Bonding, Moles & Stoichiometry

Unit 3

Bonding 101
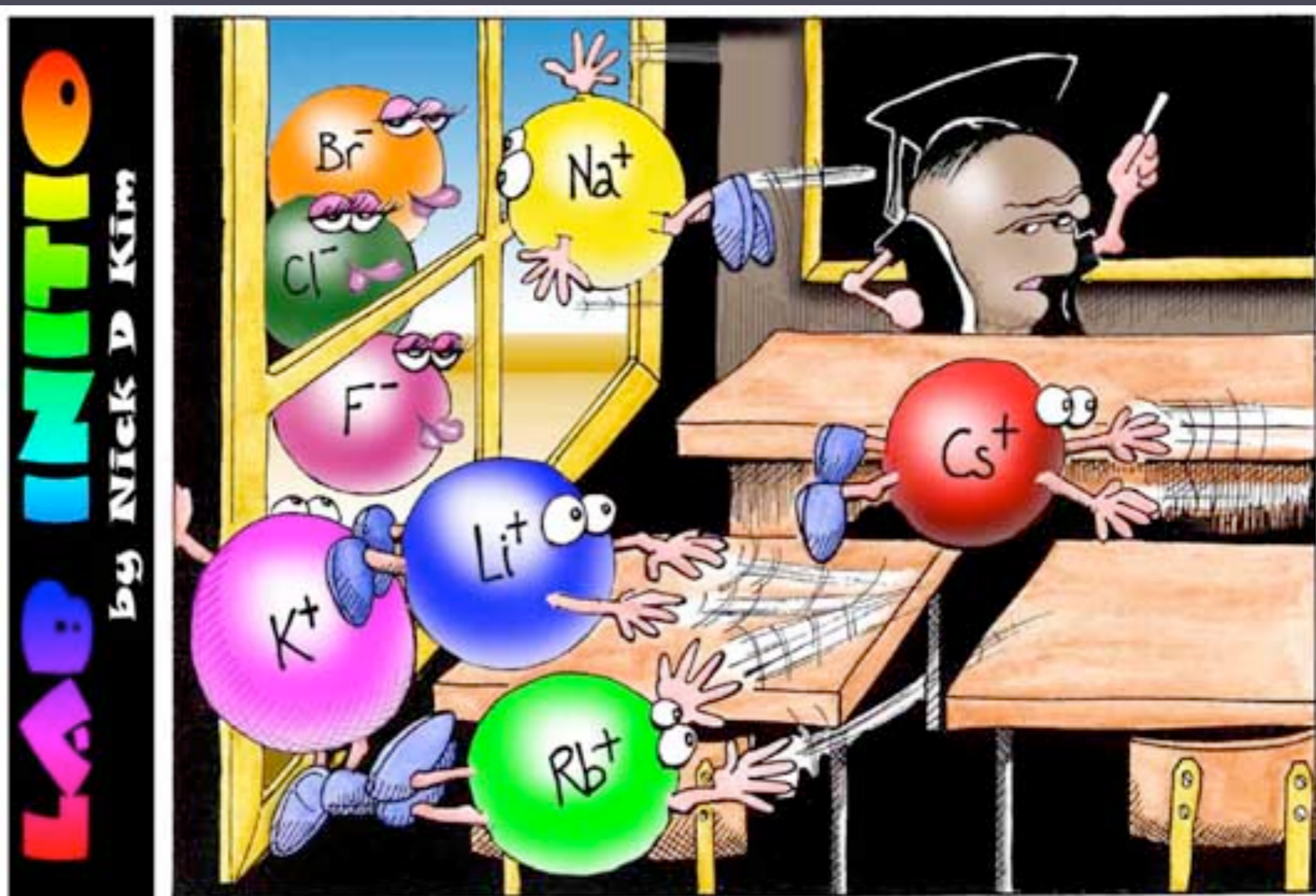
Bonding 101

What is a Bond???

Attraction between atoms or molecules

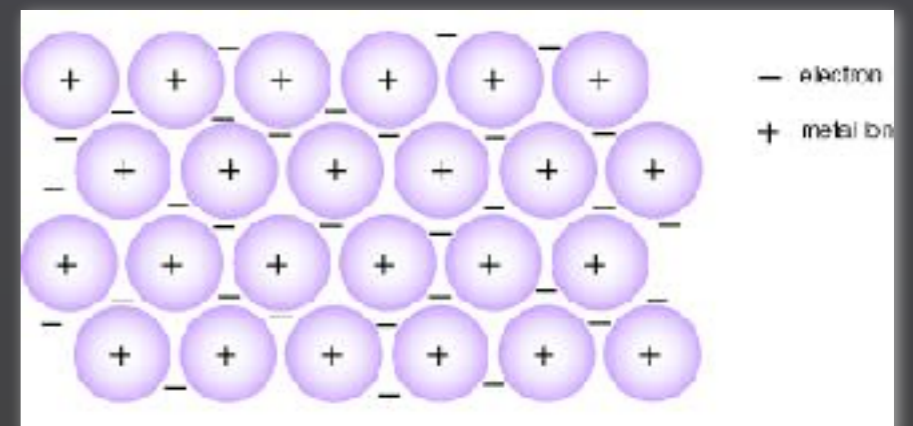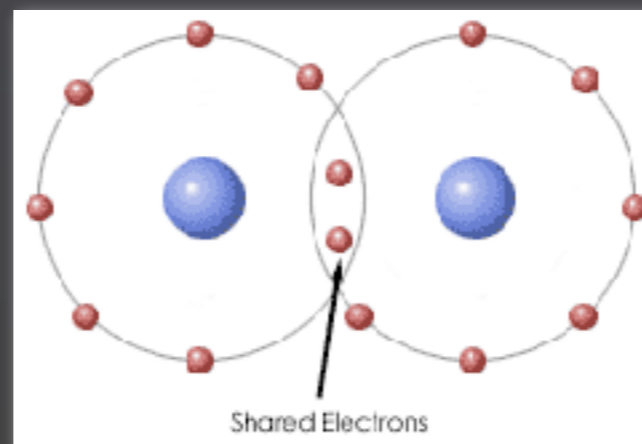**Nucleus** of one atom & **Valence electrons** of another atom

Why Bond?

STABILITY

Octet Rule Revisited
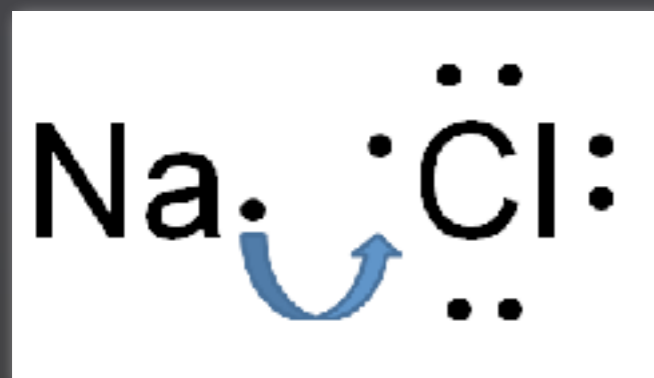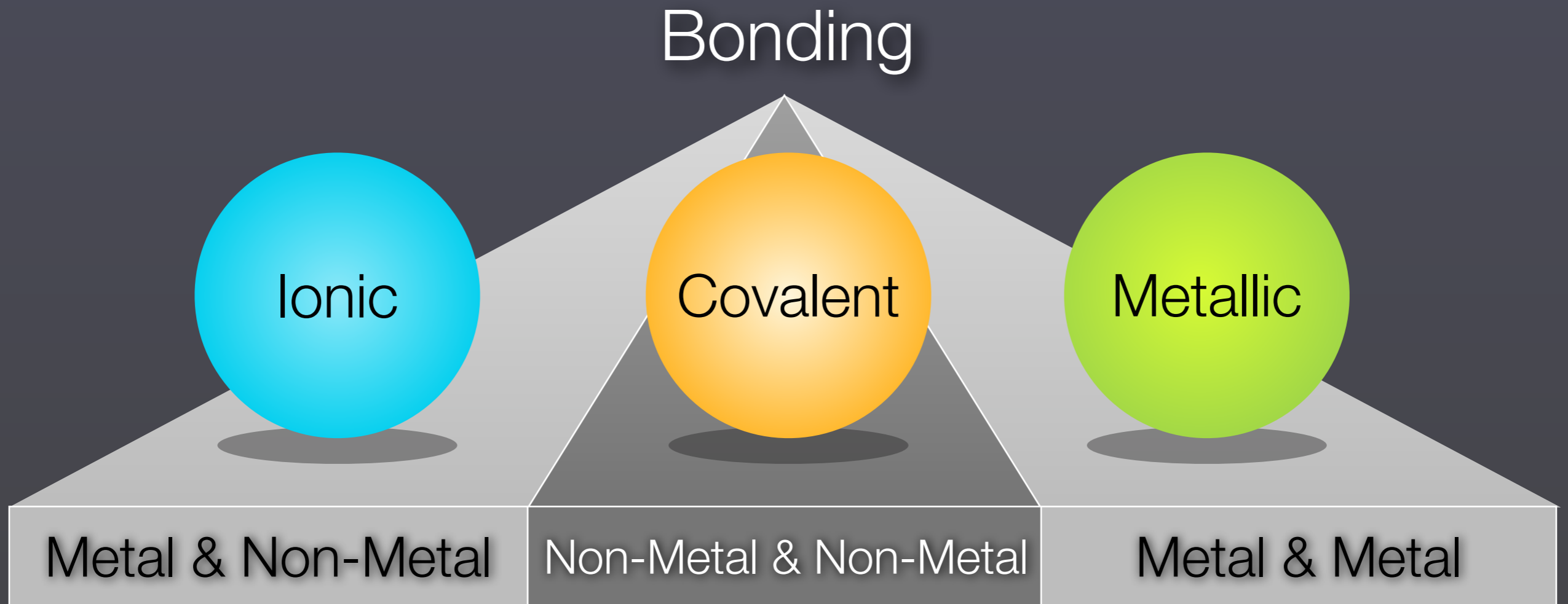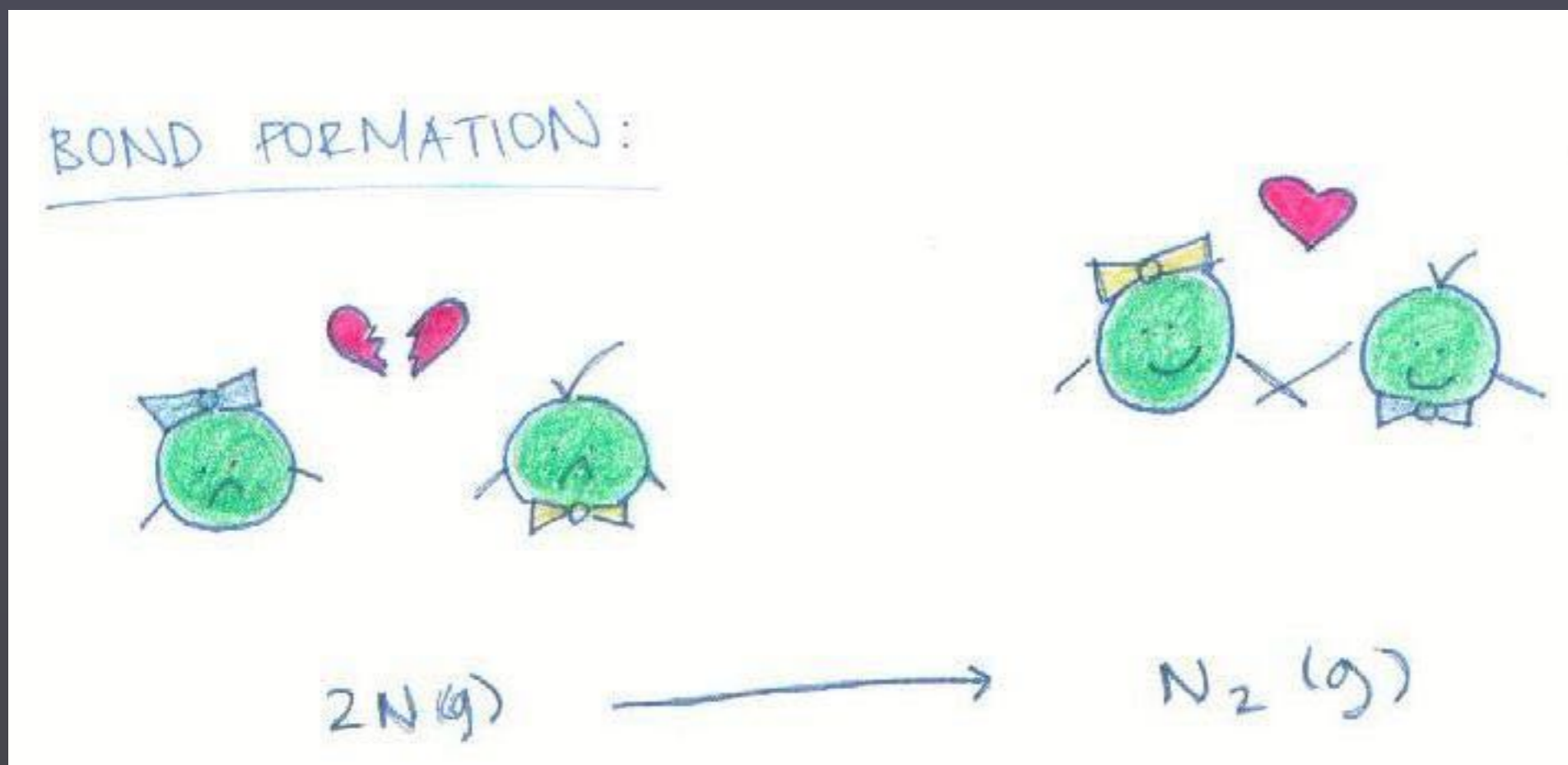

transfer

Atoms tend to gain, lose, or share one or more of their valence electrons to achieve a filled outer electron shell.

Bond Formation

High Energy to Low Energy (EXOTHERMIC)
Energy is Released!!

$2N_{(g)} \rightarrow N_{2(g)}$ **+ Energy**
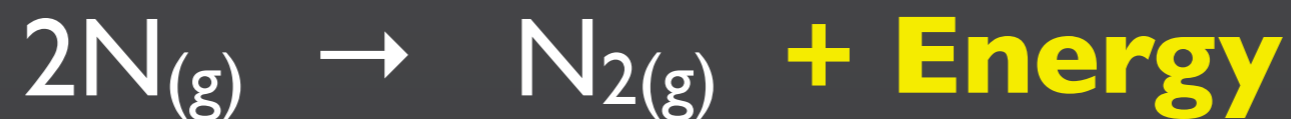
Bond Breakage
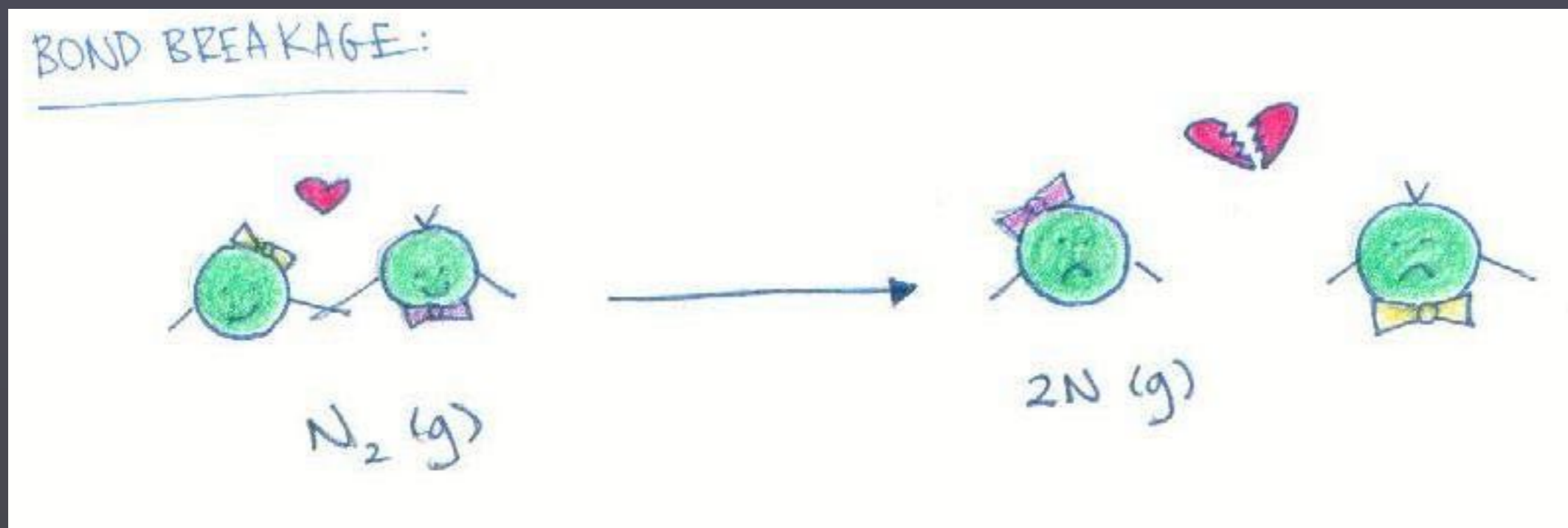
Low Energy to High Energy (ENDOTHERMIC)
Energy is Absorbed!

$$\textbf{Energy} + N_{2(g)} \rightarrow 2N_{(g)}$$

Regents Practice

Matter that is composed of two or more different elements chemically combined in a fixed proportion is classified as
(1) a compound   (3) a mixture
(2) an isotope   (4) a solution

Given the balanced equation representing a reaction:

$$Cl_2(g) \rightarrow Cl(g) + Cl(g)$$

What occurs during this change?
(1) Energy is absorbed and a bond is broken.
(2) Energy is absorbed and a bond is formed.
(3) Energy is released and a bond is broken.
(4) Energy is released and a bond is formed.

Regents Practice

Given the balanced equation:
$$I + I \rightarrow I_2$$
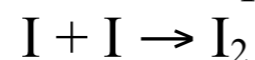
Which statement describes the process represented by this equation?
(1) A bond is formed as energy is absorbed.
(2) A bond is formed and energy is released.
(3) A bond is broken as energy is absorbed.
(4) A bond is broken and energy is released.

Which statement describes what occurs as two atoms of bromine combine to become a molecule of bromine?
(1) Energy is absorbed as a bond is formed.
(2) Energy is absorbed as a bond is broken.
(3) Energy is released as a bond is formed.
(4) Energy is released as a bond is broken.

Ionic Bonding - *How they Form*

Topic 2

A **metal** and a **nonmetal** atom bond.

- The metal **loses** the electron
- The non-metal **gains** the electron
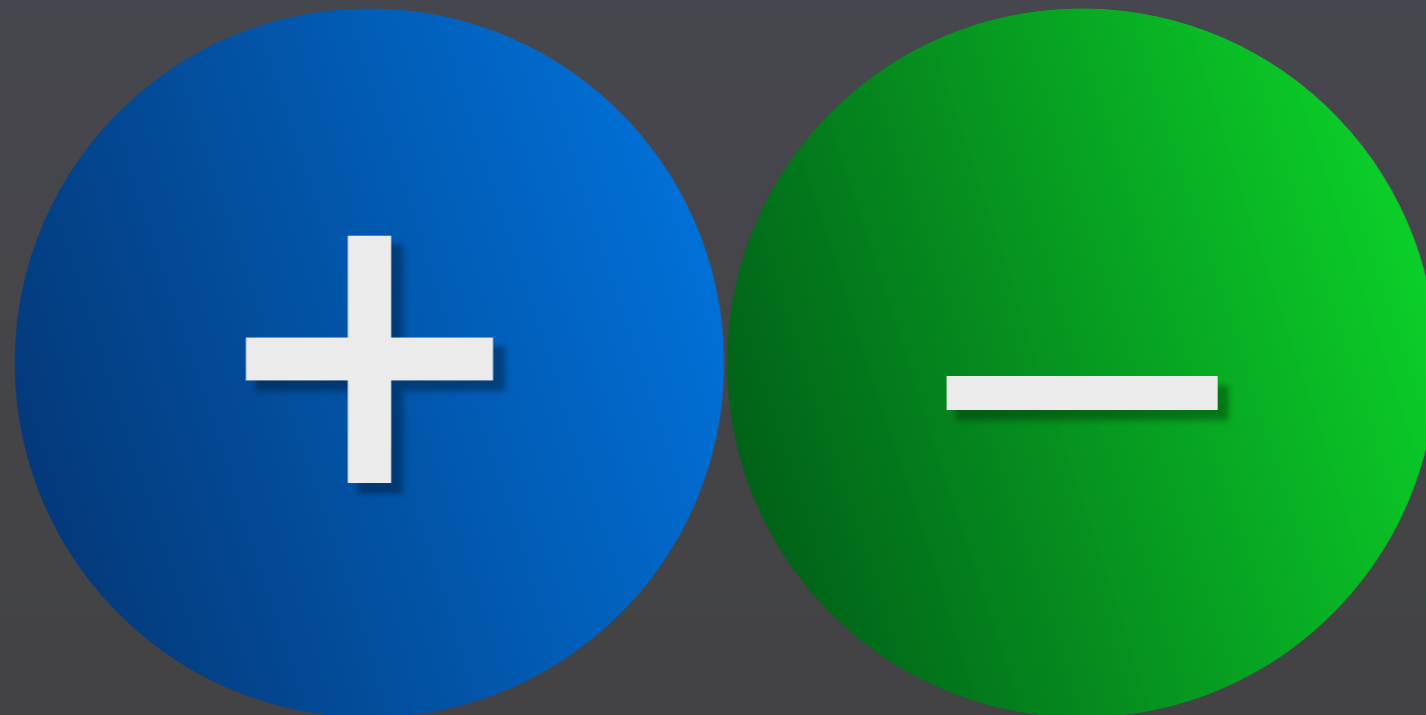
Example - *Potassium & Chlorine*

1. Chemical Formula - metal listed FIRST and the non-metal second...

<div align="center">

KCl

</div>

2. Name it - metal keeps its name, non-metal will change the end of its name to **-ide**.

Potassium chloride

Ionic compounds form crystals; smallest piece is called a **Formula unit**.

- It is NOT a molecule - electrons have been *transferred*.

- It is called an IONIC CRYSTAL.

More Practice

Show electron transfer (with arrows), draw the Lewis Diagram for the compound, write the chemical formula, and name the compound!

Sodium and **Sulfur**

Aluminum and **Bromine**

Magnesium and **Phosphorus**

Properties of Ionic Compounds

Electrostatic attraction between charged particles	MP / BP	Hardness	Conductivity	
			Liquid / Dissolved (aqueous)	Solid
	HIGH	HARD (crystalline structure)	GOOD	NONE

Formula Writing

Charge MUST balance ... compounds are electrically NEUTRAL!

$Na^+ O^{-2}$
$2Na^+$ & $1O^{-2}$
Na_2O

$Mg^{+2} + P^{-3}$	$Al^{+3} + Br^{-1}$	$Na^+ + S^{-2}$
Mg_3P_2	$AlBr_3$	Na_2S
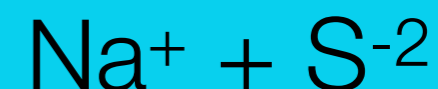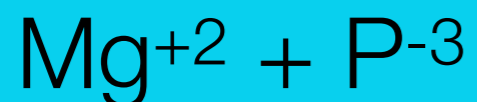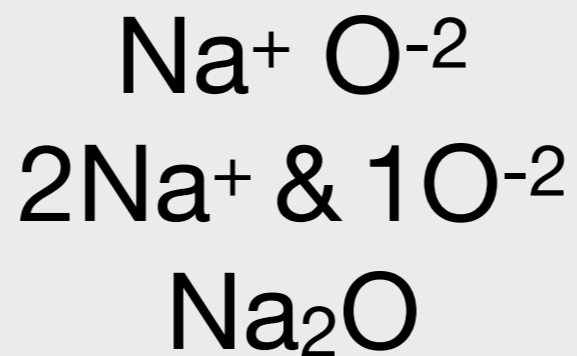
Empirical Formula

Formula of the **SIMPLEST** ratio of elements

Na_4S_2 can be reduced to:

Mg_6P_4 can be reduced to:

Na_2S

Mg_3P_2

Naming Multiply Charged Species

Aluminum (Al)   Silver (Ag)

Al^{+3} Ag^{+1}

Fe^{+2}_{+3} Pb^{+2}_{+4}
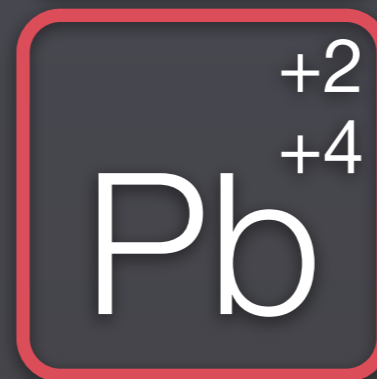
Iron (Fe)   Lead (Pb)

ROMAN NUMERALS for the charge on the METAL

Multiple Oxidation States

$CoCl_2$	$CoCl_3$
‣ Oxidation # of Co +2	‣ Oxidation # of Co +3
‣ Oxidation # of Cl -1	‣ Oxidation # of Cl -1
‣ Name:	‣ Name:
Cobalt (II) chloride	**Cobalt (III) chloride**

Name These: CuCl

CuCl$_2$

Determine the formula: iron (III) oxide

iron (II) oxide

Regents Practice

What is the chemical formula for iron(III) oxide?
(1) FeO   (3) Fe_3O
(2) Fe_2O_3 (4) Fe_3O_2

In which compound is the ratio of metal ions to nonmetal ions 1 to 2?
(1) calcium bromide   (3) calcium phosphide
(2) calcium oxide   (4) calcium sulfide

Regents Practice

When sodium and fluorine combine to produce the compound NaF, the ions formed have the same electron configuration as atoms of
(1) argon, only
(2) neon, only
(3) both argon and neon
(4) neither argon nor neon

Which formula represents an ionic compound?
(1) H_2 (3) CH_3OH
(2) CH_4 (4) NH_4Cl

Covalent Bonds

Topic 3

How Covalent Bonds Form

Non-Metal + Non-Metal = Covalent Compound

Covalent Compounds are called MOLECULAR COMPOUNDS (MOLECULES)

Naming Covalent Molecules

Overall charge = ZERO!

Formulas written with the most metallic atom FIRST!

H_2O

Prefixes used to tell us how many of each atom we have. →

- Don't use *mono* for the first element in a covalent molecule.

- Last element ends in *-ide*.

dihydrogen monoxide

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

Properties of Covalent Molecules

	State of Matter	MP / BP	Conductivity
Shared pair of electrons. Weaker bonds!	Solid / Liquid	LOW (soft as solids)	NONE

Common Names for Molecular Compounds
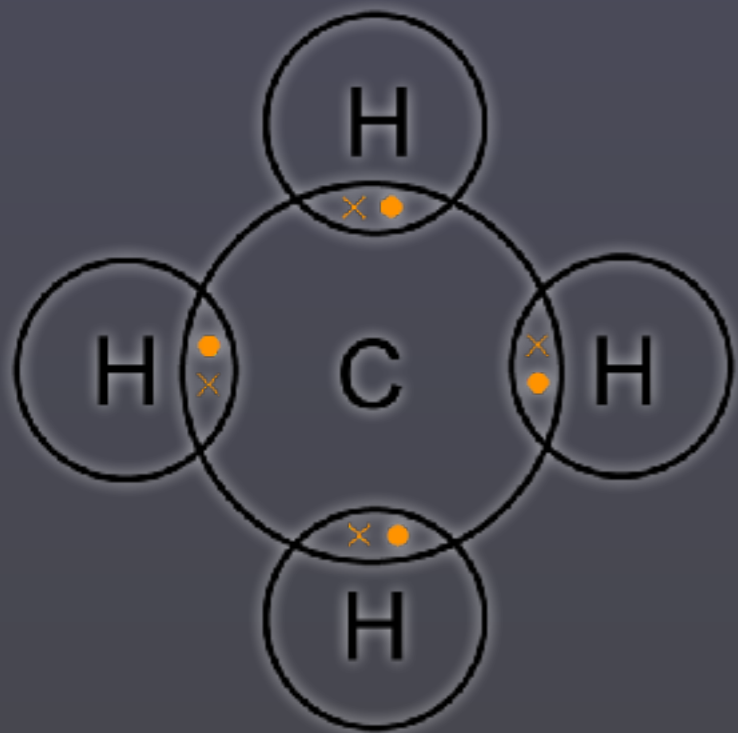
Methane (CH$_4$)
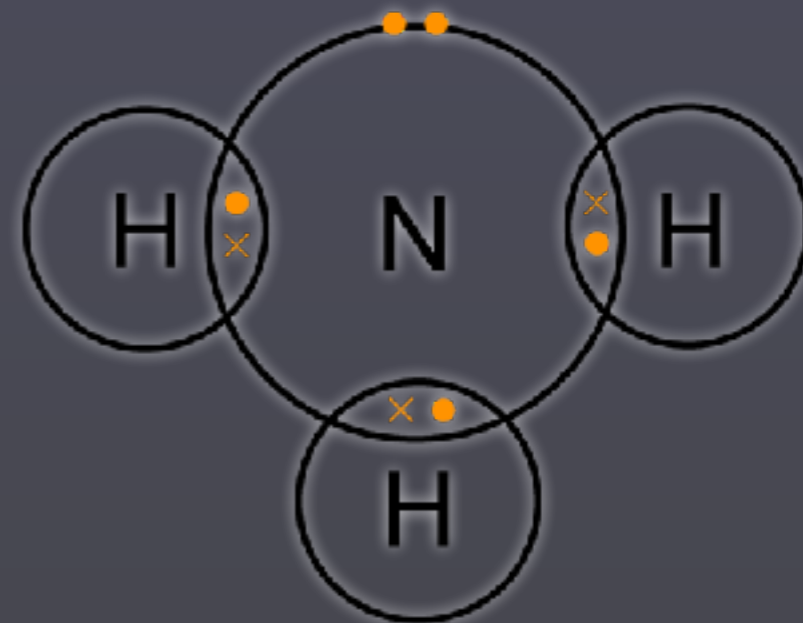
Water (H$_2$O)

Ammonia (NH$_3$)

Draw & Name - PRACTICE!!

Give the following complete octets while sharing valence electrons.

H and N   C and H

S and Br   O and F

Special cases - Multiple sharing!

O and O   N and N

Regents Practice

Which property could be used to identify a compound in the laboratory?
(1) mass   (3) temperature
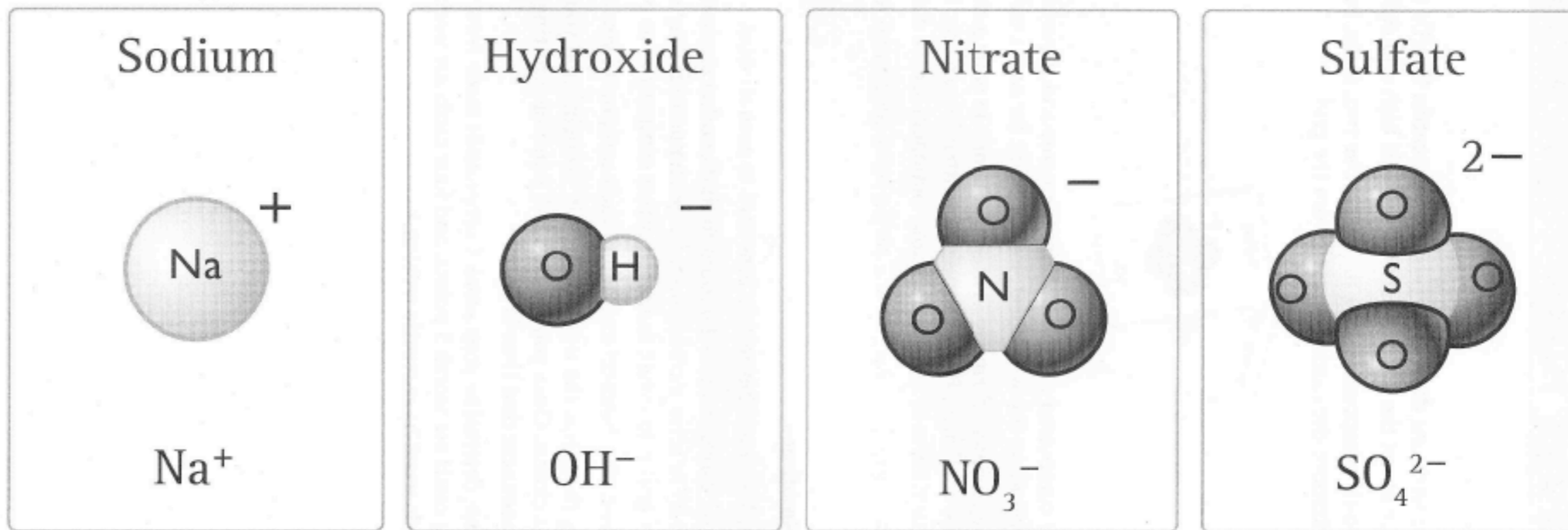(2) melting point   (4) volume

As a bond between a hydrogen atom and a sulfur atom is formed, electrons are
(1) shared to form an ionic bond
(2) shared to form a covalent bond
(3) transferred to form an ionic bond
(4) transferred to form a covalent bond

Polyatomic Ions

The cards show a sodium ion and three polyatomic ions.

Sodium	Hydroxide	Nitrate	Sulfate
Na^+	OH^-	NO_3^-	SO_4^{2-}

What do you think a polyatomic ion is?

Name 3 compounds formed between sodium ions and the polyatomic ions.

$Na(OH)$ $Na(NO_3)$ $Na_2(SO_4)$
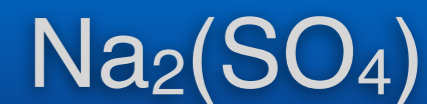
Binary & Ternary Ionic Compounds

Binary Ionic Compounds	Ternary Ionic Compounds
‣ Contain 2 elements	‣ Contain 3 elements
‣ Metal and a Non-metal	‣ Attraction of ions of opposite charge
‣ Metal named first, then the non-metal with the suffix '-ide'	‣ Polyatomic ions
	‣ TABLE **E** - use it!!
‣ $AlBr_3$ = aluminum bromide	‣ Covalent bonds inside the polyatomic ion (non-metal + non-metal)

Naming with Polyatomic Ions

Ca(SO$_4$) = Calc<u>ium</u> sulfate

Look at Table E and the endings of the ions:

Take the name off of Table E. Don't change it!

1

2

3
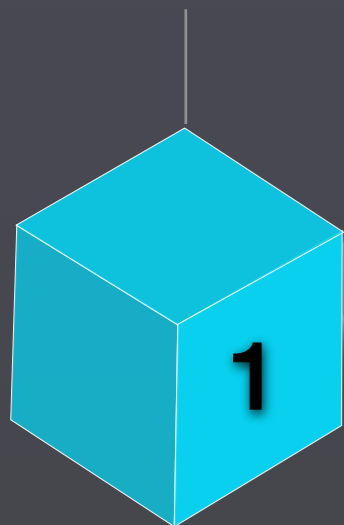
"ate" "ite"

"ium"

How does this compare to the endings of binary covalent compounds?

They're different! Binary compounds end in "-ide"

Writing Formulas for Polyatomics

Use Table E, BALANCE THE CHARGES, and write the formula for each:

Lithium sulfite

Ammonium oxide

Aluminum nitrate

Aluminum sulfate

In-Class Activity

Name the following:

MgI_2
SnS
CBr_4
K_3P
$Fe(OH)_3$
NiF_2
$Ba(SO_4)$
CO
Rb_3N
$Hg(NO_3)_2$
CS_2
$(NH_4)_2Cr_2O_7$
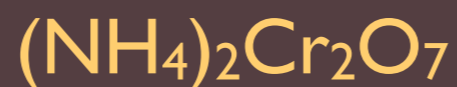
Regents Practice

Which polyatomic ion contains the greatest number of oxygen atoms?
(1) acetate   (3) hydroxide
(2) carbonate   (4) peroxide

Which formula represents lead(II) chromate?
(1) $PbCrO_4$ (3) Pb_2CrO_4
(2) $Pb(CrO_4)_2$ (4) $Pb_2(CrO_4)_3$

Magnesium nitrate contains chemical bonds that are
(1) covalent, only
(2) ionic, only
(3) both covalent and ionic
(4) neither covalent nor ionic

Balancing Equations

If 360 grams of water decompose into 320 grams of oxygen, how much hydrogen will be produced according to the reaction below?

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

Law of Conservation of Mass!

Reactions Conserve Mass

Input = Output

$2H_2O$
(4H, 2O)

Chemical Reaction

$O_2 + 2H_2$
(4H, 2O)

_2_ Na + _2_ H(OH) → _2_ NaOH + _1_ H₂

Equations

...st b... each side ...

...**coeffi**... ...u cannot change a substance

$$H_2 + O_2 \rightarrow H_2O$$

$$2H_2 \qquad + \qquad O_2 \qquad \longrightarrow \qquad 2H_2O$$

$$2H_2 + O_2 \rightarrow 2H_2O$$
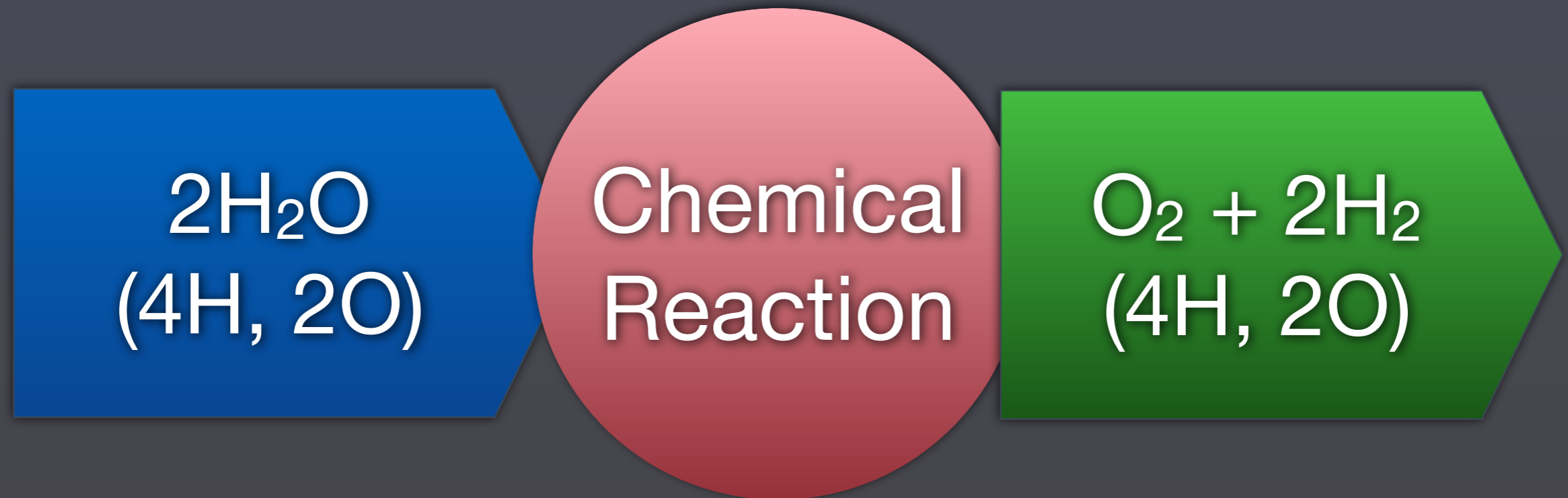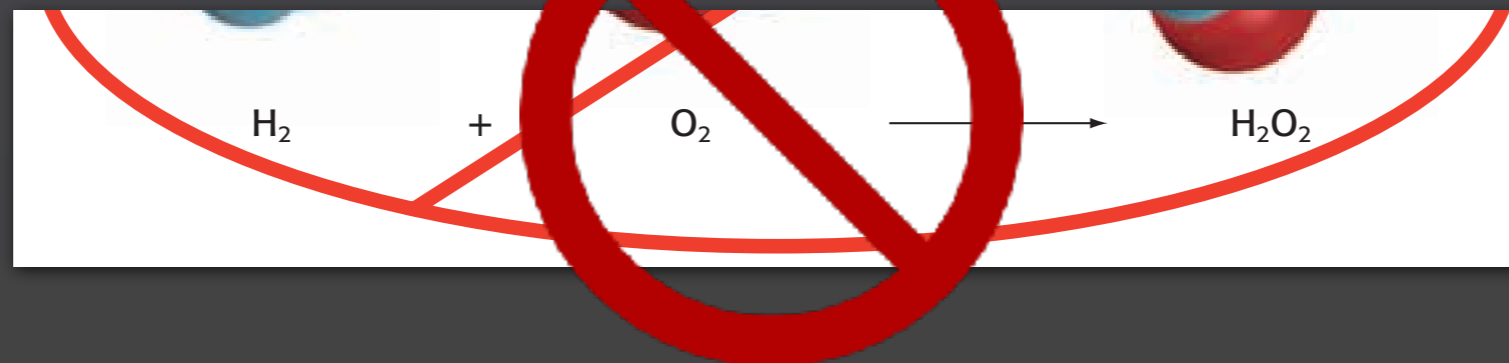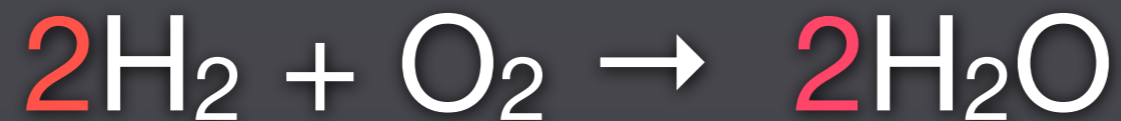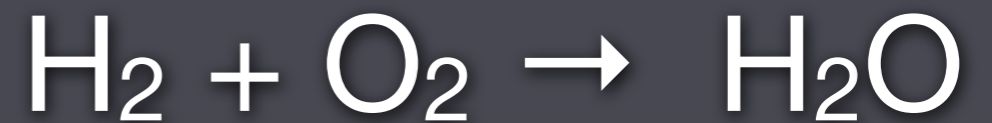
Skill Toolkit - Balancing

of atoms must be the same on each side of the arrow

Count atoms

Verify your results!

1 **2** **3** **4**
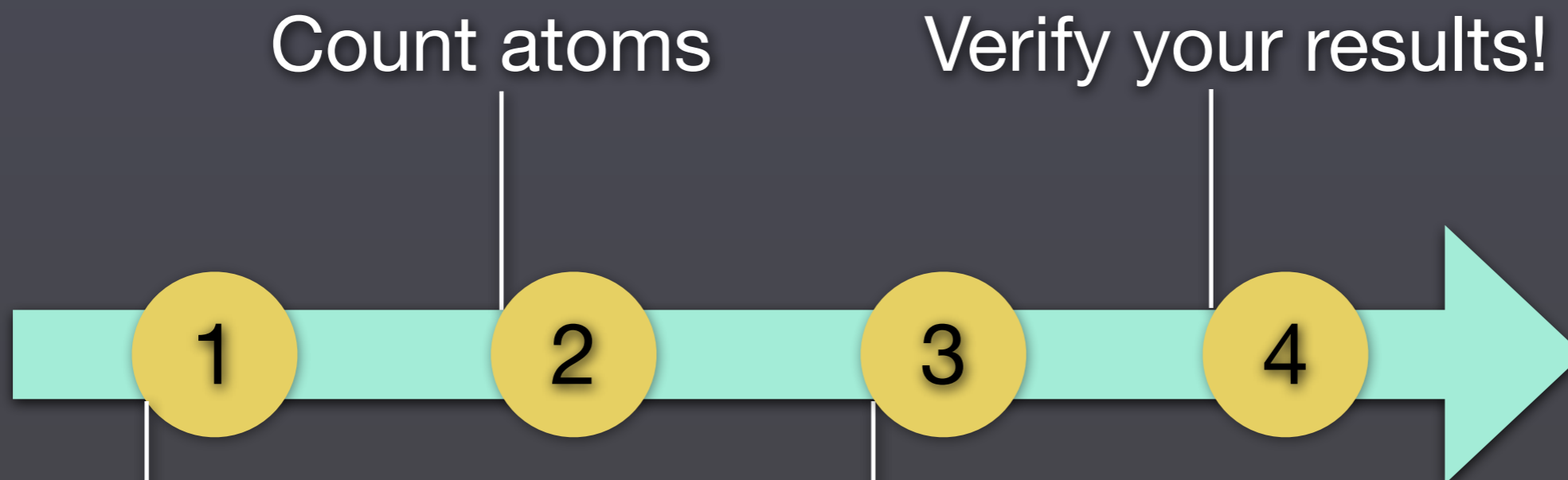
Identify reactants &
products

Insert
coefficients

Practice Time!

1.) _____ Cu + _____ O_2 → _____ CuO

2.) _____ CH_4 + _____ O_2 → _____ CO_2 + _____ H_2O

3.) _____ Fe_2O_3 + _____ Cu → _____ Cu_2O + _____ Fe

4.) _____ $Ca(NO_3)_2$ + _____ Li_3PO_4 → _____ $LiNO_3$ + _____ $Ca_3(PO_4)_2$

5.) _____ $H_2(SO_4)$ + _____ $NaOH$ → _____ H_2O + _____ $Na_2(SO_4)$
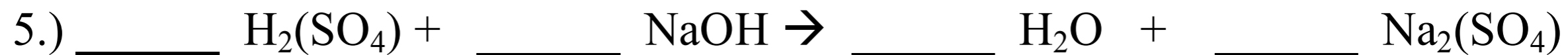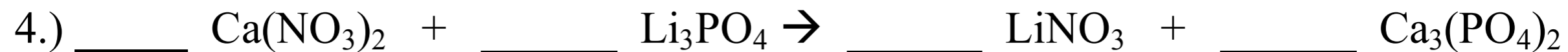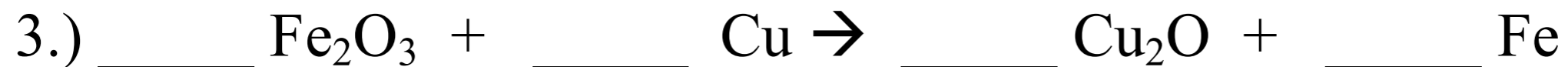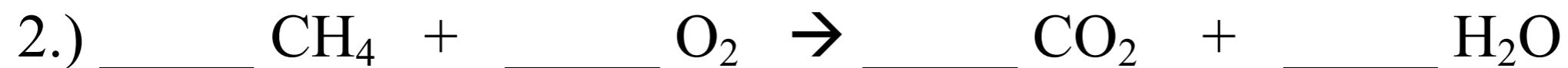
Word Equations

Sodium reacts with water to produce hydrogen gas and sodium hydroxide.

$$2Na + 2H_2O \rightarrow 1H_2 + 2NaOH$$

Nitrogen and hydrogen react to form ammonia gas.

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

The Mole & Stoichiometry

Topic 6

The Mole

Counting atoms, ions, and molecules ...
NOT EASY!

Scientists use the mole (mol) to count.
1 mole = # of atoms in 12 g of
carbon-12 $(6.022 \times 10^{23}$ atoms)

The Mole

Why 12 for Carbon?

- Atomic weight scale defines masses of atoms relative to the mass of an atom of C-12.
- 12 was chosen so that the least massive atom, Hydrogen, has a mass of 1.
- This was done w/o the knowledge of protons, neutron or electrons!!
- Avogadro's Number not discovered by Avogadro!
- The number N_A is based on the charge of a mole of electrons, which was discovered in the early 20th century *(charge of a mole = 1 Faraday)*.

Moles & Stoichiometry

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

Stoichiometry is the MATH of CHEMISTRY

Coefficients = # of moles of that substance

Chemical Reactions and Equations
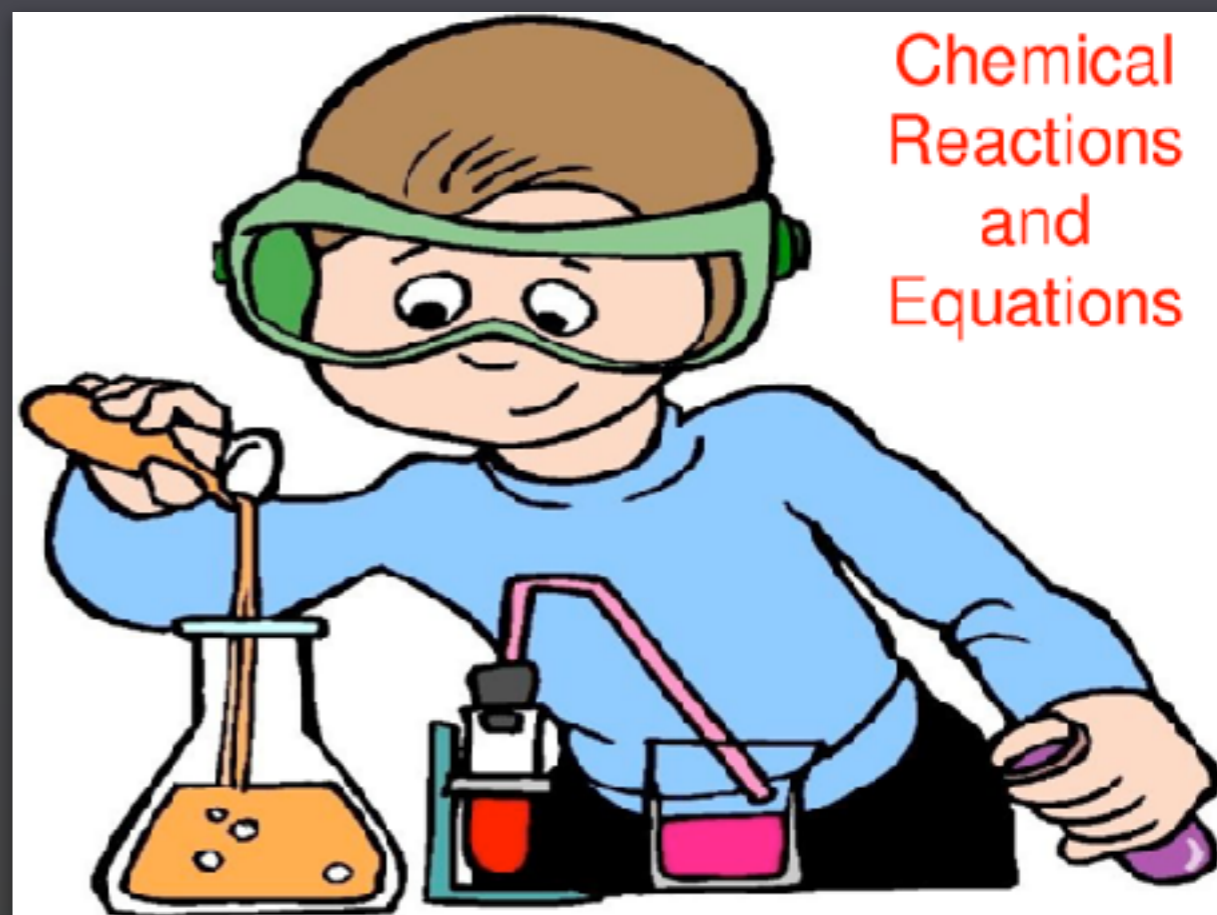
What does a Mole look like?

How many grams in 1 mole of Aluminum?

If 1 mole of Al = 27 g, how many grams would 1 mole of $AlCl_3$ be?

Atom	Atomic mass
Al (aluminum)	27 g
Cl (chlorine)	35 g
Cl (chlorine)	35 g
Cl (chlorine)	35 g

1 mole $AlCl_3$ = 132 g/mole

Gram Formula Mass!!

What does a Mole look like?

Use your periodic tables to determine the gram formula mass for each compound:

H_2O

Li_3N

$CuSO_4$

$(NH_4)_2SO_4$
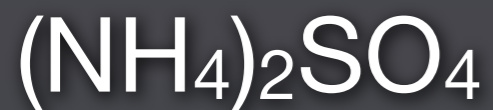
Important Note: The gram formula mass unit is *grams per mole (g/mol)*. It is the mass of ONE MOLE of the substance. The mass of ONE MOLECULE of the substance is the same number, but the unit is *atomic mass units (amu)*.

Mole / Gram Conversions

Dimensional Analysis is Back!!

I need 3.5 moles of lead (Pb) for my reaction. How many grams is that?

Example 2: I need 5 moles (mol) of H_2O for my reaction. How many grams is that?

Example 3: My beaker has 500 g of water in it. How many moles is that?

Example 4: I just made 24.62 grams of $CuSO_4$ in the lab. How many moles is that?

Unit Essentials

Topic 1 - Bonding

ESSENTIALS: Know, Understand, and Be Able To…

☐ A compound is a substance composed of two or more different elements that are chemically combined in a fixed proportion

☐ Two major categories of compounds are ionic and molecular.

☐ Compounds can be distinguished from each other and from elements by their physical and chemical properties.

☐ Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence configurations and tend not to bond.

TEXT REFERENCES: p. 48-52,186-199, 213-222

Topic 2 - Ionic Bonding

ESSENTIALS: Know, Understand, and Be Able To…

☐ Metals tend to react with nonmetals to form ionic compounds.

☐ Draw Lewis electron dot diagrams for compounds formed when valence electrons are:
   • transferred from one atom to another (ionic)

☐ Determine which noble gas electron configuration an atom will achieve by bonding.

☐ Predict the chemical formula for a compound formed by two elements or ions.

☐ A chemical compound can be represented by a specific formula and assigned a name based upon the IUPAC system.

☐ Determine the chemical formula of a compound, given its IUPAC name.

TEXT REFERENCES: p. p. 186-199, 260-263

Topic 3 - Molecular Bonding

ESSENTIALS: **Know, Understand, and Be Able To…**

- ❑Nonmetals tend to react with other nonmetals to form molecular (covalent) compounds.
- ❑Draw Lewis electron dot diagrams for compounds formed when valence electrons are:
    - • shared between atoms (covalent)
- ❑Determine which noble gas electron configuration an atom will achieve by bonding.
- ❑Predict the chemical formula for a compound formed by two elements or ions.
- ❑A chemical compound can be represented by a specific formula and assigned a name based upon the IUPAC system.
- ❑Determine the chemical formula of a compound, given its IUPAC name.

TEXT REFERENCES: p. 212-216, 268-270

Topic 4 - Polyatomic Ions

ESSENTIALS: **Know, Understand, and Be Able To…**

- ❑A polyatomic ion is a cluster of two or more atoms that is covalently bonded like a molecule, but has an electrical charge on it like an ion.
- ❑Use Reference Chart E when writing or interpreting chemical formulas.
- ❑Recognize the presence of a polyatomic ion in a formula, by knowing the difference between binary ionic and ternary ionic formulas.
- ❑Distinguish between ionic and molecular (covalent) substances, given their properties.
- ❑Determine the type of compound, given a formula.
- ❑Assign an IUPAC name to a compound, given the formula, for both ionic and molecular compounds.

TEXT REFERENCES: p. 257-258, 264-266

Topic 5 - Balancing Equations

ESSENTIALS: Know, Understand, and Be Able To…

❑In all chemical reactions there is a conservation of mass, energy, and charge.

❑A balanced chemical equation represents a conservation of atoms.

❑Balance equations, given the formulas of reactants and products.

❑Create and use models of particles to demonstrate balanced equations

TEXT REFERENCES: p. 320-329

Topic 6 - Moles & Stoichiometry

ESSENTIALS: Know, Understand, and Be Able To…

❑The formula mass of a substance is the sum of the masses of its atoms in atomic mass units. The molar mass (also called gram-formula mass) of a substance is the mass of one mole of that substance in grams.

❑Calculate the formula mass and gram-formula mass.

❑Determine the mass of a given number of moles of a substance.

❑Determine the number of moles of a substance, given its mass.

❑The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction.

❑Interpret balanced chemical equations in terms of conservation of matter and energy.

TEXT REFERENCES: p. 286-304, 352-383