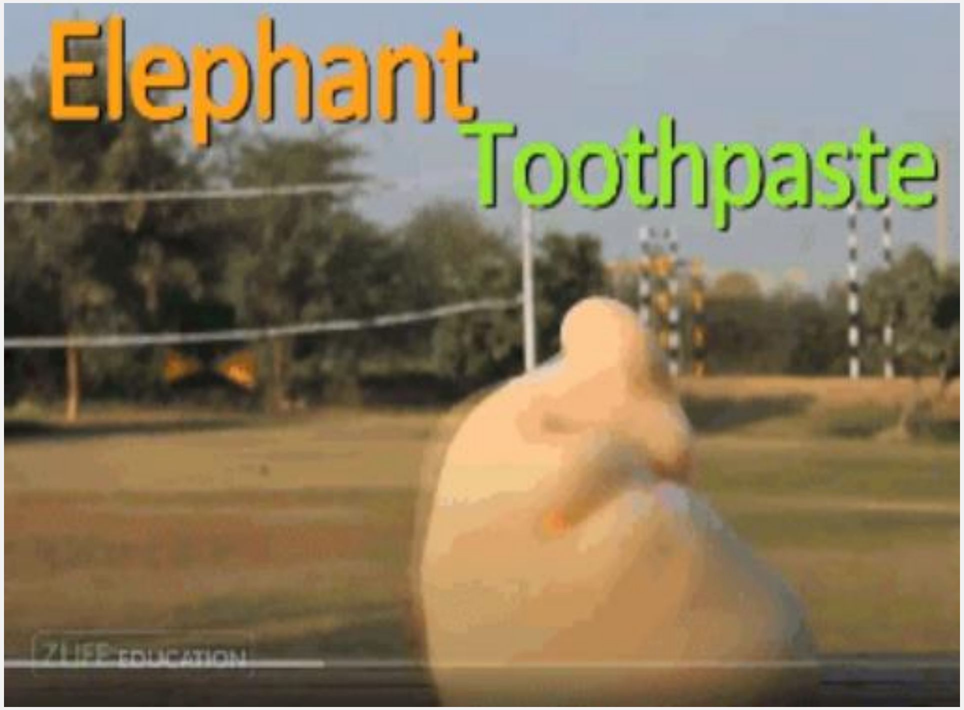
Chapter 7
Chemical Reactions

Describing Chemical Reactions

Types of Chemical Reactions



Chemical Reactions

Focus Points

- Define and incorporate the law of conservation of mass.
- Analyze components (reactants, products, coefficients) of chemical equations in order to balance them.
- Understand and calculate quantities using the Mole related to balancing chemical equations.
- Describe and identify the five types of chemical reactions (synthesis, decomposition, single replacement, double replacement, and combustion). Give examples of each type.
- Distinguish Chemical reactions that involve the transfer of electrons (reduction/oxidation reactions) based on the discovery of subatomic particles.

Describe Evidence of a chemical change.

$$2K_{(s)} + 2H_2O_{(l)} \longrightarrow 2KOH + H_{2\,(g)} + \text{heat}$$

Reaction of potassium with water:

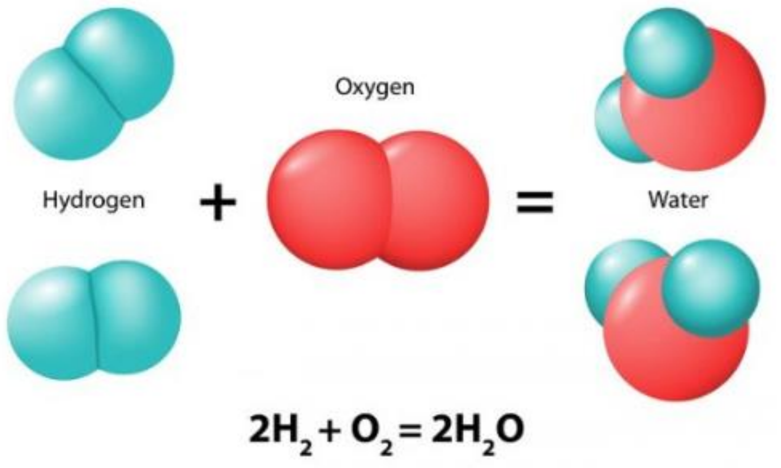
Describe Evidence of a Chemical Change.

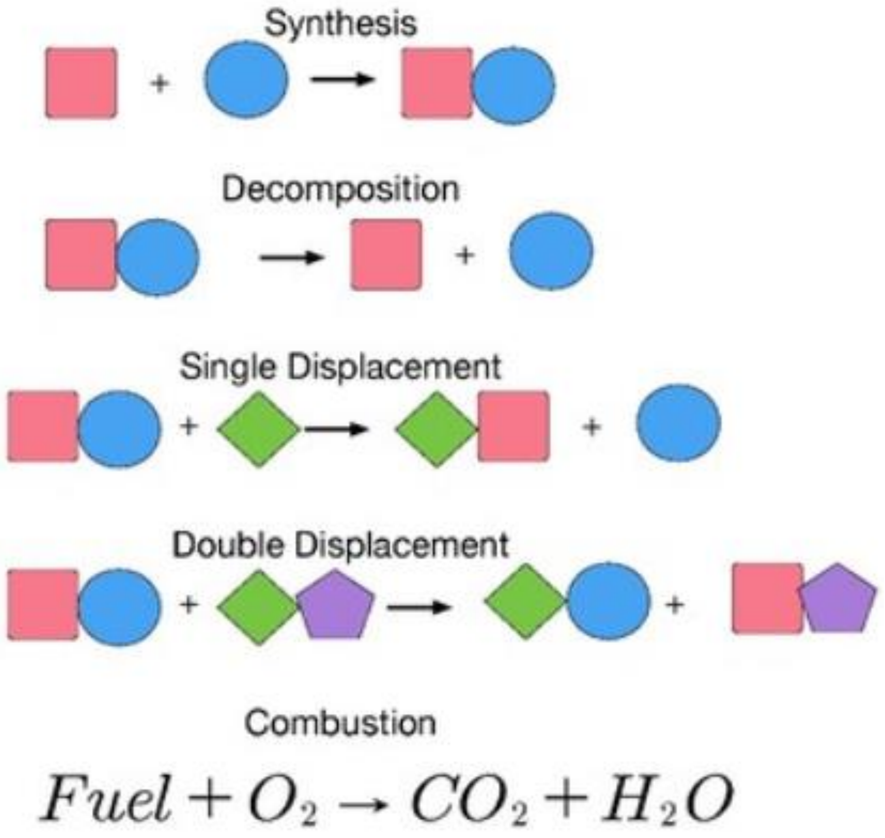
Some signs of a chemical **reaction** observed in the reaction of potassium with water:

- ☐ temperature change
- ☐ gas produced
- ☐ color change
- ☐ Smoke
- ☐ Flame

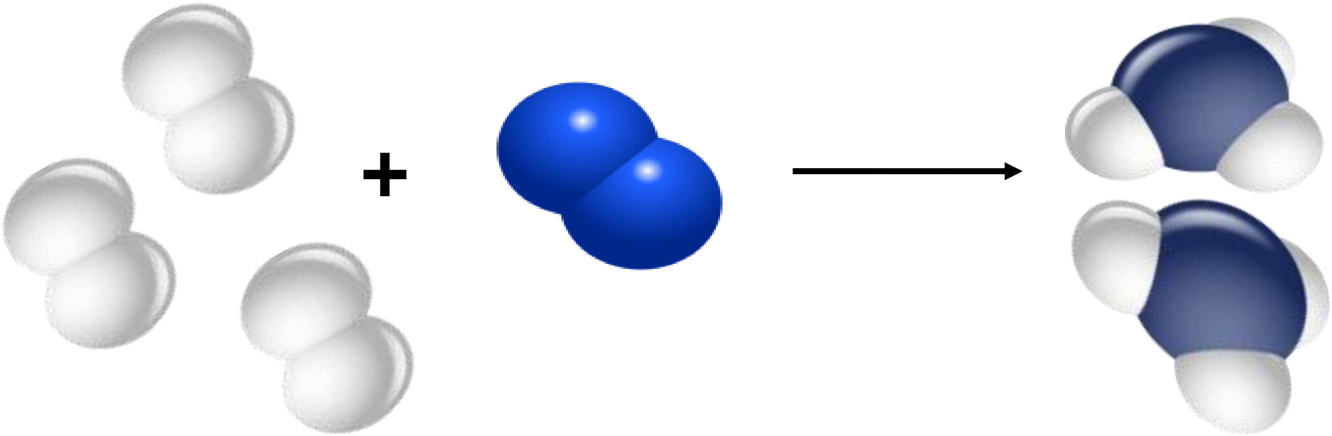
Annotating Chemical Changes

A useful way of describing chemical change is to write what is present BEFORE and AFTER the change.





Chemical Changes Expressed as Equations

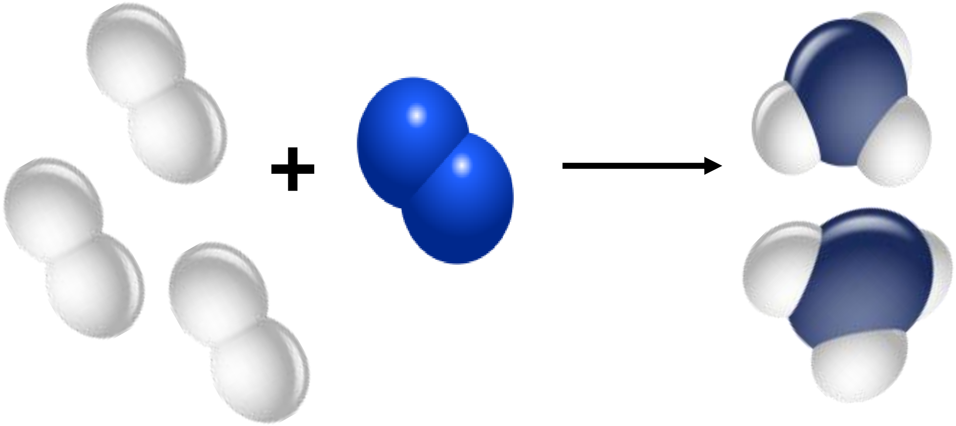


Reactants → Products

$3H_{2\,(g)} + N_{2\,(g)} \rightarrow 2NH_{3\,(g)}$

Hydrogen + Nitrogen → Ammonia

Chemical Changes Expressed as Equations



Reactants are the substances that enter into a chemical reaction.

Products are the substances that form.

A **chemical equation** is a group of chemical formulas & symbols that represent the reactants & products in a chemical reaction, expressed in words or formulas.

Hydrogen + Nitrogen → Ammonia

$$3H_{2\,(g)} + N_{2\,(g)} \rightarrow 2NH_{3\,(g)}$$

Components of Chemical Equations

Chemical Formulas are used to represent the composition of elements in a compound or molecule.

Subscripts

Indicate the number of atoms within ONE compound or molecule

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + 3O_{2\ (g)}$$

Components of Chemical Equations

Chemical Formulas are used to represent the composition of elements in a compound or molecule.

Subscripts

Indicate the number of atoms within ONE compound or molecule

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + 3\ O_{2\ (g)}$$

$$\overbrace{ClO_3 + ClO_3} = 2\ Cl + 6\ O$$

Notice, that there are 6 oxygen atoms on the left (reactants) but only 2 on the right (products) …

Components of Chemical Equations

Chemical equations must be “balanced”.

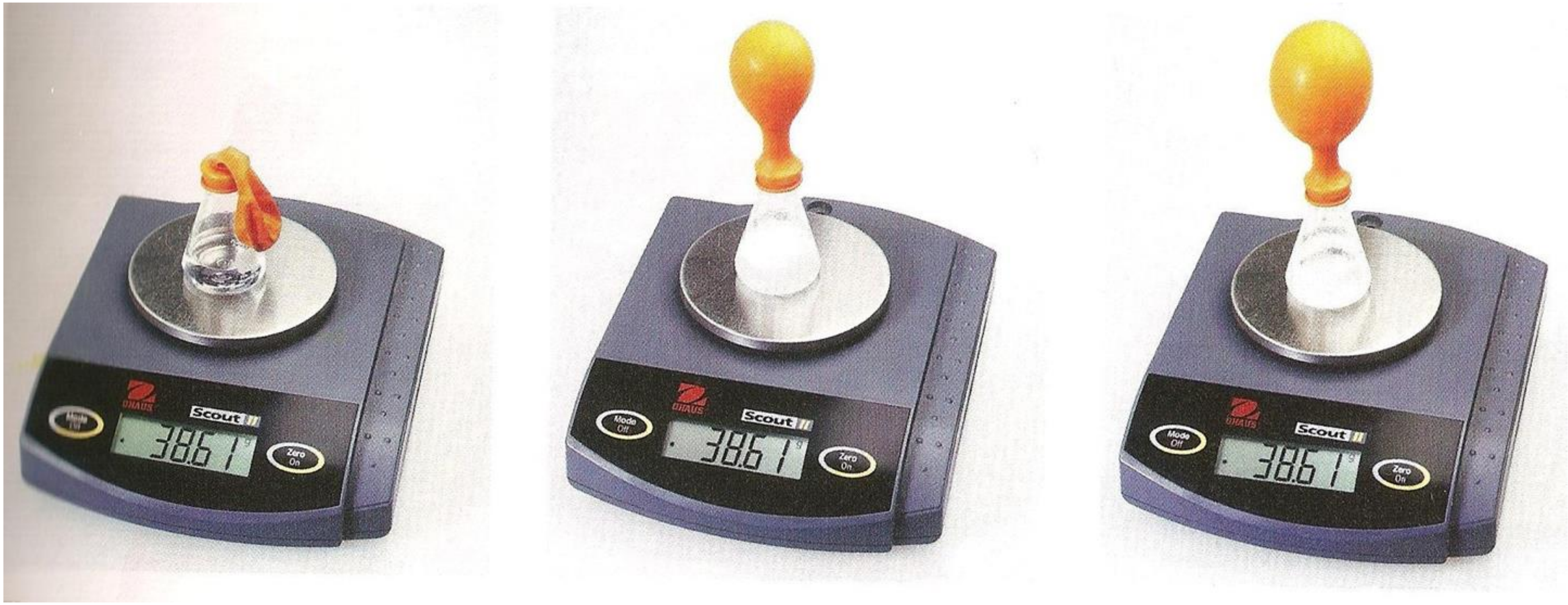
Law of Mass Conservation *Antoine Lavoisier 1787*

Matter cannot be created or destroyed;
it can only change form (transformation).

- This means that the mass of the **products** is equal to the original mass of the **reactants**.

LESSON QUESTION

Law of Mass Conservation



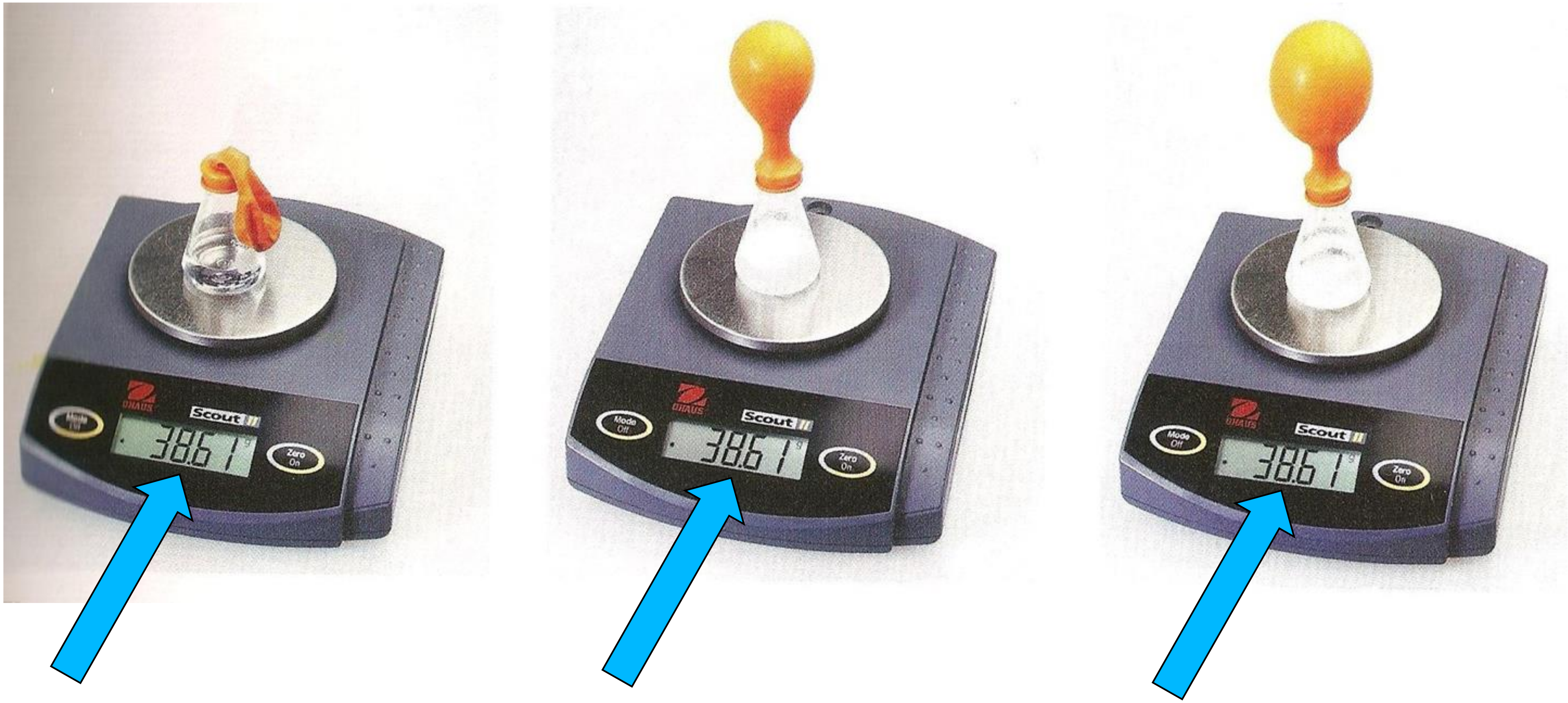
$$HCl + Na_2CO_3 \rightarrow NaCl + H_2O + \mathbf{CO_{2\,(g)}}$$

- A chemical reaction takes place & yields CO_2 gas.
- This is a “closed” system, so nothing escapes.

What happens to mass from start to finish?

LESSON QUESTION

Law of Mass Conservation



$$HCl + Na_2CO_3 \rightarrow NaCl + H_2O + \mathbf{CO_{2\,(g)}}$$

The mass does NOT change from start to finish in a chemical change.

The **Law of Mass Conservation** states that in any PHYSICAL or CHEMICAL change (reaction), mass is conserved.

- Mass remains constant for Physical Changes.

e.g. 10 g or ice melt to form 10 g of liquid water

https://screencast-o-matic.com/watch/cYfv3eBO4H
Mass of Ice Before and After Melting (0:41)

Components of Chemical Equations

Coefficients are used to balance chemical equations so that mass is conserved.

Coefficients

Indicate the number of compounds or molecules (“moles”) and are used to balance Chemical Equations or reactants & products

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + \mathbf{3}\ O_{2\ (g)}$$

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + \overbrace{\mathbf{O_{2\ (g)} + O_{2\ (g)} + O_{2\ (g)}}}$$

There are the same number of each element on each side of the equation.

1 Ca, 2 Cl, 6 O → 1 Ca, 2 Cl, 6 O

$Cu + O_2 \rightarrow CuO$

TRY IT

Is this **skeleton** equation of a chemical reaction balanced?

TRY IT

$$Cu + O_2 \rightarrow CuO$$

This **skeleton** equation of a chemical reaction is NOT balanced:

1 Cu → 1 Cu		2O → 1 O

Therefore, use a coefficient to balance the oxygens:

$$Cu + O_2 \rightarrow 2CuO$$

The oxygens are balanced, but now the copper is not balanced. Again, use a coefficient:

$$2Cu + O_2 \rightarrow 2CuO$$

Inspect:	2 Cu → 2 Cu		2O → 2 O

How Are Scientists Able to Count the Number of Particles in Matter?

You might count shoes by the pair, eggs by the dozen, or paper by the ream (500 sheets).

Chemical reactions often involve very large numbers of small particles.

How Are Scientists Able to Count the Number of Particles in Matter?

Avogadro's Number N_a

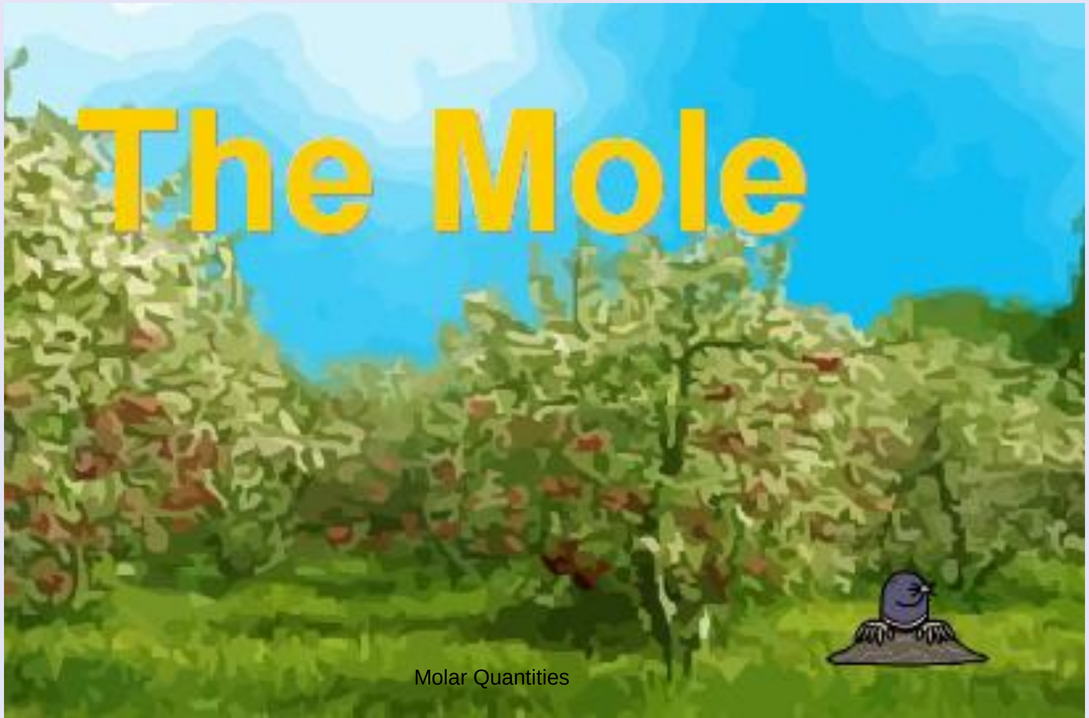
$= 6.02 \times 10^{23}$

GET YOUR CALCULATORS READY!!

Measuring Matter

Chemistry is both a qualitative and a quantitative science, meaning we observe and describe matter, and we measure and quantify matter.

To effectively measure and quantify matter, scientists use STANDARDS. Just as a “meter” is the standard unit of distance in the Metric system, scientists use the “MOLE” as a standard of chemical quantities.



What Is a Mole?

A **mole** (mol) is the amount of a substance contains **Avogadro's number** of items.

The number of particles in a mole is

$$N_a = 6.022 \text{ x } 10^{23}$$

… *particles, atoms, molecules, you name it*

One mole of anything is N_a of that item.

A mole refers to a specific quantity (count / number, mass in grams or volume in liters.

The mole concept is analogous to any set unit … e.g. a dozen (*12 of anything*)

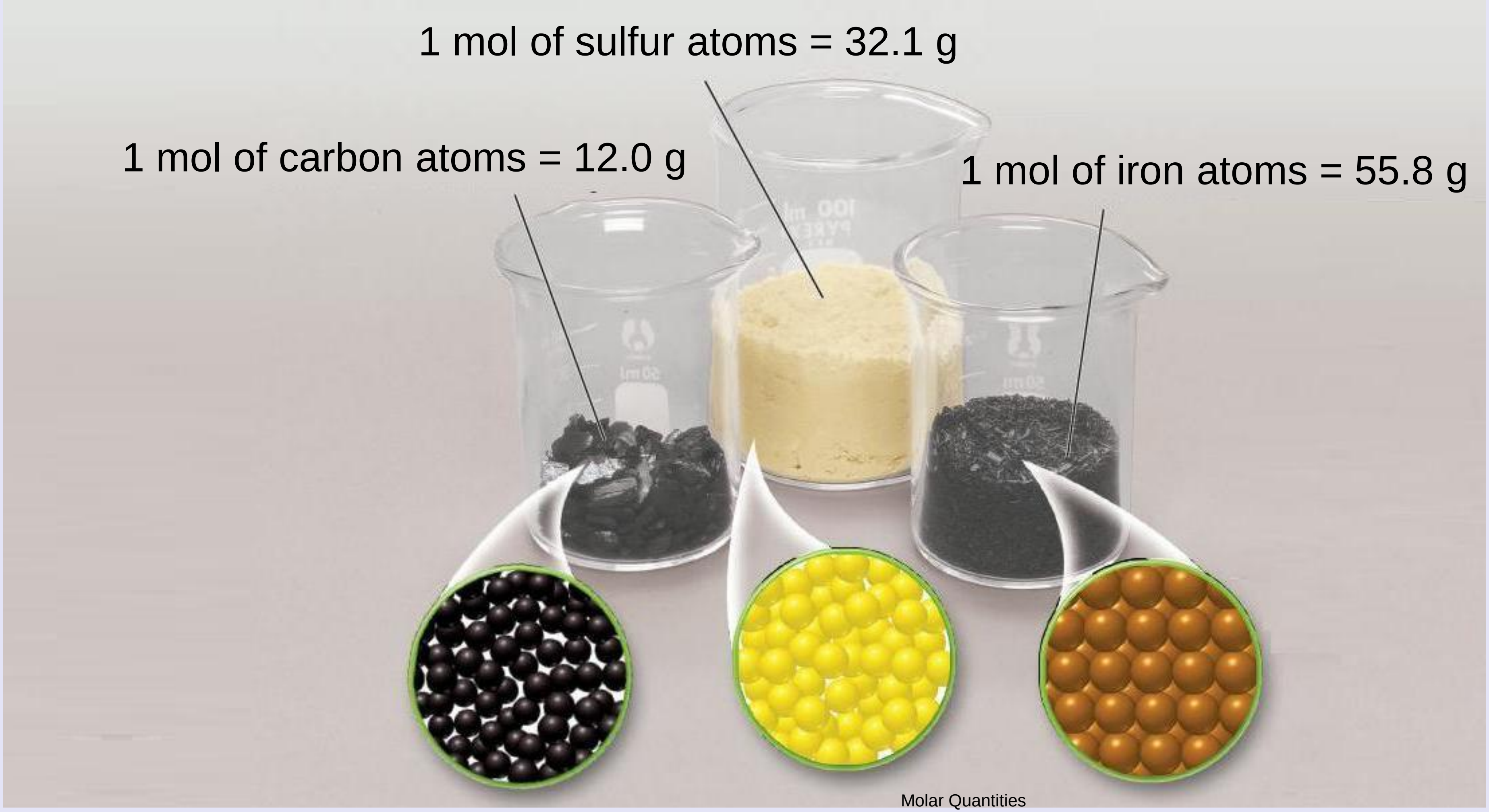
Mole Song

Happy Mole Day! (October 23)

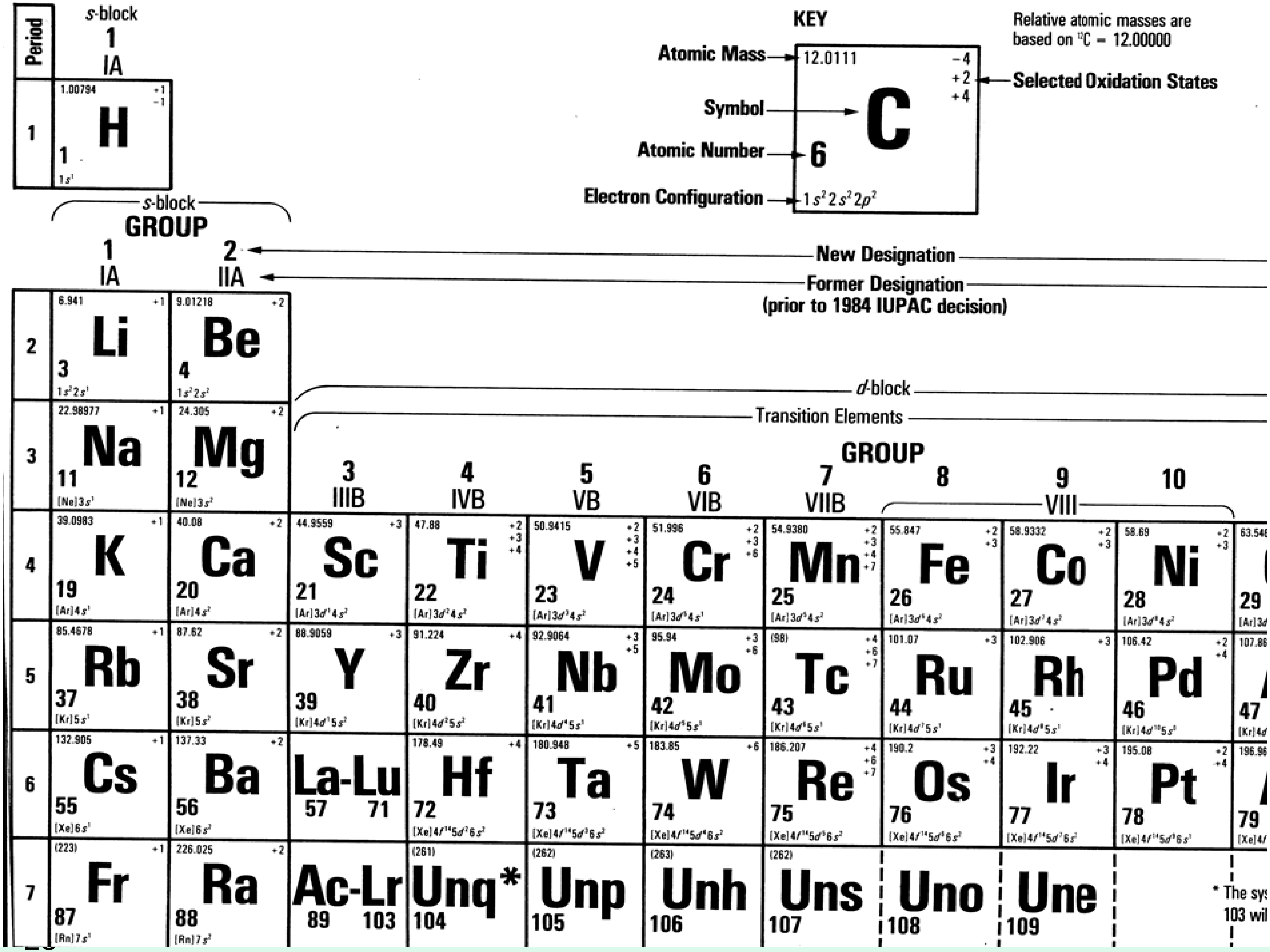
http://somup.com/cF6Qr8nnzh (1:58)

Molar Mass

Molar mass (g/mol) is when there is 1 mol or 6.02 x 10^{23} atoms/units of a particular element or compound.



Molar Quantities



KEY

Atomic Mass → 12.0111

Selected Oxidation States → −4 +2 +4

Symbol → **C**

Atomic Number → 6

Electron Configuration → $1s^2 2s^2 2p^2$

Relative atomic masses are based on ^{12}C = 12.00000

New Designation

Former Designation (prior to 1984 IUPAC decision)

s-block

d-block

Transition Elements

Period	*s*-block GROUP 1	2	3	4	5	6	7	8	9	10	
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			
1	1.00794 +1 −1 **H** 1 $1s^1$										
2	6.941 +1 **Li** 3 $1s^2 2s^1$	9.01218 +2 **Be** 4 $1s^2 2s^2$									
3	22.98977 +1 **Na** 11 $[Ne]3s^1$	24.305 +2 **Mg** 12 $[Ne]3s^2$									
4	39.0983 +1 **K** 19 $[Ar]4s^1$	40.08 +2 **Ca** 20 $[Ar]4s^2$	44.9559 +3 **Sc** 21 $[Ar]3d^1 4s^2$	47.88 +2 +3 +4 **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 +2 +3 +4 +5 **V** 23 $[Ar]3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 $[Ar]3d^5 4s^2$	55.847 +2 +3 **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 +2 +3 **Co** 27 $[Ar]3d^7 4s^2$	58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 29 [Ar]3d
5	85.4678 +1 **Rb** 37 $[Kr]5s^1$	87.62 +2 **Sr** 38 $[Kr]5s^2$	88.9059 +3 **Y** 39 $[Kr]4d^1 5s^2$	91.224 +4 **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 +3 +5 **Nb** 41 $[Kr]4d^4 5s^1$	95.94 +3 +6 **Mo** 42 $[Kr]4d^5 5s^1$	(98) +4 +6 +7 **Tc** 43 $[Kr]4d^6 5s^1$	101.07 +3 **Ru** 44 $[Kr]4d^7 5s^1$	102.906 +3 **Rh** 45 $[Kr]4d^8 5s^1$	106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86 47 [Kr]4d
6	132.905 +1 **Cs** 55 $[Xe]6s^1$	137.33 +2 **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 +4 **Hf** 72 $[Xe]4f^{14} 5d^2 6s^2$	180.948 +5 **Ta** 73 $[Xe]4f^{14} 5d^3 6s^2$	183.85 +6 **W** 74 $[Xe]4f^{14} 5d^4 6s^2$	186.207 +4 +6 +7 **Re** 75 $[Xe]4f^{14} 5d^5 6s^2$	190.2 +3 +4 **Os** 76 $[Xe]4f^{14} 5d^6 6s^2$	192.22 +3 +4 **Ir** 77 $[Xe]4f^{14} 5d^7 6s^2$	195.08 +2 +4 **Pt** 78 $[Xe]4f^{14} 5d^9 6s^1$	196.96 79 [Xe]4f
7	(223) +1 **Fr** 87 $[Rn]7s^1$	226.025 +2 **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		

* The sys
103 wil

nasses are
2.00000

lation States

s-block
18
O

p-block
GROUP

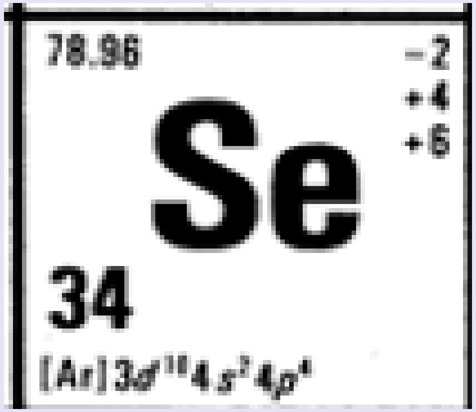
10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 O
								4.00260 0 **He** 2 $1s^2$
			10.81 +3 **B** 5 $1s^22s^22p^1$	12.0111 −4 +2 +4 **C** 6 $1s^22s^22p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^22s^22p^3$	15.9994 −2 **O** 8 $1s^22s^22p^4$	18.998403 −1 **F** 9 $1s^22s^22p^5$	20.179 0 **Ne** 10 $1s^22s^22p^6$
			26.98154 +3 **Al** 13 $[Ne]3s^23p^1$	28.0855 −4 +2 +4 **Si** 14 $[Ne]3s^23p^2$	30.97376 −3 +3 +5 **P** 15 $[Ne]3s^23p^3$	32.06 −2 +4 +6 **S** 16 $[Ne]3s^23p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 $[Ne]3s^23p^5$	39.948 0 **Ar** 18 $[Ne]3s^23p^6$
58.69 +2 +3 **Ni** 28 $[Ar]3d^84s^2$	63.546 +1 +2 **Cu** 29 $[Ar]3d^{10}4s^1$	65.39 +2 **Zn** 30 $[Ar]3d^{10}4s^2$	69.72 +3 **Ga** 31 $[Ar]3d^{10}4s^24p^1$	72.59 −4 +2 +4 **Ge** 32 $[Ar]3d^{10}4s^24p^2$	74.9216 −3 +3 +5 **As** 33 $[Ar]3d^{10}4s^24p^3$	78.96 −2 +4 +6 **Se** 34 $[Ar]3d^{10}4s^24p^4$	79.904 −1 +1 +5 **Br** 35 $[Ar]3d^{10}4s^24p^5$	83.80 0 +2 **Kr** 36 $[Ar]3d^{10}4s^24p^6$
106.42 +2 +4 **Pd** 46 $[Kr]4d^{10}5s^0$	107.868 +1 **Ag** 47 $[Kr]4d^{10}5s^1$	112.41 +2 **Cd** 48 $[Kr]4d^{10}5s^2$	114.82 +3 **In** 49 $[Kr]4d^{10}5s^25p^1$	118.71 +2 +4 **Sn** 50 $[Kr]4d^{10}5s^25p^2$	121.75 −3 +3 +5 **Sb** 51 $[Kr]4d^{10}5s^25p^3$	127.60 −2 +4 +6 **Te** 52 $[Kr]4d^{10}5s^25p^4$	126.905 −1 +1 +5 +7 **I** 53 $[Kr]4d^{10}5s^25p^5$	131.29 0 +2 +4 +6 **Xe** 54 $[Kr]4d^{10}5s^25p^6$
195.08 +2 +4 **Pt** 78 $[Xe]4f^{14}5d^96s^1$	196.967 +1 +3 **Au** 79 $[Xe]4f^{14}5d^{10}6s^1$	200.59 +1 +2 **Hg** 80 $[Xe]4f^{14}5d^{10}6s^2$	204.383 +1 +3 **Tl** 81 $[Xe]4f^{14}5d^{10}6s^26p^1$	207.2 +2 +4 **Pb** 82 $[Xe]4f^{14}5d^{10}6s^26p^2$	208.980 +3 +5 **Bi** 83 $[Xe]4f^{14}5d^{10}6s^26p^3$	(209) +2 +4 **Po** 84 $[Xe]4f^{14}5d^{10}6s^26p^4$	(210) **At** 85 $[Xe]4f^{14}5d^{10}6s^26p^5$	(222) 0 **Rn** 86 $[Xe]4f^{14}5d^{10}6s^26p^6$

Molar Mass

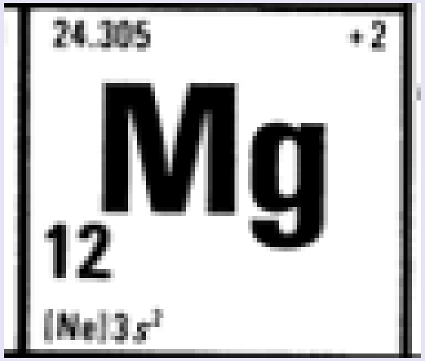
GAM (Gram Atomic Mass)

The molar mass of an element, in grams per mole, has the same value as the average atomic mass of the element in amu's.

E.g. $_{34}Se^{79}$ atomic mass =



Similarly, ____ is the molar mass of magnesium, meaning that 1 mol (*or 6.02 x* 10^{23} *atoms of magnesium*) has a mass of ? g.



TRY IT

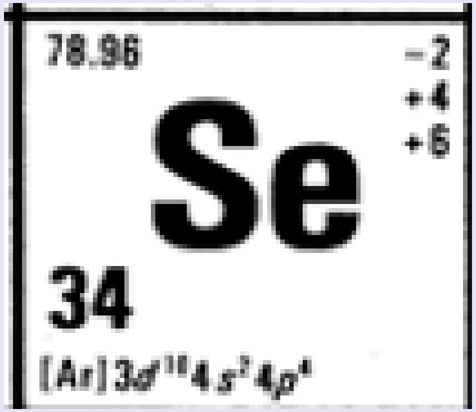
Molar Mass

GAM (Gram Atomic Mass)

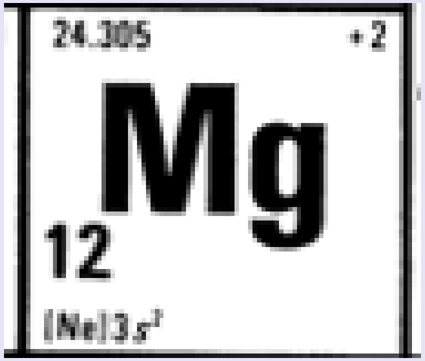
The molar mass of an element, in grams per mole, has the same value as the average atomic mass of the element in amu's.

e.g. $_{34}\mathrm{Se}^{79}$ atomic mass = 79.0 amu

GAM = 79.0 g/mol



Similarly, 24.3 g/mol is the molar mass of magnesium, meaning that 1 mol (*or 6.02 x 10*^{23} *atoms of magnesium*) has a mass of 24.3 g.



TRY IT

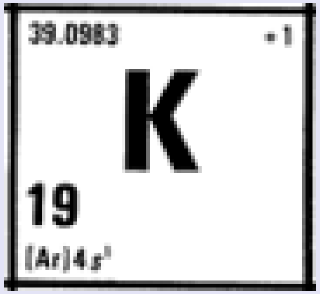
Molar Mass

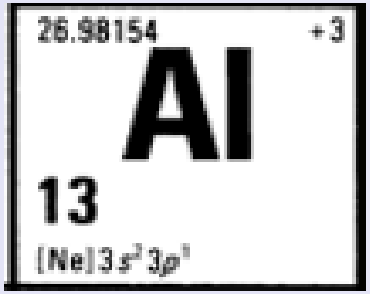
GAM (Gram Atomic Mass)

The molar mass of an element, in grams per mole, has the same value as the average atomic mass of the element in amu's.

What are the molar mass (GAM) of the following elements?

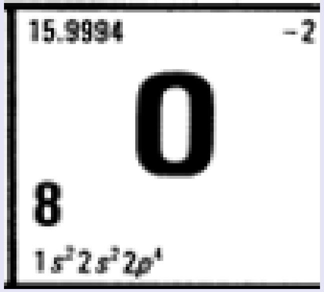
1 mole of potassium atoms (K) = ?





1 mole of aluminum atoms (Al) = ?

1 mole of oxygen molecules (O_2) = ?



TRY IT

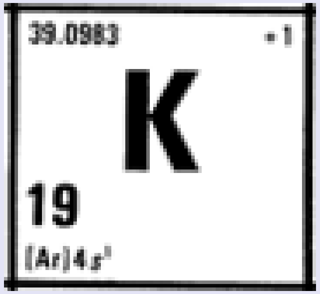
Molar Mass

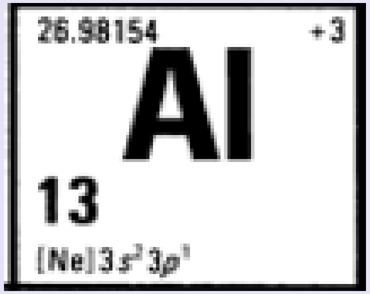
GAM (Gram Atomic Mass)

The molar mass of an element, in grams per mole, has the same value as the average atomic mass of the element in amu's.

What are the molar mass (GAM) of the following elements?

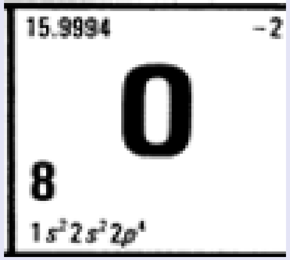
1 mole of potassium atoms (K) = 39.1 g/mol





1 mole of aluminum atoms (Al) = 27.0 g/mol

1 mole of oxygen molecules (O_2) = 16.0 x 2 = 32.0 g/mol



Remember Professor HOFBrINCl? (diatomic elements)

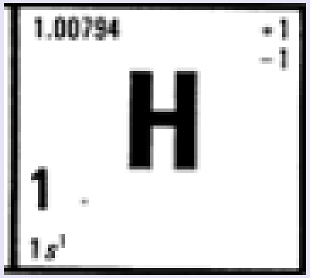
TRY IT

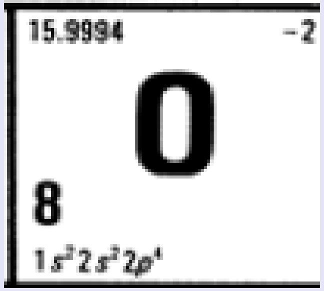
The Mass of a Mole of a Compound

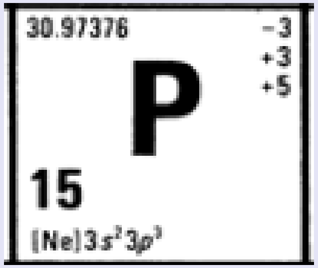
Molar Mass

To find the molar mass of a compound, add the atomic masses of the atoms that make up the molecule.

A molecule of H_3PO_4 is composed of three Hydrogen atoms, one Phosphorus atom, and four of oxygen atoms (*round masses*).







H_3PO_4

TRY IT

Atom	# atoms in Formula	x	Atomic Mass	=	Total Mass of Element
H					
P					
O					

The Mass of a Mole of a Compound Molar Mass

To find the molar mass of a compound, add the atomic masses of the atoms that make up the molecule.

A molecule of H_3PO_4 is composed of three Hydrogen atoms, one Phosphorus atom, and four of oxygen atoms (*round masses*).

H_3PO_4					
Atom	# atoms in Formula	x	Atomic Mass	=	Total Mass of Element
H	3		1		3
P	1		31		31
O	4		16		64
					98 amu

TRY IT

1 mol of H_3PO_4 has a mass of 98 g.

This is the mass of 6.02 x 10^{23} molecules of H_3PO_4 .

Chemical Calculations

TRY IT

In a balanced chemical equation, the number of atoms of each element on the left equals the number of atoms of each element on the right.

Formation of Water

Equation	$2H_2$ +	O_2 →	$2H_2O$
Moles			
Molar Mass*			
Overall Mass R → P			

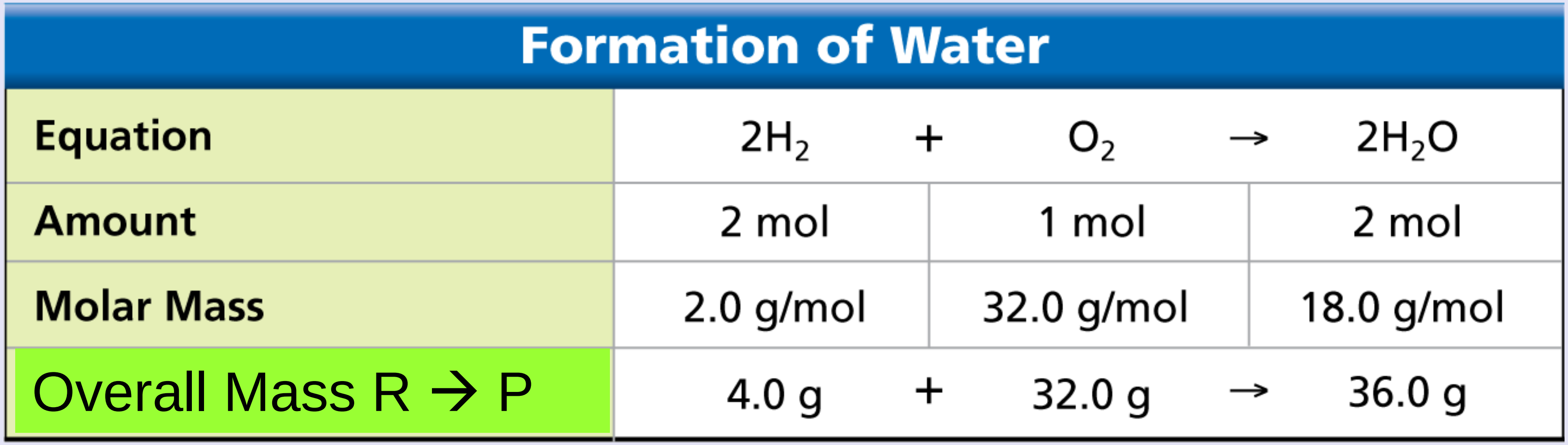
R (reactants) → P (products)

**Use the Periodic Table to find the information.*

Chemical Calculations

TRY IT

In a balanced chemical equation, the number of atoms of each element on the left equals the number of atoms of each element on the right.



Formation of Water

Equation	$2H_2$	+	O_2	→	$2H_2O$
Amount	2 mol		1 mol		2 mol
Molar Mass	2.0 g/mol		32.0 g/mol		18.0 g/mol
Overall Mass R → P	4.0 g	+	32.0 g	→	36.0 g

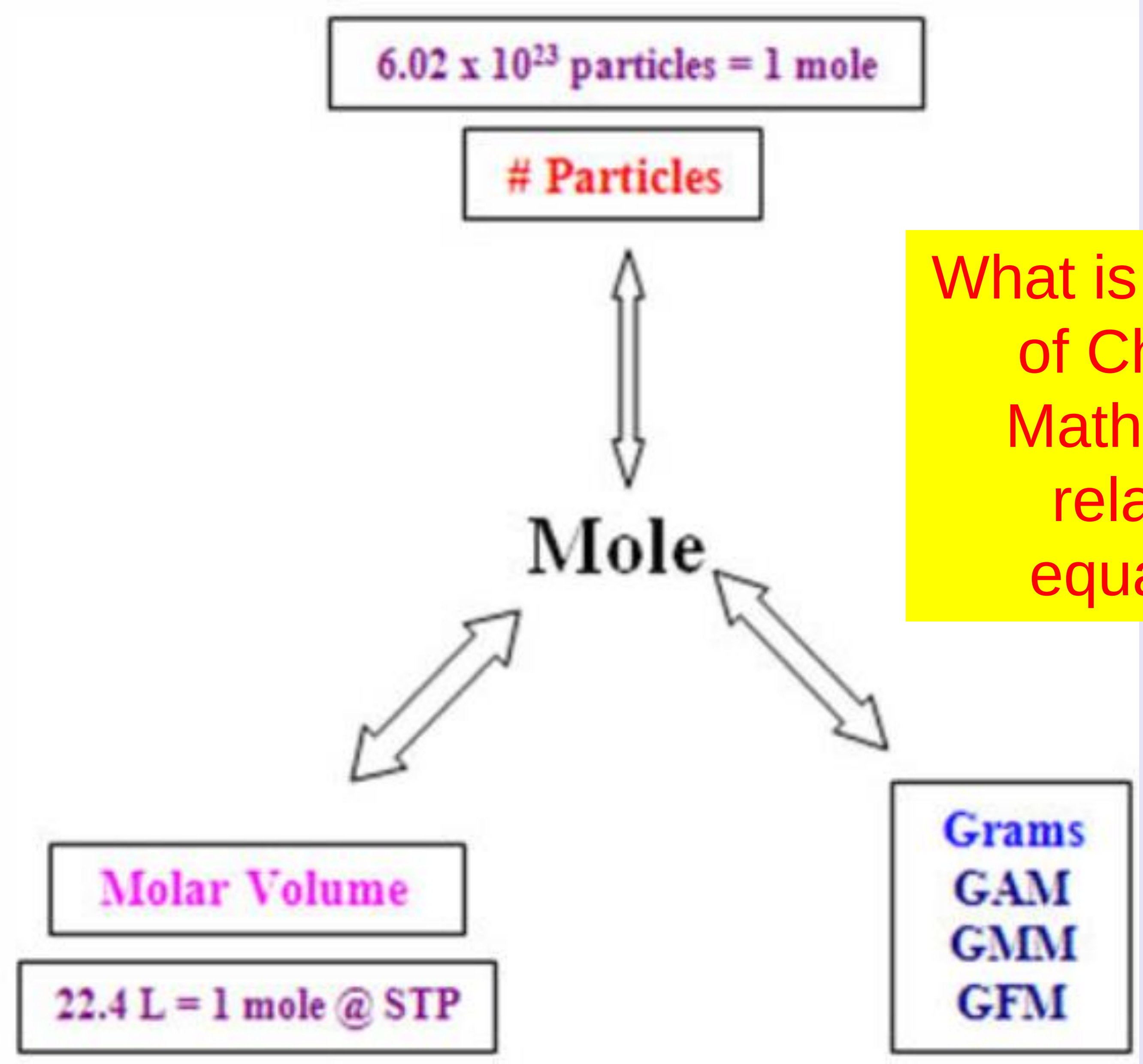
$2H_2 \rightarrow 2 \times 1$ g/mol = 2 g/mol

$2O_2 \rightarrow 2 \times 16$ g/mol = 32 g/mol

$2H_2O \rightarrow 2[2(1$ g/mol) + 16 g/mol] = 2[18 g/mol] = 36 g/mol

Notice the conservation of mass from reactants to products.

Mole



6.02×10^{23} particles = 1 mole

Particles

Mole

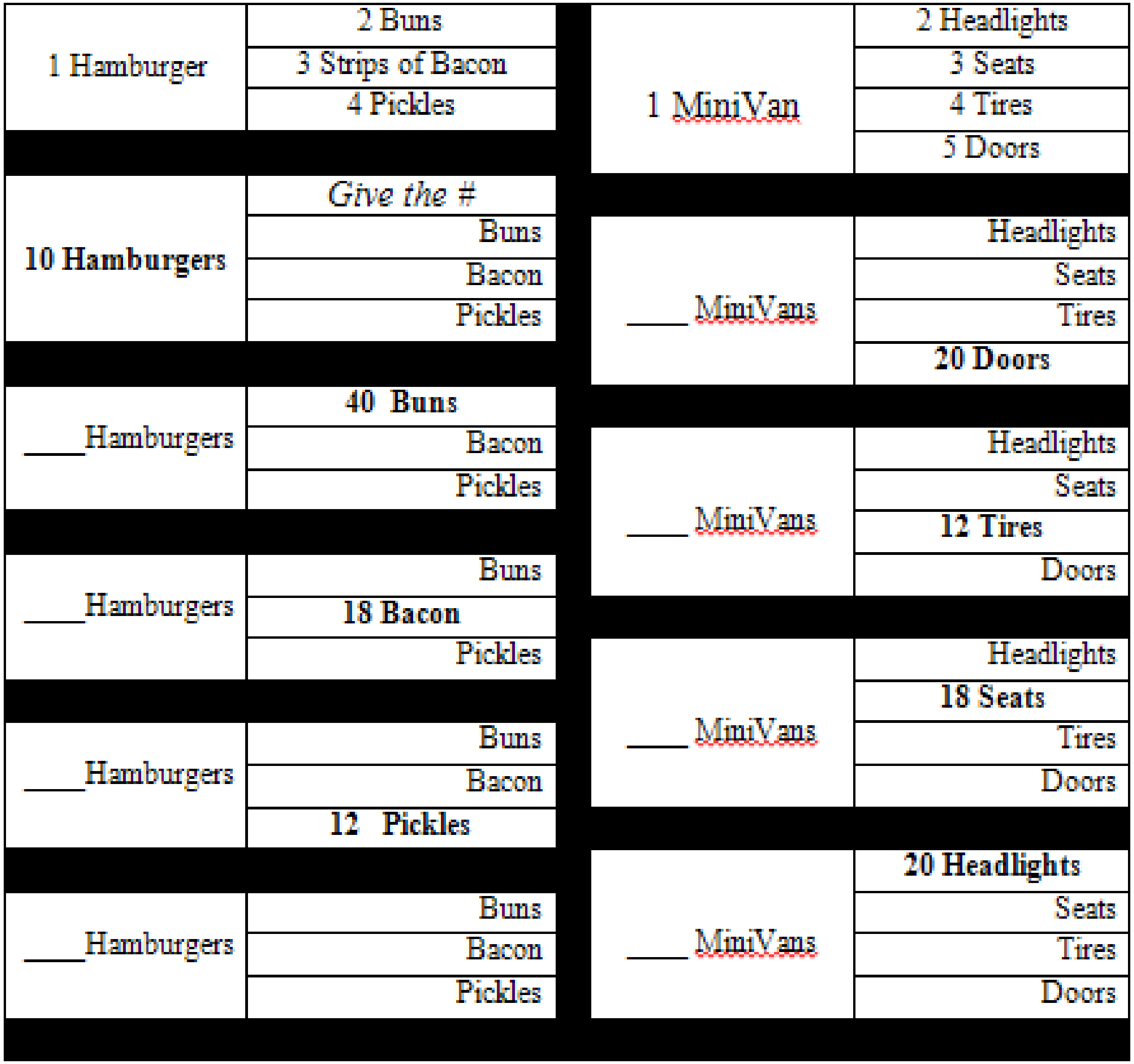
Molar Volume

22.4 L = 1 mole @ STP

Grams
GAM
GMM
GFM

What is the center of Chemical Mathematics related to equations?

Simple Analogy
Fill in the table below:

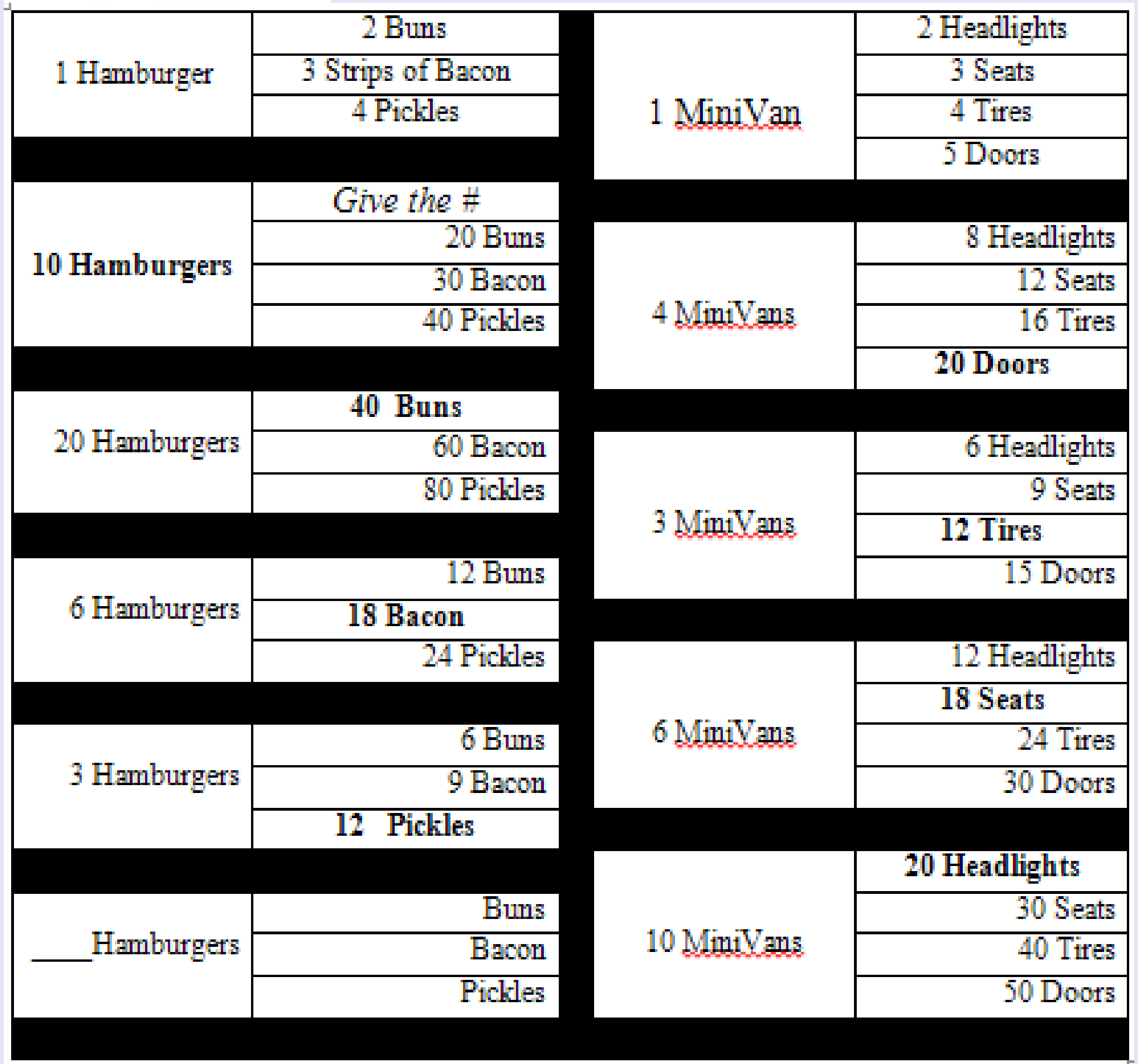


1 Hamburger	2 Buns 3 Strips of Bacon 4 Pickles
10 Hamburgers	*Give the #* Buns Bacon Pickles
____Hamburgers	**40 Buns** Bacon Pickles
____Hamburgers	Buns **18 Bacon** Pickles
____Hamburgers	Buns Bacon **12 Pickles**
____Hamburgers	Buns Bacon Pickles

1 MiniVan	2 Headlights 3 Seats 4 Tires 5 Doors
____ MiniVans	Headlights Seats Tires **20 Doors**
____ MiniVans	Headlights Seats **12 Tires** Doors
____ MiniVans	Headlights **18 Seats** Tires Doors
____ MiniVans	**20 Headlights** Seats Tires Doors

Simple Analogy

Fill in the table below:



1 Hamburger	2 Buns
	3 Strips of Bacon
	4 Pickles
10 Hamburgers	*Give the #*
	20 Buns
	30 Bacon
	40 Pickles
20 Hamburgers	**40 Buns**
	60 Bacon
	80 Pickles
6 Hamburgers	12 Buns
	18 Bacon
	24 Pickles
3 Hamburgers	6 Buns
	9 Bacon
	12 Pickles
____Hamburgers	Buns
	Bacon
	Pickles

1 MiniVan	2 Headlights
	3 Seats
	4 Tires
	5 Doors
4 MiniVans	8 Headlights
	12 Seats
	16 Tires
	20 Doors
3 MiniVans	6 Headlights
	9 Seats
	12 Tires
	15 Doors
6 MiniVans	12 Headlights
	18 Seats
	24 Tires
	30 Doors
10 MiniVans	**20 Headlights**
	30 Seats
	40 Tires
	50 Doors

NOTE:

The number of hamburgers & minivans were the STANDARDs of comparison.

It works the same way using “Moles”.

This is why we use COEFFICIENTS in chemical equations.

Mole Ratios

Comparing buns, bacon, and pickles to burgers or doors, tires, seats, and headlights to minivans is the exact same process used to balance chemical equations.

The comparison was based on ratios.

In chemistry, mole ratios are used to balance the equations.

Mole ratios are based on the COEFFICIENTS in chemical equations.

QUICK CHECK

Learning Mole Ratios

$$2\ C_2H_{2\ (l)}\ +\ 5\ O_{2\ (g)} \rightarrow 4\ CO_{2\ (g)}\ +\ 2\ H_2O\ _{(g)}$$

__ mol of $C_2H_{2\ (l)}$ react with __ mol $O_{2\ (g)}$ to yield __ mol of CO_2 and __ mol of water.

6 mol of $C_2H_{2\ (l)}$ would react with __ mol $O_{2\ (g)}$ to yield __ mol of CO_2 and __ mol of water.

If only 1 mol of CO_2 is produced, then __ mol of $C_2H_{2\ (l)}$ react with __ mol $O_{2\ (g)}$ to yield __ mol of water.

QUICK CHECK

Learning Mole Ratios

$$2\ C_2H_{2\ (l)}\ +\ 5\ O_{2\ (g)} \rightarrow 4\ CO_{2\ (g)}\ +\ 2\ H_2O_{\ (g)}$$

2 mol of $C_2H_{2\ (l)}$ react with 5 $O_{2\ (g)}$ to yield 4 mol of CO_2 and 2 mol of water.

6 mol of $C_2H_{2\ (l)}$ would react with 15 $O_{2\ (g)}$ to yield 12 mol of CO_2 and 6 mol of water.

If only 1 mol of CO_2 is produced, then 0.5 mol of $C_2H_{2\ (l)}$ react with 1.25 mol $O_{2\ (g)}$ to yield 0.5 mol of water.

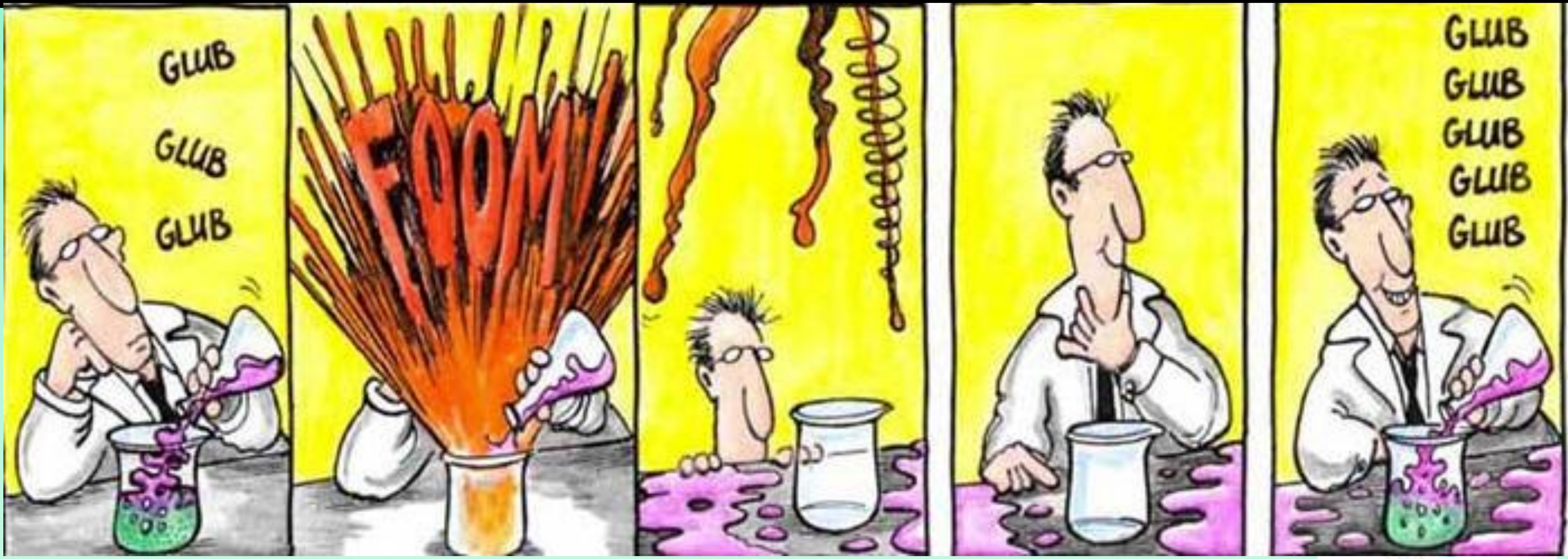
Rules for Writing and Balancing Equations

STRATEGY

1. Determine the correct formulas for all the reactants and products.
2. Write the skeleton equation by placing the formulas for the reactants on the left and the formulas for the products on the right with a yields sign (→) in between. If two or more reactants or products are involved, separate their formulas with plus signs.
3. Determine the number of atoms of each element in the reactants and products. Count a polyatomic ion as a single unit if it appears unchanged on both sides of the equation.
4. Balance the elements one at a time by using coefficients. When no coefficient is written, it is assumed to be 1. Begin by balancing elements that appear only once on each side of the equation. Never balance an equation by changing the subscripts in a chemical formula. Each substance only has one correct formula.
5. Check each atom or polyatomic ion to be sure that the number is equal on both sides of the equation.
6. Make sure all the coefficients are in the lowest possible ratio.

LESSON QUESTION

What are the Types of Chemical Reactions?



$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Types of Chemical Reactions

There are FIVE general types of Chemical reactions:

synthesis

decomposition

single-replacement

double-replacement

combustion

Not all chemical reactions fit uniquely into one category, but may fit equally well into two categories. For instance:

e.g. If one of the reactants in a synthesis reaction is oxygen gas [O_2], the reaction is also a combustion reaction.

Types of Chemical Reactions

There are FIVE general types of Chemical reactions:

synthesis

decomposition

single-replacement

double-replacement

combustion

https://screencast-o-matic.com/watch/cF6wqiYJWW

(3:56)

Types of Chemical Reactions

Synthesis or Combination Reactions

A synthesis or combination reaction is a chemical change in which two or more substances react to form **ONE** single new substance (**ONE PRODUCT**): $\mathbf{A} + \mathbf{X} \rightarrow \mathbf{AX}$

e.g. Magnesium metal and oxygen gas react chemically. Write a balanced equation for this synthesis reaction:

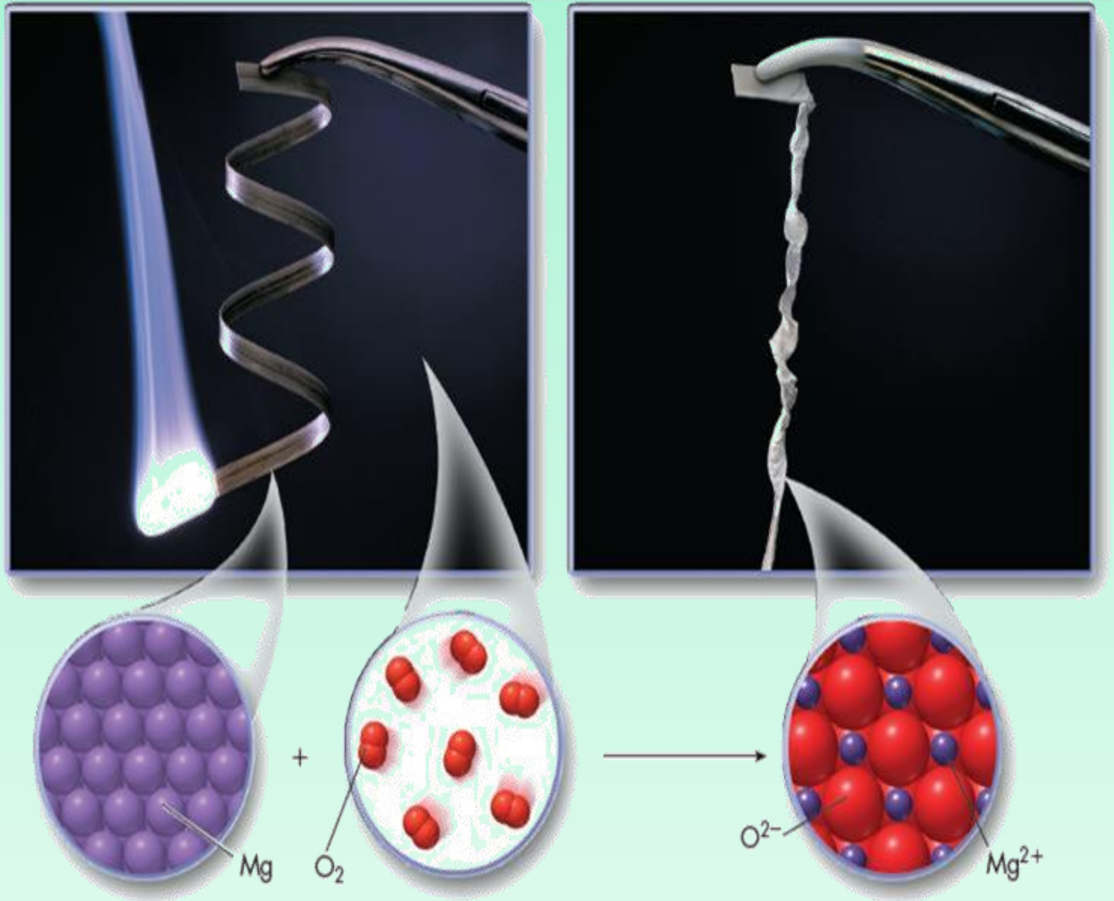
TRY IT

http://somup.com/cF6wlpnh8s (3:21)

Synthesis Reactions

e.g. Magnesium metal and oxygen gas combine to form the compound magnesium oxide. Write a balanced equation for this synthesis reaction (one product):

$$2Mg^{0}\,(s) + O_2^{0} \rightarrow 2Mg^{+2}O^{-2}(s)$$



Synthesis Reactions

Synthesis of Water

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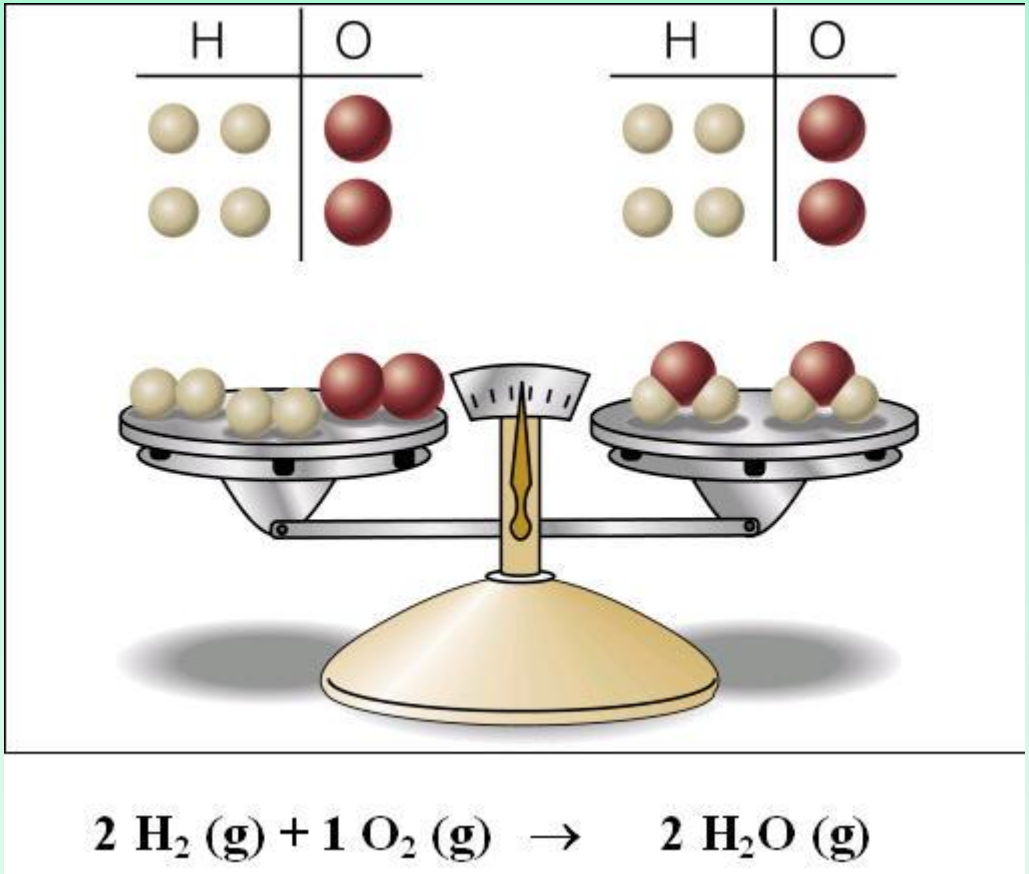
http://somup.com/cF6vqwnhdr (0:38)

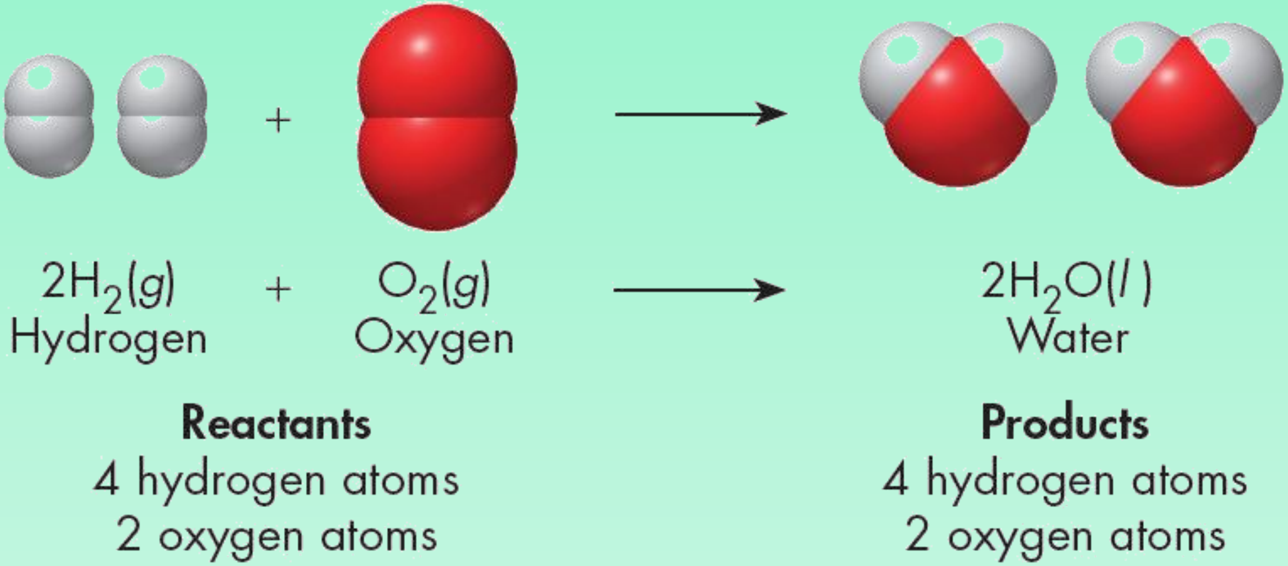
hydrogen + oxygen → water



$$2\ H_2\ (g) + 1\ O_2\ (g) \rightarrow 2\ H_2O\ (g)$$

Synthesis Reactions

Notice the balanced chemical equation for synthesis of water.



$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

Hydrogen + Oxygen → Water

Reactants	**Products**
4 hydrogen atoms	4 hydrogen atoms
2 oxygen atoms	2 oxygen atoms

Types of Chemical Reactions

Decomposition Reactions

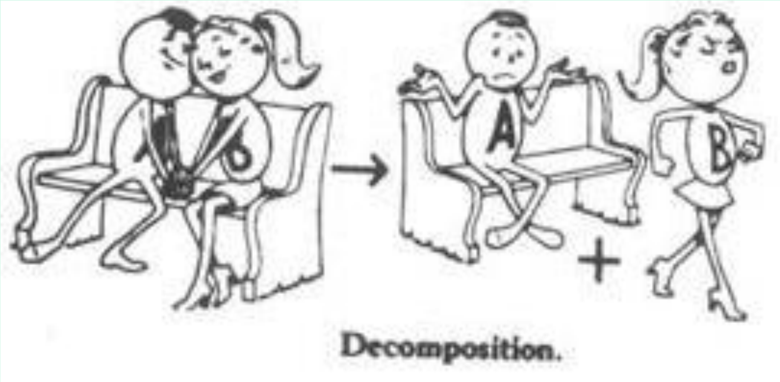
Decomposition reactions are the opposite of synthesis reactions.

ONE substance breaks down into simpler substances.

ONE REACTANT breaks down to more than one product.

$$AX \xrightarrow{\Delta} A + X$$

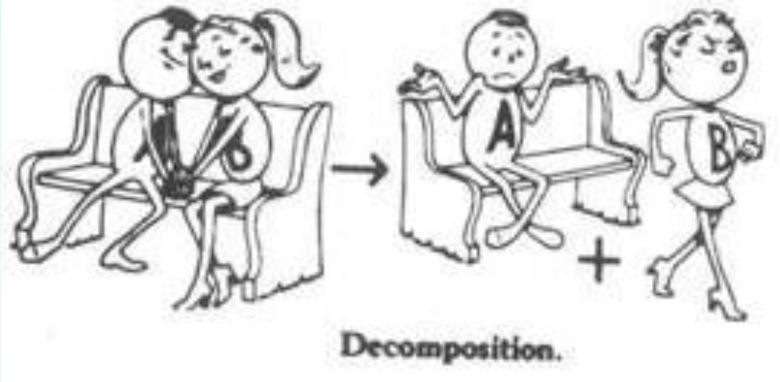
Most decomposition reactions require energy in the form of heat, light, or electricity (**ENDOthermic**).



Decomposition Reactions

TRY IT

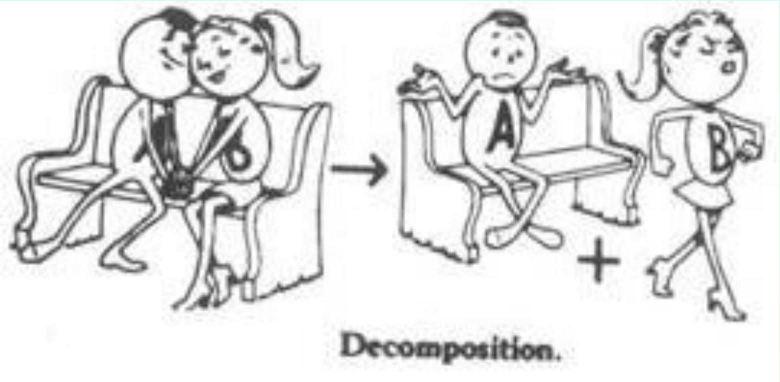
At room temperature and pressure magnesium nitride is a greenish yellow powder sometimes used as a catalyst. Write and balance the equation for the decomposition of magnesium nitride.



Decomposition Reactions

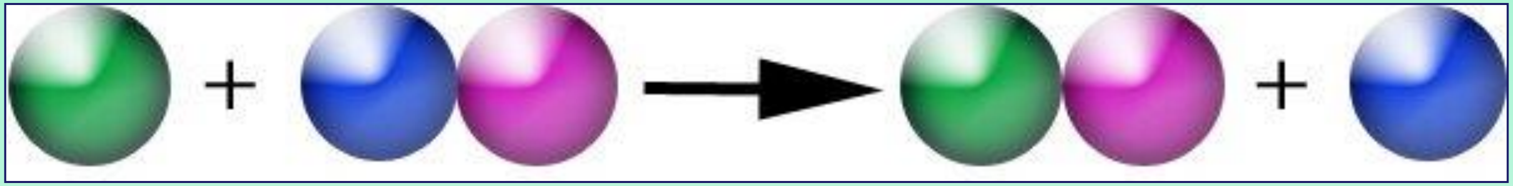
At room temperature and pressure magnesium nitride is a greenish yellow powder sometimes used as a catalyst. Write and balance the equation for the decomposition of magnesium nitride.

$$Mg_3{}^{+2}N_2{}^{-3}(s) \rightarrow 3Mg^0\,(s) + N_2{}^0\,(g)$$



Single-Replacement Reactions:

*A **more ACTIVE** element will displace a less active element that is already part of a compound.*



A + BC → AC + B

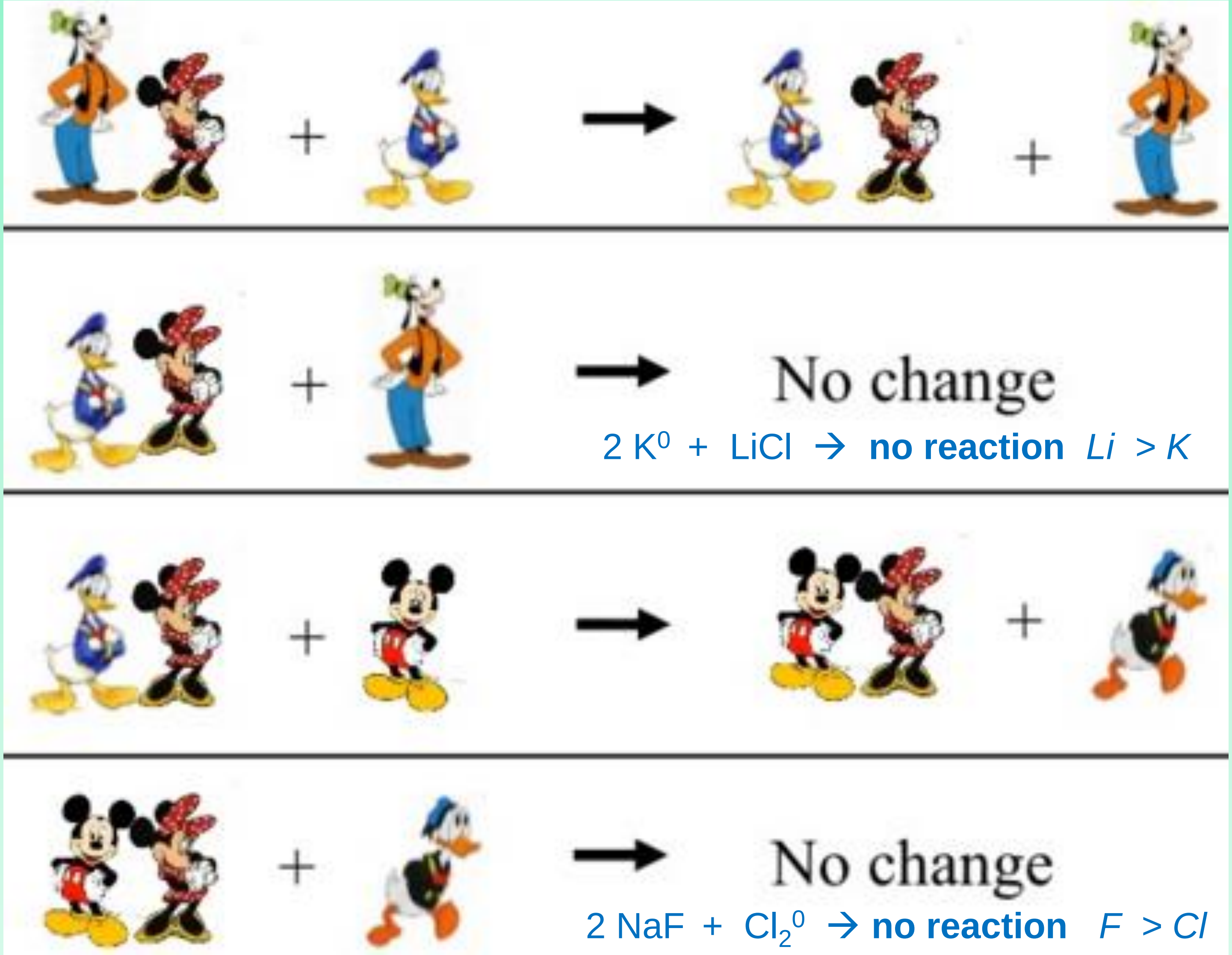
A **metal** may displace another **metal**:

AN + **B** → **B**N + A

A **non-metal** may display another **non-metal**:

M**X** + **Y** → M**Y** + **X**

Single Replacement Reactions



$2\ K^0$ + LiCl → **no reaction** *Li* > *K*

2 NaF + Cl_2^0 → **no reaction** *F* > *Cl*

Whether a certain **metal** replaces another **metal** or a **non-metal** replaces another **non-metal** is determined by the activity series.

Single Replacement Reactions

TRY IT

(**metals**)

Consider the following and determine whether a reaction will occur. If so, write a balanced equation to show the reaction.

Aluminum added to IronIII Oxide

Potassium added to ZincII Chloride

Potassium added to Lithium Chloride

Activity Series of Metals	
Lithium	Li
Potassium	K
Sodium	Na
Magnesium	Mg
Aluminum	Al
Zinc	Zn
Iron	Fe
Lead	Pb
Copper	Cu
Mercury	Hg
Silver	Ag

(**metals**)

Consider the following and determine whether a reaction will occur. If so, write a balanced equation to show the reaction.

Aluminum added to IronIII Oxide

$2Al^0 + Fe_2^{+3}O_3^{-2} \rightarrow Al_2^{+3}O_3^{-2} + 2Fe^0$

… ***Al*** > *Fe*

Potassium added to ZincII Chloride

$2\ K^0 + Zn^{+2}Cl_2^{-1} \rightarrow 2\ K^{+1}Cl^{-1} + Zn^0$

… ***K*** > *Zn*

Potassium added to Lithium Chloride

$2\ K^0 + Li^{+1}Cl^{-1} \rightarrow$ **no reaction**

… ***Li*** > *K*

Activity Series of Metals	
Lithium	Li
Potassium	K
Sodium	Na
Magnesium	Mg
Aluminum	Al
Zinc	Zn
Iron	Fe
Lead	Pb
Copper	Cu
Mercury	Hg
Silver	Ag

Single Replacement Reactions

$F_2 > Cl_2 > Br_2 > I_2$

Activity Series for Halogens (**non-metals**)

A halogen can also replace another halogen from a compound.

The activity of halogens *decreases* as you go down Group VIIA of the periodic table — fluorine, chlorine, bromine, and iodine.

TRY IT

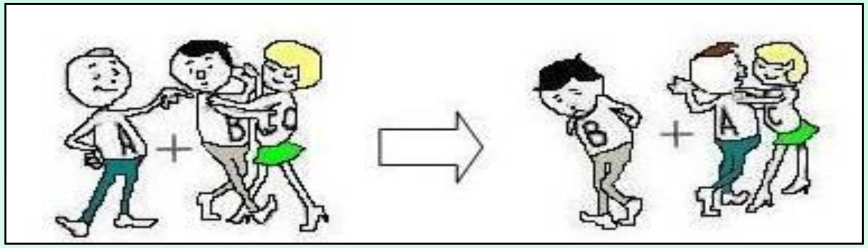
Consider the following:

$$Br_2^0\,(aq) + Na^+I^-(aq) \rightarrow$$

$$Br_2^0\,(aq) + Na^+Cl^-(aq) \rightarrow$$

$$Na^+Br^-(aq) + Cl_2^0\,{}_{(g)} \rightarrow$$

$$Na^+F^-(aq) + Cl_2^0 \rightarrow$$



Single Replacement Reactions

$F_2 > Cl_2 > Br_2 > I_2$

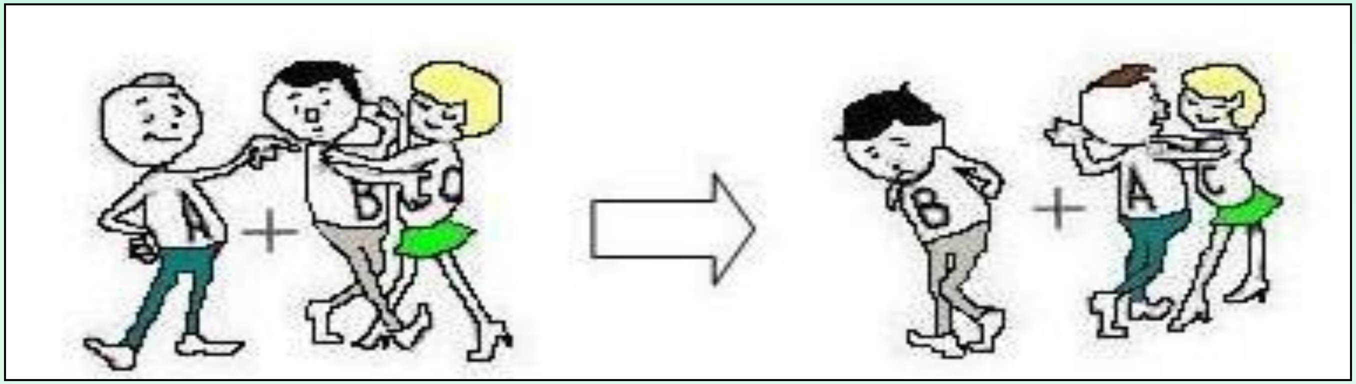
Activity Series for Halogens (**non-metals**)

$Br_2^0\,(aq) + Na^+I^-(aq) \rightarrow 2NaBr(aq) + I_2(aq)$ ... *Br > I*

$Br_2^0\,(aq) + Na^+Cl^-(aq) \rightarrow$ No reaction **... Cl > *Br***

$Na^+Br^-(aq) + Cl_2^0\,_{(g)} \rightarrow 2NaCl(aq) + Br_2^0\,_{(s)}$ **... Cl > *Br***

$Na^+F^-(aq) + Cl_2^0 \rightarrow$ **no reaction** **... F > Cl**

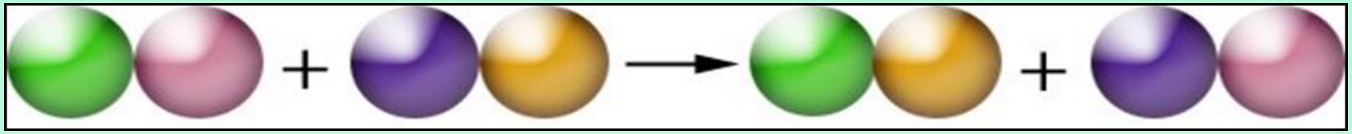


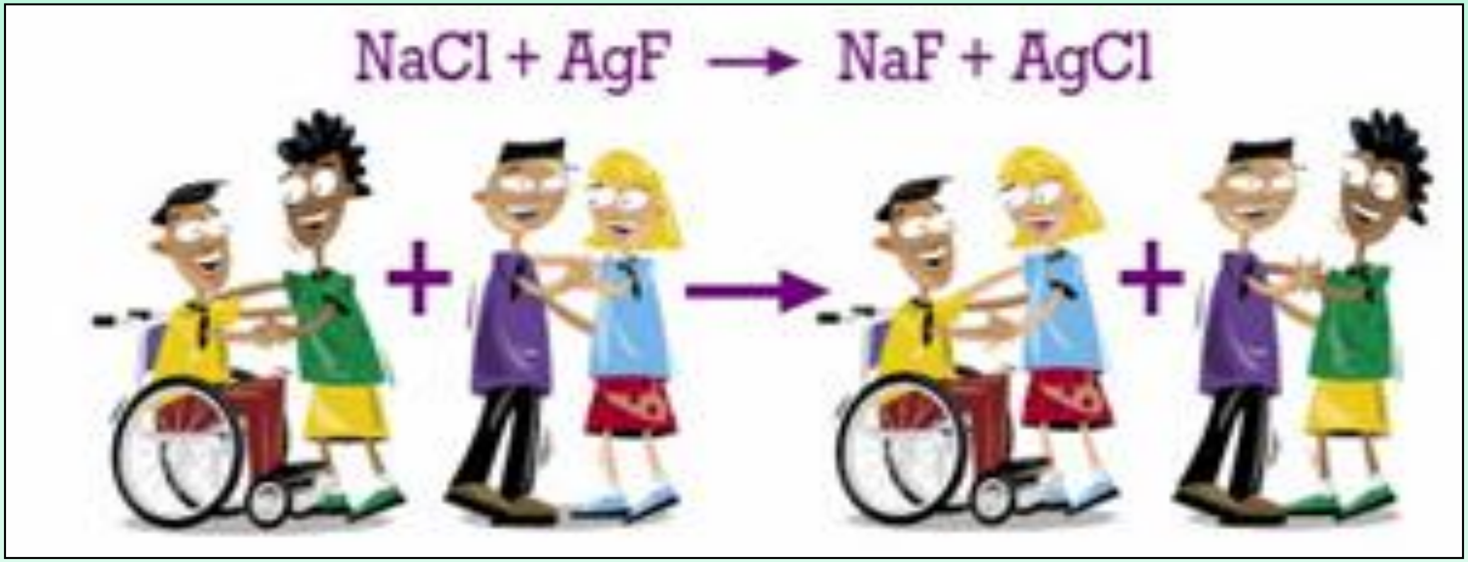
Types of Chemical Reactions

Double-Replacement Reactions

When two **ionic compounds** are mixed **and they react**, the positive and negative ions of the two compounds are interchanged

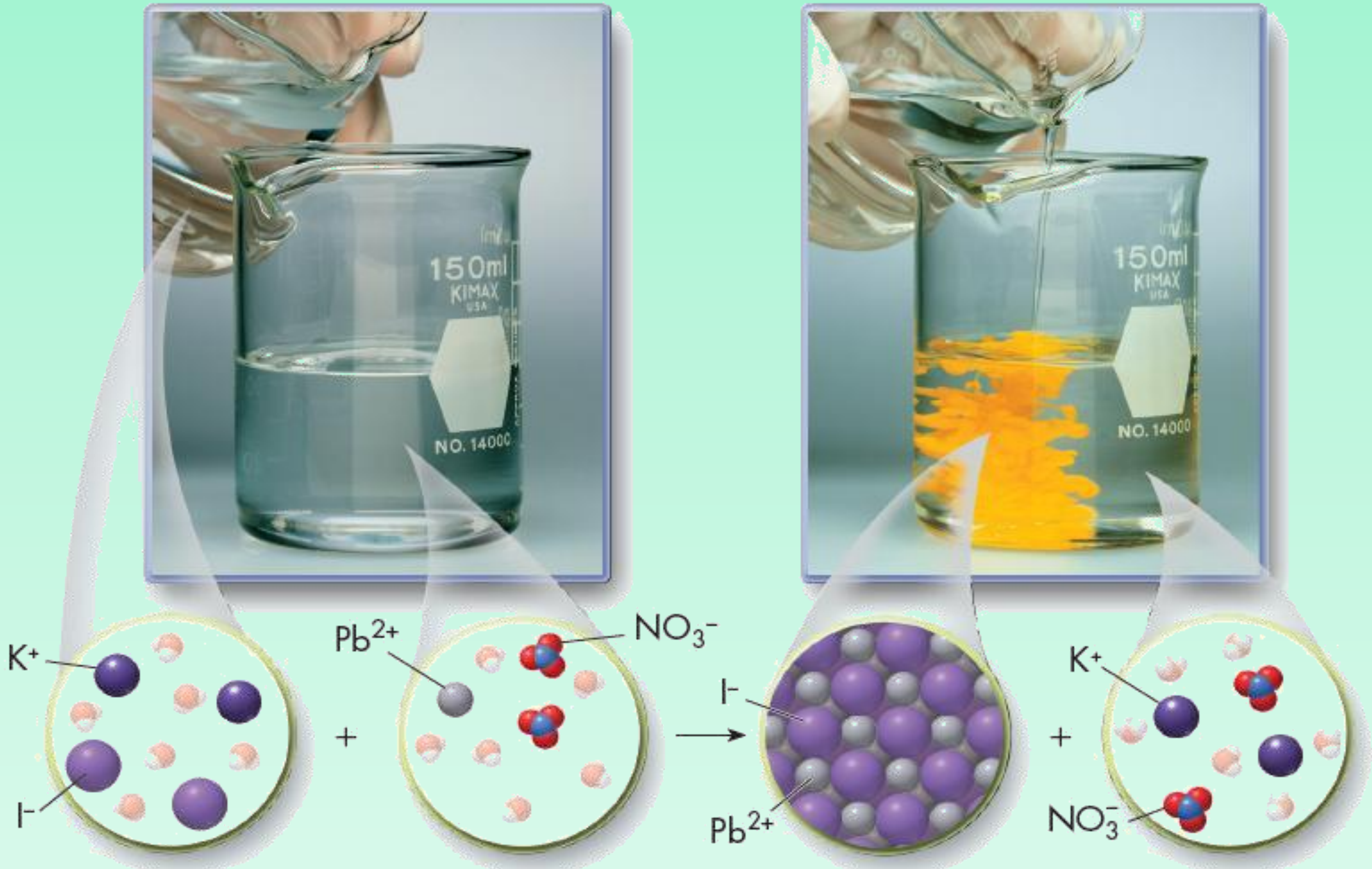
$$AX + BY \rightarrow AY + BX$$





Double Replacement Reactions

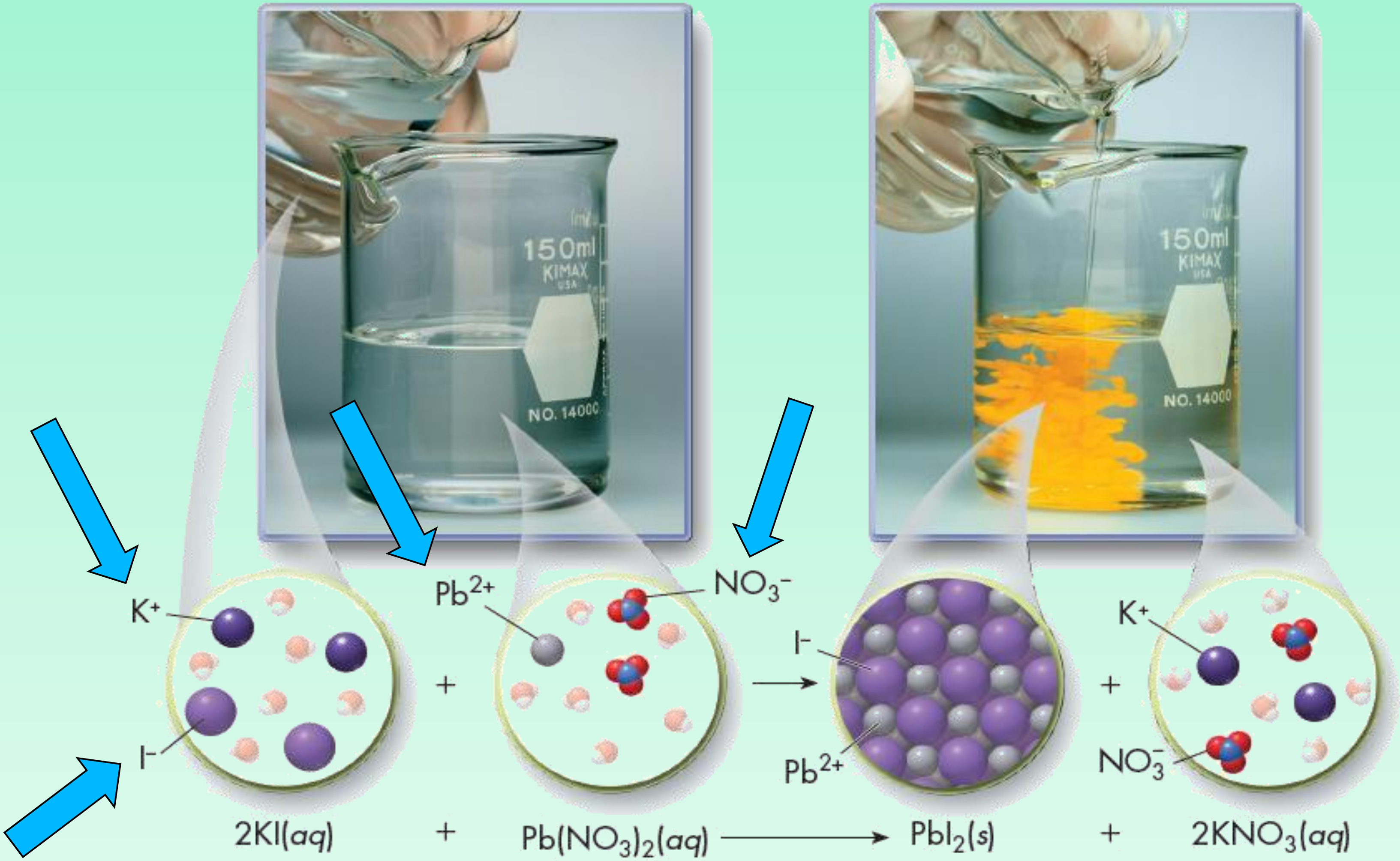
Mixing aqueous solutions of potassium iodide and lead(II) nitrate results in a chemical reaction in which a **yellow precipitate** of solid lead(II) iodide is formed.



$$2KI(aq) + Pb(NO_3)_2(aq) \longrightarrow PbI_2(s) + 2KNO_3(aq)$$

Double Replacement Reactions

AQUEOUS (dissolved in water) means to "**dissociate**" or **split into ions**. Notice how both aqueous solutions became "free" ions that can rearrange to form a new product when mixed.



$$2KI(aq) + Pb(NO_3)_2(aq) \longrightarrow PbI_2(s) + 2KNO_3(aq)$$

Double Replacement Reactions

Double-replacement reactions are also referred to as **ION exchange** or double-displacement reactions.

To determine if a double displacement reaction has taken place, look at the PRODUCTS of the reaction.

One of the following products will have formed:

- a **gas** is evolved in the reaction (g) or ↑
- **Precipitate** formation (s) or ↓
- A molecular (covalently bonded) substance, **water** is formed

Double Replacement Reactions

Look at the following Double-Replacement Reactions. Write a balanced chemical equation based on the type of product formed:

A colored precipitate forms:

$$Ba^{+2}Cl_2^{-}{}_{(aq)} + K_2^{+}CO_3^{-2}{}_{(aq)} \rightarrow Ba^{+2}CO_3^{-2}\downarrow + 2\ K^{+}Cl^{-}{}_{(aq)}$$

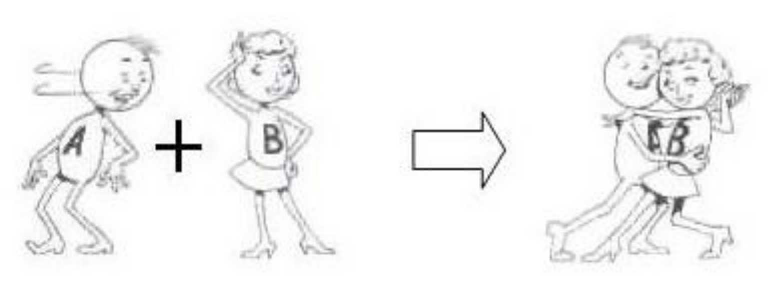
Geologists test mineral content in rocks:

$$Ca^{+2}CO_3^{-2}{}_{(aq)} + 2\ HCl^{-}{}_{(aq)} \rightarrow Ca^{+2}Cl_2^{-}{}_{(aq)} + H_2CO_3^{-2}\uparrow$$

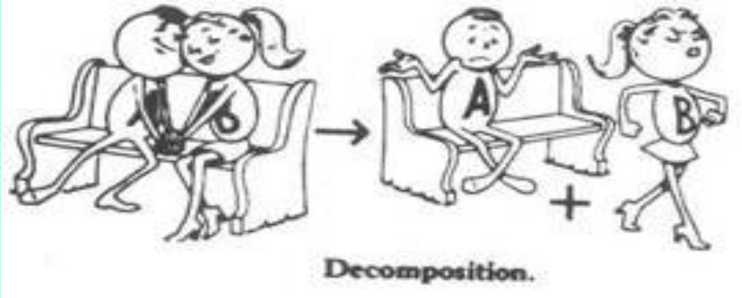
Acid-Base Reactions producing water:

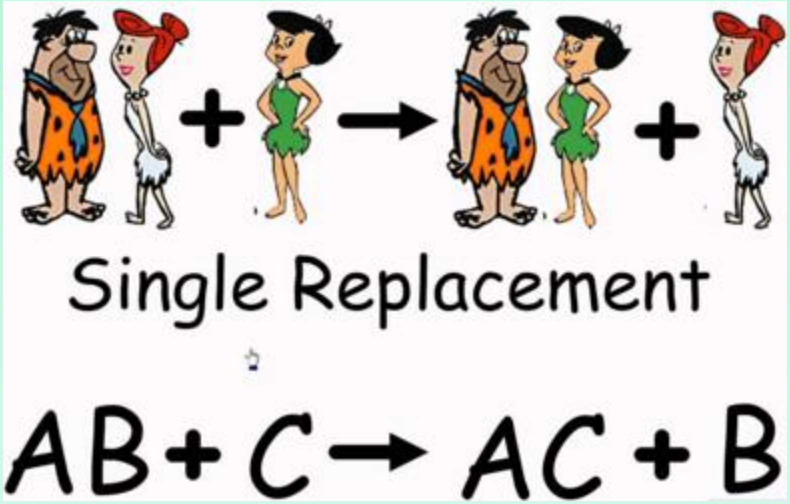
$$2\ Na^{+}OH^{-}{}_{(aq)} + H_2SO_4^{-2}{}_{(aq)} \rightarrow Na_2^{+}SO_4^{-2}{}_{(aq)} + 2\ HOH^{-}$$

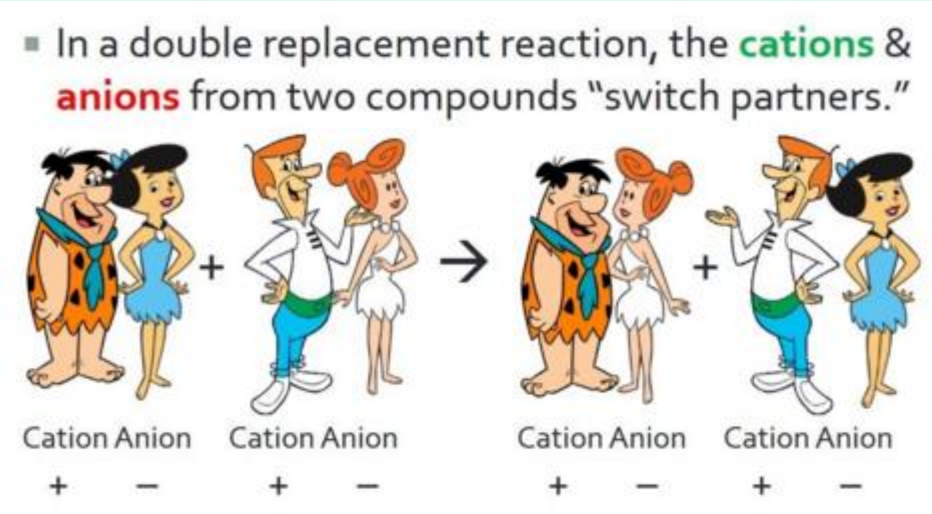
Review 4 Chemical Reactions



Synthesis



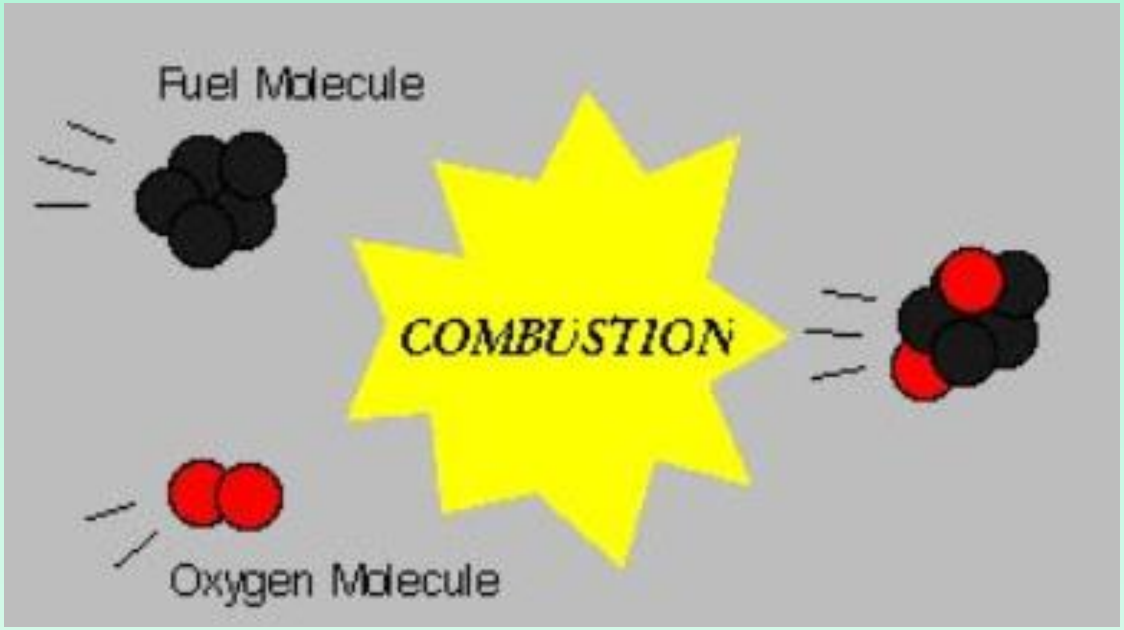




- In a double replacement reaction, the **cations** & **anions** from two compounds "switch partners."

Combustion Reactions

A **combustion reaction** is a chemical change in which an element or a compound reacts with **oxygen**, often producing energy in the form of **heat** and **light**.



Metals Exhibit Combustion

If you heat the **metal** magnesium to a high enough temperature in the presence of **oxygen**, the following **synthesis** reaction occurs:

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

Watch at:

http://somup.com/cF6vqrnhdl (1:22)

QUICK CHECK

Name the type of Chemical Reactions.

$2\,K + F_2 \rightarrow 2\,KF$

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

$Ca(ClO_3)_2 \rightarrow CaCl_2 + 3\,O_2$

$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

$CaCl_2 + 2AgNO_3 \longrightarrow Ca(NO_3)_2 + 2AgCl$

$Cl_2 + 2\,NaBr \rightarrow 2\,NaCl + Br_2$

QUICK CHECK

Name the type of Chemical Reactions.

$2\ K + F_2 \rightarrow 2\ KF$

Synthesis

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

Combustion reaction

$Ca(ClO_3)_2 \rightarrow CaCl_2 + 3\ O_2$

Decomposition reaction

$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

Single replacement (metals)

$CaCl_2 + 2AgNO_3 \longrightarrow Ca(NO_3)_2 + 2AgCl$

Double Displacement reaction

$Cl_2 + 2\ NaBr \rightarrow 2\ NaCl + Br_2$

Single replacement (non-metals)

Reduction/Oxidation Reactions (REDOX)

Most of the types of chemical reactions are also **REDOX** reactions, meaning that electrons are transferred from one reactant to another.

Synthesis
Decomposition
Single Replacement
Combustion
Can be REDOX reactions.

Name the type of Chemical Reactions.

$2K^0 + F_2^0 \rightarrow 2K^{+1}F^{-1}$

Synthesis

$C_2^{-4}H_6^{+1} + 5O_2^0 \longrightarrow 3C^{+4}O_2 + 4H_2^{+1}O^{-2}$

***Combustion reaction**

$Ca^{+2}(Cl^{+5}O_3^{-2})_2 \rightarrow Ca^{+2}Cl_2^{-1} + 3O_2^0$

Decomposition reaction

$Fe_2^{+3}O_3^{-2} + 2Al^0 \longrightarrow Al_2^{+3}O_3^{-2} + 2Fe^0$

***Single replacement** (metals)

$Cl_2^0 + 2 Na^{+1}Br^{-1} \rightarrow 2 Na^{+1}Cl^{-1} + Br_2^0$

***Single replacement** (non-metals)

Notice how the **charges** of atoms charge from reactant to product.

***always REDOX**

Reduction/Oxidation Reactions (REDOX)

Reduction

An element gains electrons so that their charge decreases.

$$O + 2e^{-} \rightarrow O^{2-}$$

The oxygen atom gains two electrons, it becomes an ion with a charge of 2^{-}.

Oxidation

An element loses electrons so that their charge increases.

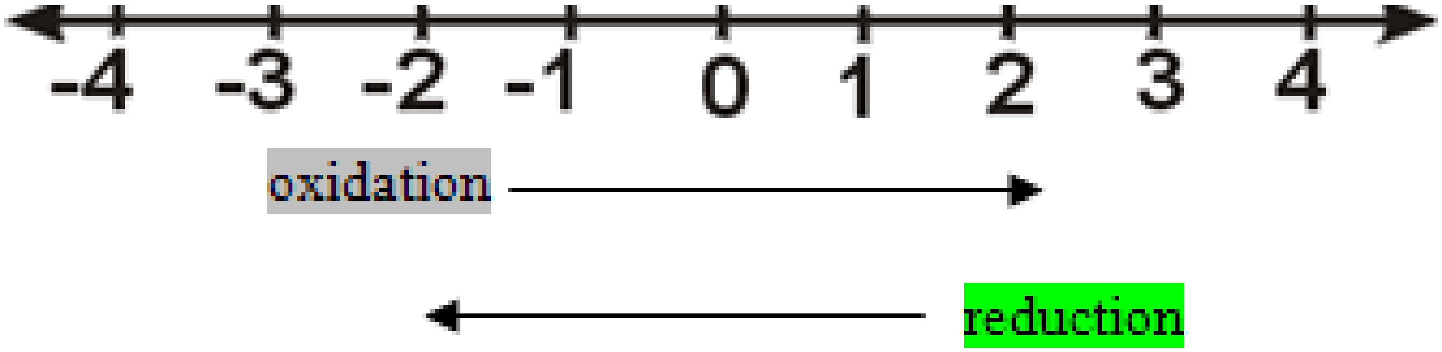
$$Ca \rightarrow Ca^{2+} + 2e^{-}$$

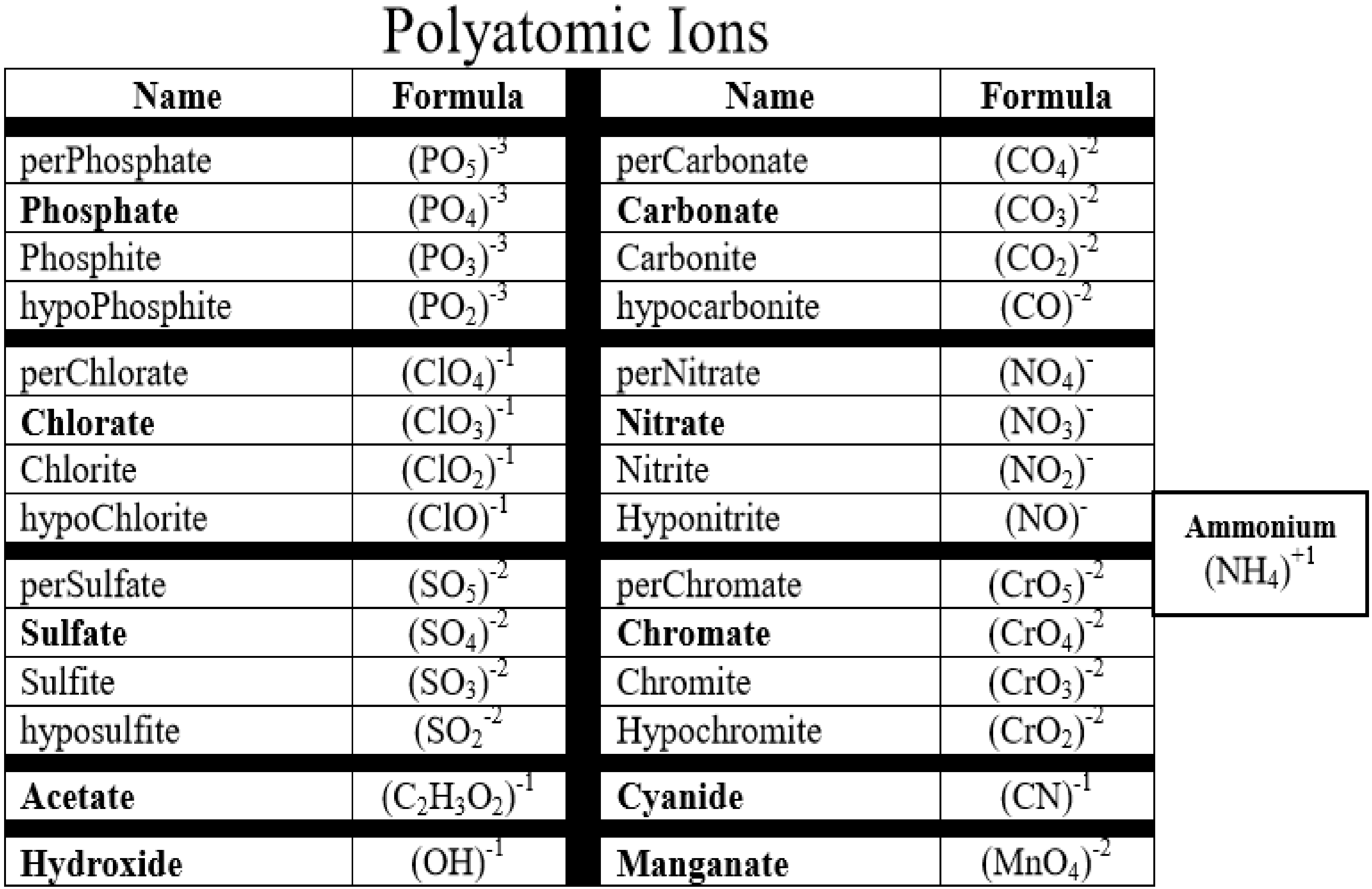
The calcium atom loses two electrons, it becomes an ion with a charge of 2^{+}.

Reduction/Oxidation Reactions (REDOX)

Oxidation and reduction always occur together.

- When one element loses electrons, another element must gain electrons.
- A reactant is said to be reduced if it gains electrons. A reactant is oxidized if it loses electrons.





Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium
$(NH_4)^{+1}$