Agenda

- 4.1 Notes
- 4.1 Video and practice problems
- 4.2 Notes
- 4.2 Video and practice problems

Unit 4

- 9 topics
- 7-9% of the exam
- Tentative unit exam:
  - Nov 6th

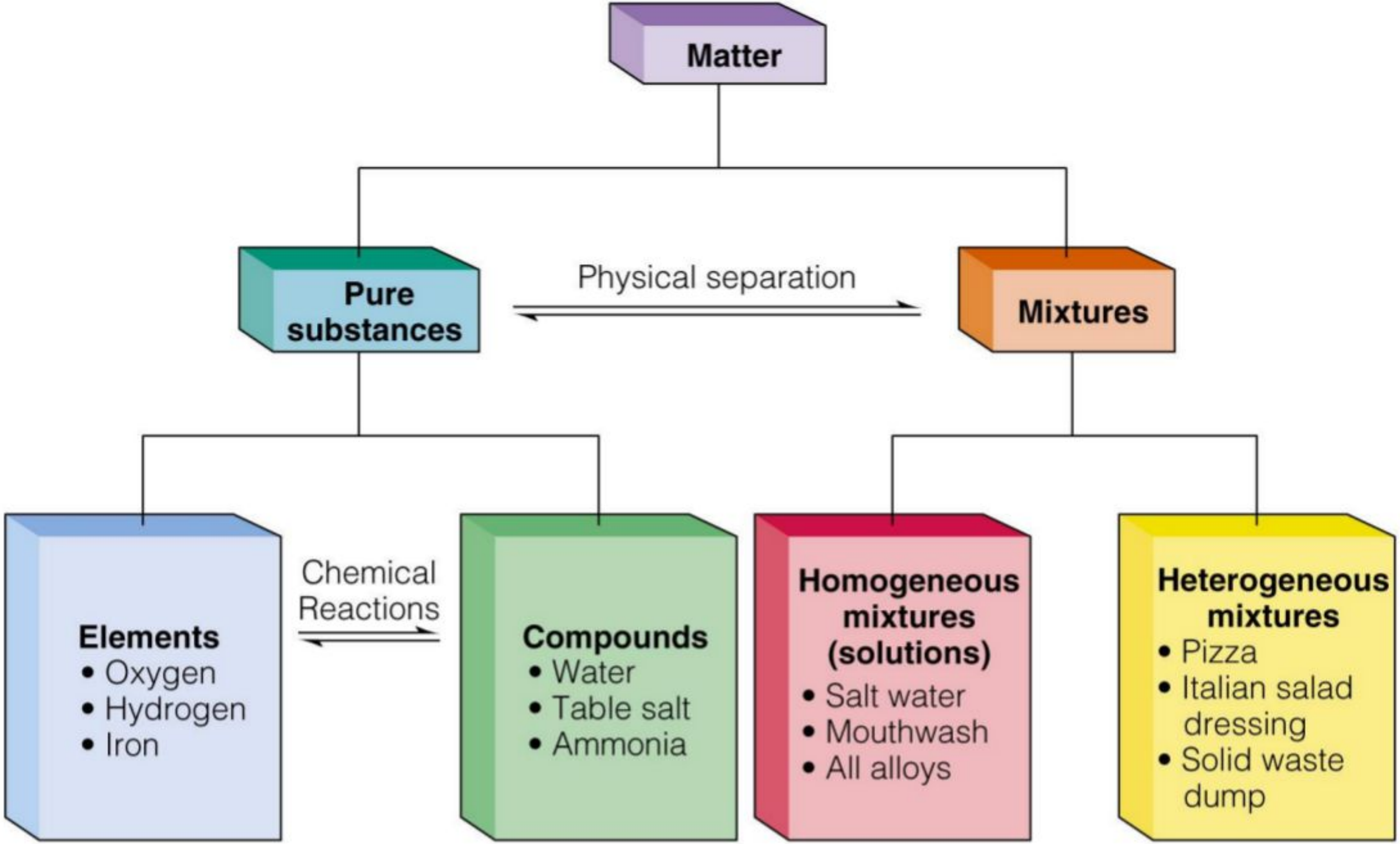
TOPIC: 4.1 INTRODUCTION FOR REACTIONS

ENDURING UNDERSTANDING:	
TRA-1	**A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.**
LEARNING OBJECTIVE:	
TRA-1.A	**Identify evidence of chemical and physical changes in matter.**

Organization of Matter

Matter – occupies space and contains mass

- **Homogeneous Mixture:** visibly indistinguishable parts
- **Heterogeneous Mixture:** visibly distinguishable parts
- **Pure Substance:** substance with one constant composition
- **Compound:** a substance with constant composition that can be broken down into elements by chemical process
- **Elements:** substance that cannot be decomposed into simpler substances by chemical or physical means


Matter
Physical separation
Pure substances
Mixtures
Chemical Reactions
Elements
• Oxygen
• Hydrogen
• Iron
Compounds
• Water
• Table salt
• Ammonia
Homogeneous mixtures (solutions)
• Salt water
• Mouthwash
• All alloys
Heterogeneous mixtures
• Pizza
• Italian salad dressing
• Solid waste dump

Changes in Matter

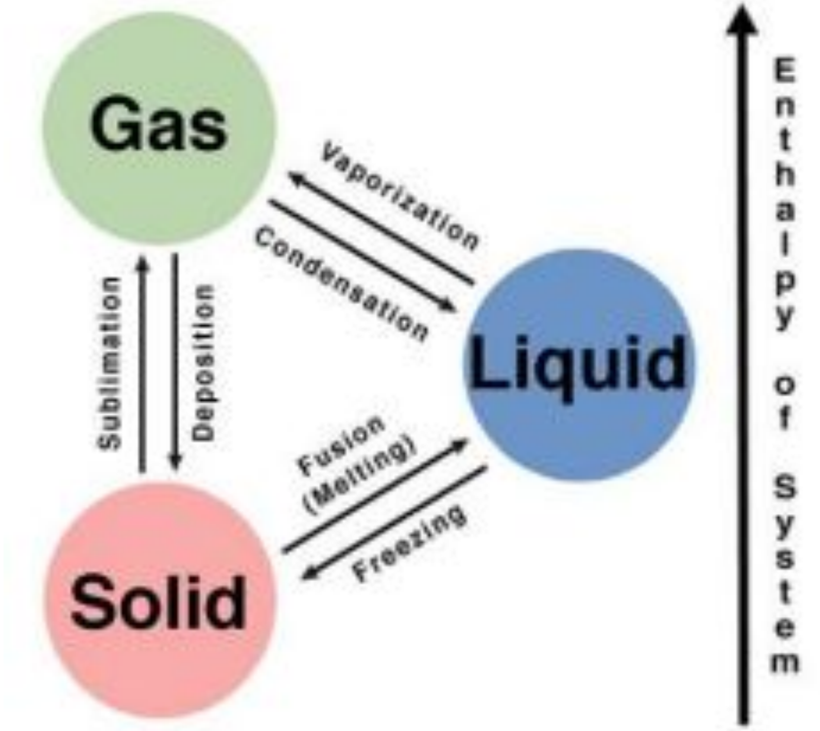
Physical Change - physical property of a substance changes without changing the composition.

Chemical Change - property of a substance changes- breaking of bonds and formation of new bonds.

Physical Changes - Examples = Phase Change

You are responsible for the names of phase changes.

The key feature of a physical change is that the atoms are **not** rearranged. The physical properties (shape, color, texture, flexibility, density, and mass) are changed. Physical changes are *usually* reversible.



Chemical Changes = Reactions

Chemical changes produce new substances with new properties.

Evidence of chemical reactions include:

- Production of a precipitate (a substance of a new phase, such as the solids forming from a solution)
- Color Change
- Change in Energy - light, temperature, or sound
- Gas production (bubbles)

Reaction Types

- Synthesis/Combination
- Decomposition
- Single Replacement
- Double Replacement
- Combustion

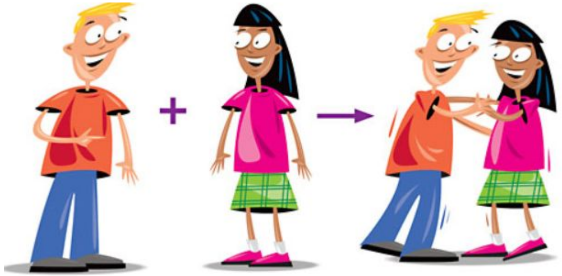
Synthesis/Combination Reactions

Definition: **Two or more substances combine to form a single new substance.**

Generic Equation: $A + B \rightarrow AB$

Example: $2Na(s)+Cl_2(g) \rightarrow 2NaCl(s)$

What to look for: **More than one reactant, single product.**



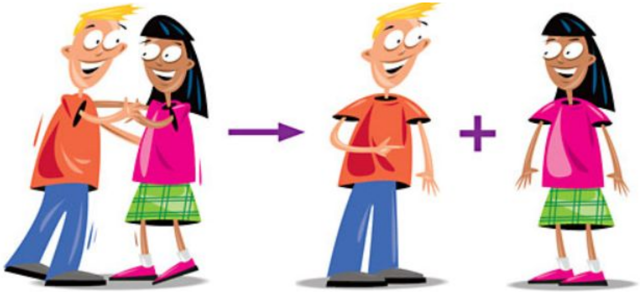
Decomposition Reactions

Definition: A compound breaks down into two or more simpler substances.

Generic Equation: $AB \rightarrow A + B$

Example: $2HgO(s) \rightarrow 2Hg(l) + O_2(g)$

What to look for: Single reactant, more than one product



Single Replacement Reaction

Definition: **One element replaces a similar element in a compound.**

Generic Equation: **AB + C → AC + B**

Example: $Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

What to look for: **Compound + element reactants, new compound + element products.**

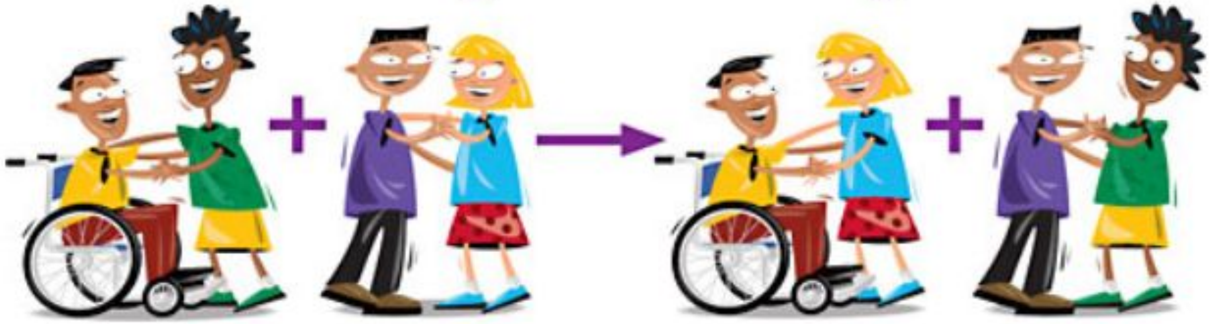
Double Replacement Reaction

Definition: The positive and negative ions of two ionic compounds exchange places to form two new compounds.

Generic Equation: AB + CD → AC + BD

Example: $AgNO_3$ + NaCl → AgCl + $NaNO_3$

What to look for: The switch



Combustion Reaction

Definition: **Commonly called burning, a chemical reaction where a substance reacts quickly with oxygen gas releasing energy in the form of light and heat.**

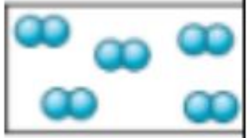
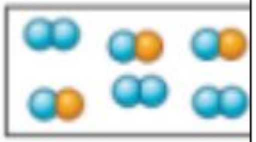
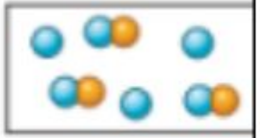
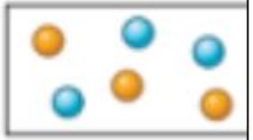
Generic Equation: $C_xH_y + O_2 \rightarrow CO_2 + H_2O$

Example: $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

What to look for: **Carbon dioxide and water products**

Together

1. Using the images below, describe the types of matter (elements or compounds) and whether it is a pure substance or a mixture.

Images	 i	 ii	 iii	 iv	 v	 vi
Type of Matter						
Pure Substance or Mixture						

You Do We Review

2. For each of the following examples, decide if a chemical or physical change has taken place.
    a. Over time, solutions of iodine and water gradually lose color as the iodine evaporates.
    b. When a drop of acid landed on the chemistry teacher's pants, a small hole appeared.
    c. When a solution of lead (II) nitrate and a solution of sodium chloride are mixed a cloudy white precipitate forms.
    d. At Halloween many people use Dry Ice, solid carbon dioxide, in their decorations. It sublimes into a gas and creates a foggy effect.

You Do

ENDURING UNDERSTANDING:	
TRA-1	**A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.**
LEARNING OBJECTIVE:	
TRA-1.B	**Represent changes in matter with a balanced chemical or net ionic equation:** **a. For physical changes.** **b. For given information about the identity of the reactants and/orproduct.** **c. For ions in a given chemical reaction.**

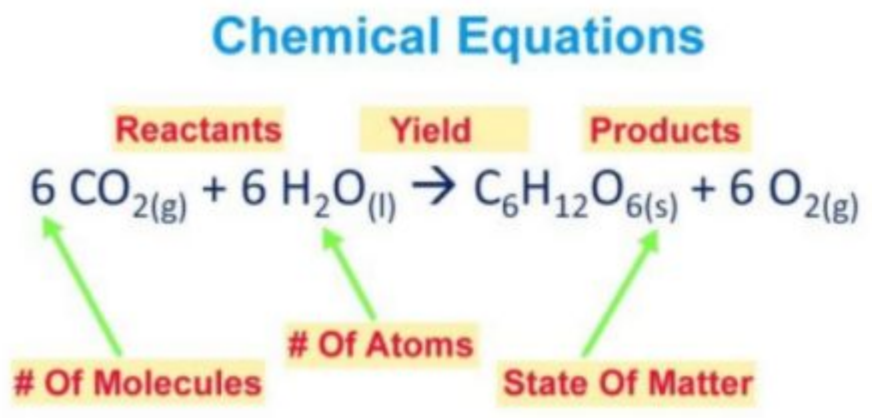
Chemical Equations

Chemical equations represent chemical changes.

These changes are the result of a rearrangement of atoms into new combinations.

Any representation of a chemical change must contain equal numbers of atoms of every element before and after the change occurred.

Equations demonstrate that mass is conserved in chemical reactions.



Law of Conservation of Mass

A balanced equations follow the **law of conservation of matter/mass** that states that in any chemical or physical reaction no matter can be created or destroyed.

Coefficients are used to change the number of each particle in the reaction. The subscripts are NEVER changed to balance a chemical equation.

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

C=1		C=1
H=4	=	H=4
O=4		O=4

States of Matter

We can include the states of matter in the equation to provide more information. In a physical reaction, only the states of matter change.

$$2\,H^{+}_{(aq)} + CO_{3(aq)}{}^{2-} \longrightarrow CO_{2(g)} + H_2O_{(l)}$$

aq = aqueous, g = gas, l = liquid, s = solid

Don't Forget Old Professor HOFBrINCl

When a word problem says oxygen it means O_2!

The atoms that are diatomic in their natural state are:

Bromine, Br_2
Iodine, I_2
Nitrogen, N_2
Chlorine, Cl_2
Hydrogen, H_2
Oxygen, O_2
Fluorine, F_2

Balancing Equations

The steps to balancing an equation (using the guess and check method) are as follows:

1) Write out the equation
2) Count the atoms on each side of the equation
3) Compare the counts, if they are the same then stop, if they are different then continue to 4.
4) Change a coefficient to make one element correct
5) Recount the atoms
6) Compare the counts, if they are the same then stop, if different return to 4.

Example: $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

Different Types of Balanced Equations

Word equation:

sodium carbonate + barium nitrate → sodium nitrate + barium carbonate

Complete chemical equation:

$Na_2CO_3 + Ba(NO_3)_2 \rightarrow 2NaNO_3 + BaCO_3\,(s)$

Total ionic equation:

$2Na^{+1} + CO_3^{-2} + Ba^{+2} + 2NO_3^{-1} \rightarrow 2Na^{+1} + 2NO_3^{-1} + BaCO_3(s)$

Net ionic equation:

$2\cancel{Na}^{+1} + CO_3^{-2} + Ba^{+2} + 2\cancel{NO}_3^{-1} \rightarrow 2\cancel{Na}^{+1} + 2\cancel{NO}_3^{-1} + BaCO_3(s)$

$Ba^{+2} + CO_3^{-2} \rightarrow BaCO_3(s)$

Total (or Overall) Ionic

Overall ionic equations show how ionic compounds dissociate into their ions when they dissolve in water. If you have solutions (look for (aq)) of an ionic compound (particularly any **sodium, potassium, ammonium, and nitrate salts**) they should be written as their ions if you are showing an overall ionic equation.

Precipitation Reaction	
Balanced Chemical Equation:	$Pb(NO_3)_{2\,(aq)} + 2\ NaCl_{\,(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbCl_{2(s)}$
Overall Ionic Equation:	$Pb^{2+}{}_{(aq)} + 2\ NO_3^{-}{}_{(aq)} + 2\ Na^{+}{}_{(aq)} + 2\ Cl^{-}{}_{(aq)} \rightarrow 2\ Na^{+}{}_{(aq)} + 2\ NO_3^{-}{}_{(aq)} + PbCl_{2(s)}$

Net Ionic Equations

The net ionic equation only shows the particles that change in the reaction. It cancels out the spectator ions. A spectator ion is one that isn't involved in the reaction and stays the same phase throughout.

In the example below, the sodium ions and the nitrate ions are the same phase throughout the reaction and are unchanged, they should be cancelled out to create a net ionic equation.

Precipitation Reaction	
Balanced Chemical Equation:	$Pb(NO_3)_{2\,(aq)} + 2\ NaCl_{(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbCl_{2(s)}$
Overall Ionic Equation:	$Pb^{2+}_{(aq)} + 2\ NO_3^-{}_{(aq)} + 2\ Na^+_{(aq)} + 2\ Cl^-_{(aq)} \rightarrow 2\ Na^+_{(aq)} + 2\ NO_3^-{}_{(aq)} + PbCl_{2(s)}$
Net Ionic Equation:	$Pb^{2+}_{(aq)} + 2\ Cl^-_{(aq)} \rightarrow PbCl_{2(s)}$

Together

1. A solution of ammonium carbonate, $(NH_4)_2CO_3$, reacts with a solution of silver nitrate, $AgNO_3$, to form a white silver carbonate precipitate as shown in the image.

   Write the balanced chemical equation:

   Write the overall ionic equation:

   Identify the spectator ions:

   Write the net ionic equation:

You Do, We Review

2. A reaction occurs when aqueous solutions of lithium hydroxide, $LiOH$, and hydrobromic acid, HBr, undergo a neutralization reaction that produces salt and water.

    a. Write the balanced chemical equation:

    b. Write the overall ionic equation:

    c. Identify the spectator ions:

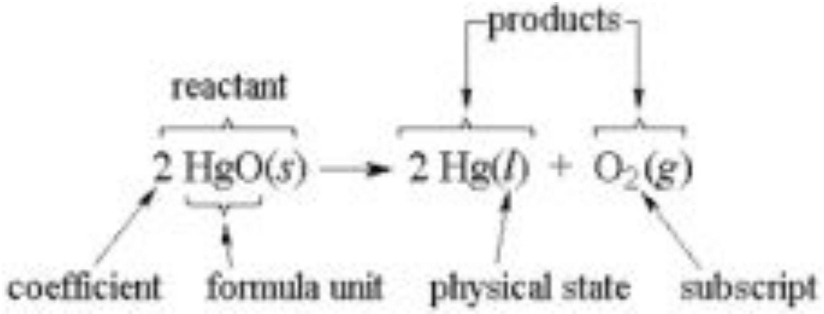
    d. Write the net ionic equation

4.3 Representations of Reactions

ENDURING UNDERSTANDING:	
TRA-1	**A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.**
LEARNING OBJECTIVE:	
TRA-1.C	**Represent a given chemical reaction or physical process with a consistent particulate model.**

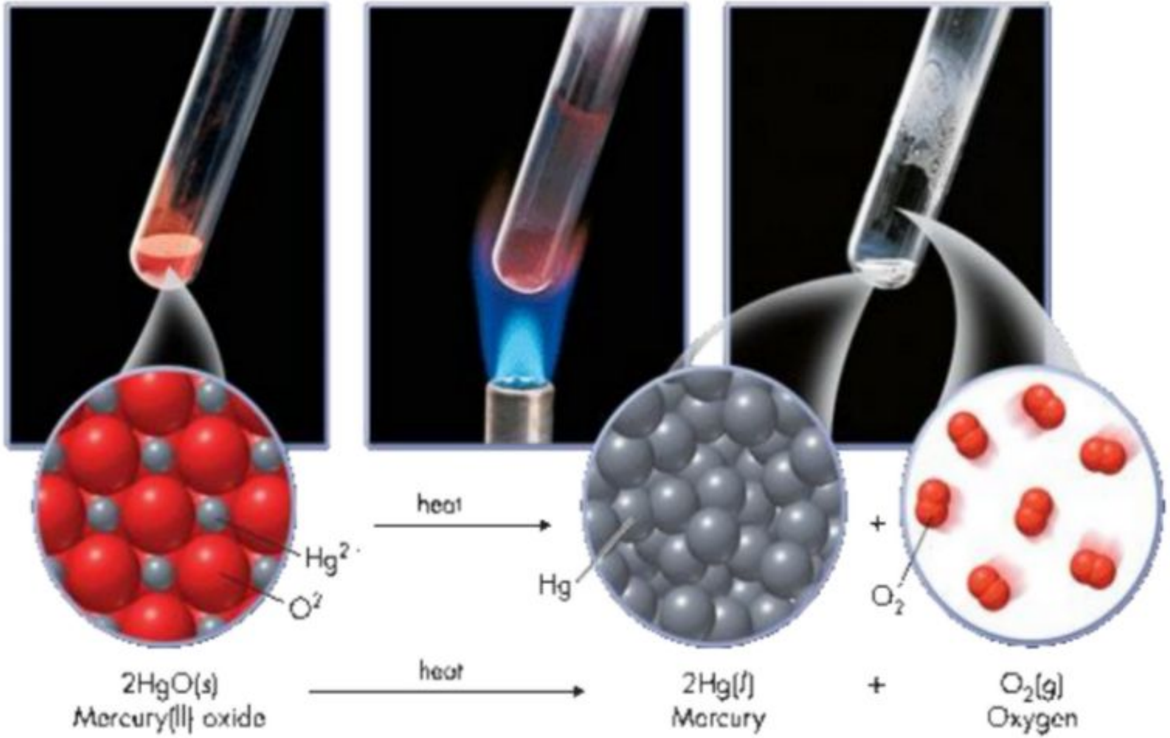
Chemical Reactions

There are many important pieces of information that are conveyed in a chemical reactions.



Particulate Models

Chemists often create particulate models to represent reactions on a molecular level as way to visualize the changes that take place as the atoms rearrange.



Important Parts of Representation

1. **Relative location**
    a. Phase or State of matter
        i. **Solid** particles should be in close contact in an order that maximizes attractions and minimizes repulsions.
        ii. **Liquid** particles should be close but show some disorder (movement) but majority of particles with attractions and repulsions correctly.
        iii. **Gas** particles should be spread out as far as possible to fill the space they are in.
        iv. **Aqueous solutions**- sometimes only show the solute particles- ions should be dissociated and include charge. Solvent (water) particles when included should be oriented with the dipoles in the correct direction to maximize attractions and minimize repulsions with solvent and solute particles. Consider if the substance will ionize or not, if ions are present, orient the water molecules correctly.

Important Parts of Representation

1. **Relative location**
    b. Context clues
        i. Surface or interstices of an alloy
        ii. Precipitate (solid particles should be at the bottom once they have settled. A few may remain throughout)
        iii. Interfaces–where two different substances meet (water and air)

Important Parts of Representation

2. **Amount**
    a. Use the proper number of atoms of each element when given a formula
    b. Use relative amounts of atoms when given a quantity (mol, concentration, coefficient in equation, etc.)
    c. Observe the law of conservation of mass (keep the same number of each type of atom present before and after the reaction, just rearrange them appropriately).

Important Parts of Representation

3. **Species**
   a. Use distinct shapes, symbols, colors, or shades to identify atoms/ions of different elements. Use a key or elemental symbol from periodic table
   b. Show charges and align them appropriately
      i. Use partial charges on polar molecules if there are intermolecular forces (IMF)
      ii. Make sure the charges and dipole moments align properly to maximize attractions and minimize repulsions
   c. Use appropriate sizing
      i. Atoms of the same element should be roughly the same size
      ii. Atoms of different elements should follow atomic/ionic trends on periodic table for relative size

Together

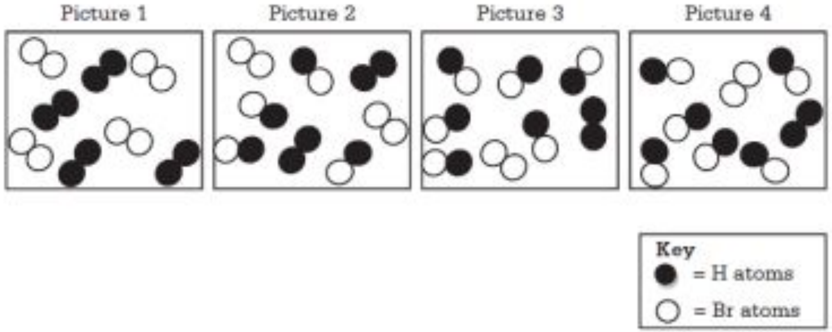
The pictures below show the process of a reaction as H2 and Br2 react. This reaction doesn't go to completion; rather it reaches a state of equilibrium.

A) What are the formulas for the reactants (Picture 1)?
B) What is the formula for the product?

C) What is the balanced equation for the reaction? (include states of matter)

D) What is the difference between picture 2 and picture 3?

E) What do you notice about the total atoms of each element in all of the pictures? What concept does this represent?



You Do, We Review

Draw the representation of 4 molecules of hydrogen and 4 molecules of oxygen completely reacting to form water.

4.4 Physical & Chemical Changes

ENDURING UNDERSTANDING:	
TRA-1	**A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.**
LEARNING OBJECTIVE:	
TRA-1.D	**Explain the relationship between macroscopic characteristics and bond interactions for: a. Chemical Processes b. Physical Processes**

Physical Changes

A **Physical Process** occurs when a substance undergoes a change in properties, but not a change in composition such as a phase change or mixture separation.

Example: $H_2O(s) \rightarrow H_2O(l)$

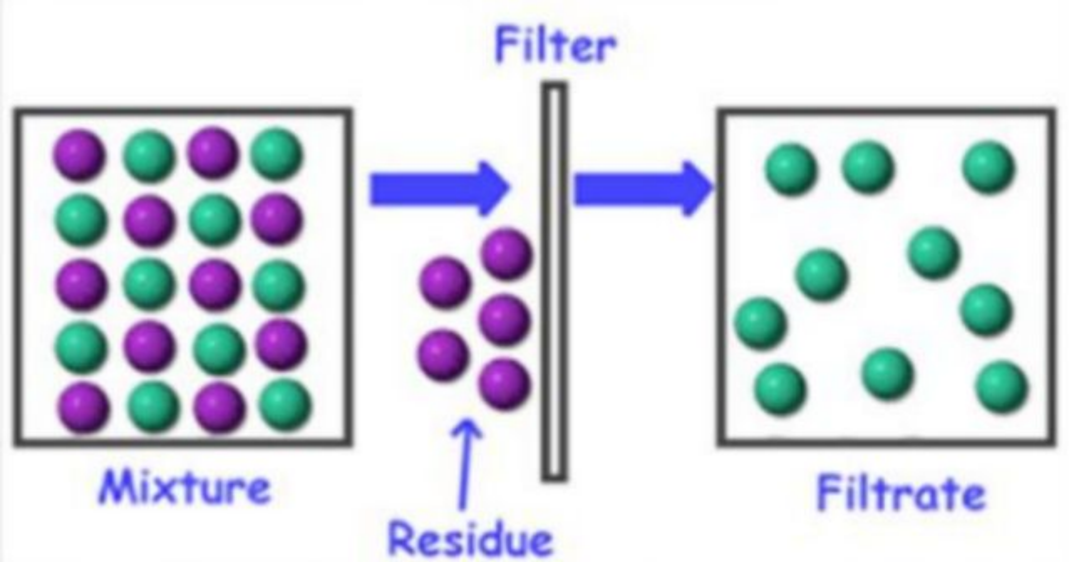
When water melts the chemical makeup of the water does not change (there are still two hydrogen atoms covalently bonded to one hydrogen atom in ice and liquid water). However, the physical properties did change (the particles have a different arrangement).

Physical Changes

Another example of a physical process is a mixture separation.

When mixtures are separated using a physical process their nature does not change, just their form.

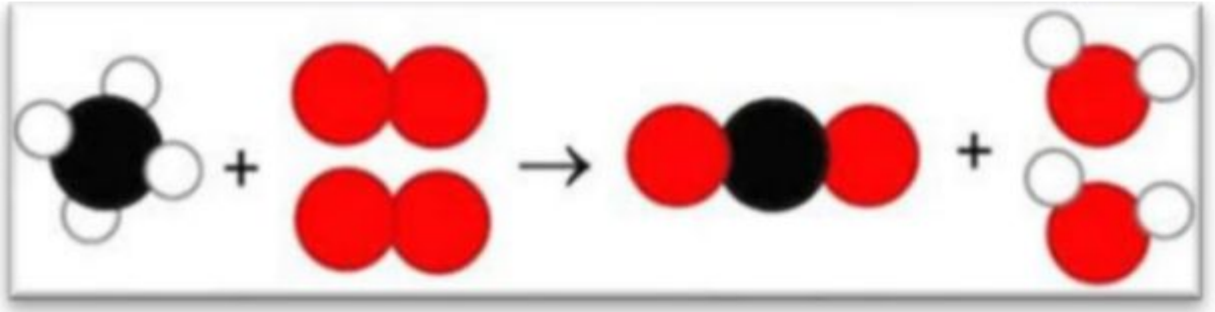
Mixture separation techniques include distillation, filtration, and chromatography.



Chemical Changes

A Chemical Process occurs when a substance is transformed into a new substance with a different composition.

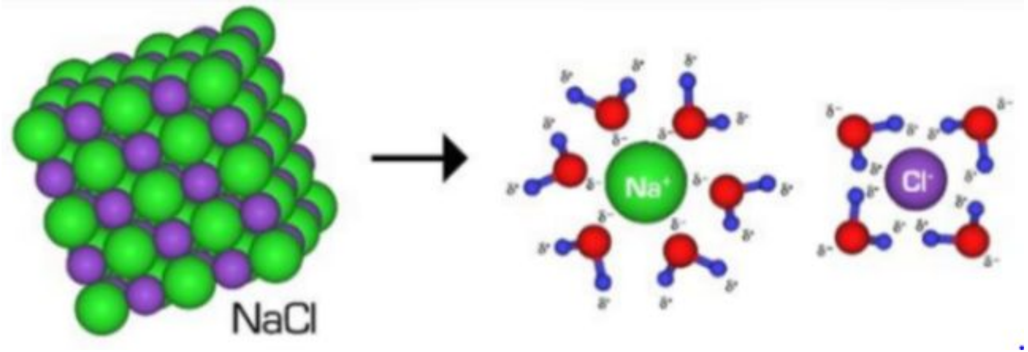
During a chemical process bonds are broken/formed.



What type of chemical reaction is occurring in the image?

Iffy Classification

Sometimes an argument can be made that a physical process involves a chemical change. The dissolution of salt in water is one of these cases.



When salt is dissolved in water the ionic bonds between the sodium (Na^+) and chloride (Cl^-) ions are broken and new ion-dipole interactions are formed between the ion and the water.

TOGETHER

1. Label each process below as physical or chemical as well as the type of forces (intramolecular forces/intermolecular forces) broken/formed during the process.

   a. $CH_3OH\ (l) \rightarrow CH_3OH\ (g)$

   b. $4Fe\ (s) + 3O_2\ (g) \rightarrow 2Fe_2O_3\ (s)$

   c. $2Al_2O_3\ (s) \rightarrow 4\ Al\ (s) + 2O_2\ (g)$

   d. $CO_2\ (s) \rightarrow CO_2\ (g)$

You Do, We Review

2. Draw/Label a particle diagram of liquid HCl (hydrochloric acid) becoming a gas. Explain how this is a physical process.

Happy Mole Day!!!!

- Complete your goal setting bellwork

Agenda

- Bellwork
- Stoichiometry review
- 4.5 notes
- Practice kahoot

4.5 Stoichiometry

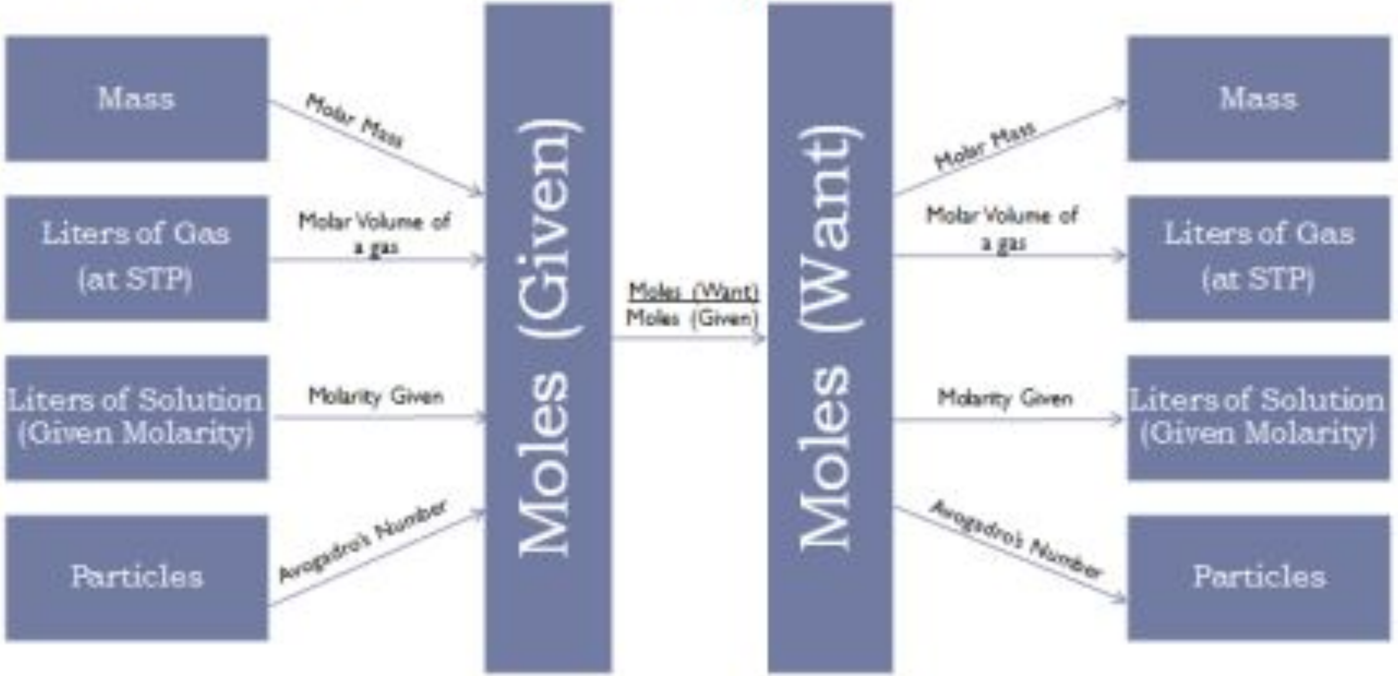
ENDURING UNDERSTANDING:	
SPQ-4	**When a substance changes into a new substance, or when its properties change, no mass is lost or gained.**
LEARNING OBJECTIVE:	
SPQ-4A	**Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.**

With your Group

- Spend 7 minutes and write down what you remember about stoichiometry
  - Hints:
    - What is it?
    - How can we convert from one substance to another?
    - What is a limiting reactant

Stoichiometry Map

Make sure that you have a balanced equation before you begin!
Start on the left and work to the right.



Useful Information:

Avogadro's Number is 6.022×10^{23} particles /1 Mole
Molar Volume of a Gas at STP is 22.4 Liters/1 Mole

Molarity needs to be provided in the problem (moles/1 L)
Molar Mass is calculated using the periodic table and the chemical formula. (grams/1 mole)

Stoichiometry Example

Stoichiometry Example:

How many grams of water can be produced by decomposing 1.0 grams of hydrogen peroxide?

$$H_2O_2 \rightarrow H_2O + O_2$$

Limiting Reagent

In some cases you will be given information about more than one of the reactants. This signals that you will have a **limiting reagent** in the problem.

The limiting reagent is the reactant that runs out first and the excess reactant is the one is not completely consumed.

Conceptually it is often easier to consider how much product each reacting particle can produce separately, and then compare the values, reporting the answer that produces the least.

Limiting Reagent Example

The reaction between iron and oxygen produces rust, iron (III) oxide, Fe_2O_3.

Reacting 15 grams of iron with 6.5 L of oxygen gas at STP, produces how many grams of rust would form?

**Treat each reactant separately, and then compare to find the limiting reagent and the theoretical yield of rust in grams.*

Start with a balanced equation:

$$4\,Fe_{(s)} + 3\,O_{2\,(g)} \rightarrow 2\,Fe_2O_{3\,(s)}$$

$$\frac{15\ grams\ Fe}{1} \times \frac{1\ mole\ Fe}{55.85\ grams\ Fe} \times \frac{2\ moles\ Fe_2O_3}{4\ moles\ Fe} \times \frac{159.69\ grams\ Fe_2O_3}{1\ moles\ Fe_2O_3} = 21\ \text{grams}\ Fe_2O_3\ ✓$$

$$\frac{6.5\ L\ O_2}{1} \times \frac{1\ mole\ O_2}{22.4\ L\ O_2} \times \frac{2\ moles\ Fe_2O_3}{3\ moles\ O_2} \times \frac{159.69\ grams\ Fe_2O_3}{1\ moles\ Fe_2O_3} = 31\ \text{grams}\ Fe_2O_3\ ✗$$

What do the Results tell us?

The smaller value is the one is the correct answer. So, 21 grams of Fe_2O_3 will form from a reaction between 15 grams of iron and 6.5 Liters of oxygen gas. This tells you that the **iron was the limiting reagent** and the **oxygen was excess**.

But what if we perform this experiment with the amounts given and only get 19.8 grams of Fe_2O_3?

Percent Yield

In a lab situation the predicted amount of product might not be produced, so one can calculate the percent yield by comparing the experimental value to the predicted value. Often the actual yield is different from the theoretical yield. That is normal; in the lab the goal is always to get your actual yield as close as possible to the theoretical yield.

Theoretical Yield (or predicted value or calculated mass) = how much you should be able to make based on the amounts given in the problem.

Actual Yield (or experimental yield or actual mass obtained) = the amount that you actually make in the experiment.

Percent Yield is a way to describe how close your experimental yield was to the amount predicted.

$$\textbf{Percent Yield} = \frac{\textbf{Actual Yield}}{\textbf{Theoretical Yield}} \times 100$$

Together

1. What is the percent yield in the reaction between 46.1 g of cesium and 13.4 g of oxygen if 28.3 g of cesium oxide (Cs_2O) are collected?

You Do, We Review

2. How much excess reactant is left over when 50 mL of .250 M iron (III) chloride ($FeCl_3$) is reacted with 50 mL of .250 M sodium carbonate (Na_2CO_3) solution?

Agenda

- Bellwork
- Start of 4.7
- 4.6 notes and practice problems
- Titration lab

Sulfuric acid (H_2SO_4) is aqueous in water. Sulfuric acid is mixed with NaOH. Write the complete molecular equation and the net ionic for the reaction that occurs between sulfuric acid and NaOH.

4.7 Types of Chemical Rxns

ENDURING UNDERSTANDING:	
TRA-2	A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.
LEARNING OBJECTIVE:	
TRA-2A	Identify a reaction as acid-base,oxidation-reduction,or precipitation.

Types of Rxns:

There are a few basic types of reactions that we see in chemistry.

Composition (synthesis)	Decomposition	Single Ionic Replacement	Double Ionic Replacement	Combustion of a hydrocarbon (or a metal)
$A + B \rightarrow AB$	$AB \rightarrow A + B$	$A + BC \rightarrow AC + B$	$AB + CD \rightarrow AD + CB$	C_xH_y (with or without O) $+ O_2 \rightarrow CO_2 + H_2O$ $M + O_2 \rightarrow M_xO_y$
$Na + Cl_2 \rightarrow NaCl$	$KClO_3 \rightarrow KCl + O_2$	$Mg + HCl \rightarrow MgCl_2 + H_2$	$LiCl + AgNO_3 \rightarrow LiNO_3 + AgCl$	$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ $Mg + O_2 \rightarrow MgO$

Double Replacement includes acid/base neutralization and precipitation reactions.

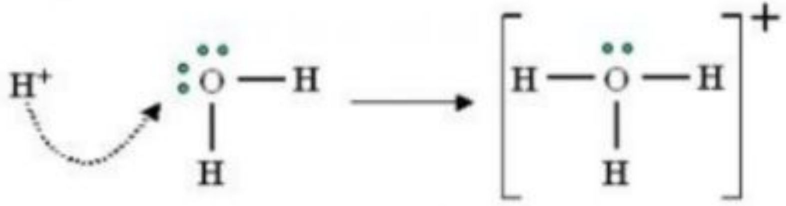
All of these can be considered RedOx (Oxidation-Reduction) reactions except for double replacement reactions.

Acid-Base Rxns

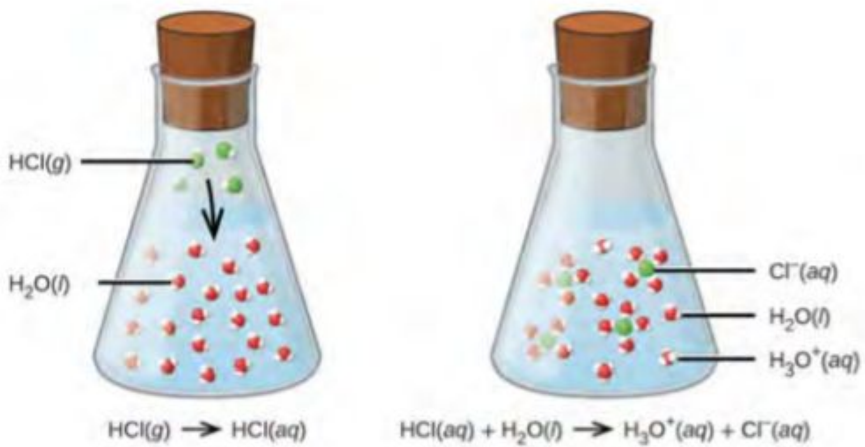
Acid-base reactions involve **transfer of one or more protons** between chemical species.

According to the Brønsted-Lowry definition, **acids are proton donors** and **bases are proton acceptors**.

Protons are hydrogen ions. When a hydrogen ion reacts with a water molecule, **hydronium ions** form. The terms proton, hydrogen ions and hydronium ions are often all used interchangeably in acid-base chemistry.



Acid Strength

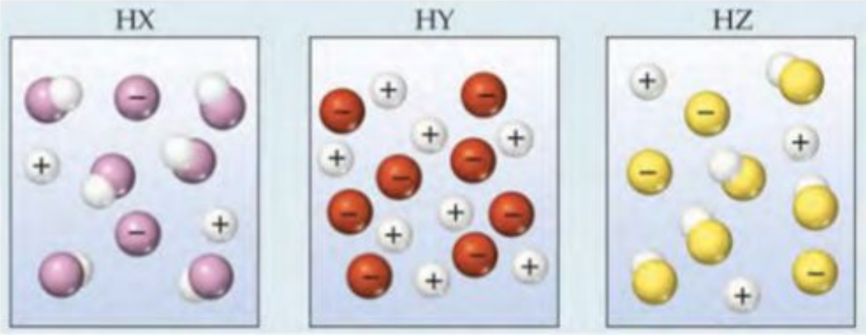


Acids, like HCl and HNO_3, that *dissociate 100%* are described as ***strong acids***.

Other acids, like CH_3COOH will *dissociate < 1%* and are described as ***weak acids***.

The *proportion* of *dissociated molecules* in a diagram can be used to identify the *strongest acid*:

HY > HZ > HX



pH and pOH

$$pH + pOH = 14$$

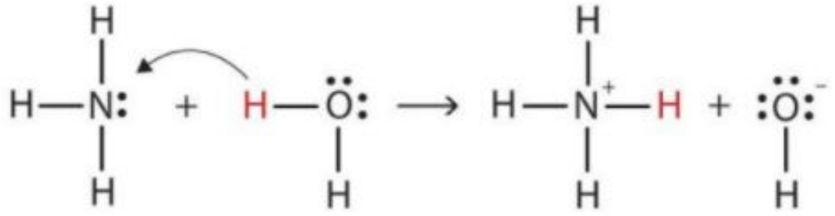
$$[H^+][OH^-] = 1x10^{-14}$$

$-\log [H^+] = pH$ (Or replace H^+ with OH^- and pH with pOH)

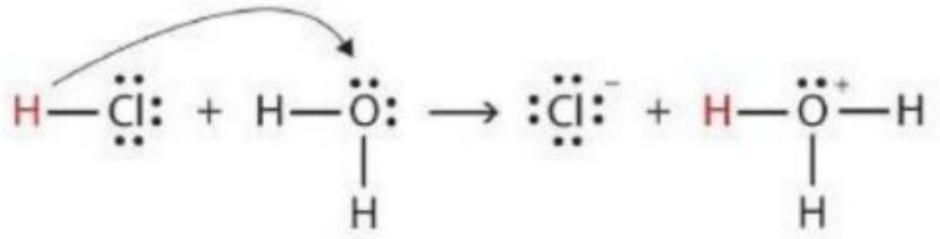
$10^{-pH} = [H^+]$ (Or replace H^+ with OH^- and pH with pOH)

Amphiprotic Species - Act as Proton donor OR acceptor

Water can act as the acid and **donate a proton.**



Water can act as a base and **accept a proton**.

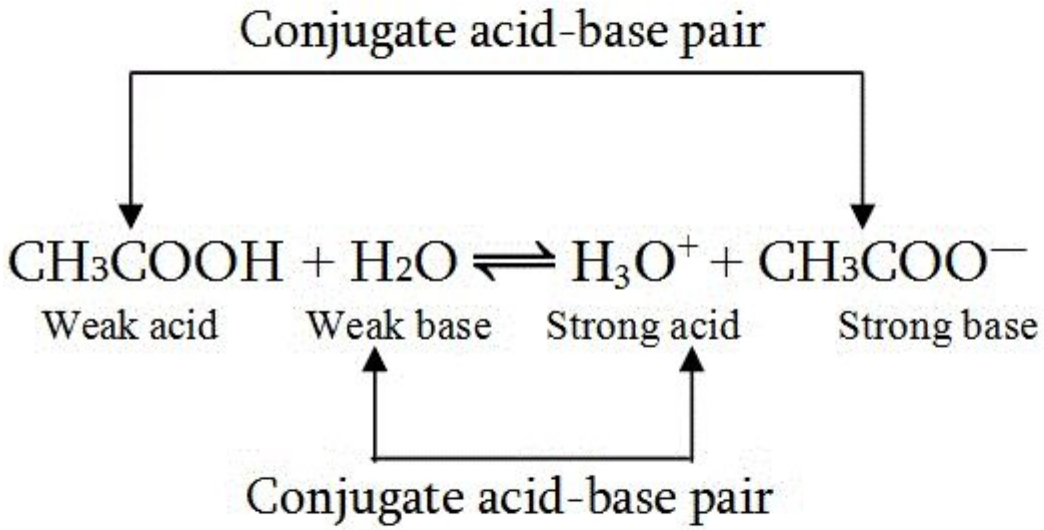


Substances that can act as an acid or a base are called **amphiprotic.**

Conjugate Acids and Bases

Conjugate Acid - A base that has gained one proton.

Conjugate Base - An acid that has lost one proton.



Acid-Base Rxns Summary (We will go into more detail tomorrow)

- Look for exchange of protons (H^+)
- Often produce water and a salt

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} \rightarrow \underset{\text{water}}{H_2O} + \underset{\text{salt}}{NaCl}$$

4.6 Introduction to Titration

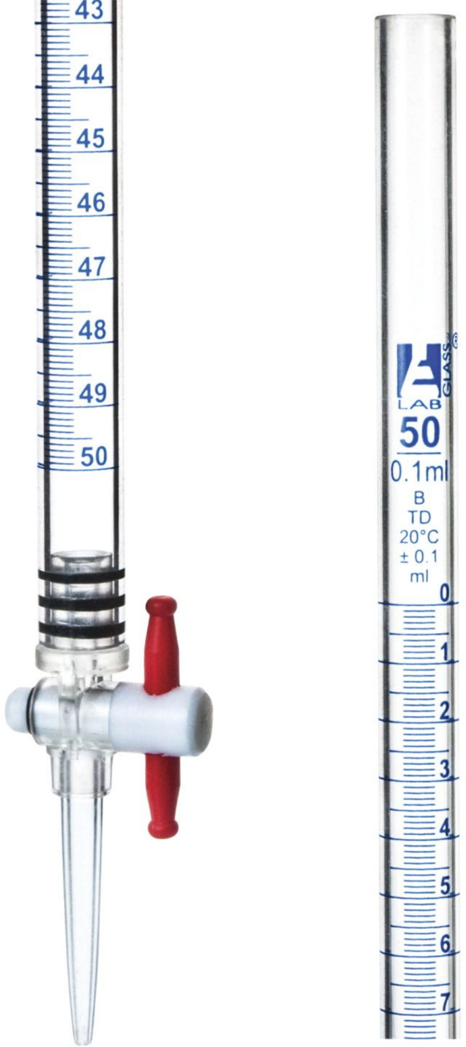
ENDURING UNDERSTANDING:	
SPQ-4	When a substance changes into a new substance, or when its properties change, no mass is lost or gained.
LEARNING OBJECTIVE:	
SPQ-4B	Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.

Titrations

A **titration** is an analytical lab technique where a known volume and molarity of a **titrant** is dispensed from a buret into a flask containing a measured quantity of the **analyte** (the thing being analyzed).

Using the balanced chemical equation specific to the reaction, moles of the titrant can be determined at the equivalence point. The **equivalence point** is when the moles of the titrant and moles of analyte are stoichiometrically equivalent.

In order to know when this point is reached, a color change is often used to signal the end point.



Three types of common titrations:

1. **Acid-Base Titrations**: either the acid or the base can be the titrant. An acid-base indicator which changes color at a pH close to 7 is added to determine the end point of a strong acid/base reaction. Sometimes pH meters are used to determine equivalence point.
2. **Redox Titrations:** during these reactions, a color change is produced when the oxidation state of a metal ion in the reaction changes.
3. **Precipitation Titrations**: when the titrant reacts with ions in the analyte, a precipitation can occur. The formation of a precipitate or its color change can signal the end point.

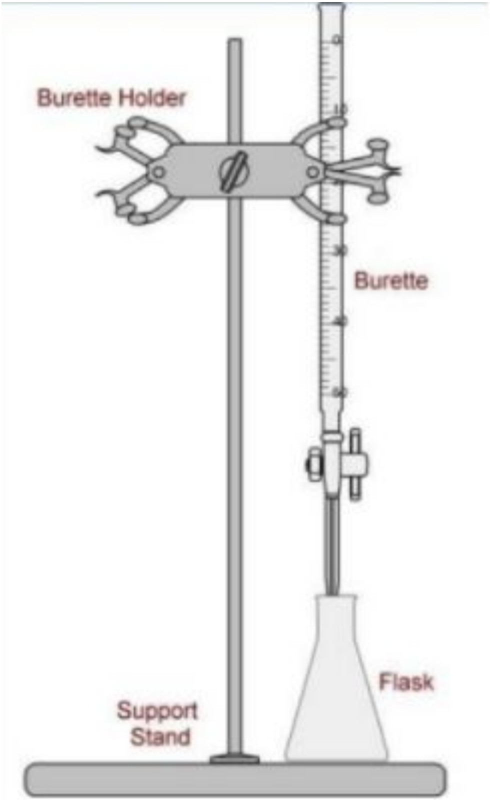
Lab Equipment needed

• **buret** - holds titrant and dispenses specific, measured amounts

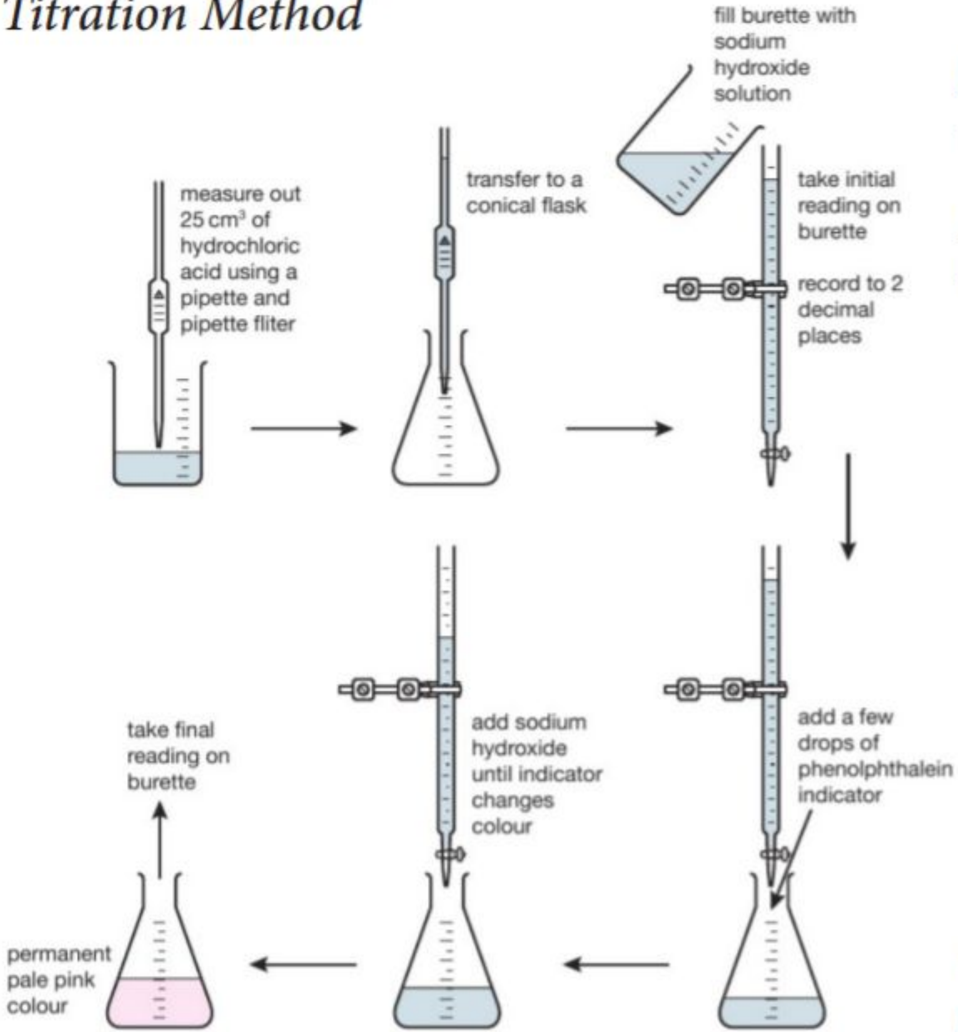
• **volumetric pipet** - to get a specific volume of the analyte solution OR • **lab balance** to mass a sample

• **Erlenmeyer flask**

• **acid/base indicator** OR • **pH meter**

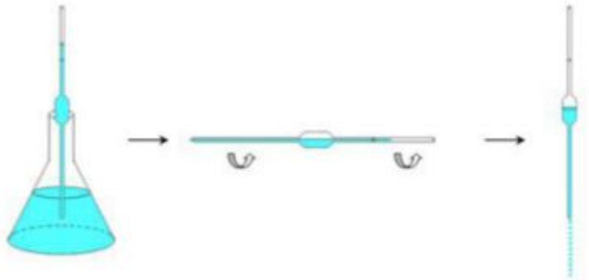


Titration Method



Pipette and *burette* should be washed several times with *water*.

Pipette should then be washed out, at least twice, with the ***analyte*** solution.



Burette should be washed out, at least twice, with the ***titrant*** solution.

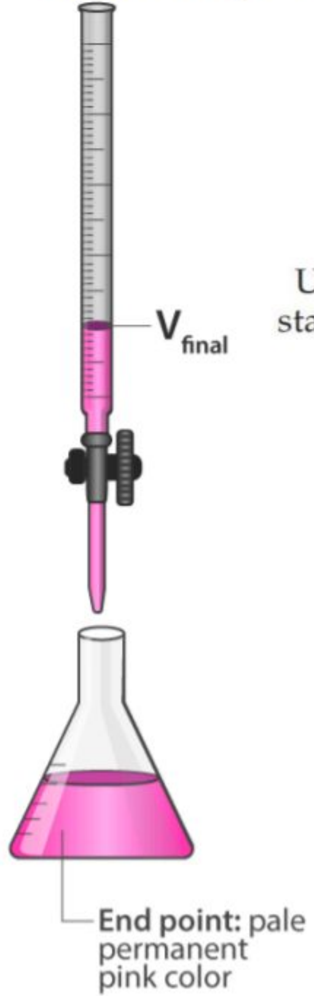
Burette readings should be taken at eye-level and to ***two decimal places***.

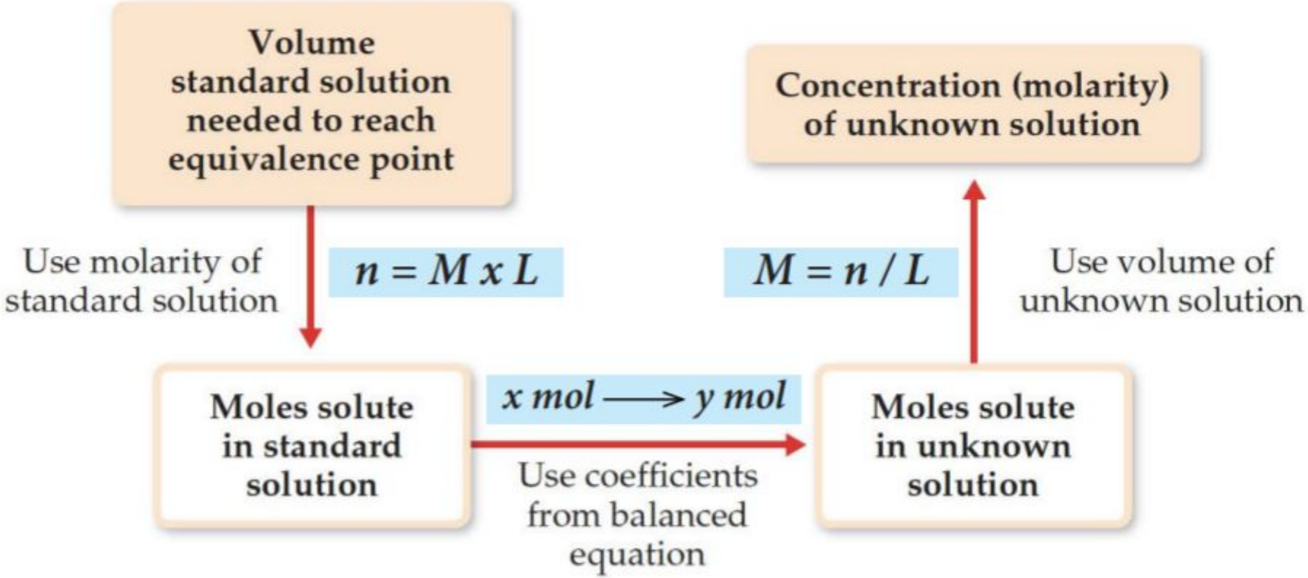
Titrations should be *repeated* until three ***concordant*** results are obtained.

The data needed to be recorded include:

- molarity of titrant
- initial volume of titrant
- final volume of titrant
- volume or mass of analyte

Stoichiometry - Titration Calculations





Example 1: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

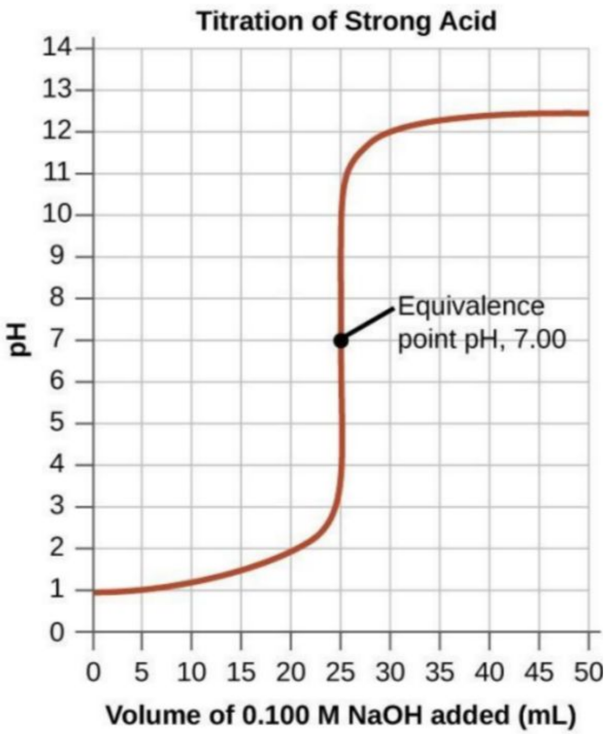
The end point in a titration of a 50.00-mL sample of aqueous HCl was reached by addition of 35.23 mL of 0.250 M NaOH titrant.

What is the molarity of the HCl?

Results

If a pH meter is used to monitor an acid/base titration, it’s common for pH and volume of titrant to be plotted on a graph. For example:

By dropping a vertical line down at the equivalence point,vit can be determined that 25 mL of 0.100 M NaOH were required to react fully to the strong acid.



Together

1. 10.00 mL of hydrochloric acid (HCl) were dispensed into an Erlenmeyer flask using a volumetric pipet. 25.00 mL of water were added to the flask as well as 3 drops of phenolphthalein. 0.400 M sodium hydroxide (NaOH) solution was poured into a buret and the initial volume was read at 0.51 mL. The NaOH solution was added to the flask in 1 mL increments until a pink color briefly appeared and then disappeared. The NaOH was then added drop by drop until the pink color lingered for 30 seconds. The final volume of the NaOH was read as 18.50 mL. Find the molarity of the HCl solution.

YOu Do, We Review

2. Hydrogen peroxide (H_2O_2) reacts with potassium permanganate ($KMnO_4$) in an acidic solution according to the following oxidation-reduction reaction:

$$2\ MnO_4^-{}_{(aq)} + 6\ H^+{}_{(aq)} + 5\ H_2O_{2\ (aq)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 8\ H_2O_{(l)} + 5\ O2(g)$$

Calculate the amount of H_2O_2 in grams in the sample if 1.00 mL of H_2O_2 solution required 15.10 mL of 0.0250 M $KMnO_4$.

4.7 Types of Chemical Rxns

ENDURING UNDERSTANDING:	
TRA-2	A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.
LEARNING OBJECTIVE:	
TRA-2A	Identify a reaction as acid-base,oxidation-reduction,or precipitation.

Types of Rxns:

There are a few basic types of reactions that we see in chemistry.

Composition (synthesis)	Decomposition	Single Ionic Replacement	Double Ionic Replacement	Combustion of a hydrocarbon (or a metal)
$A + B \rightarrow AB$	$AB \rightarrow A + B$	$A + BC \rightarrow AC + B$	$AB + CD \rightarrow AD + CB$	C_xH_y (with or without O) + $O_2 \rightarrow CO_2 + H_2O$ $M + O_2 \rightarrow M_xO_y$
$Na + Cl_2 \rightarrow NaCl$	$KClO_3 \rightarrow KCl + O_2$	$Mg + HCl \rightarrow MgCl_2 + H_2$	$LiCl + AgNO_3 \rightarrow LiNO_3 + AgCl$	$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ $Mg + O_2 \rightarrow MgO$

Double Replacement includes acid/base neutralization and precipitation reactions.

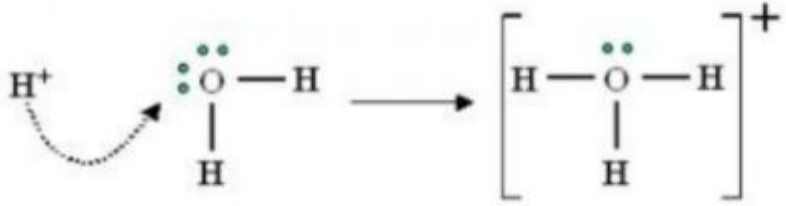
All of these can be considered RedOx (Oxidation-Reduction) reactions except for double replacement reactions.

Acid-Base Rxns

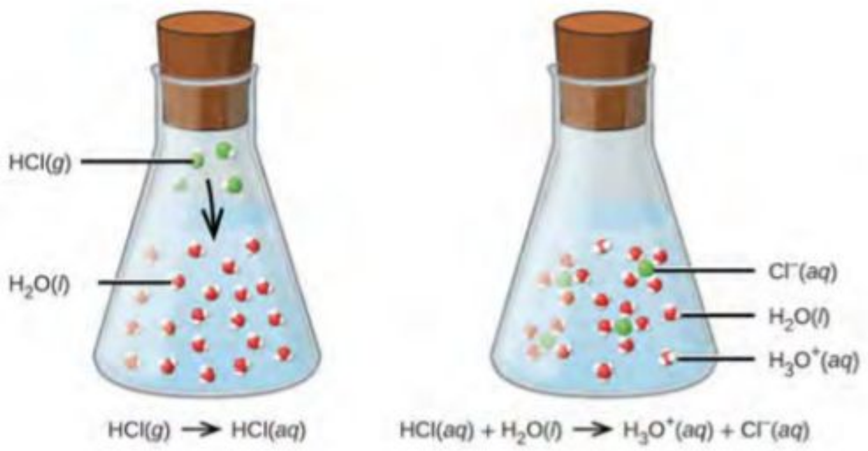
Acid-base reactions involve **transfer of one or more protons** between chemical species.

According to the Brønsted-Lowry definition, **acids are proton donors** and **bases are proton acceptors**.

Protons are hydrogen ions. When a hydrogen ion reacts with a water molecule, **hydronium ions** form. The terms proton, hydrogen ions and hydronium ions are often all used interchangeably in acid-base chemistry.



Acid Strength

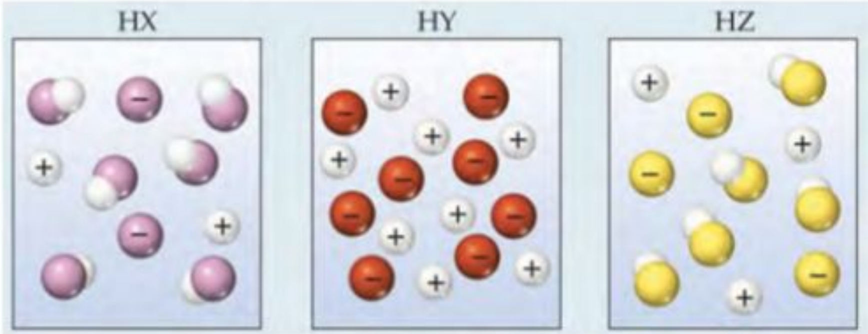


Acids, like HCl and HNO_3, that *dissociate 100%* are described as ***strong acids***.

Other acids, like CH_3COOH will *dissociate < 1%* and are described as ***weak acids***.

The *proportion* of *dissociated molecules* in a diagram can be used to identify the *strongest acid*:

HY > HZ > HX



pH and pOH

$$pH + pOH = 14$$

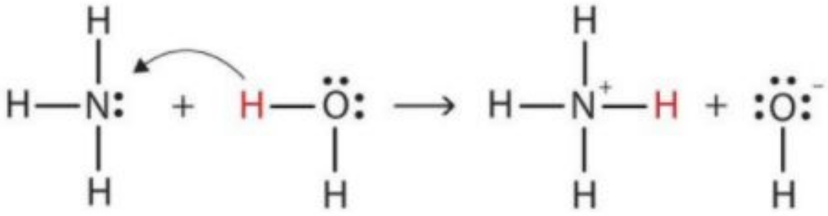
$$[H^+][OH^-] = 1x10^{-14}$$

$-\log [H^+] = pH$ (Or replace H^+ with OH^- and pH with pOH)

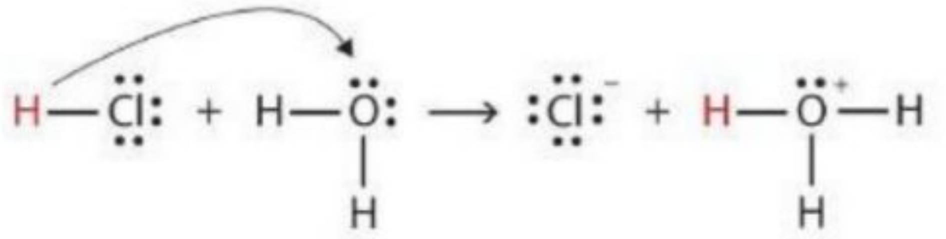
$10^{-pH} = [H^+]$ (Or replace H^+ with OH^- and pH with pOH)

Amphiprotic Species - Act as Proton donor OR acceptor

Water can act as the acid and **donate a proton.**



Water can act as a base and **accept a proton**.

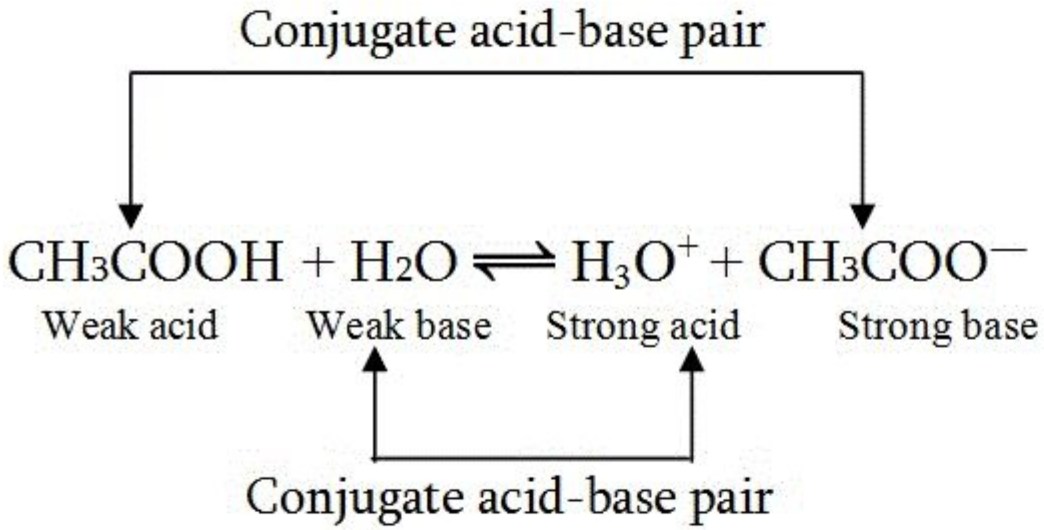


Substances that can act as an acid or a base are called **amphiprotic.**

Conjugate Acids and Bases

Conjugate Acid - A base that has gained one proton.

Conjugate Base - An acid that has lost one proton.



Acid-Base Rxns Summary (We will go into more detail tomorrow)

- Look for exchange of protons (H^+)
- Often produce water and a salt

$$\underbrace{HCl}_{\text{acid}} + \underbrace{NaOH}_{\text{base}} \rightarrow \underbrace{H_2O}_{\text{water}} + \underbrace{NaCl}_{\text{salt}}$$

Oxidation-Reduction (Redox) Reactions

In some chemical reactions there is a transfer of electrons between two of the substances. When this occurs, the reaction is considered a "RedOx" reaction.

Oxidation refers to the LOSS of electrons, while reduction refers to the GAIN of the electrons.

Mnemonics: **LEO** the lion says **GER**

OIL RIG

Redox Example

$Cu(NO_3)_2(aq) + 2\ Na(s) \rightarrow Cu(s) + 2\ NaNO_3(aq)$

We can see from the chemical equation that it is single replacement. We use the net ionic equation to recognize that it is also a REDOX reaction:

$Cu^{2+}{}_{(aq)} + 2\ Na_{(s)} \rightarrow Cu_{(s)} + 2\ Na^{+}(aq)$

Which species was reduced (gained electrons)?

Which was oxidized (lost electrons)?

Oxidation Numbers

Rule	Examples
1) Elements always have an oxidation number of zero.	0 0 0 $Zn_{(s)}$ $O_{2\,(g)}$ $C_{60(s)}$
2) Hydrogen in a compound is always +1. Exception: *Hydride ion which is -1	0 +1 -2 +1 -1 -4 +1 +1 -1 $H_{2(s)}$ $H_2O_{(l)}$ $HCl_{(aq)}$ $CH_{4(g)}$ *NaH
3) Oxygen in a compound is always -2. Exception: **Peroxide ion which is -1.	0 +1 -2 +4 -2 +6 -2 $O_{2\,(g)}$ $H_2O_{(l)}$ $CO_{2(g)}$ $SO_4^{2-}{}_{(aq)}$
4) Oxidation numbers for monoatomic ions equal their charge. Group 1 ions are ***ALWAYS +1, Group 2 ions are ***ALWAYS +2, Fluorine is -1	+1 -2 +3 +1 $Na^+{}_{(aq)}$ $O^{2-}{}_{(aq)}$ $Fe^{3+}{}_{(aq)}$ $Ag^+{}_{(aq)}$
5) The oxidation numbers of neutral compounds will always sum to 0.	+1 -2 $H_2O_{(l)}$ 2 (+1) + 1 (-2) = 0
6) The oxidation numbers of polyatomic ions will always sum to the charge of the ion.	+6 -2 $SO_4^{2-}{}_{(aq)}$ 1 (+6)+ 4 (-2) =-2

***well, not always, but always in AP Chemistry.

Combustion is REDOX

Combustion reactions are examples of oxidation and reduction reactions. Carbon dioxide and water are always products of combustion.

$$\overset{-2}{C}_2\overset{+1}{H}_4 + \overset{0}{O}_2 \rightarrow \overset{+4}{C}\overset{-2}{O}_2 + \overset{+1}{H}_2\overset{-2}{O}$$

Looking at the oxidation numbers we can see that oxygen was reduced (and gained electrons) while carbon was oxidized (and lost electrons).

Precipitation Rxns

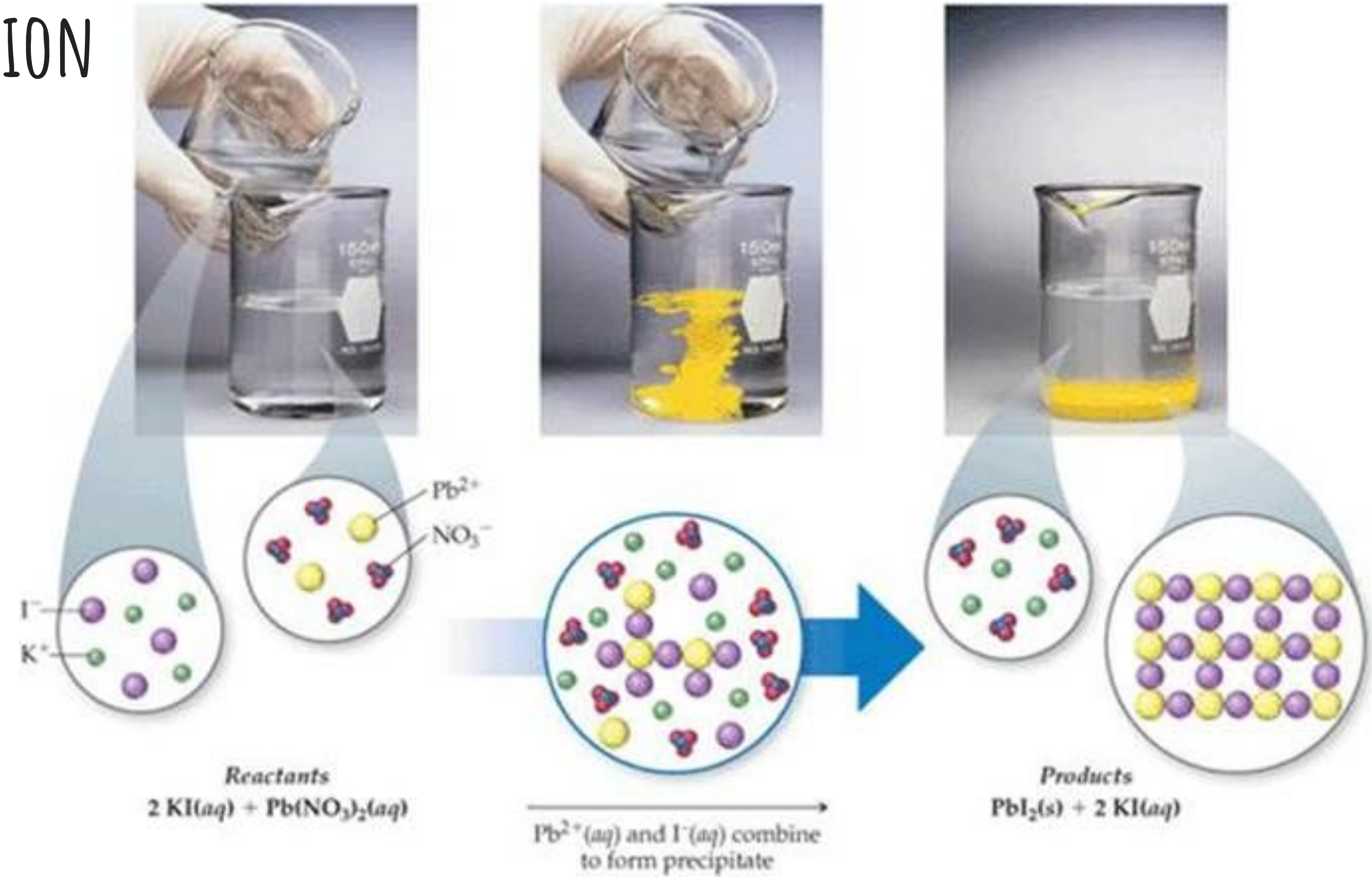
Usually mixing ions in aqueous solution to produce an insoluble or sparingly soluble ionic compound.

*All Na, K, NH_4^+, and NO_3^- salts are soluble in water and NEVER form precipitate.

Precipitation reactions are a subclass of double replacement reactions. They result in an insoluble product. This often appears cloudy or milky and will settle to the bottom of a test tube.

*You must be able to predict the products of a reaction by recombining cations with anions.

Precipitation Example



Together

1. Sodium metal, Na, reacts with a solution of sulfuric acid, H_2SO_4, to form hydrogen gas, H_2, and a solution of sodium sulfate, Na_2SO_4.

   a. Write and balance the equation

   b. Assign oxidation numbers

   c. Use the oxidation numbers to determine which substance was oxidized and which was reduced.

You Do, We Review

2. Complete the reaction between nitrous acid, HNO_2 and the hydrogen sulfide ion, HS^-, then identify the acid, base, conjugate acid and conjugate base.

Rust

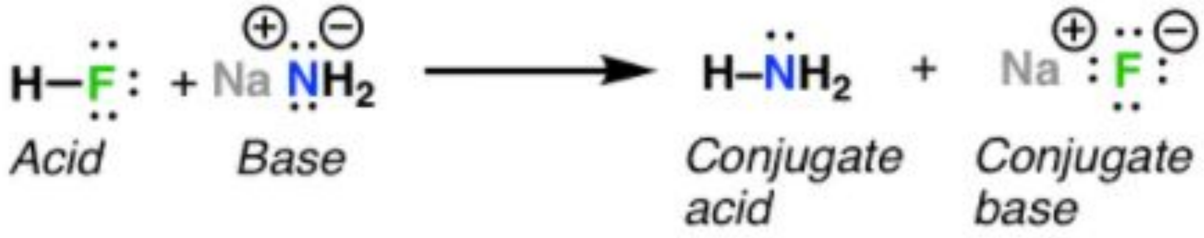
4.8 Introduction to Acid Base Rxns

ENDURING UNDERSTANDING:	
TRA-2	**A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.**
LEARNING OBJECTIVE:	
TRA-2B	**Identify species as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.**

Acid-Base Reactions

Reactions in which a proton, H^+, is transferred from one species (the acid) to another species (the base).

It is important not only to be able to identify if a reaction is an acid-base reaction, but also to be able to identify the acids and bases within an acid-base reaction.



Conjugate Acids and Bases

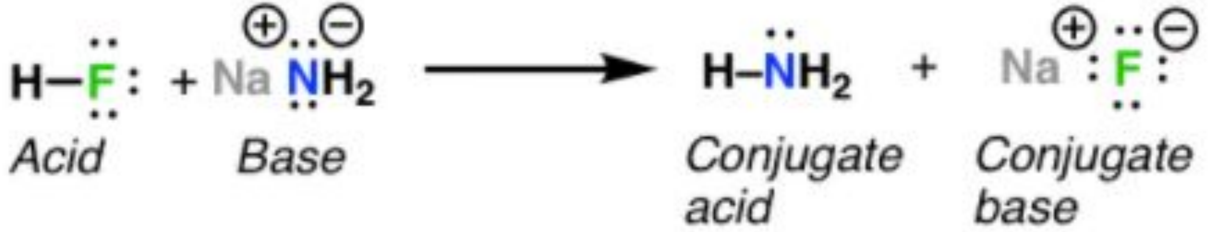
Brønsted-Lowry definitions:

Acid = proton (H^+) donor, and a base = proton (H^+) acceptor

When an acid transfers a proton to a base, it becomes the **conjugate base**. The acid and the conjugate base make a conjugate acid-base pair.

When a base accepts a proton from an acid, it becomes a **conjugate acid**. The base and the conjugate also make a conjugate acid-base pair.

A conjugate acid-base pair will always differ by **only one proton**.



General Formulas with Water

$HA + H_2O \rightarrow H_3O^+ + A^-$

Acid + Base → Conjugate Acid + Conjugate Base

*HA and A^- are a conjugate acid-base pair, and H_2O and H_3O^+ are a conjugate acid-base pair.

$B + H_2O \rightarrow OH^- + HB^+$

Base + Acid → Conjugate Base + Conjugate Acid

*B and HB^+ are a conjugate acid-base pair, and H_2O and OH^- are a conjugate acid-base pair.

Notice water can act as a proton acceptor (base) or a proton donor (acid). Species that can act as both an acid and a base are called **amphiprotic**.

Acid and Base Strength

A strong acid or base will ionize completely in water, but a weak acid or base will have less than 100% ionization.

HCl is a strong acid so the reaction with water is shown with a single arrow to indicate that at the end of the reaction no HCl remains and 100% of it has become H_3O^+ and Cl^-:

$$\mathbf{HCl + H_2O \rightarrow H_3O^+ + Cl^-}$$

By contrast, a weak acid such as acetic acid, $HC_2H_3O_2$ is shown with a double arrow to indicate that at the end of the reaction some $HC_2H_3O_2$ will remain because less than 100% of it has become H_3O^+ and $C_2H_3O_2^-$:

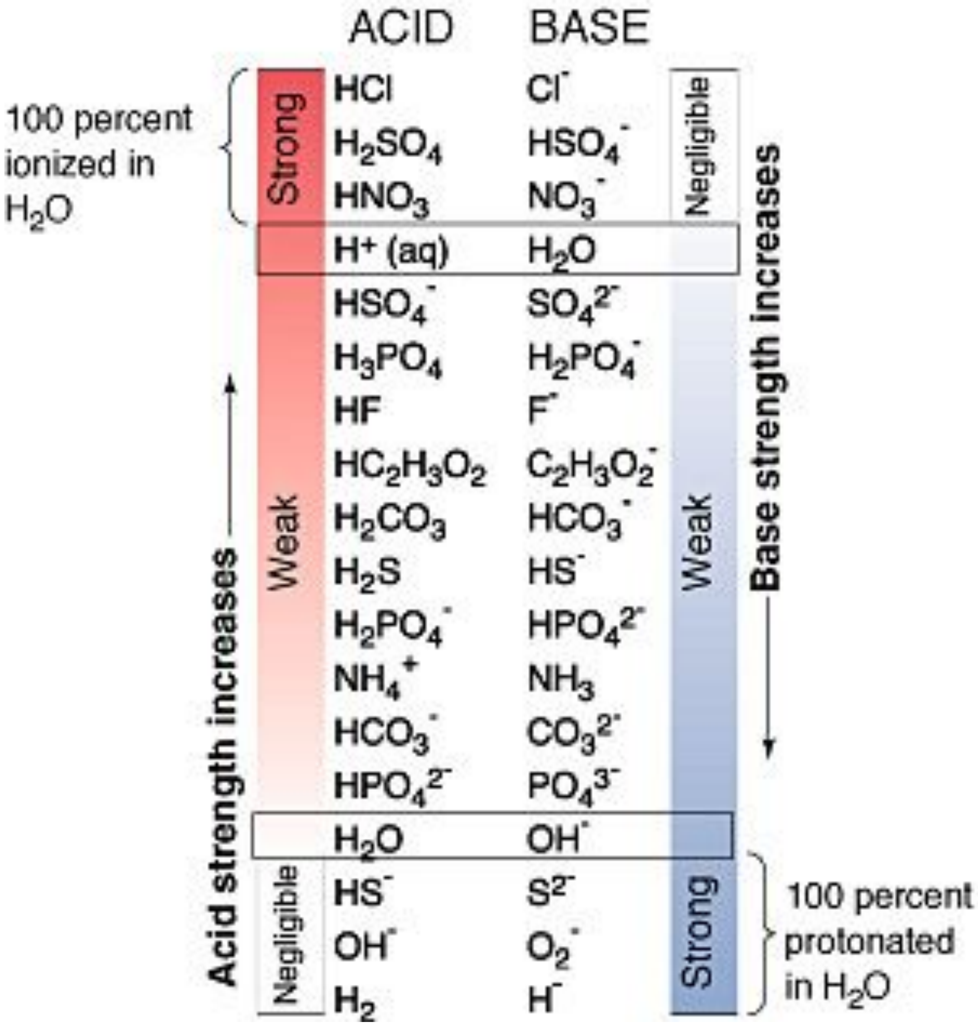
$$\mathbf{HC_2H_3O_2 + H_2O \leftrightarrow H_3O^+ + C_2H_3O_2^-}$$

Conjugate Strength

The conjugate of a strong acid or strong base has **no acidic or basic properties**.

Conjugate of a weak acid or base is a stronger base/acid.

Conjugate of a stronger acid or base is a weaker base/acid.



Strong Acids

Acid Name	Chemical Composition
Chloric acid	$HClO_3$
Hydrobromic acid	HBr
Hydrochloric acid	HCl
Hydroiodic acid	HI
Nitric acid	HNO_3
Perchloric acid	$HClO_4$
Sulfuric acid	H_2SO_4

Strong Bases

Base Name	Chemical Composition
Lithium Hydroxide	$LiOH$
Sodium Hydroxide	$NaOH$
Potassium Hydroxide	KOH
Rubidium Hydroxide	$RbOH$
Calcium Hydroxide	$Ca(OH)_2$
Strontium Hydroxide	$Sr(OH)_2$
Barium Hydroxide	$Ba(OH)_2$

Together

1. Identify which of the following reactions is an acid-base reaction. Then identify the acid, base, conjugate acid, and conjugate base in the reaction.

   a. $3Cu_{(s)} + 2Al^{3+}{}_{(aq)} \rightarrow 2Al_{(s)} + 3Cu^{2+}{}_{(aq)}$

   b. $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O(l)$

   c. $NH_{3(g)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

   d. $Cu^{2+}{}_{(aq)} + OH^-{}_{(aq)} \rightarrow Cu(OH)_{2(s)}$

You do, We Review

2. $NO_2^-{}_{(aq)} + H_2O_{(l)} \leftrightarrow HNO_{2(aq)} + OH^-(aq)$

   a. Identify two conjugate acid-base pairs in the reaction shown above.

   b. If nitrite, NO_2^-, is a stronger base than hydrogen oxalate, $HO_2C_2O_2^-$, then which is the stronger acid, nitrous acid, HNO_2, or oxalic acid, $HO_2C_2O_2H$? Justify your answer.

Happy Halloween

Agenda

- Bellwork
- 4.9 Notes, video, practice
- Finish 4.7

Bellwork

Write down 6 of the 7 strong bases

Rust

4.9 Oxidation-Reduction (REDOX) Rxns

ENDURING UNDERSTANDING:	
TRA-2	A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.
LEARNING OBJECTIVE:	
TRA-2C	Represent a balanced redox reaction equation using half-reactions.

Redox Reactions

- **Redox is the transfer of electrons from one element to another**.
- Oxidation reaction cannot occur without reduction. One substance must gain the e^-s lost by the other substance.
- All chemical reactions, except double replacement (precipitation reactions) and neutralization reactions, are Redox reactions.
- The substance that undergoes oxidation is called the **reducing agent*** while the substance that undergoes reduction is called the **oxidizing agent***. (**not tested on the AP Exam)

LEO GER or OIL RIG

Oxidation: Oxidation occurs when an atom undergoes an **increase** in oxidation number by **losing** electrons.

$$Ca_{(s)} \rightarrow Ca^{2+} + 2e^-$$

Reduction: Reduction occurs when an atom undergoes a **decrease** in oxidation number by **gaining** electrons.

$$2e^- + I_{2(s)} \rightarrow 2I^-$$

Oxidation number Rules

a. An atom in its elemental form has an oxidation number of 0.
   1. Na, N_2, Cu, O_3 all = 0
b. Any monoatomic ion has the oxidation number equal to the charge on the ion.
   1. Fe^{3+} = +3
c. Oxygen in a compound has an oxidation number of -2 (exceptions are peroxides, $O_2{}^{2-}$ =-1).
   1. CO_2, SO_3
   2. Exception: Na_2O_2 (Na= +1 and O = -1)
d. Hydrogen in a compound has an oxidation number of +1 (exceptions are hydrides where H = -1).
   1. NH_3, HCl
   2. Exception: LiH
e. In binary compounds, the more electronegative atom is given the oxidation state of its species (ie. the common ion of its group). Fluorine is always -1.
f. Atoms in groups 1 and 2 are +1 and +2, respectively.
g. The sum of the oxidation state must be equal to the overall charge of the species.

Example Redox Reactions

Synthesis

$2\ Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$

$Na_{(s)}$ = 0 changed to Na in NaCl = +1 : Na lost an e

$Cl_{2(g)}$ = 0 changed to Cl in NaCl = −1 : Cl gained an e

Decomposition

$CaO_{(s)} \rightarrow Ca_{(s)} + O_{2(g)}$

Ca in $CaO_{(s)}$ = +2 changed to $Ca_{(s)}$ = 0 : Ca gained 2 e

O in $CaO_{(s)}$ = −2 changed to $O_{2(g)}$ = 0 : O lost 2 e

Example Redox Reactions

Single Replacement (oxidation of metals by acid and salts)

$Zn_{(s)} + HCl_{(aq)} \rightarrow H_{2\,(g)} + ZnCl_{2\,(aq)}$

$Al_{(s)} + CuCl_{2\,(aq)} \rightarrow Cu_{(s)} + AlCl_{3\,(aq)}$

Use an activity series table to determine if the reaction will occur. If the elemental metal is more reactive than the one it is replacing then a reaction will occur. The above reactions will occur, but the reverse of either will not.

Combustion of hydrocarbons:

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

The O in O_2 =0, and the O in both CO_2 and H_2O has a -2 oxidation number (reduction occurs; gain 2 e^-) The C in CH_4 = -4, while the oxidation number of C in CO_2 is +4 (oxidation occurs; lost 8e^-)

Rules for Balancing using the RedOx method (Standard method, not in an acid or base):

You already know how to balance equations using the “guess and check” method. Here is a second method for redox equations.

1. Assign Oxidation Numbers
2. Write Oxidation and Reduction half reactions.
   a. Balance Half Reactions for ATOMS
   b. Balance Half Reactions for CHARGE by adding electrons
3. Make electrons lost equal to the electrons gained by multiplying the entire half reactions
4. Put the coefficients into the reaction; then balance the remaining atoms. Do not change the coefficients for the species involved in the redox.
5. Check to make sure that the total charge is the same on both side of the equation.

Example

$$H_2O + ClO_3^- + SO_2 \rightarrow SO_4^{2-} + Cl^- + H^+$$

1. Assign Oxidation Numbers
2.

Oxidation ½ Reaction:	Balance Atoms	Balance Charge

3.

Reduction ½ Reaction:	Balance Atoms	Balance charge

Example

4. Make electrons lost equal to the electrons gained by multiplying the entire half reactions

Balanced ½ Reaction	Multiply by	New ½ Reaction

$$H_2O + ClO_3^- + 3\ SO_2 \rightarrow 3\ SO_4^{2-} + Cl^- + H^+$$

5. Balance the remaining atoms

$$3\ H_2O + ClO_3^- + 3\ SO_2 \rightarrow 3\ SO_4^{2-} + Cl^- + 6\ H^+$$

6. Check charges!

Do not write electrons in final equation.

You Do, We Review

1. Assign oxidation numbers to all atoms in the following:

    a. CO_2

    b. SF_6

    c. NO_3^-

You Do, We Review

2. Identify the elements that are oxidized and reduced in the following reaction

$$2Al_{(s)} + 3\ I_{2\ (s)} \rightarrow 2\ AlI_{3\ (s)}$$