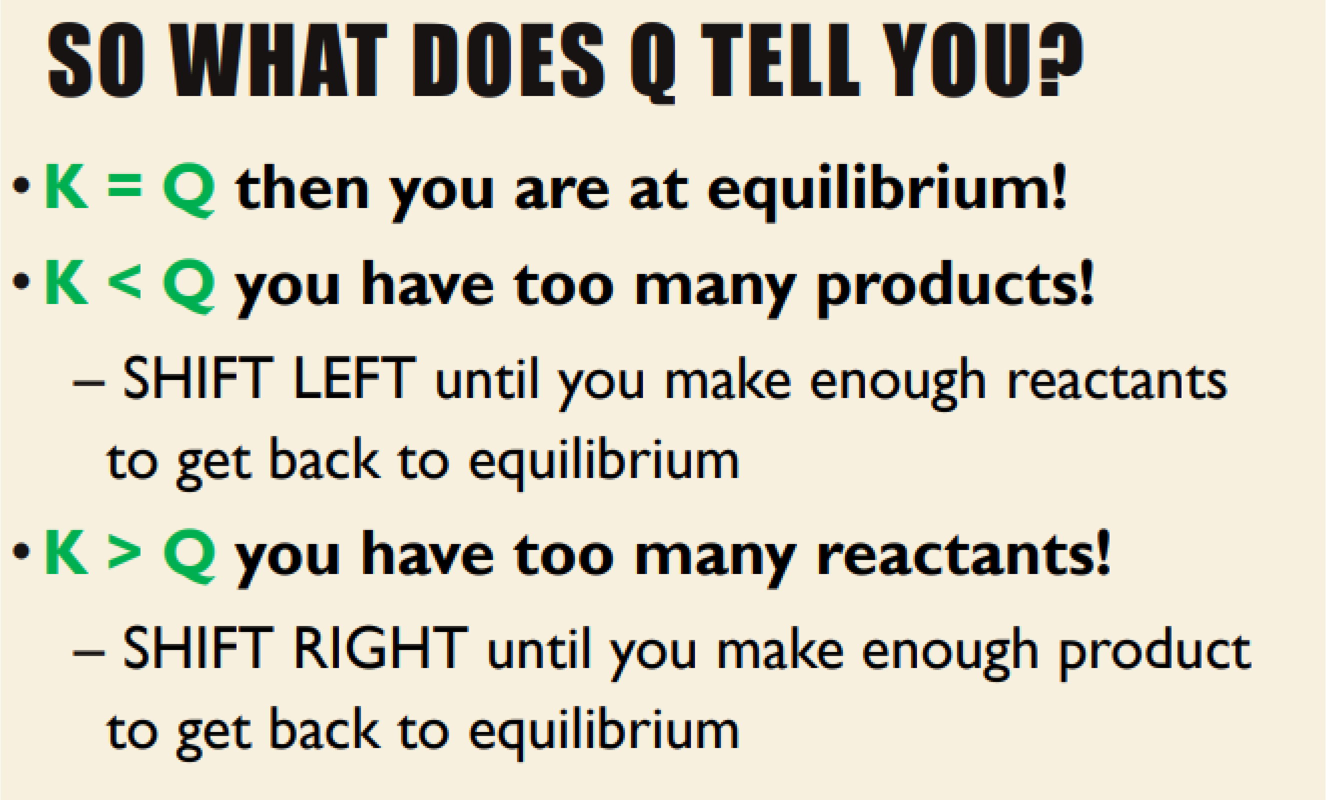
- Calculate the values you have, and compare them to the K_{eq} value
  - Reaction Quotient is what it is called if it isn't at equilibrium

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

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

Equilibrium Quotient

Jump back to title slide

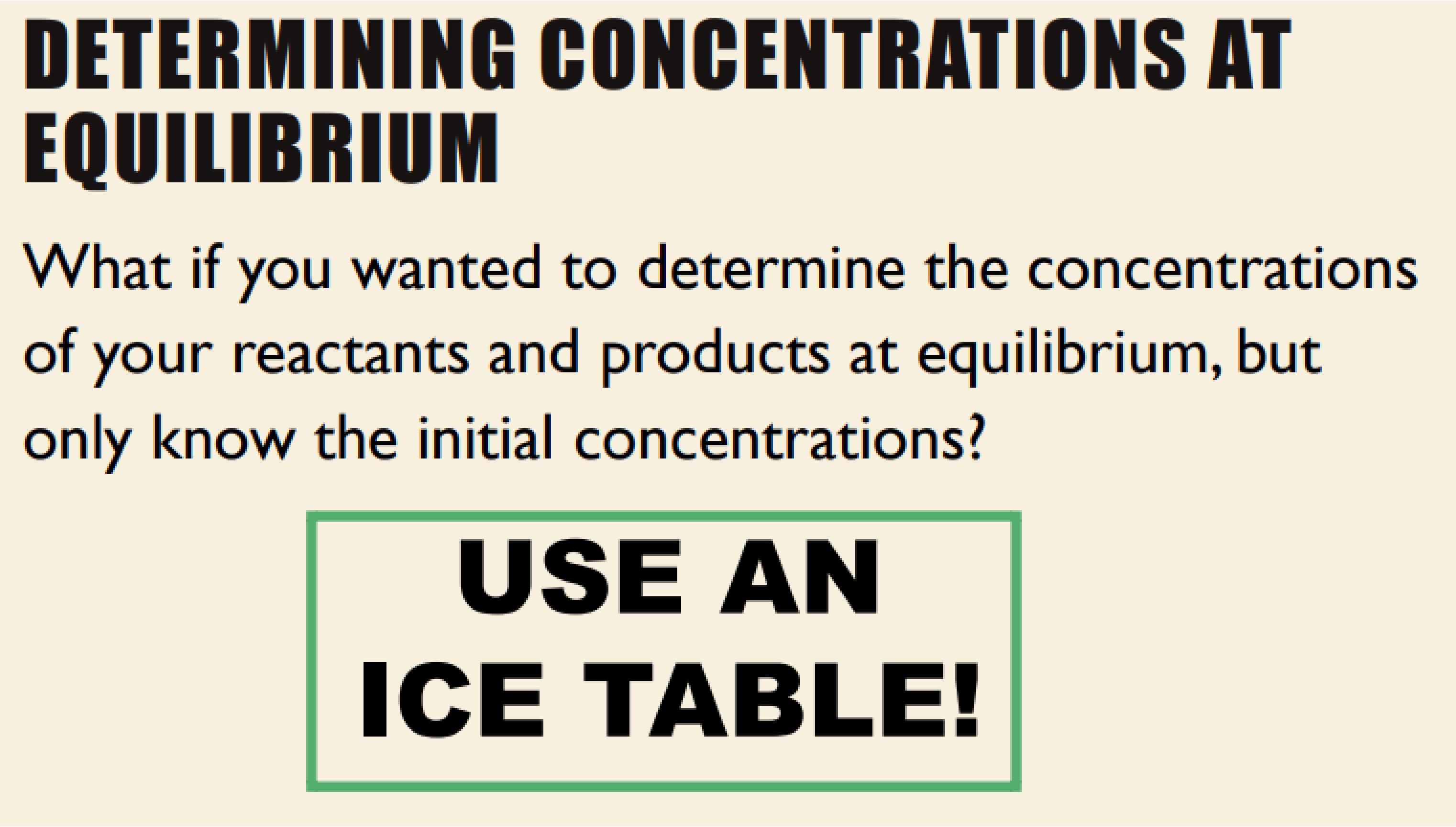


SO WHAT DOES Q TELL YOU?

- 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

ICE Tables

Jump back to title slide



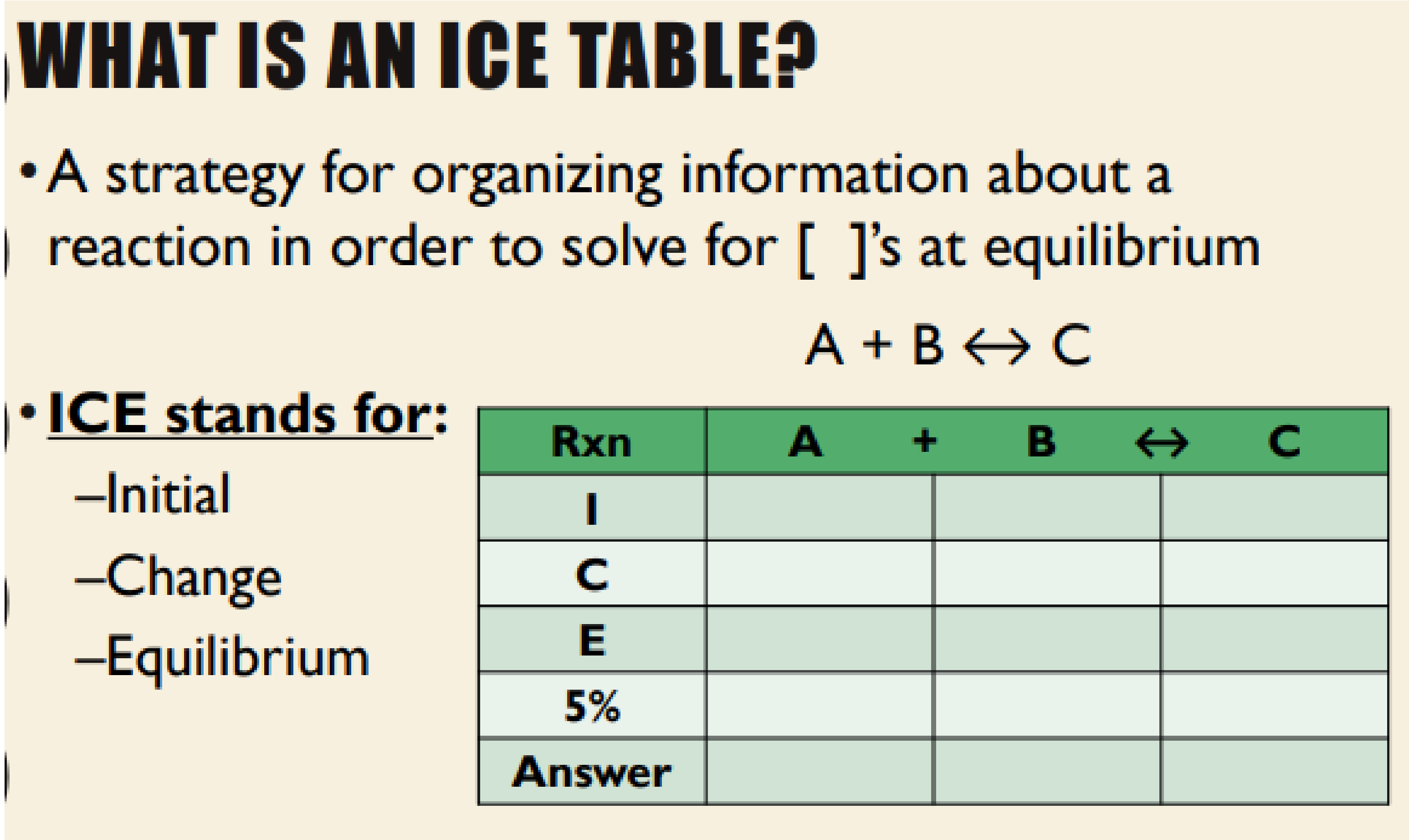
DETERMINING CONCENTRATIONS AT EQUILIBRIUM

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?

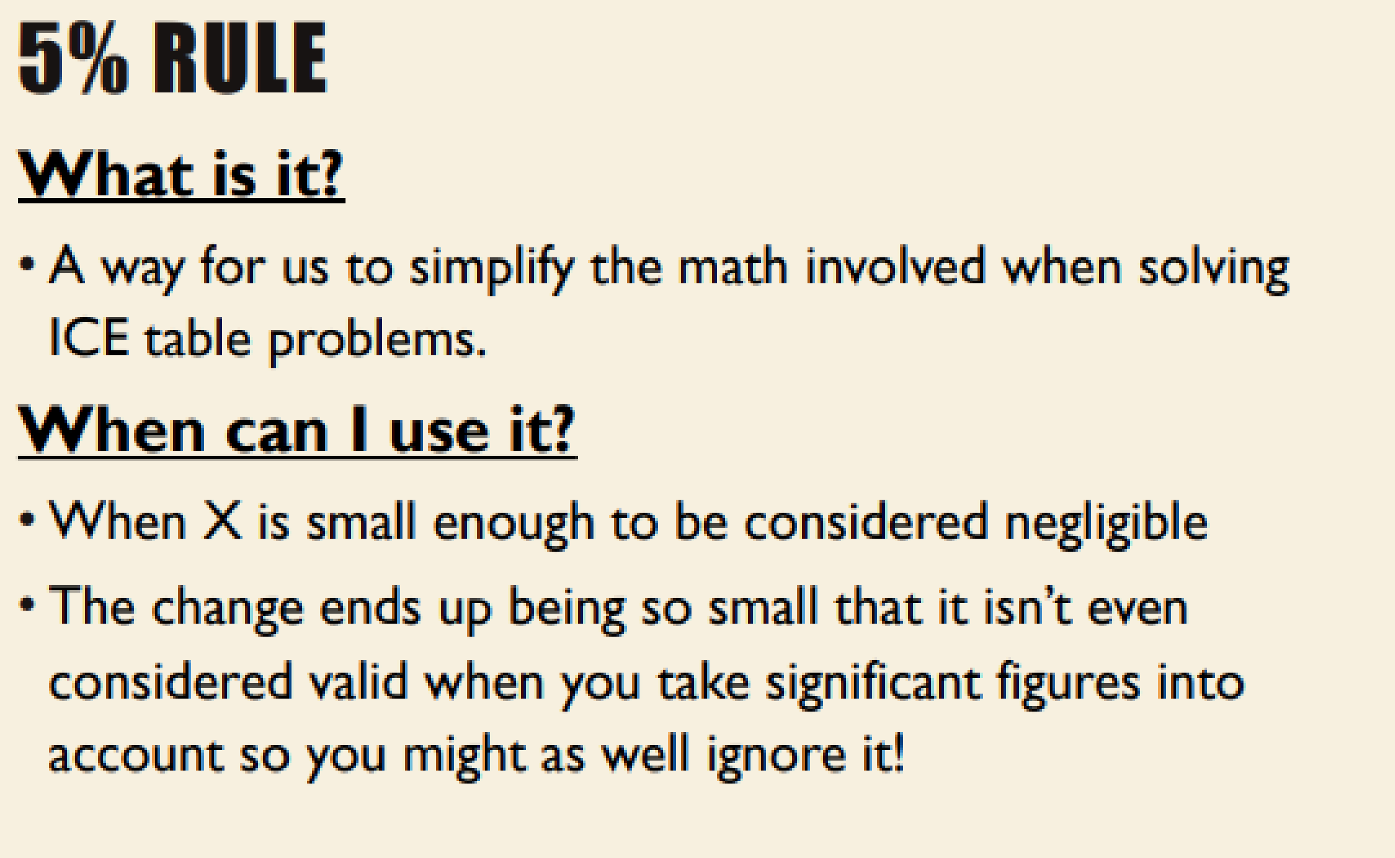
- A strategy for organizing information about a reaction in order to solve for [ ]'s at equilibrium

$A + B \leftrightarrow C$

- **ICE stands for:**
  - –Initial
  - –Change
  - –Equilibrium

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

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

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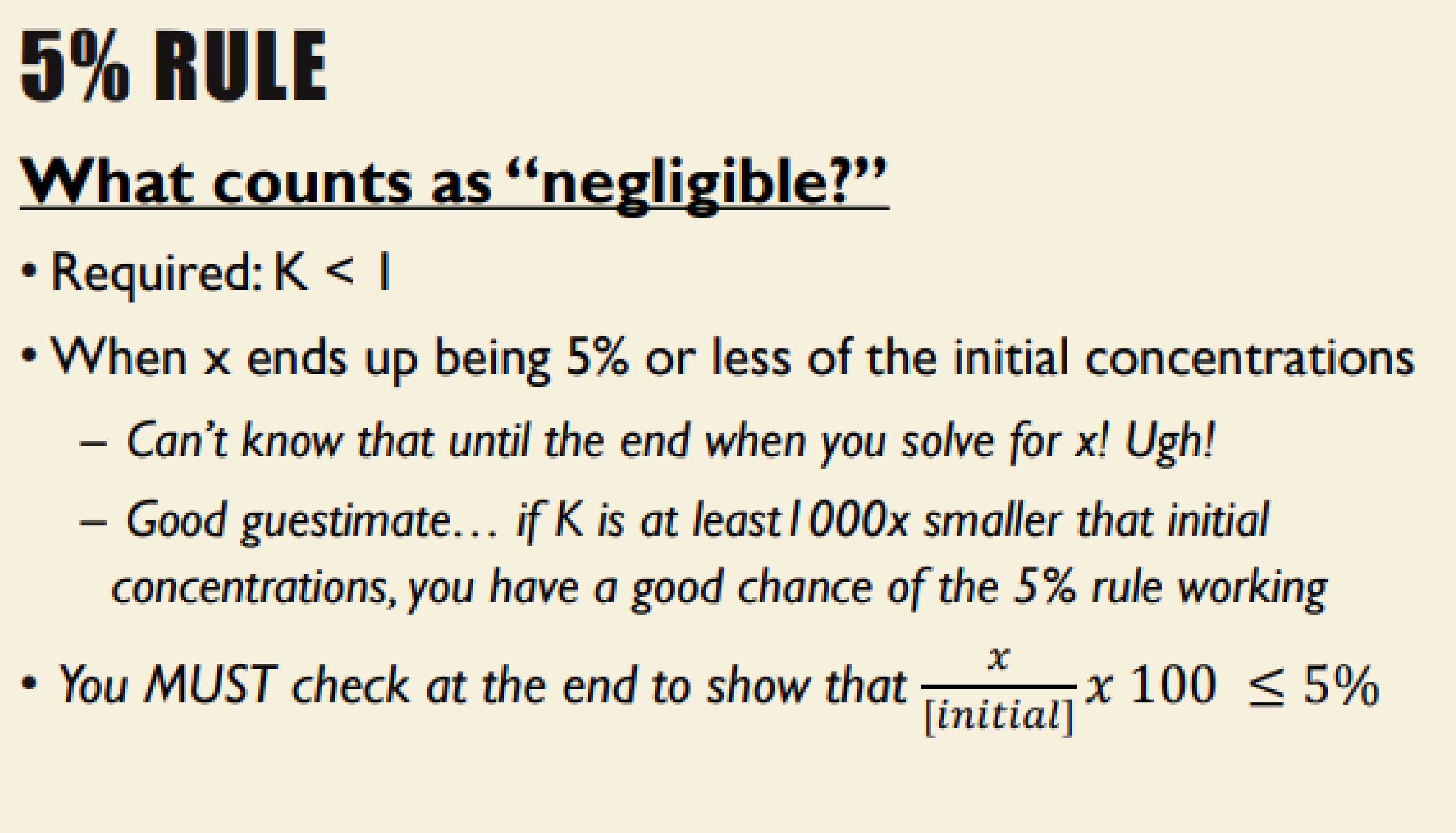


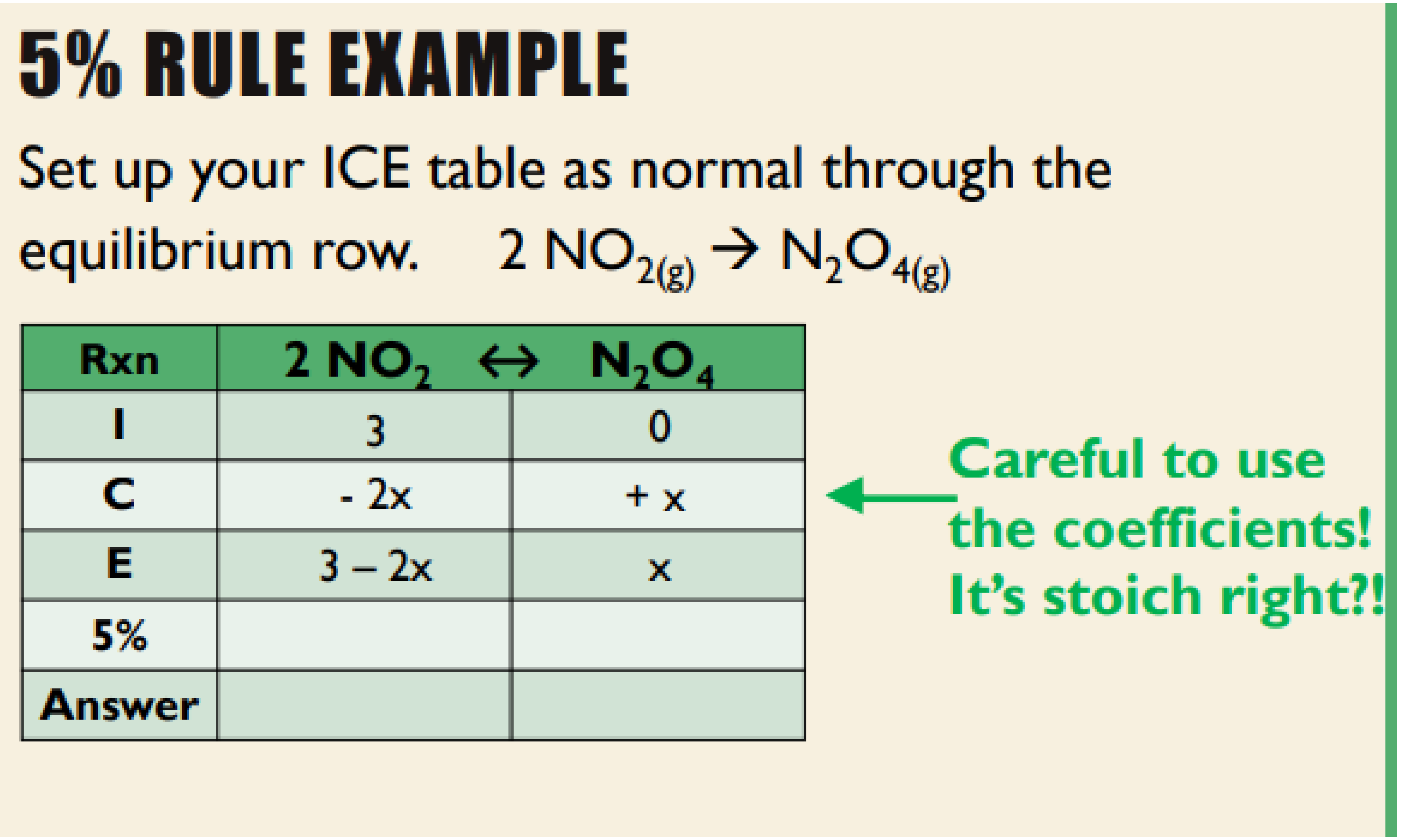
5% RULE

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 least 1000x smaller that initial concentrations, you have a good chance of the 5% rule working*
- *You MUST check at the end to show that* $\frac{x}{[initial]} x\ 100 \le 5\%$

ICE Tables

[Jump back to title slide]



5% RULE EXAMPLE

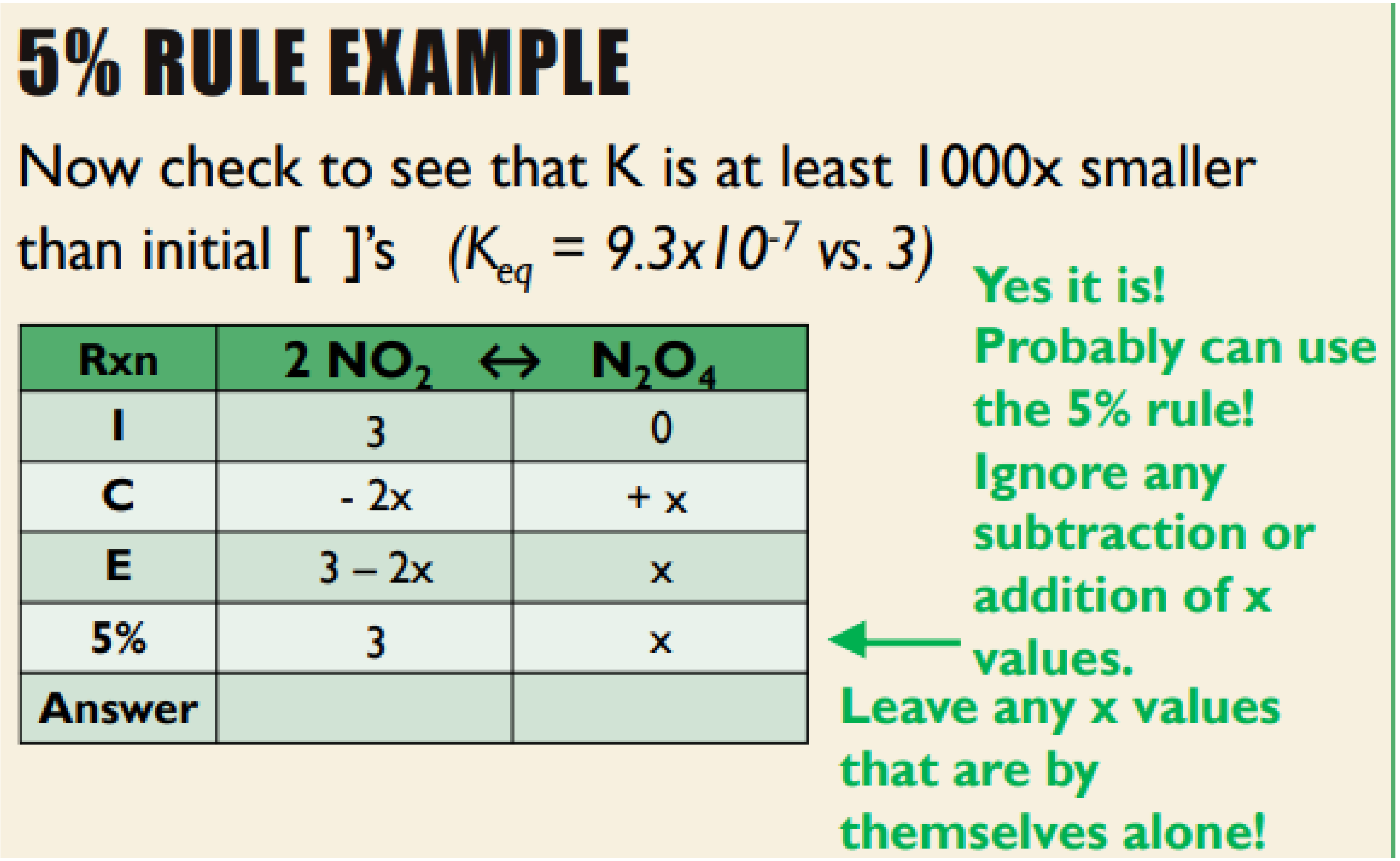
Set up your ICE table as normal through the equilibrium row. $2\ NO_{2(g)} \rightarrow N_2O_{4(g)}$

Rxn	$2\ NO_2 \leftrightarrow N_2O_4$	
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		

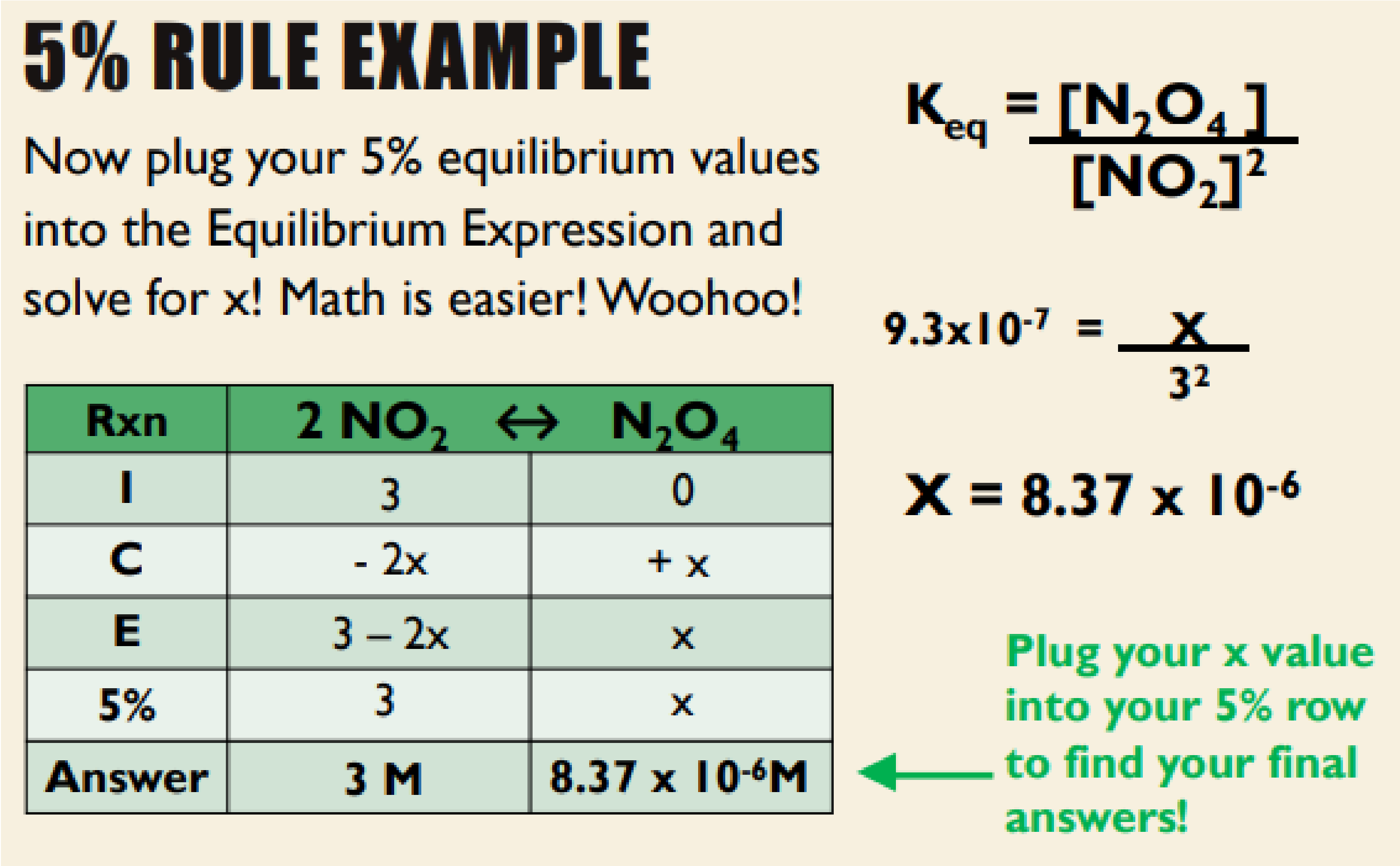
Yes it is!

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!

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

$$9.3\times10^{-7} = \frac{X}{3^2}$$

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

Rxn	$2\ NO_2$ ↔	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

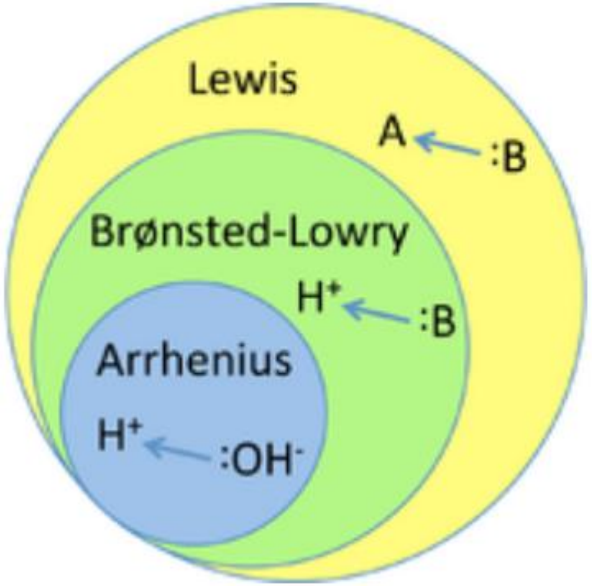
- Acids make H^+ ions in aqueous solutions
- Bases make OH^- ions in solution

Bronsted-Lowry

- Acids donate protons
- Bases accept protons

Lewis

- Acids accept electron pairs
- Bases donate electron pairs



Concepts

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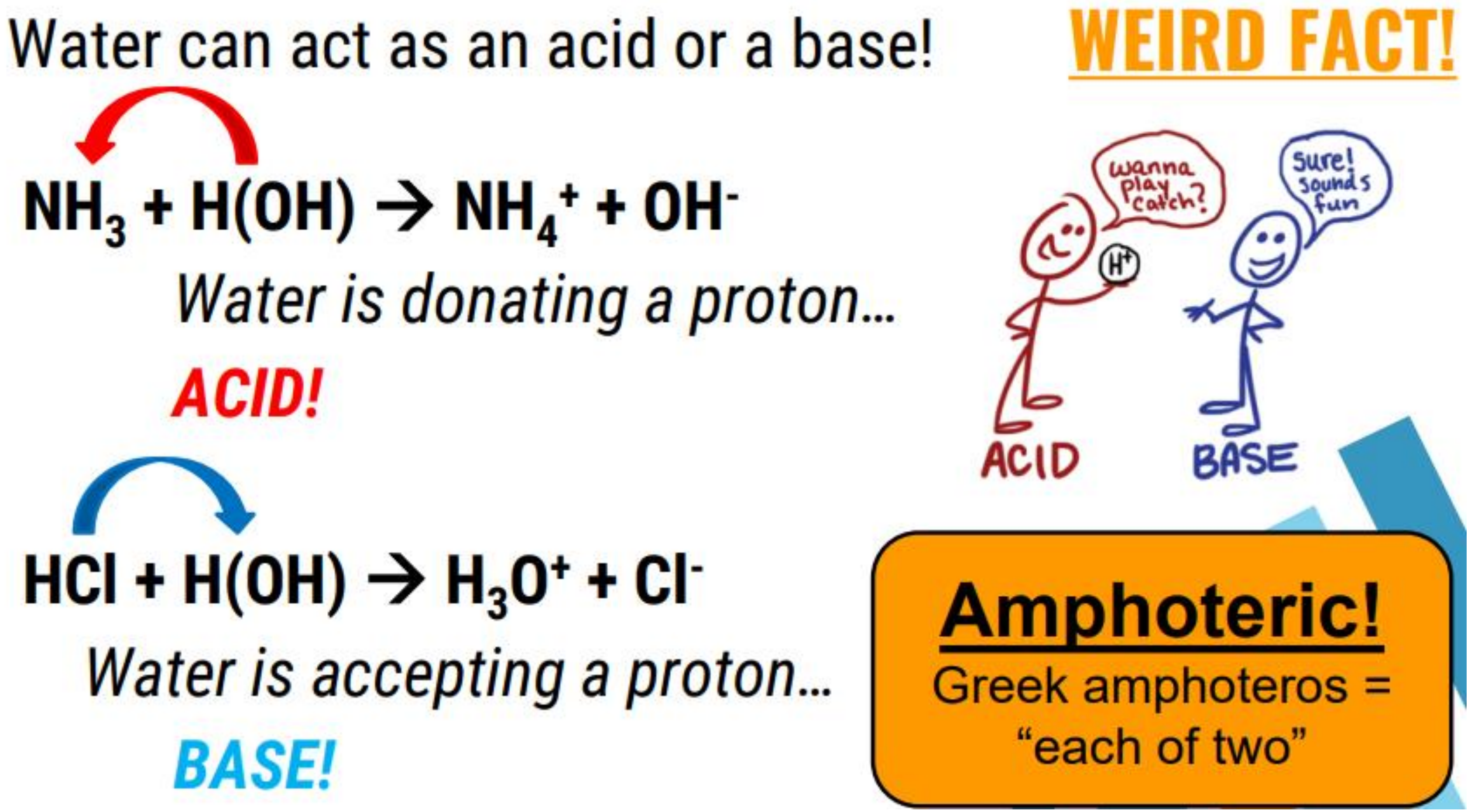


Water can act as an acid or a base!

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

Water is donating a proton…

ACID!

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

Water is accepting a proton…

BASE!

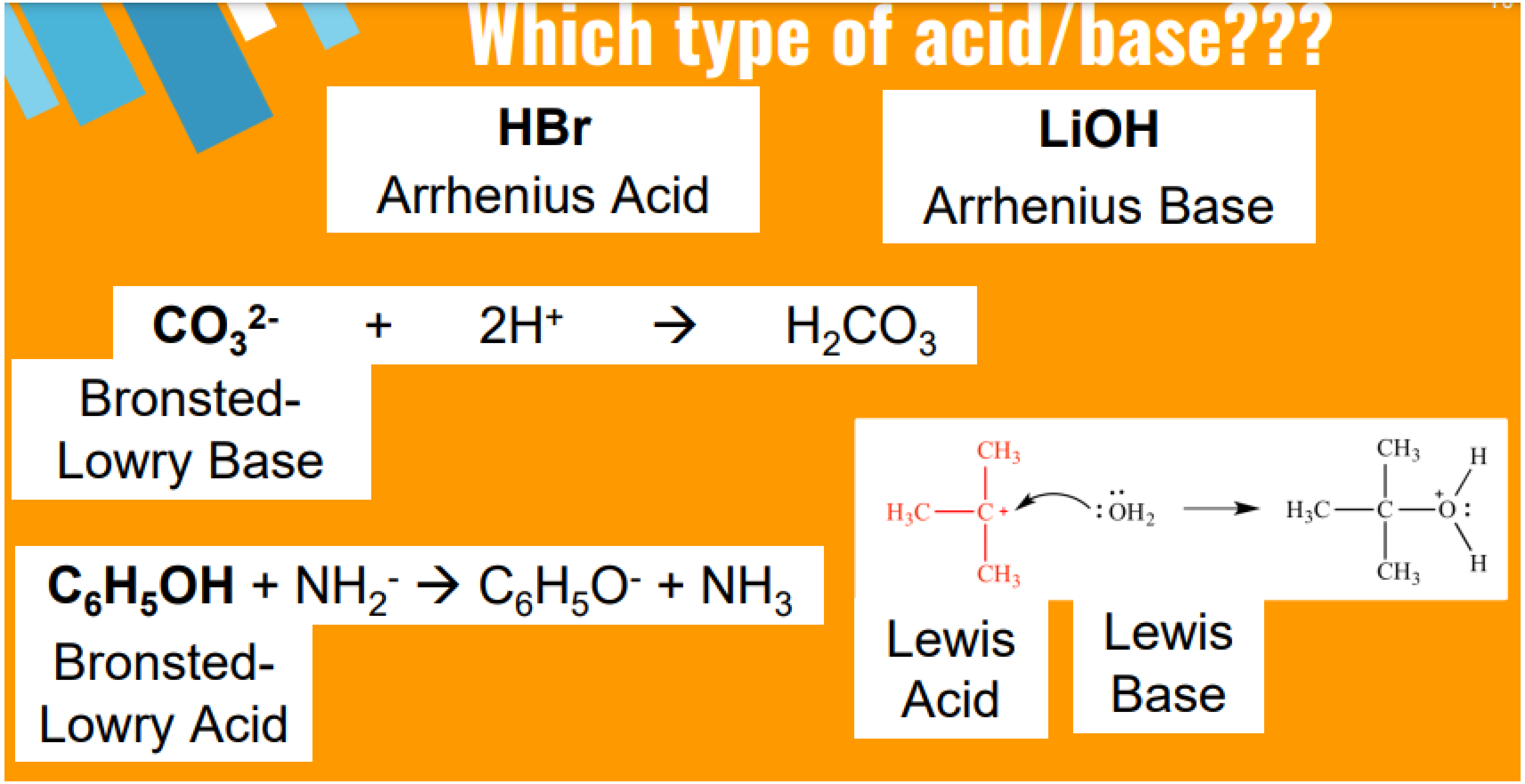
WEIRD FACT!

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

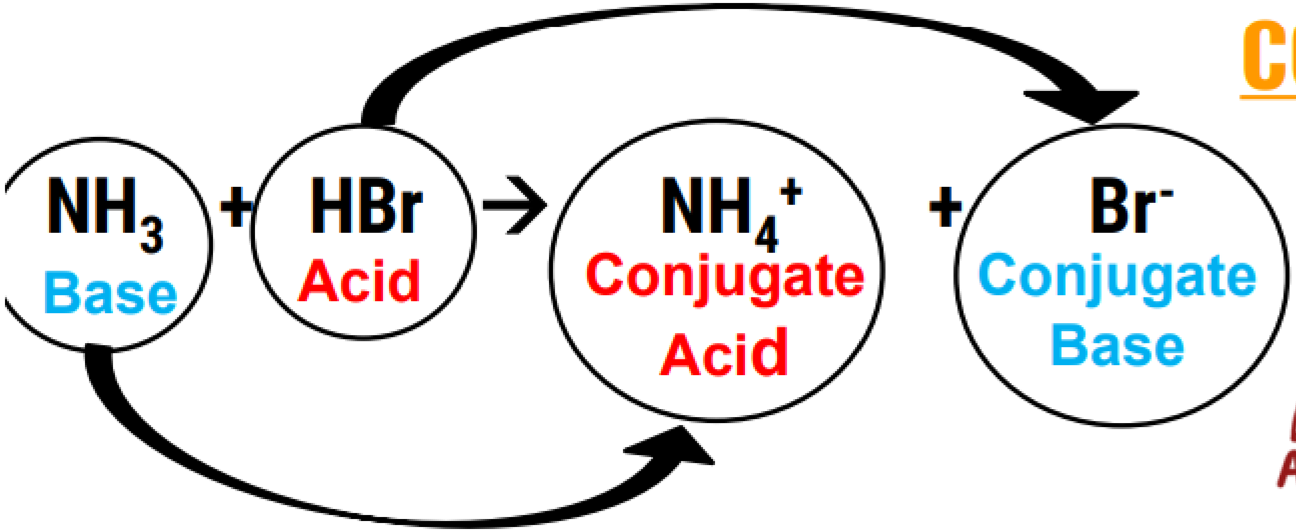
Lewis Acid

Lewis Base

Concepts

Jump back to title slide

CONJUGATES



NH_3 + HBr → NH_4^+ + Br^-

NH_3	HBr	NH_4^+	Br^-
Base	Acid	Conjugate Acid	Conjugate Base

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

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.

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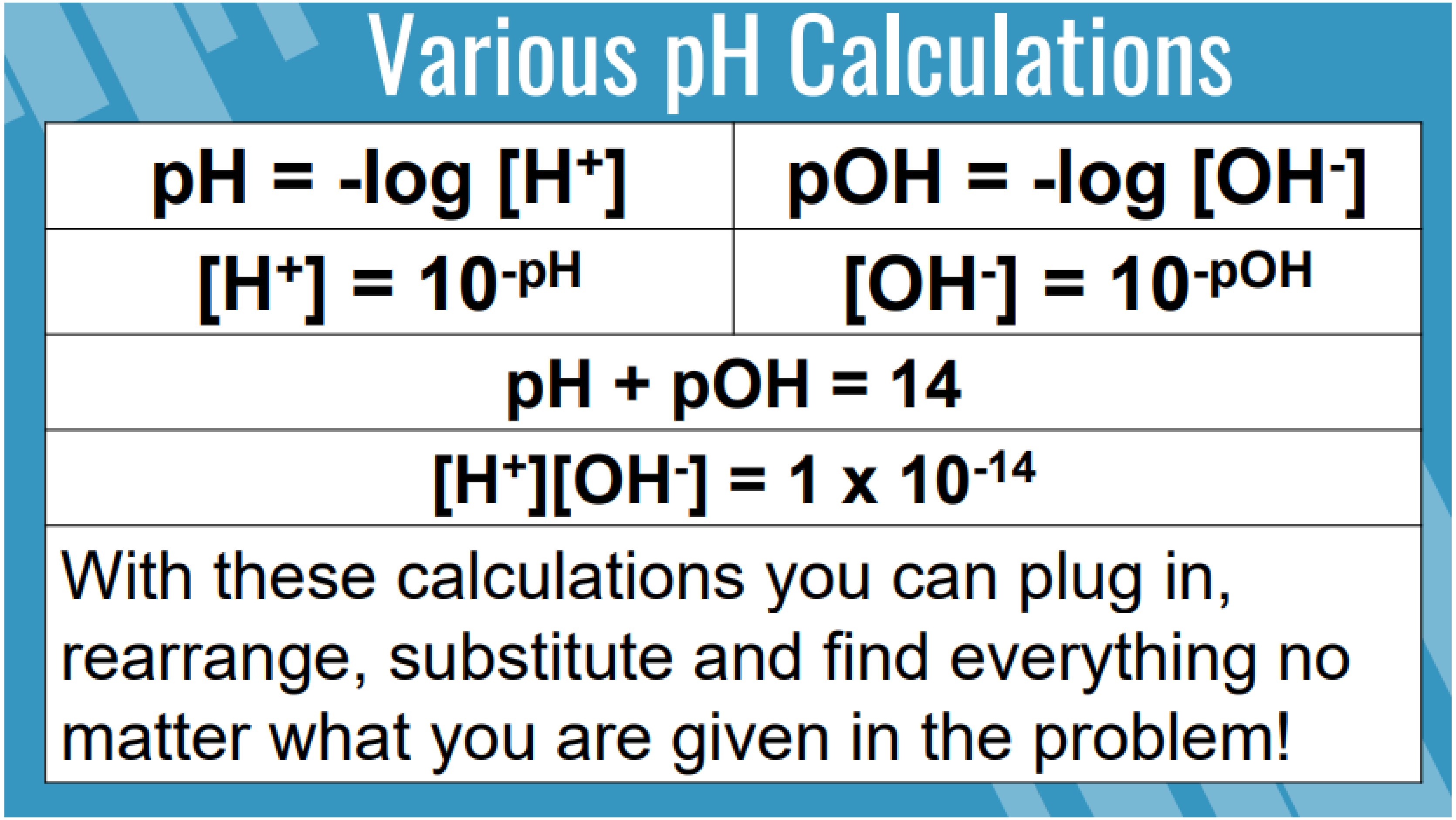
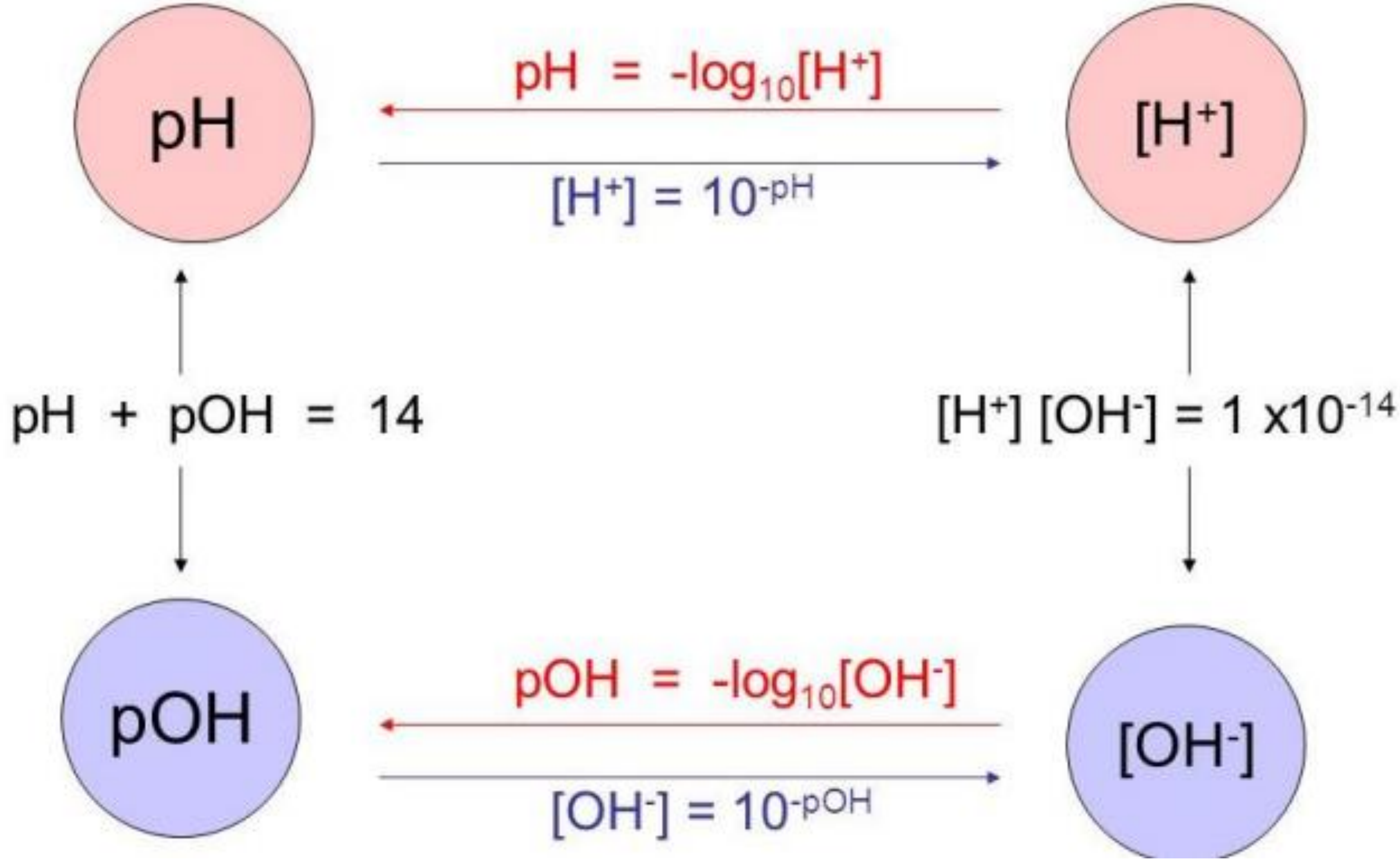


Various pH Calculations

$pH = -\log [H^+]$	$pOH = -\log [OH^-]$
$[H^+] = 10^{-pH}$	$[OH^-] = 10^{-pOH}$
$pH + pOH = 14$	
$[H^+][OH^-] = 1 \times 10^{-14}$	
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



pH

[H^+]

$pH = -\log_{10}[H^+]$

$[H^+] = 10^{-pH}$

$pH + pOH = 14$

$[H^+][OH^-] = 1 \times 10^{-14}$

pOH

[OH^-]

$pOH = -\log_{10}[OH^-]$

$[OH^-] = 10^{-pOH}$

Strong Acids and Bases

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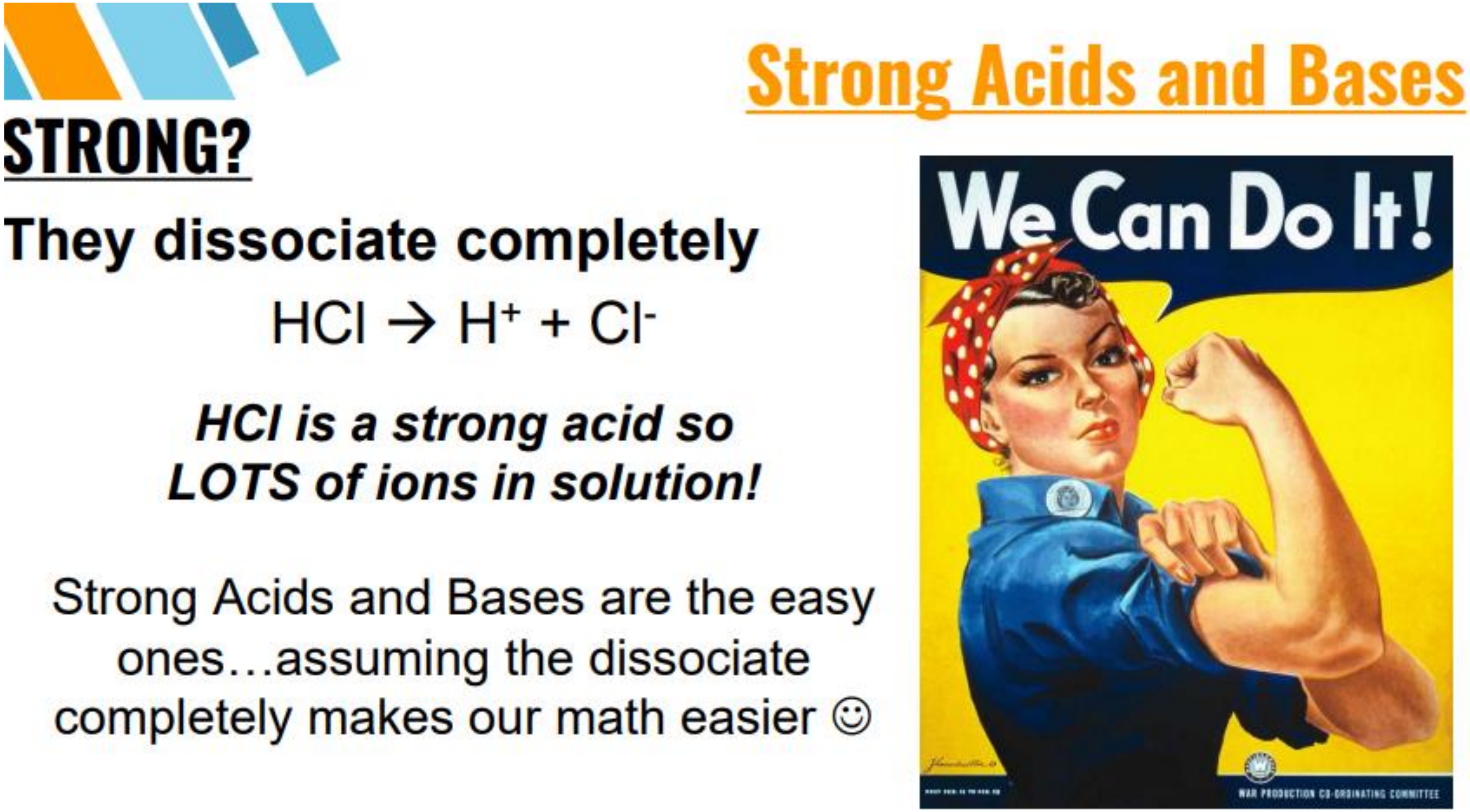

STRONG?

Strong Acids and Bases

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

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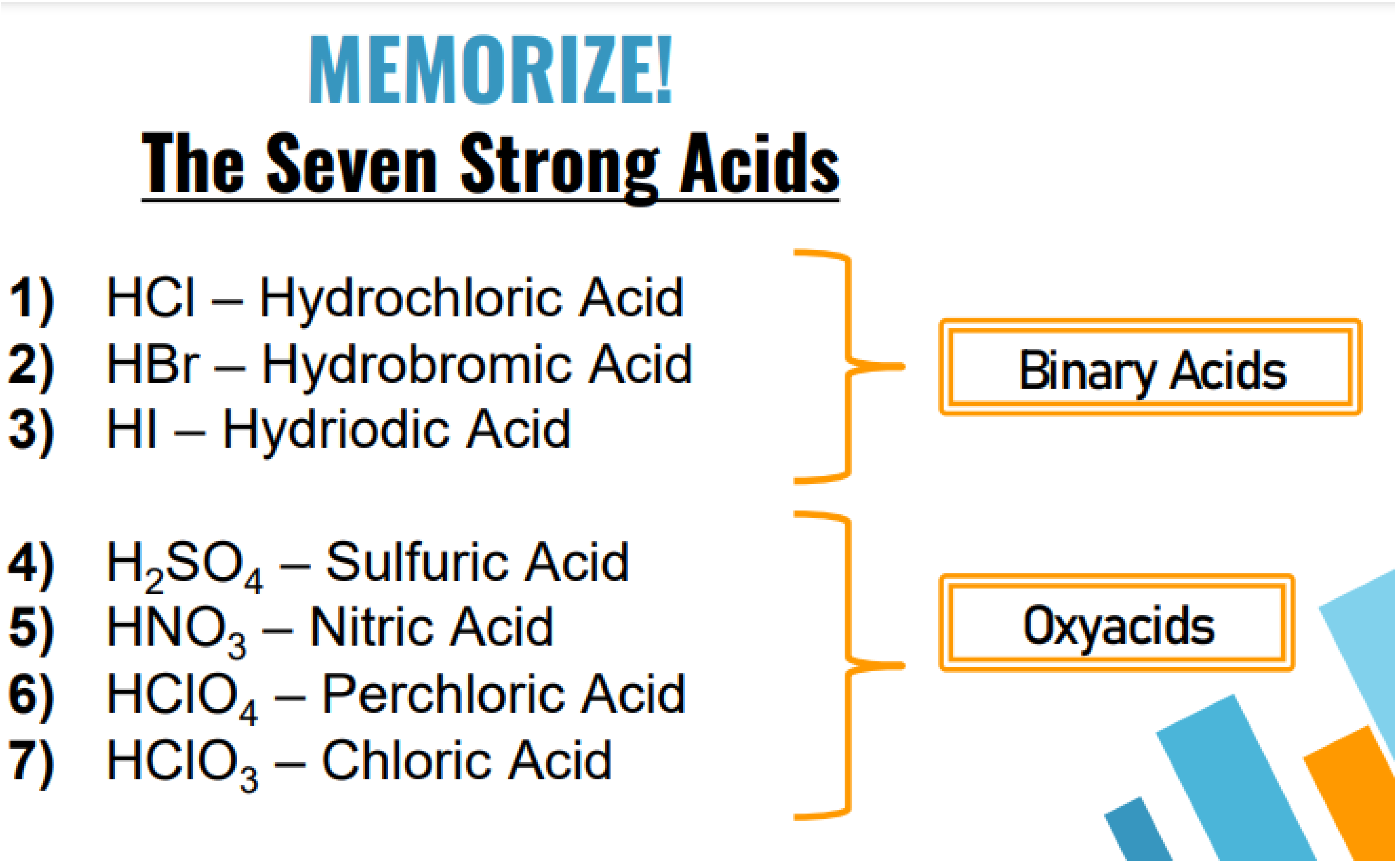


MEMORIZE!

The Seven Strong Acids

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

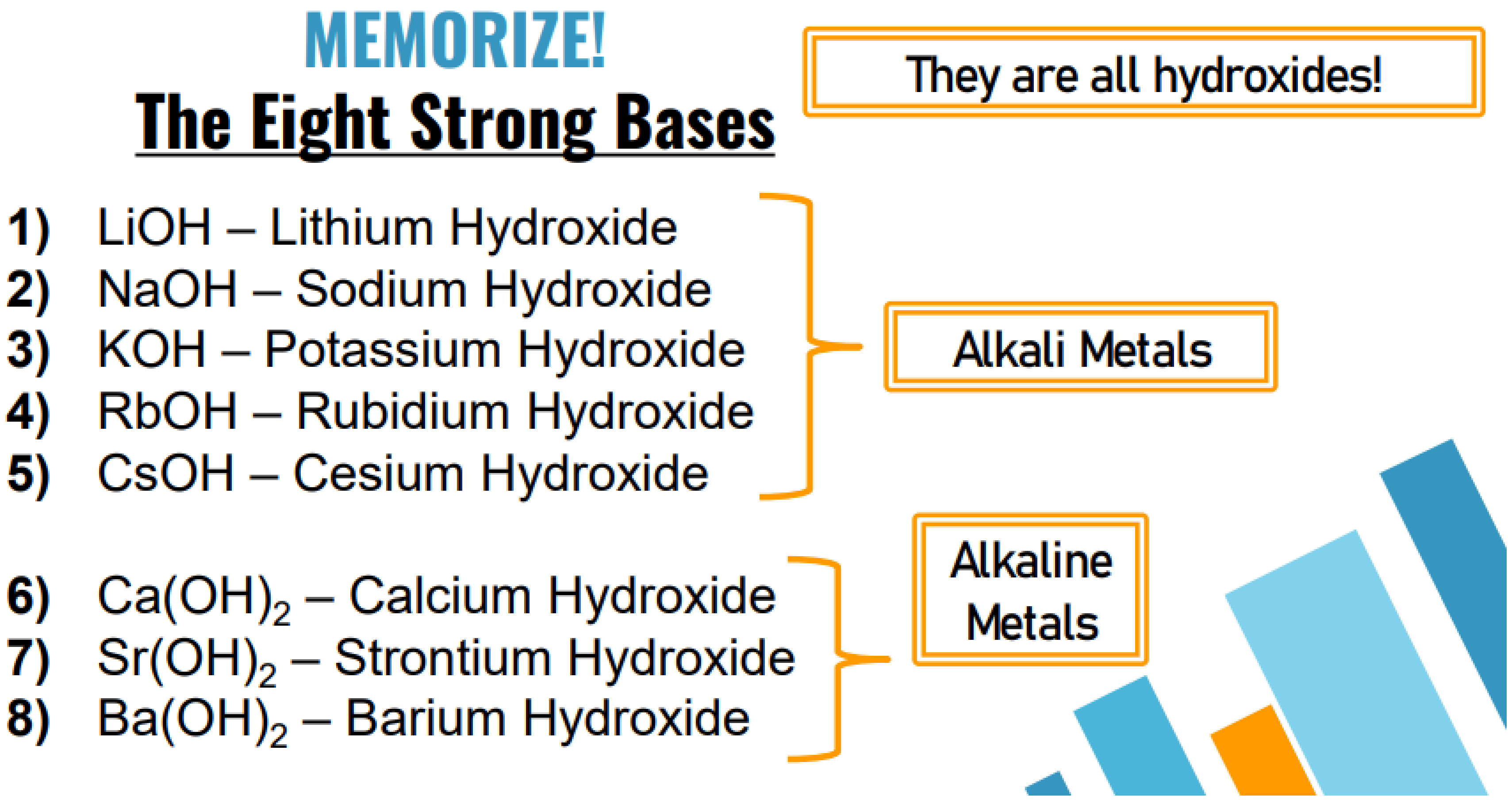
Binary Acids

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!

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

Alkali Metals

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

Alkaline Metals

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 <u>both</u> equal to 1.0×10^{-7}M at 25°C.

NOTICE ANYTHING???

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

$$1.0 \times 10^{-14} = [1.0 \times 10^{-7}] \times [1.0 \times 10^{-7}]$$

Jump back to title slide

Self Ionization of Water

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

$$1.0\text{x}10^{-14} = [1.0\text{x}10^{-7}] \text{ x } [1.0\text{x}10^{-7}]$$

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!

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 = 1.8×10^{-5}. $HOAc + H_2O \leftrightarrow H_3O + OAc^-$

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!!!

$$pH = -\log [H_3O^+]$$

$$pH = -\log (4.2 \times 10^{-3})$$

$$pH = 2.37$$

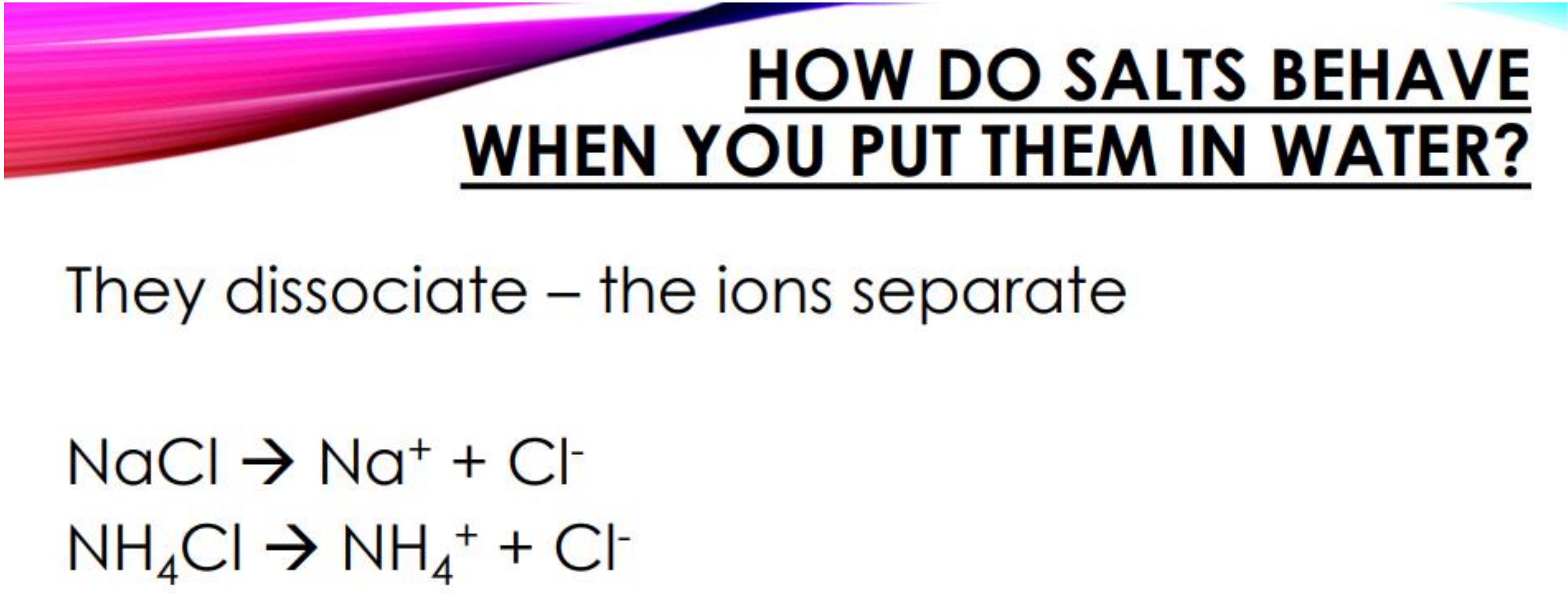
$$Ka = \frac{[H_3O^+][OAc^-]}{[HOAc]}$$

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

$$x = 4.2 \times 10^{-3}$$

Salts

Jump back to title slide



HOW DO SALTS BEHAVE WHEN YOU PUT THEM IN WATER?

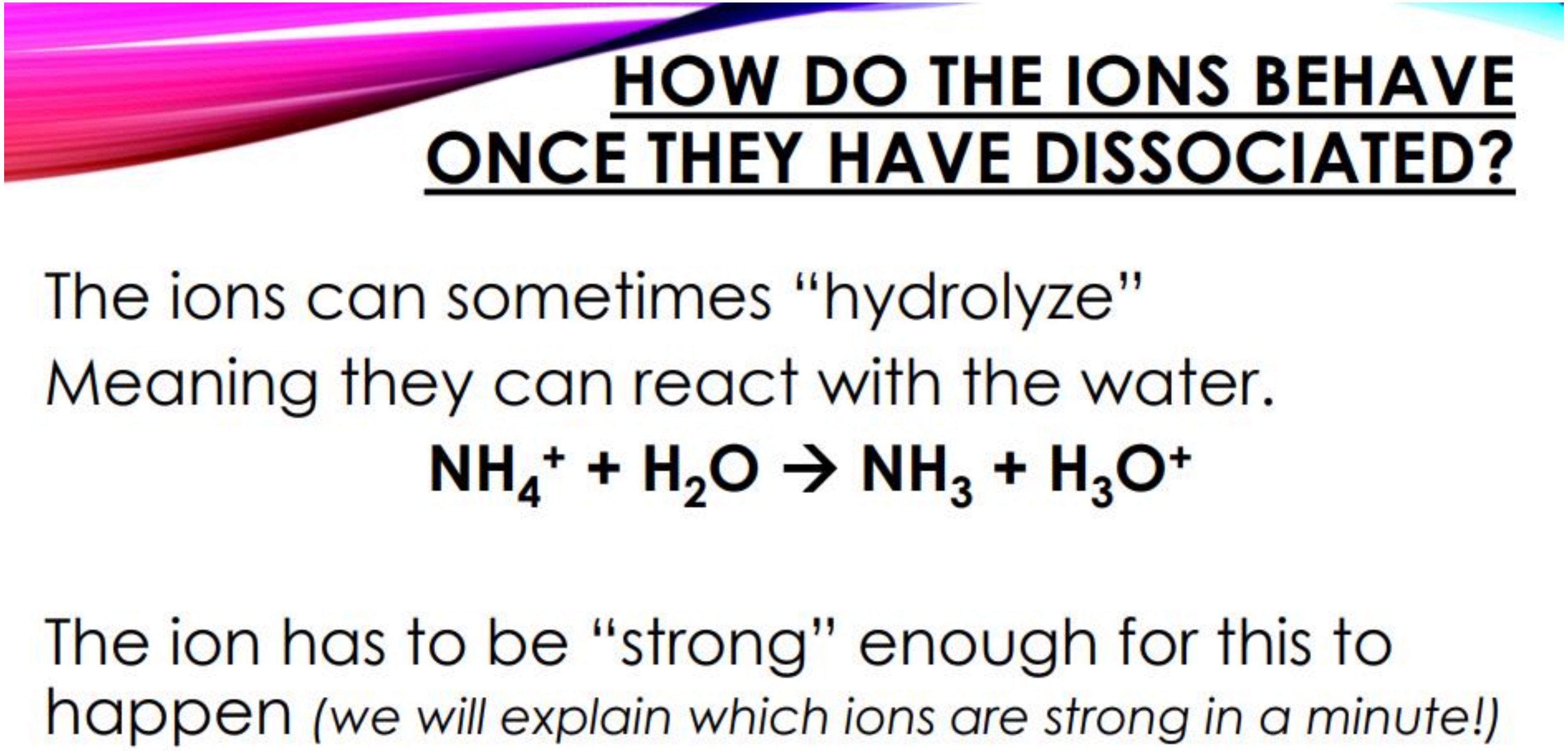
They dissociate – the ions separate

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

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

Salts

Jump back to title slide



HOW DO THE IONS BEHAVE ONCE THEY HAVE DISSOCIATED?

The ions can sometimes "hydrolyze"

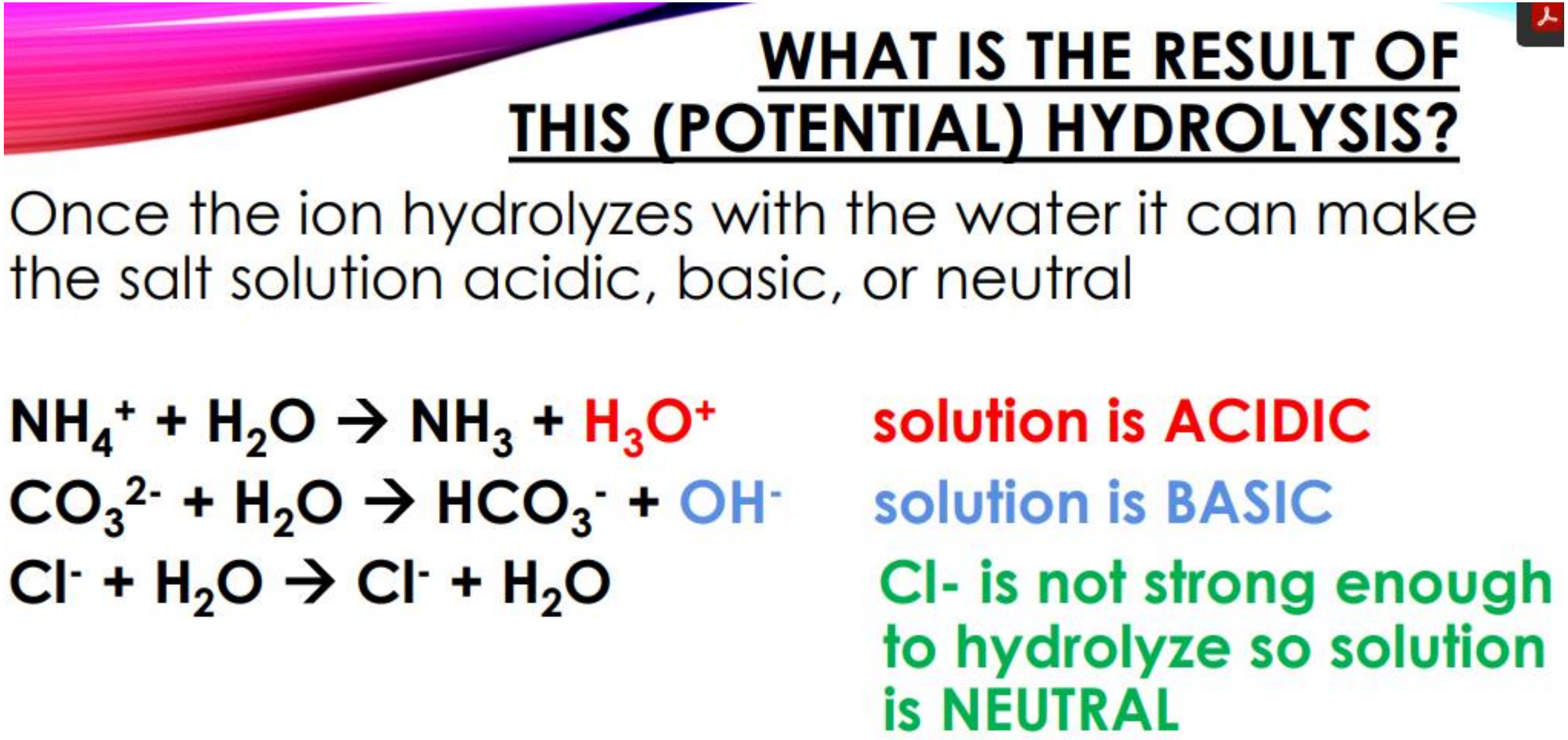
Meaning they can react with the water.

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

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

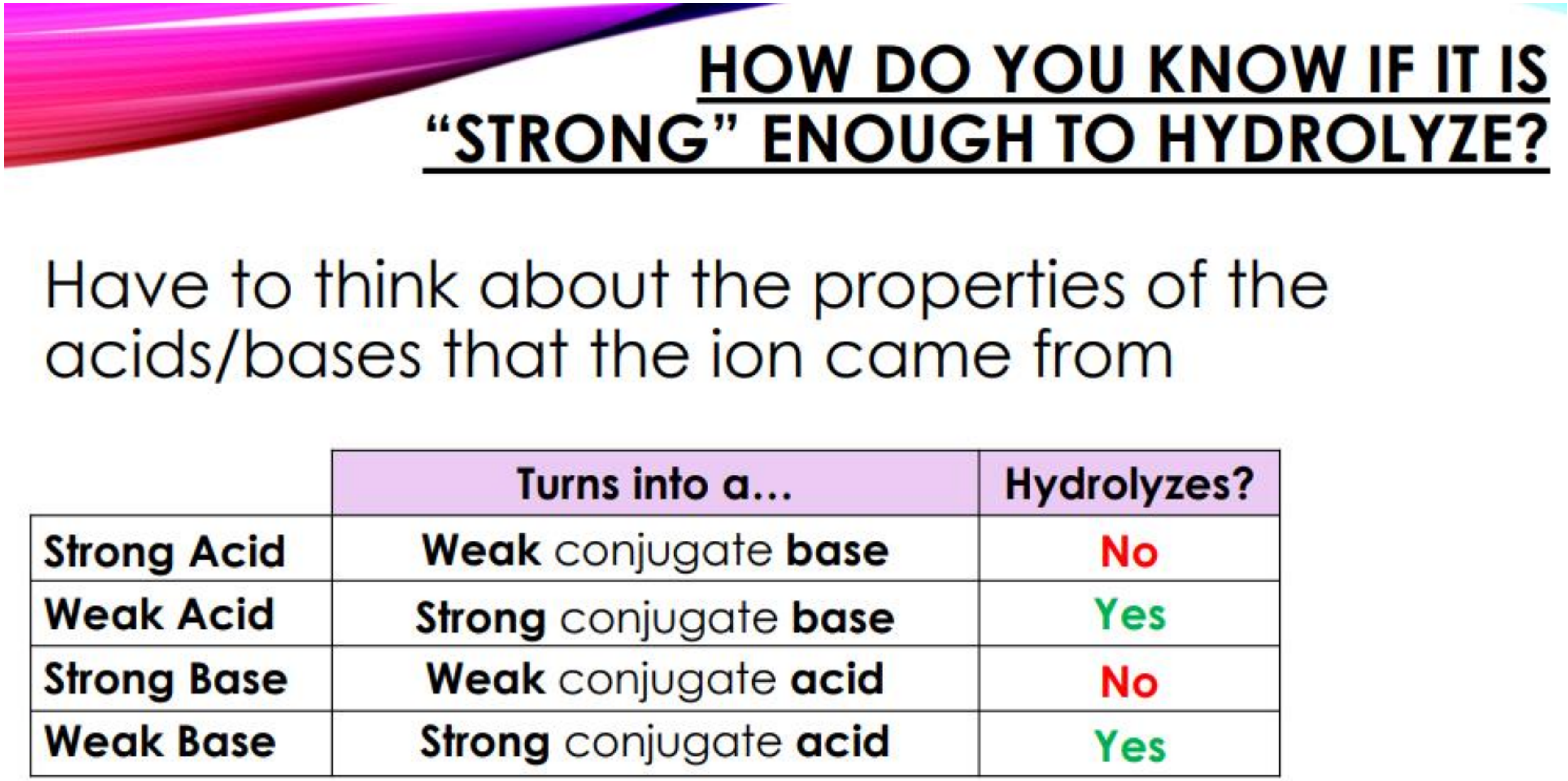
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$ solution is ACIDIC

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

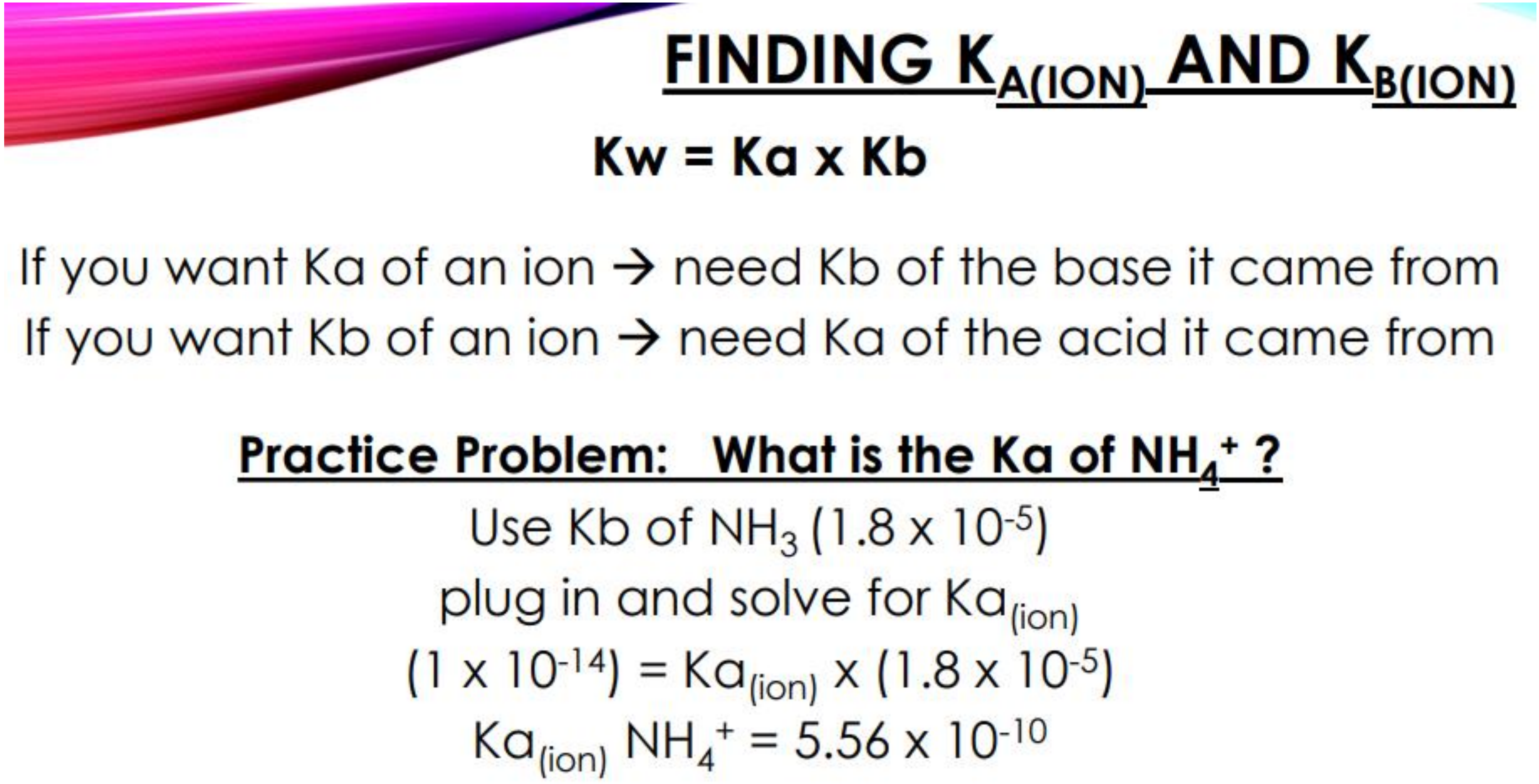
	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weak** conjugate **base**	No	Neutral
Weak Acid	**Strong** conjugate **base**	Yes	Basic
Strong Base	**Weak** conjugate **acid**	No	Neutral
Weak Base	**Strong** conjugate **acid**	Yes	Acidic

	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})

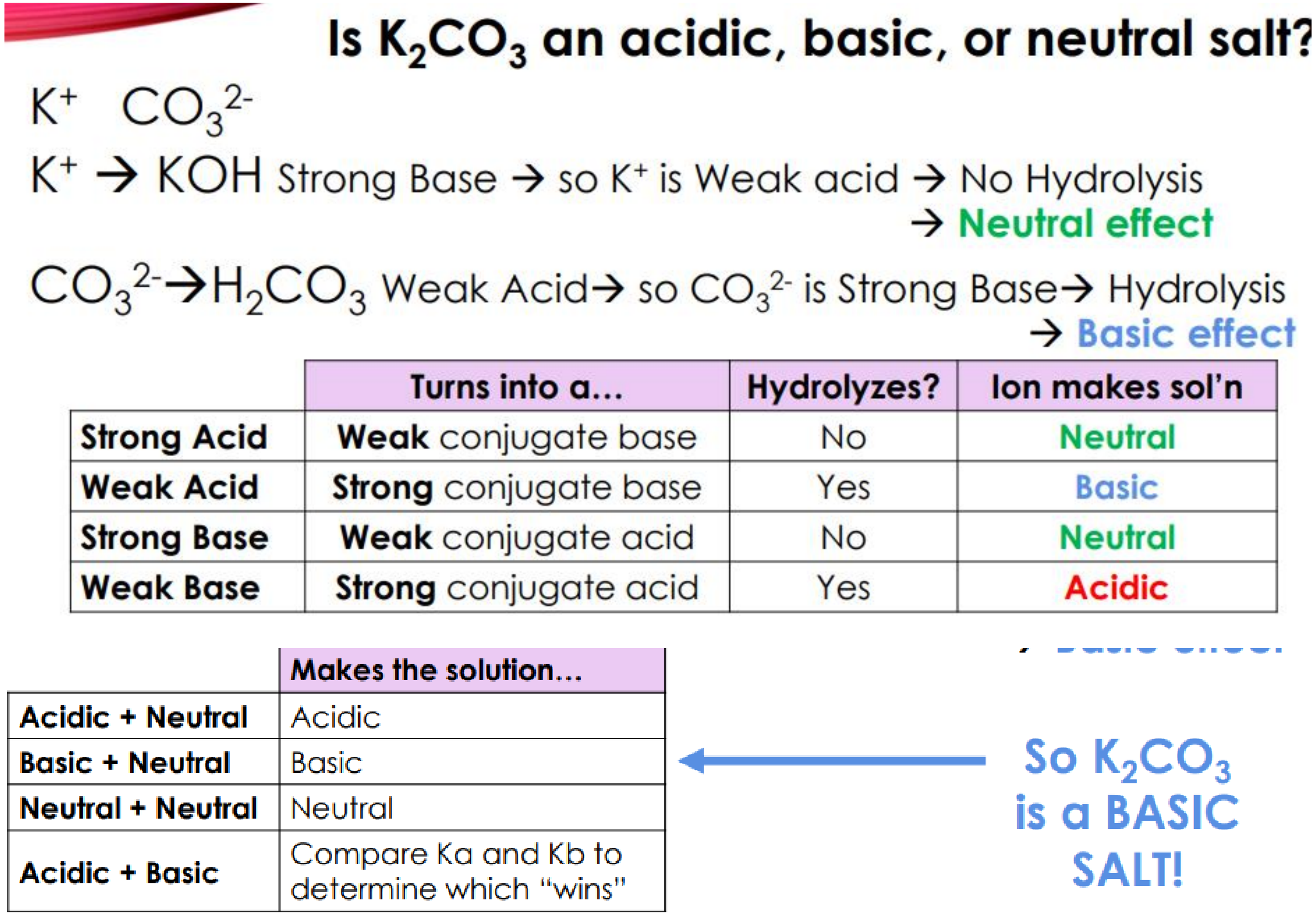
plug in and solve for $Ka_{(ion)}$

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

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

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**

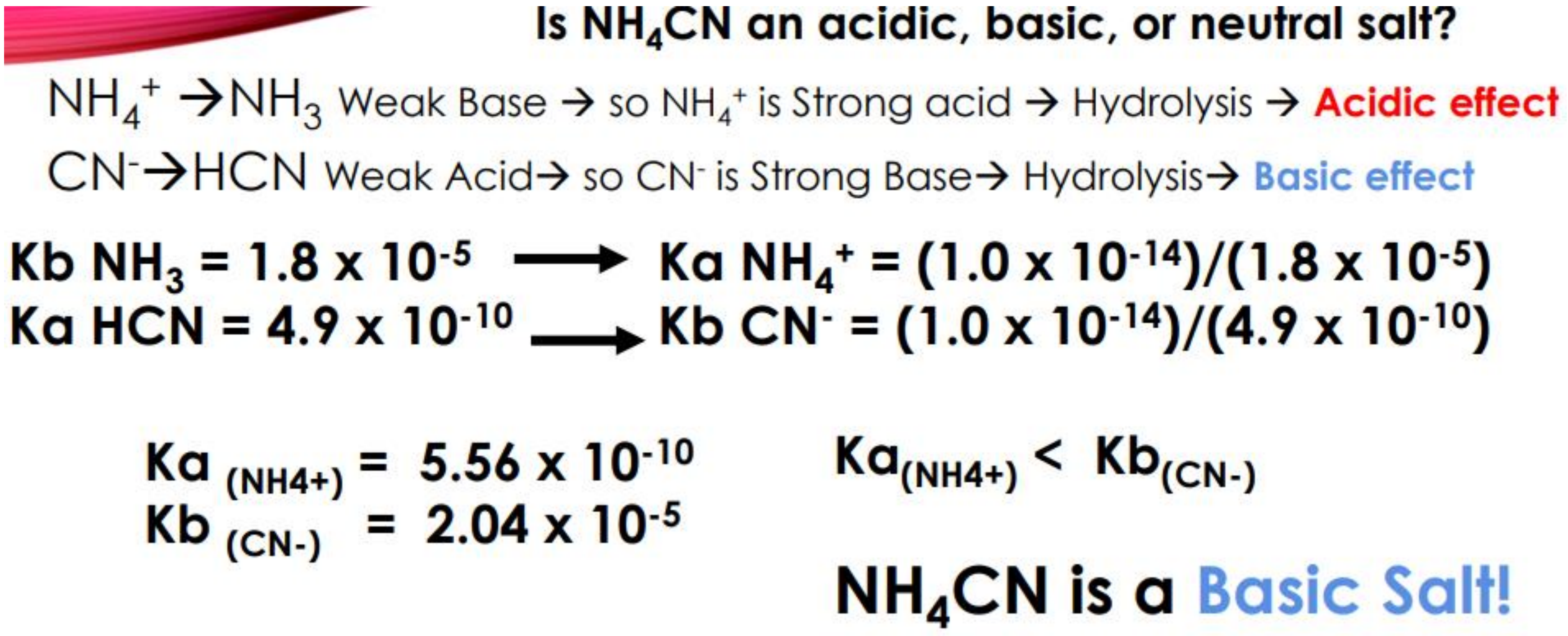
	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

←

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

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

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

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

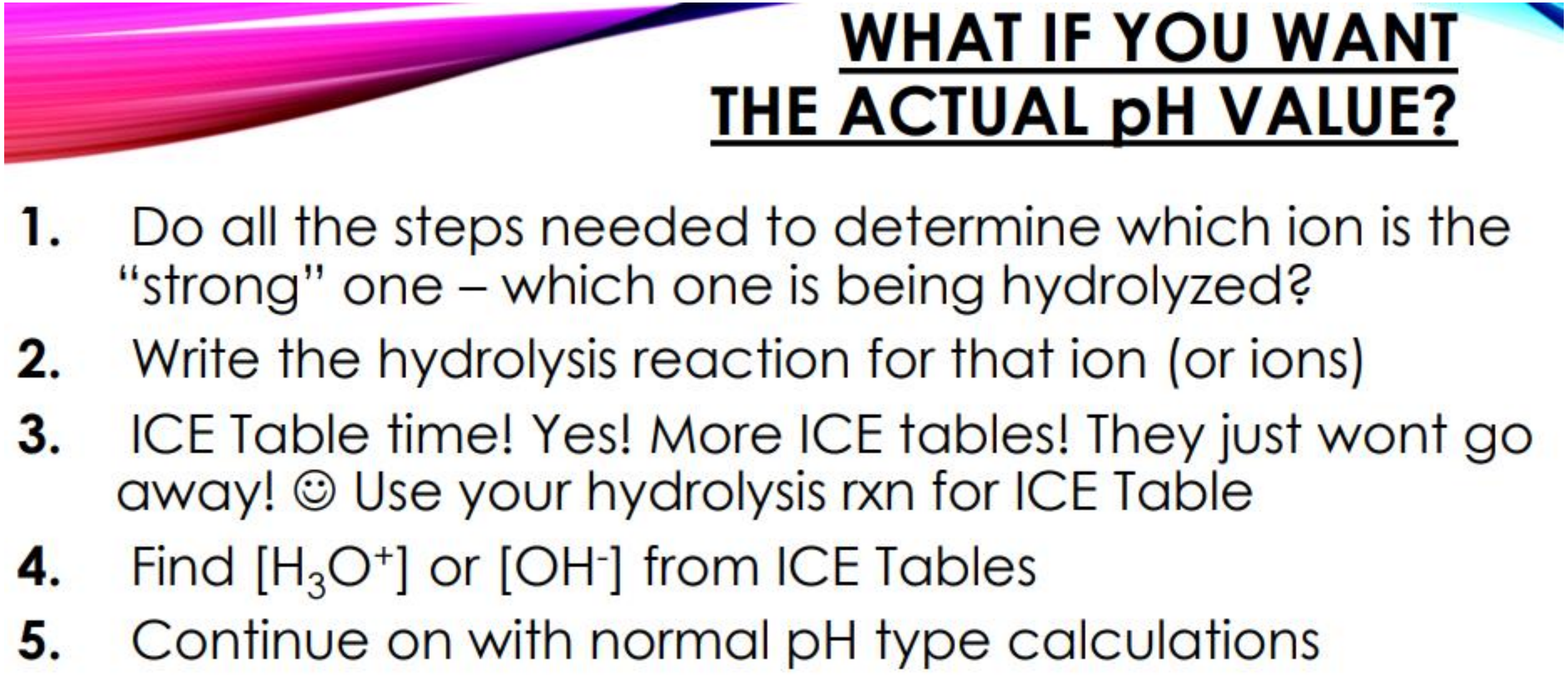
$$Ka_{(NH4+)} = 5.56 \times 10^{-10}$$

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

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

NH_4CN is a Basic Salt!

Jump back to title slide

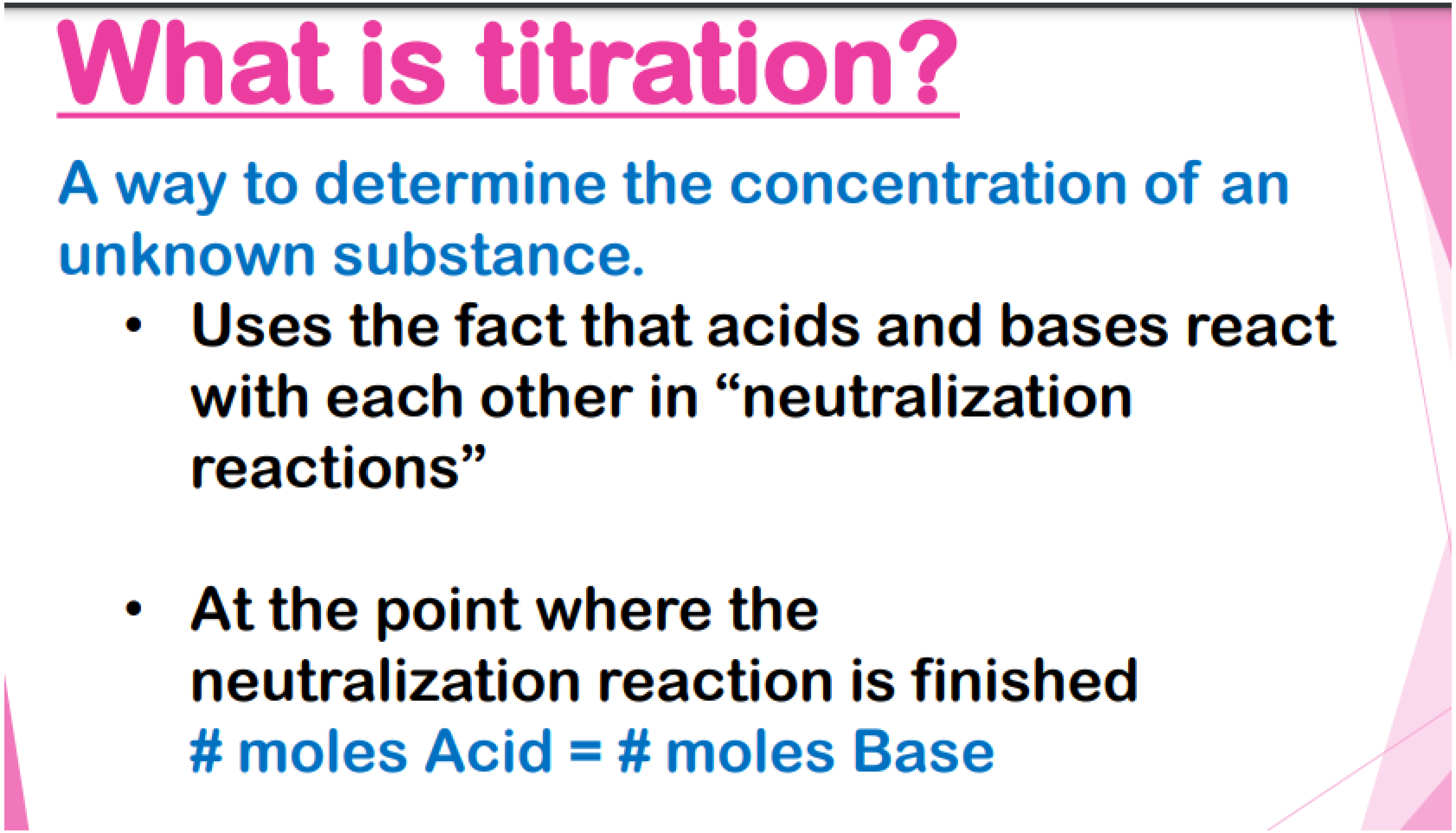


WHAT IF YOU WANT THE ACTUAL pH VALUE?

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

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

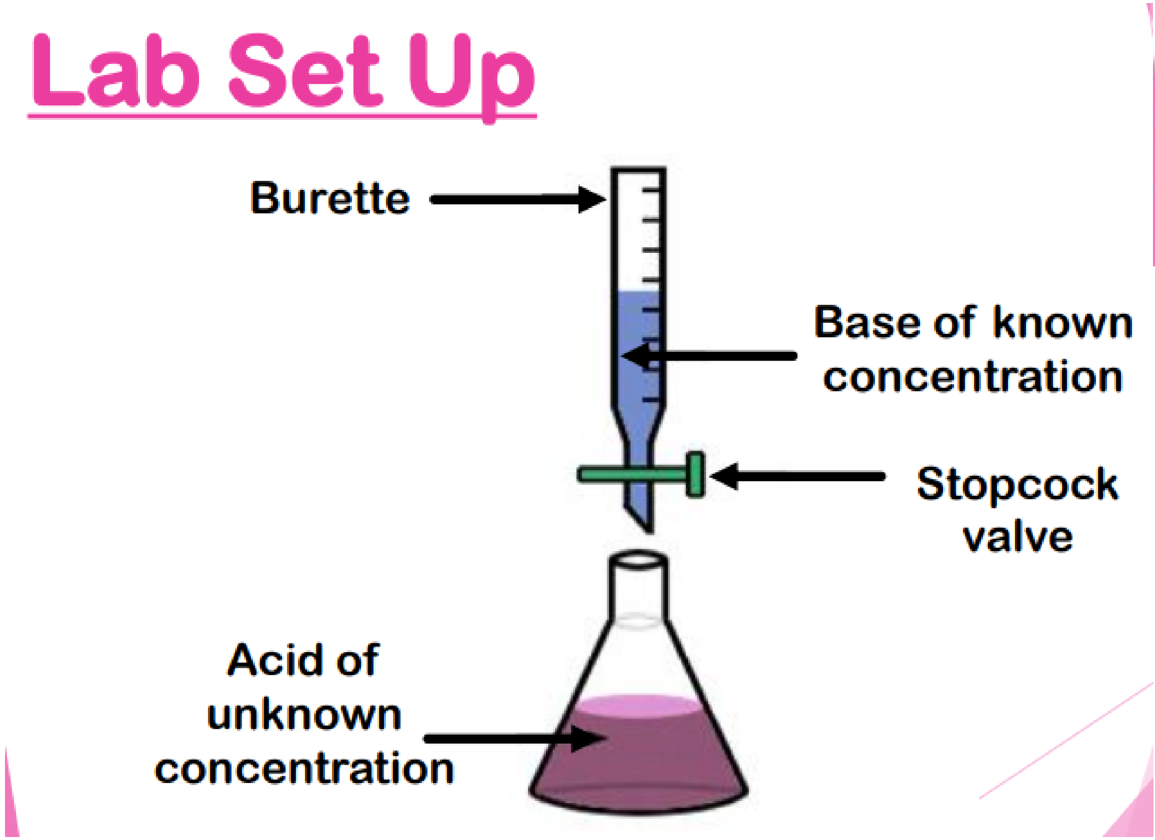
How do you know you reached the end point?

Use an **INDICATOR**

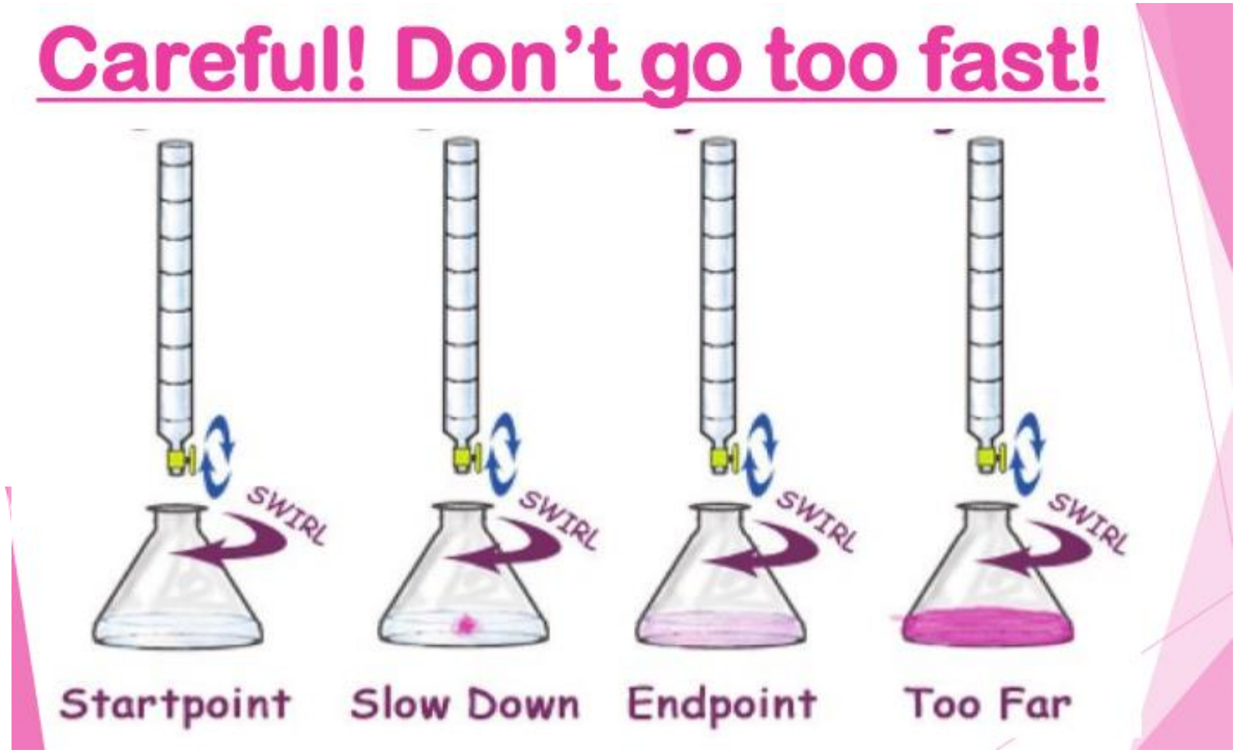
Turns colors based on pH – can show you visually when you have reached the end point.

Titrations

Jump back to title slide



Lab Set Up



Careful! Don't go too fast!

Titrations

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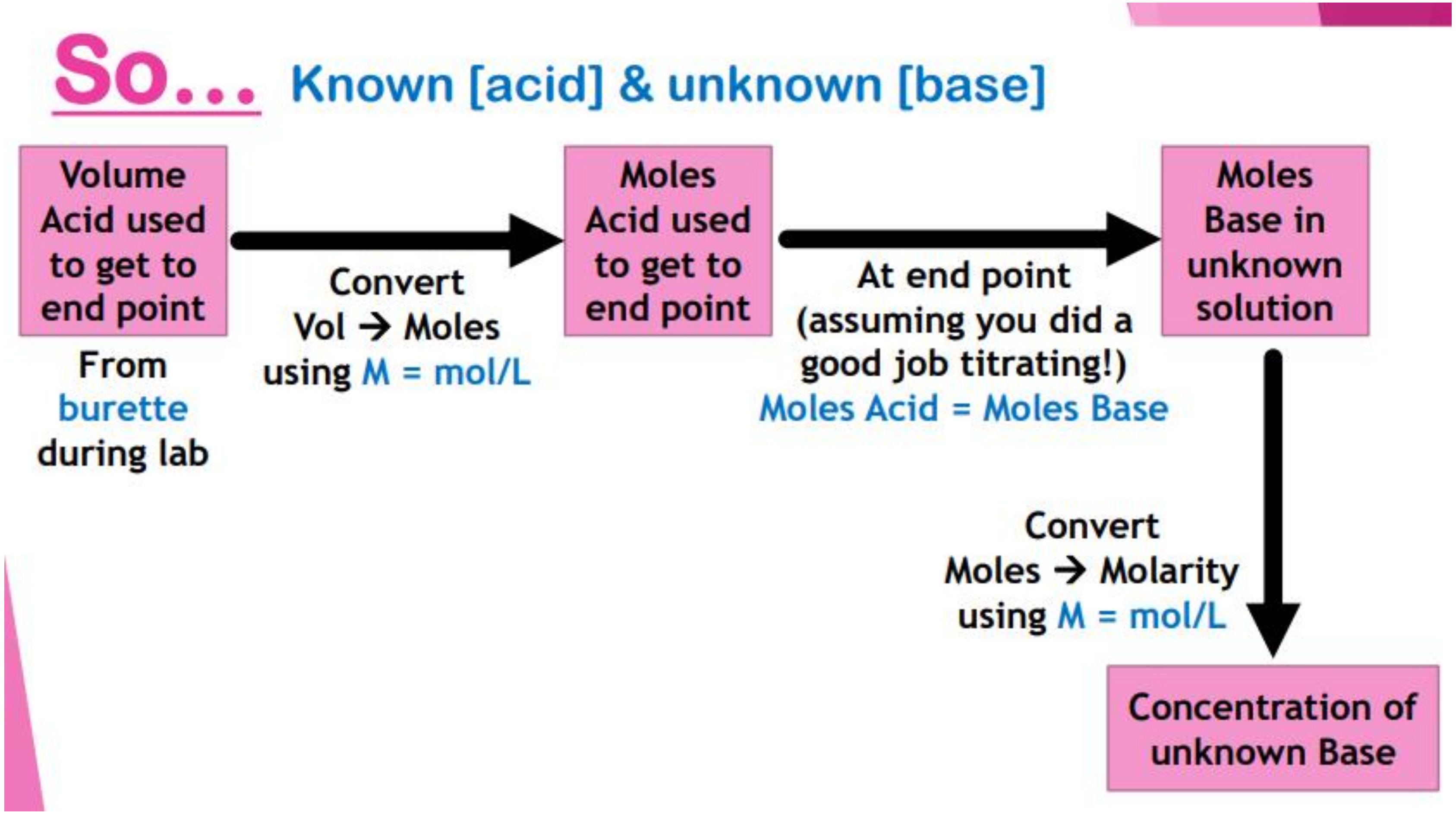

So… Known [acid] & unknown [base]

Volume Acid used to get to end point

From burette during lab

Convert Vol → Moles using M = mol/L

Moles Acid used to get to end point

At end point (assuming you did a good job titrating!) Moles Acid = Moles Base

Moles Base in unknown solution

Convert Moles → Molarity using M = mol/L

Concentration of unknown Base

Titrations

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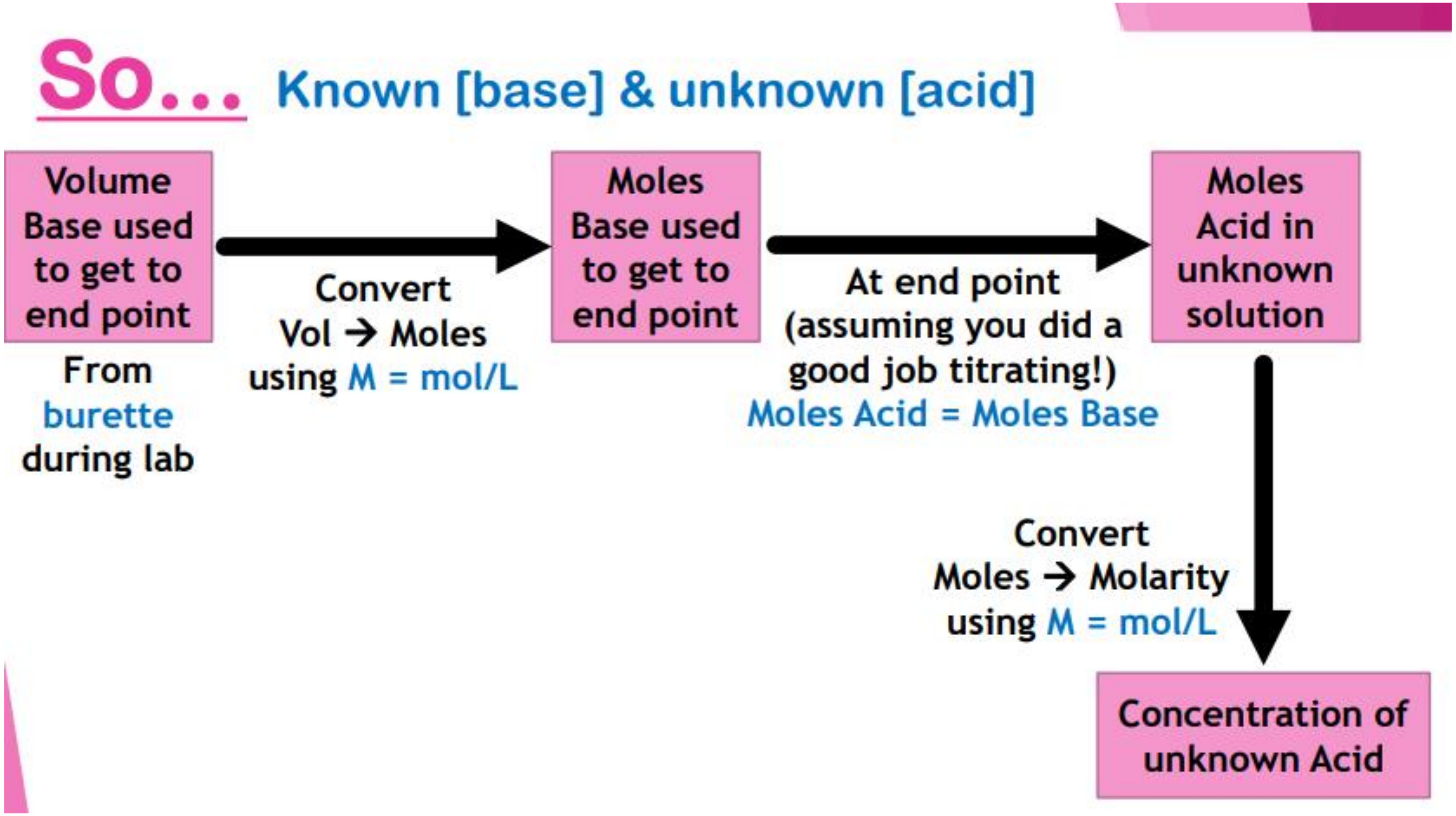

So… Known [base] & unknown [acid]

Volume Base used to get to end point

From burette during lab

Convert Vol → Moles using M = mol/L

Moles Base used to get to end point

At end point (assuming you did a good job titrating!) Moles Acid = Moles Base

Moles Acid in unknown solution

Convert Moles → Molarity using M = mol/L

Concentration of unknown Acid

Titrations

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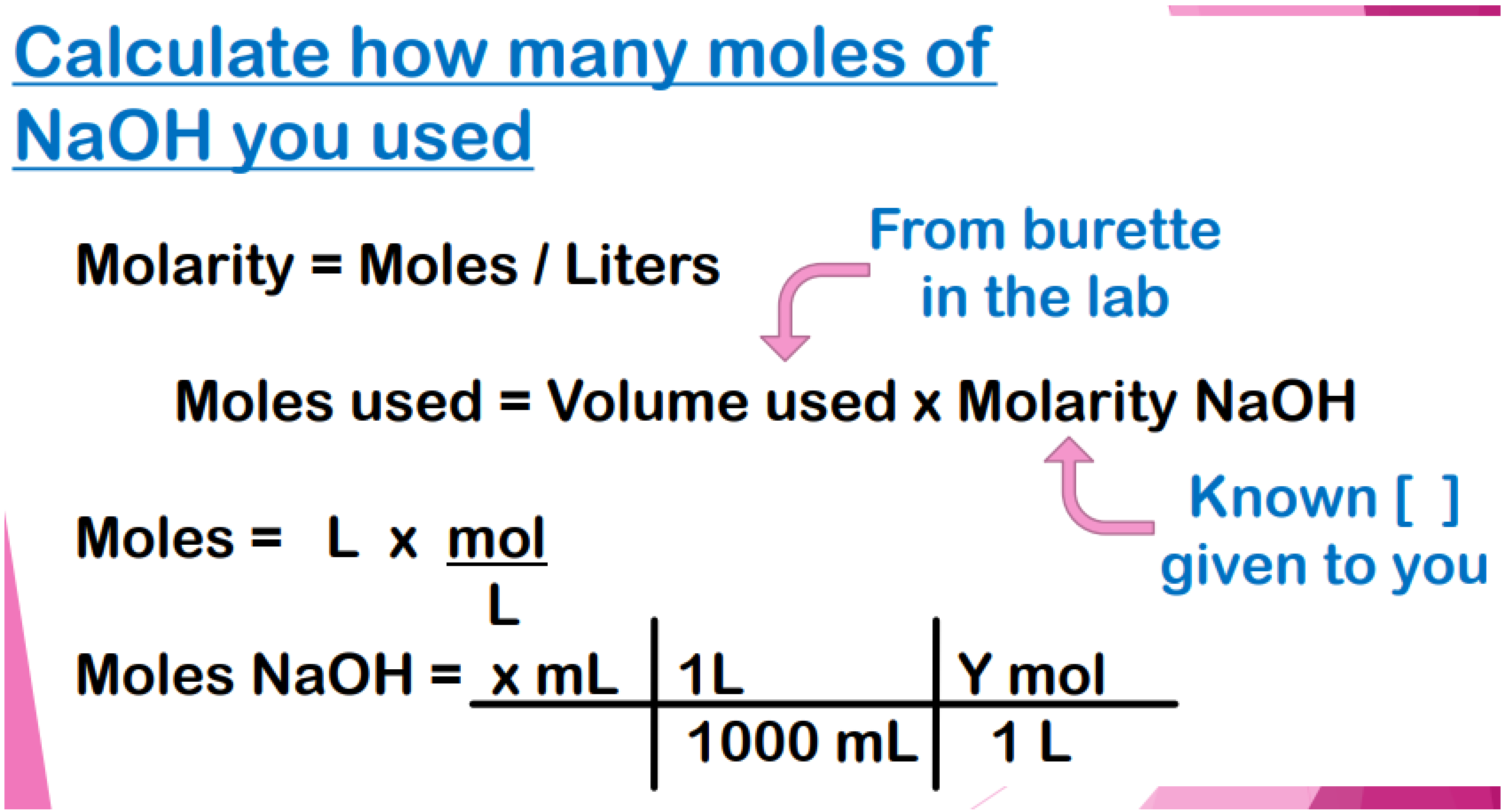

Calculate how many moles of NaOH you used

Molarity = Moles / Liters

From burette in the lab

Moles used = Volume used x Molarity NaOH

Known [ ] given to you

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

$$\text{Moles NaOH} = \begin{array}{c|c|c} x\text{ mL} & 1\text{L} & Y\text{ mol} \\ \hline & 1000\text{ mL} & 1\text{ L} \end{array}$$

Titrations

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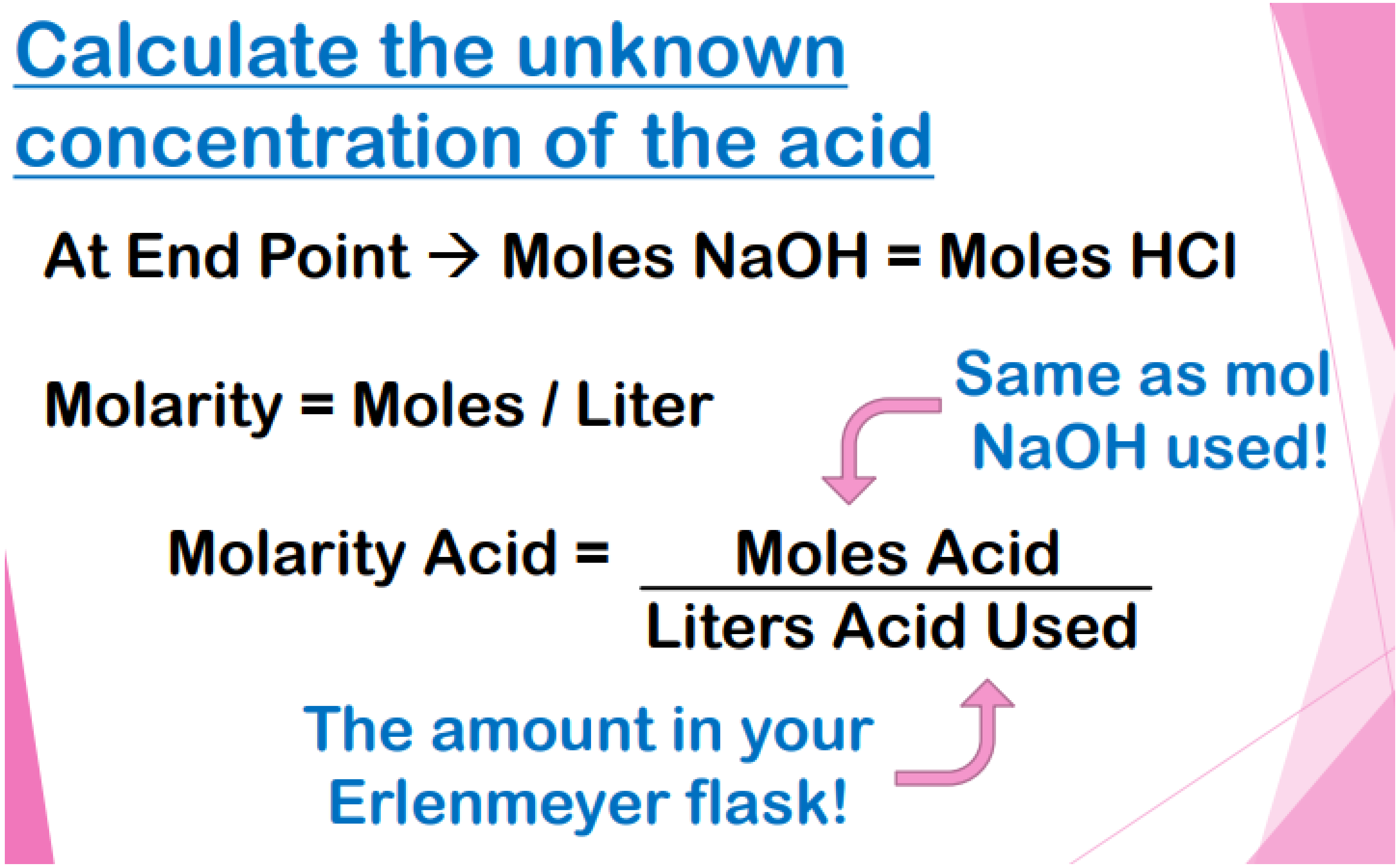

Calculate the unknown concentration of the acid

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

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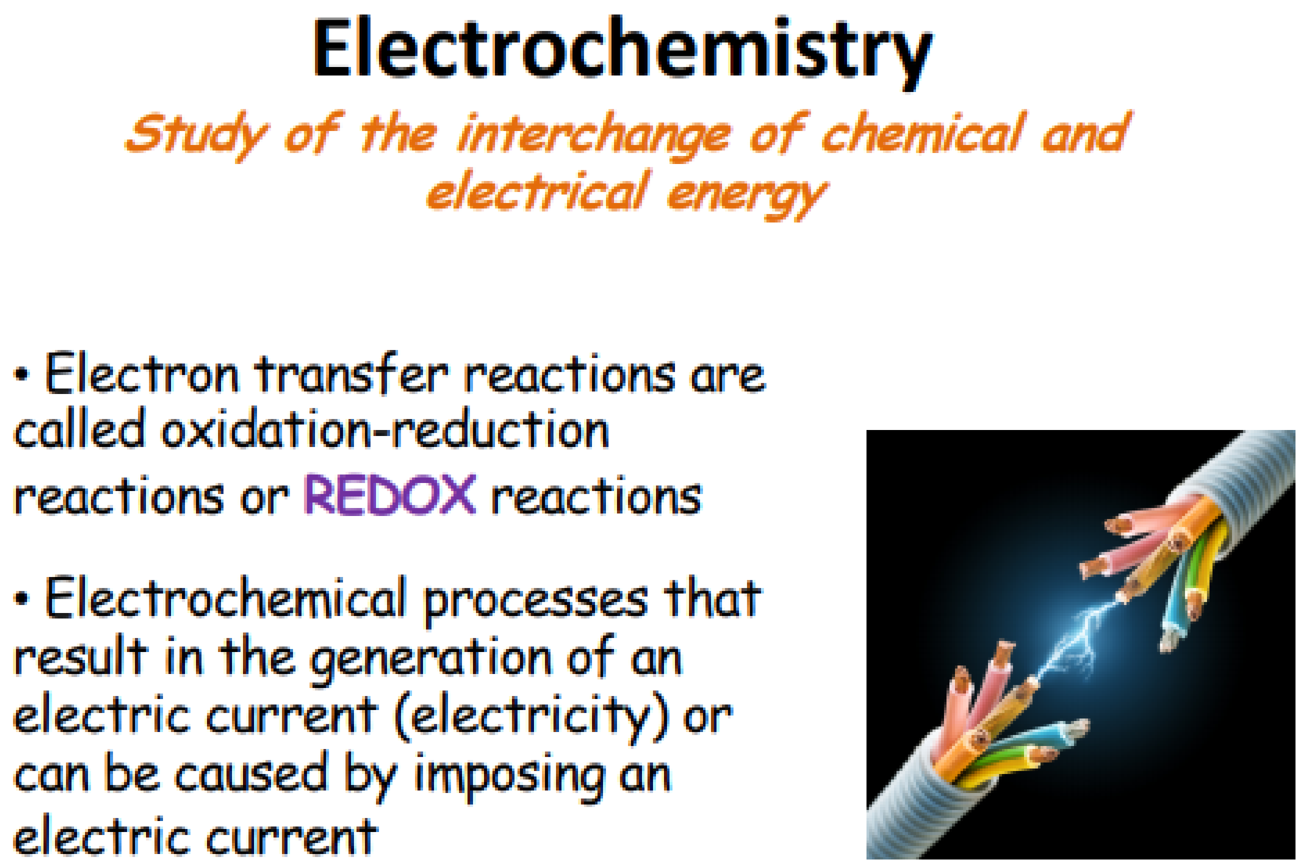

Electrochemistry

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

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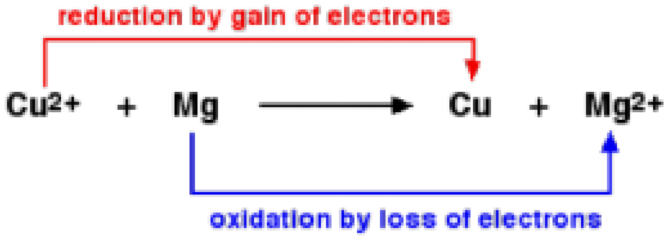
Redox Reactions

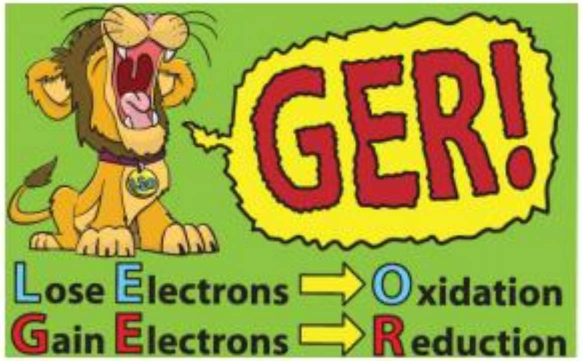
- **OXIDATION NUMBER:** Assigned charge on an atom
- **OXIDATION:** Loss of electrons (increase in oxidation number or charge… "+")
- **REDUCTION:** Gain of electrons (decrease in oxidation number or charge… "-")



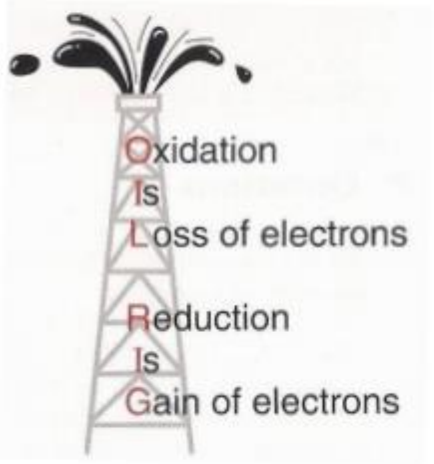
$Cu^{2+} + Mg \longrightarrow Cu + Mg^{2+}$

- **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

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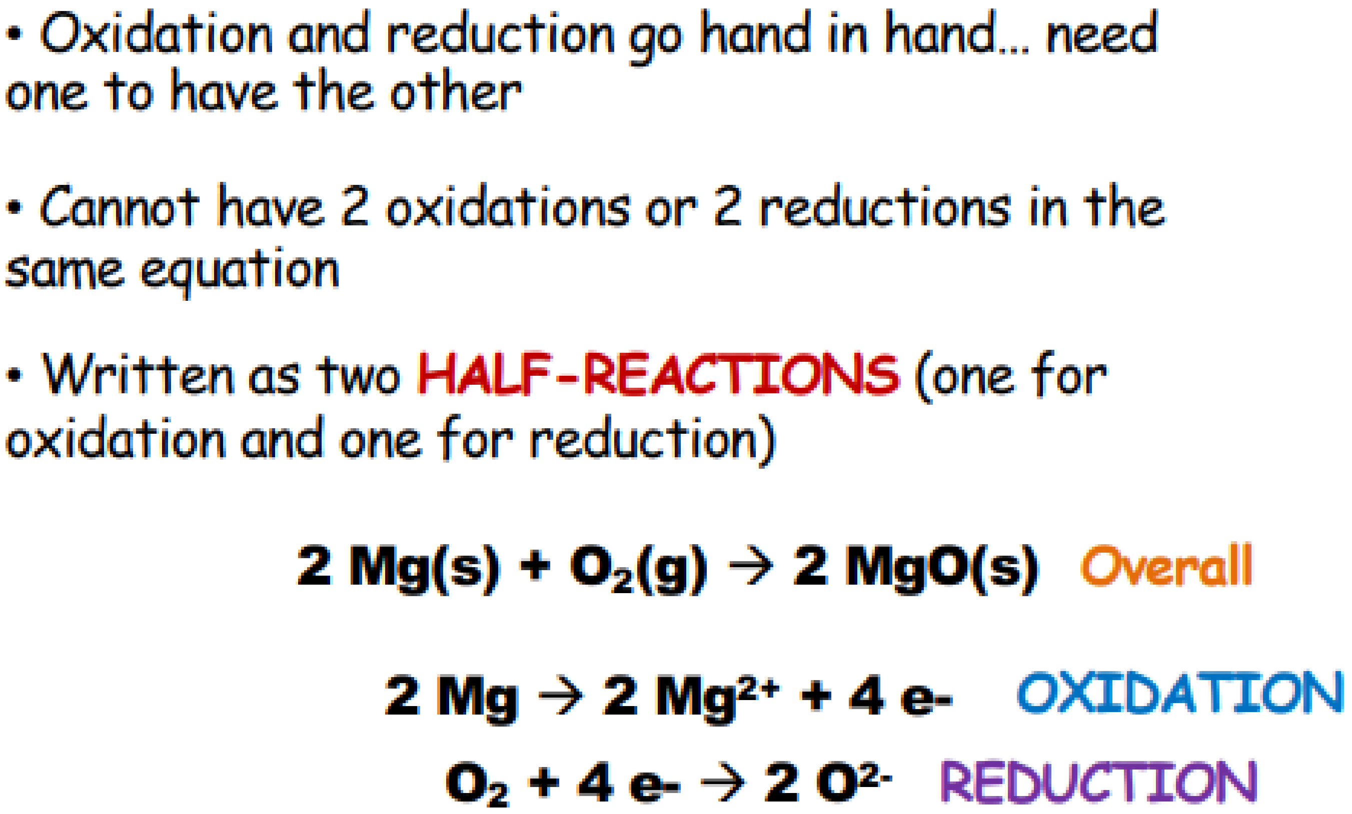

- Oxidation and reduction go hand in hand… need one to have the other
- Cannot have 2 oxidations or 2 reductions in the same equation
- Written as two HALF-REACTIONS (one for oxidation and one for reduction)

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

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

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

Oxidation Numbers

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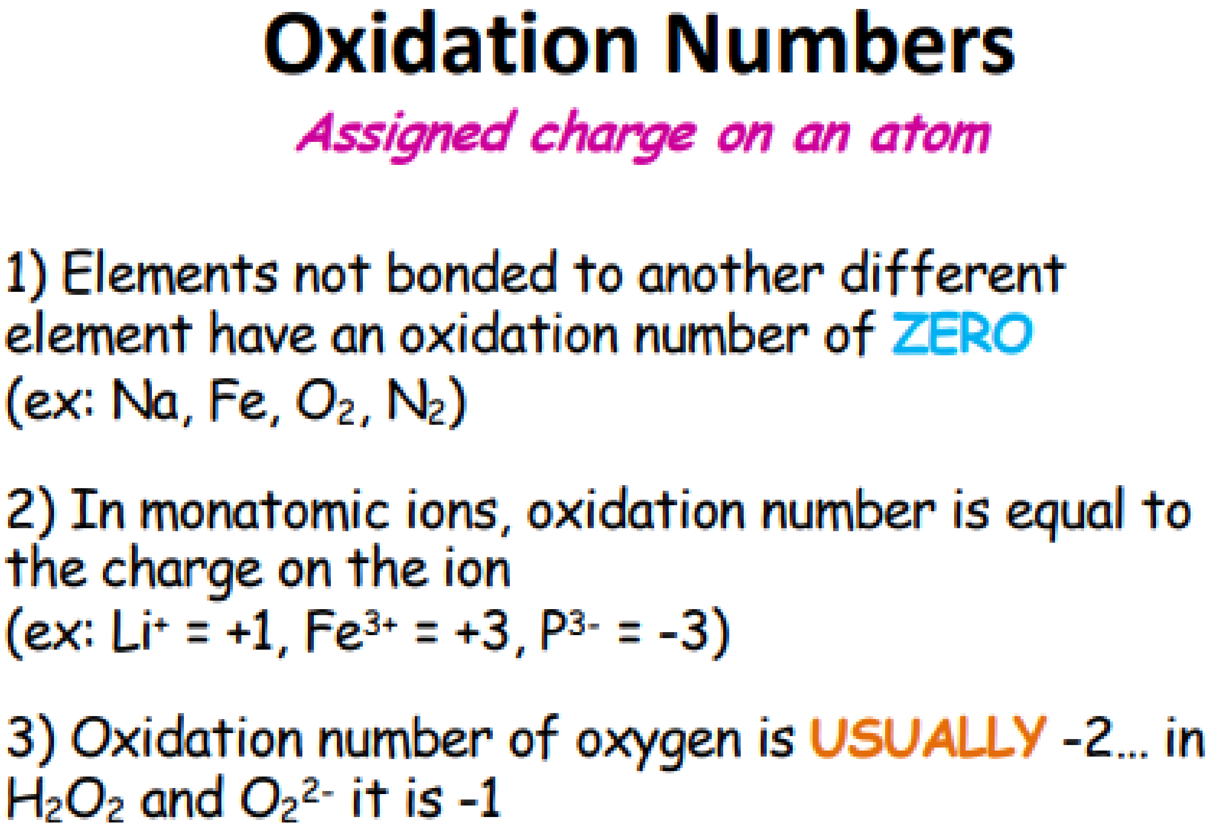


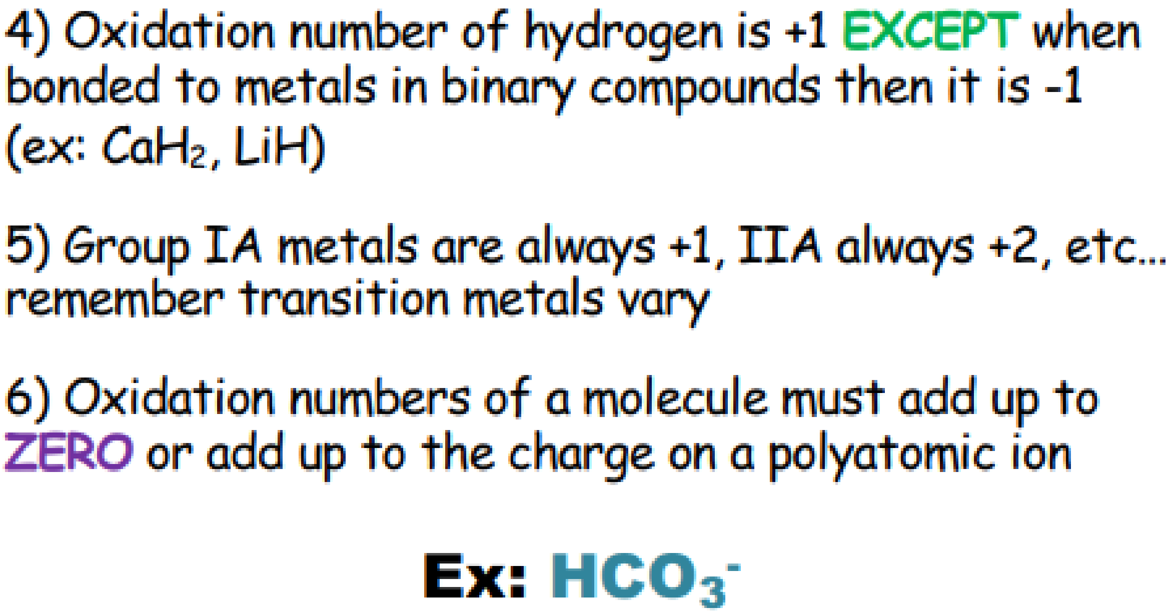
Oxidation Numbers

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

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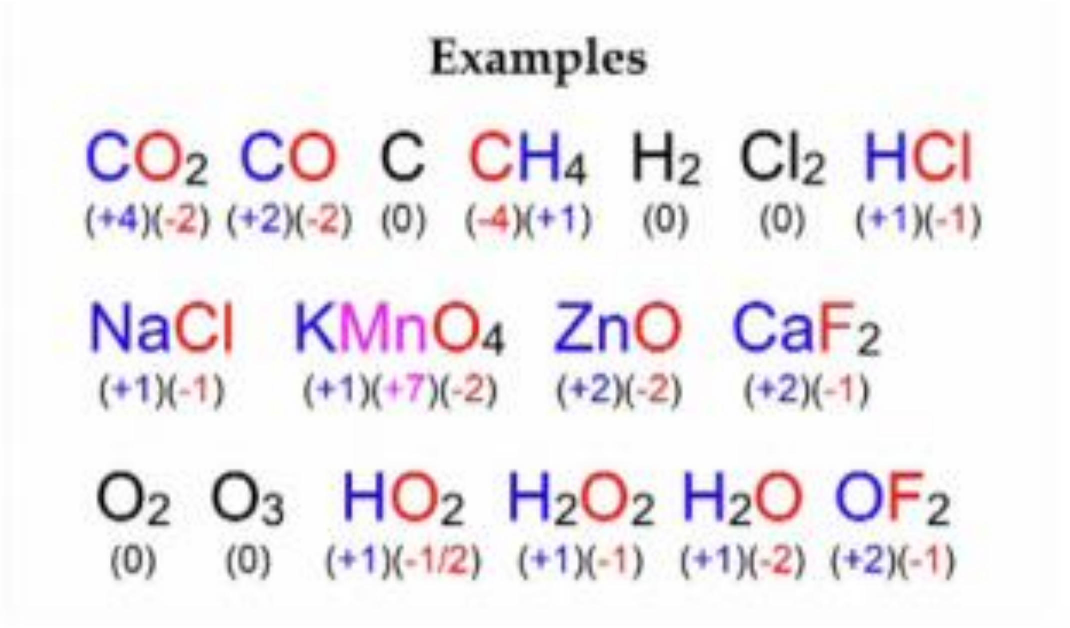

Examples

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

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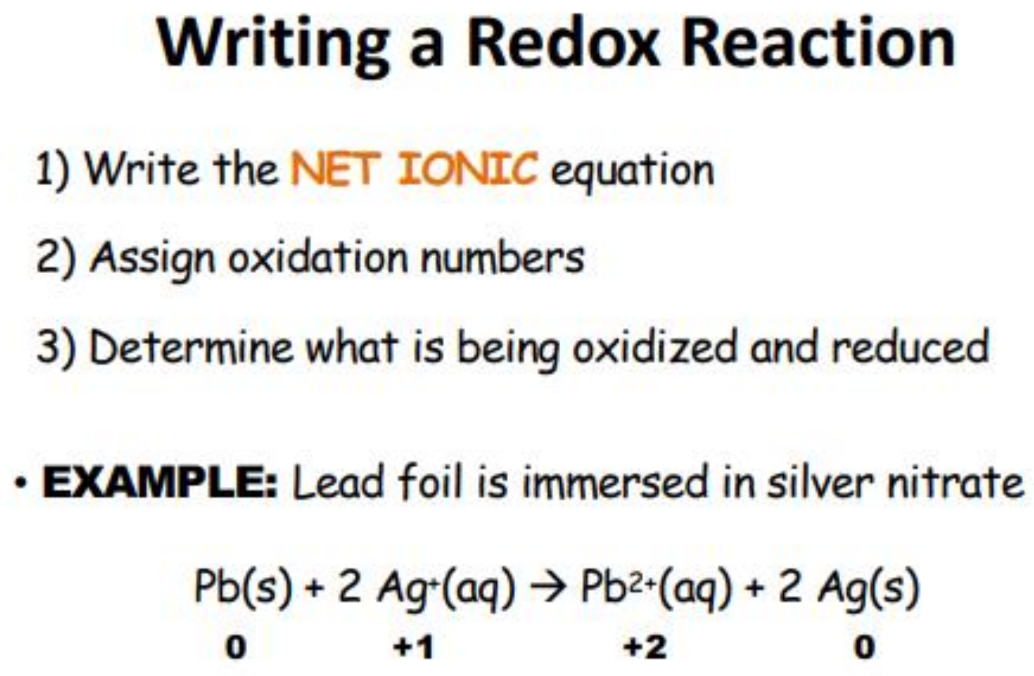


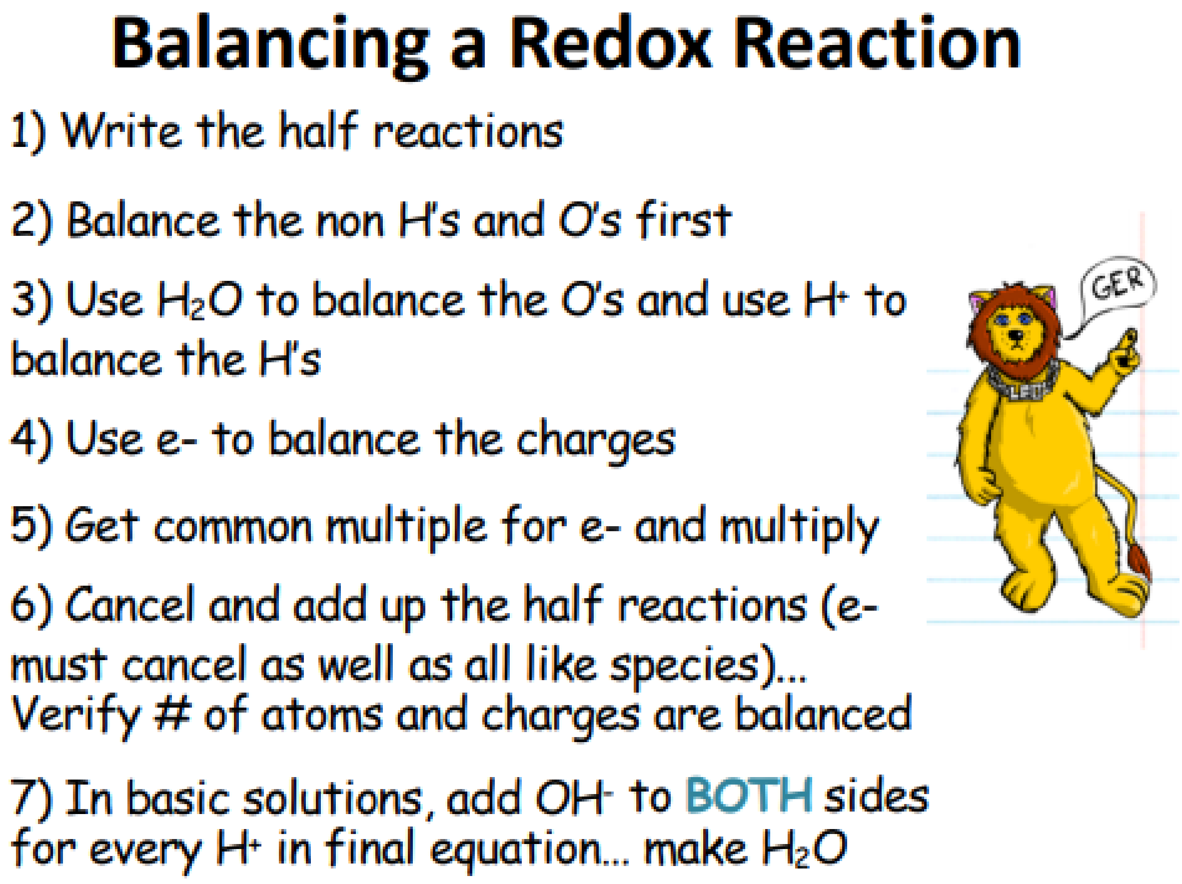
Writing a Redox Reaction

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

$Pb(s) + 2\ Ag^{+}(aq) \rightarrow Pb^{2+}(aq) + 2\ Ag(s)$

0 +1 +2 0



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

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

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

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

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

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

STEP #1

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**