Chemical Reactions

Types of Reactions

- There are five types of chemical reactions we will talk about:
  1. Synthesis/Formation/combination reactions
  2. Decomposition reactions
  3. Single displacement reactions
  4. Double diplacement reactions
  5. Combustion reactions
- You need to be able to identify the type of reaction and predict the product(s)

Steps to Writing Reactions

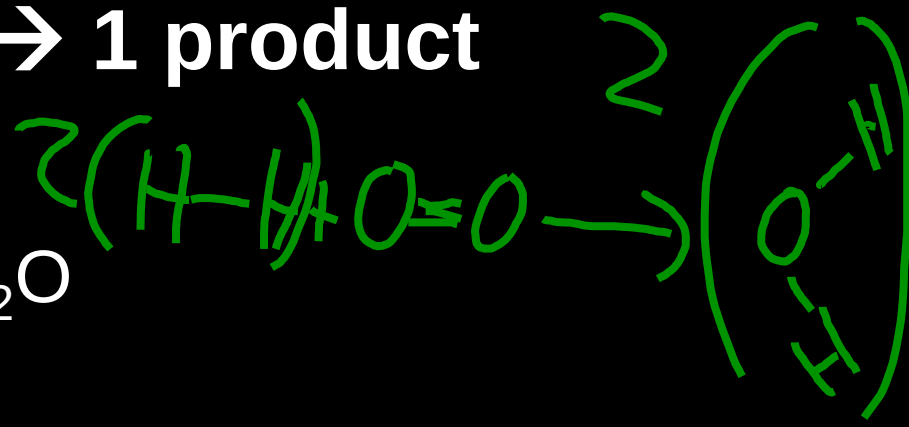
- Some steps for doing reactions
  1. Identify the type of reaction
  2. Predict the product(s) using the type of reaction as a model
  3. Balance it
- Don't forget about the diatomic elements! (H, O, F, Br, I, N, Cl) For example, Oxygen is O_2 <u>as an element.</u>
- In a compound, it can't be a diatomic element because it's not an element anymore, it's a compound!

1. Synthesis reactions

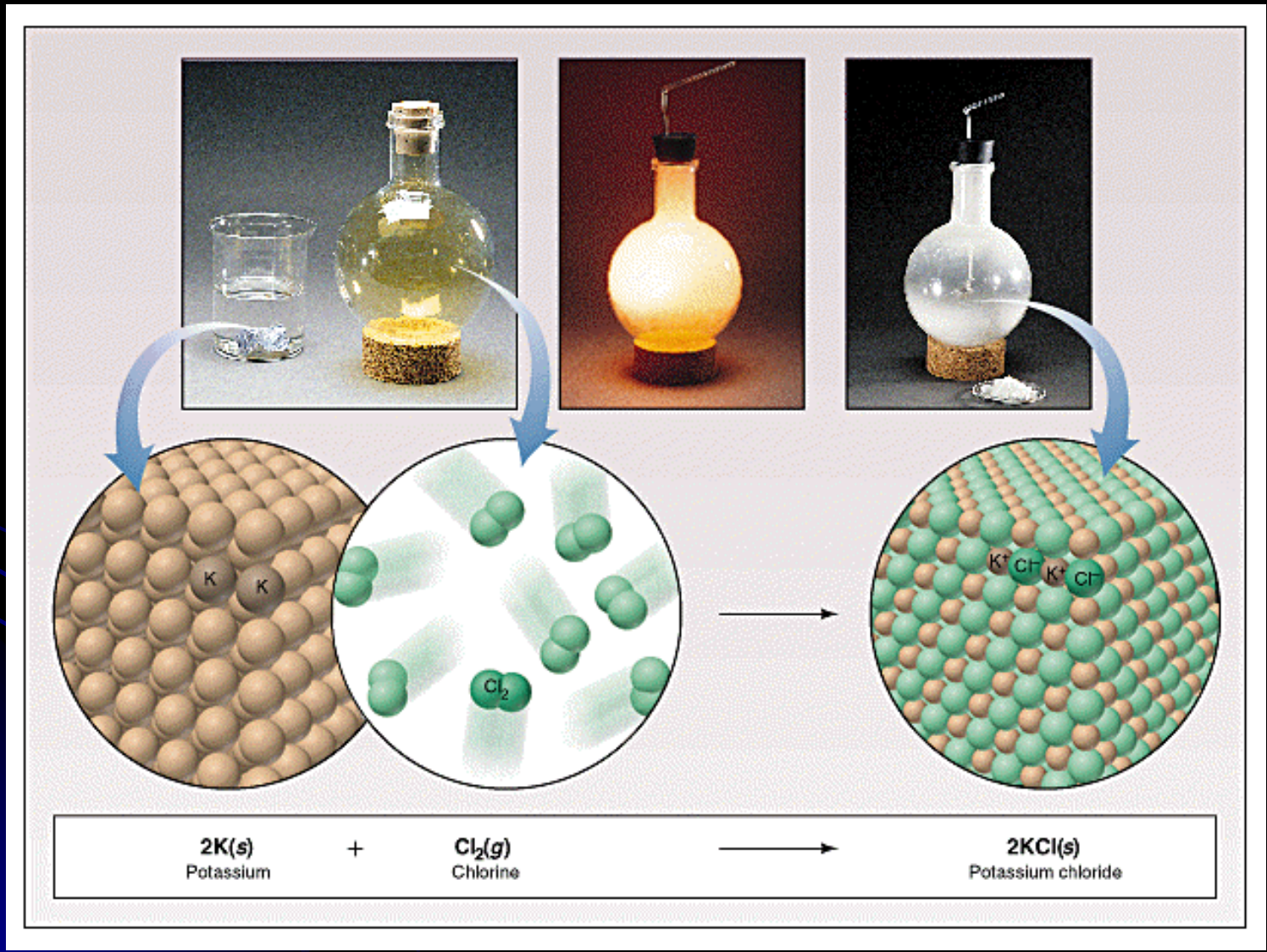
- **Synthesis reactions** occur when two substances (generally **elements**) combine and form a compound. (Sometimes these are called combination, formation or addition reactions.)

  reactant + reactant → 1 product

- Basically: A + B → AB
  - Example: $2H_2 + O_2 \rightarrow 2H_2O$
  - Example: $C + O_2 \rightarrow CO_2$



Synthesis Reaction Ex.



Practice

- Predict the products. Write and balance the following synthesis reaction equations.
- Sodium metal reacts with chlorine gas

  $2\ Na^{+}_{(s)} + Cl^{-}_{2(g)} \rightarrow 2NaCl_{(s)}$
- Solid Magnesium reacts with fluorine gas

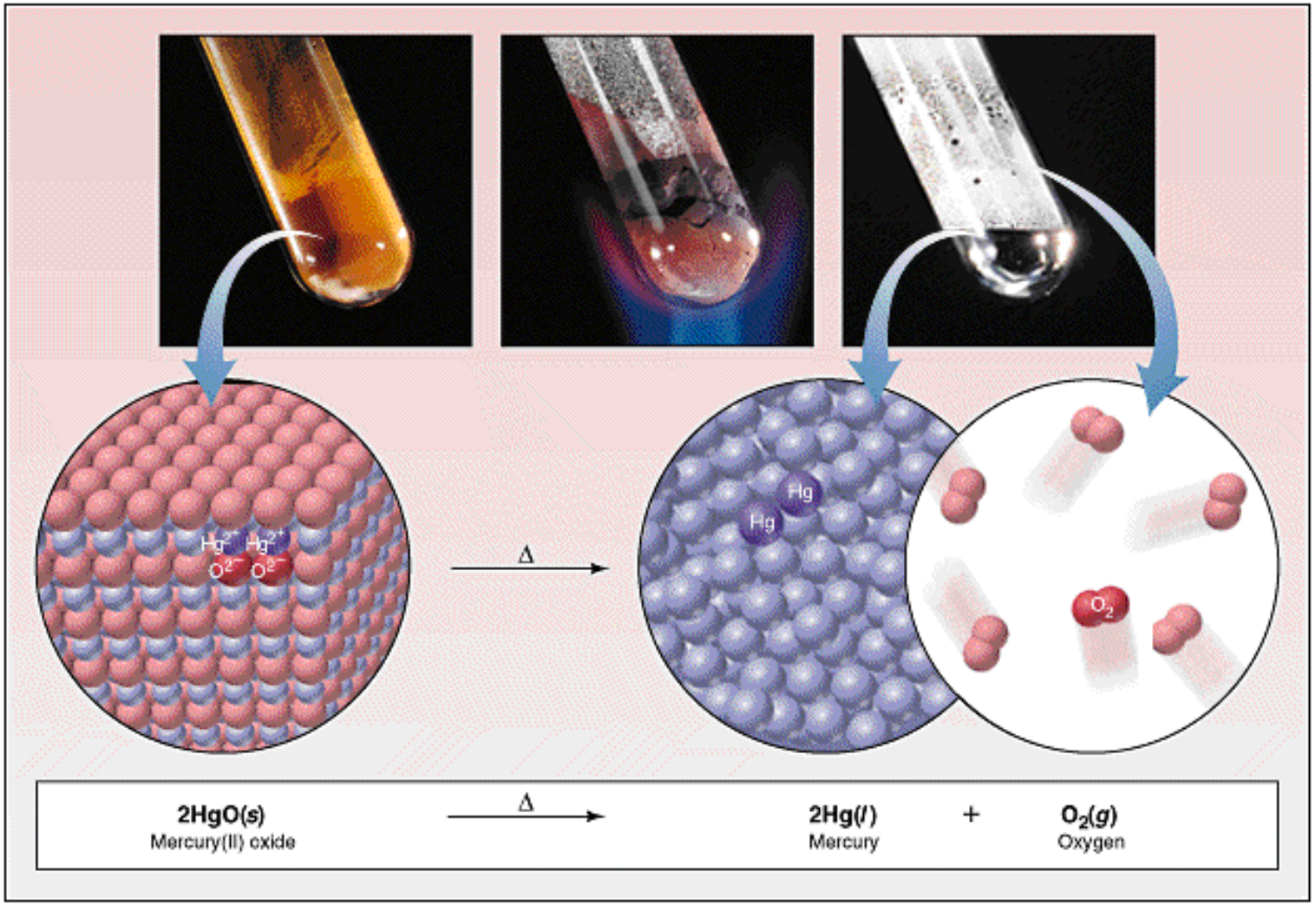
  $Mg^{2+}_{(s)} + F_{2(g)} \rightarrow MgF_{2(s)}$
- Aluminum metal reacts with fluorine gas

  $2Al_{(s)} + 3F_{2(g)} \rightarrow 2AlF_{3(s)}$

2. Decomposition Reactions

- **Decomposition reactions** occur when a compound breaks up into the elements or in a few to simpler compounds
- **1 Reactant → Product + Product**
- In general: AB → A + B
- Example: 2 H_2O → 2H_2 + O_2
- Example: 2 HgO → 2Hg + O_2

Decomposition Reaction Ex.



Decomposition Exceptions

- Carbonates and chlorates are special case decomposition reactions that do not go to the elements.
  - Carbonates (CO_3^{2-}) decompose to carbon dioxide and a metal oxide
    - Example: $CaCO_3 \rightarrow CO_2 + CaO$
  - Chlorates (ClO_3^-) decompose to oxygen gas and a metal chloride
    - Example: $2\ Al(ClO_3)_3 \rightarrow 2\ AlCl_3 + 9\ O_2$
  - There are other special cases, but we will not explore those in Chemistry I

Practice

- Predict the products. Then, write and balance the following decomposition reaction equations:
- Solid Lead (IV) oxide decomposes

$$PbO_{2(s)} \rightarrow Pb_{(s)} + O_{2(g)}$$

- Aluminum nitride decomposes

$$2AlN_{(s)} \rightarrow 2\,Al_{(s)} + N_{2(g)}$$

Practice

Identify the type of reaction for each of the following synthesis or decomposition reactions, and write the balanced equation:

$N_{2(g)} + O_{2(g)} \rightarrow 2\ NO_{(g)}$

$BaCO_{3(s)} \rightarrow BaO_{(s)} + CO_{2\ (g)}$

$2\ Co_{(s)} + 3\ S_{(s)} \rightarrow Co_2S_{3\ (s)}$

$NH_{3(g)} + H_2CO_{3(aq)} \rightarrow (NH_4)_2CO_{3(s)}$

$2\ NI_{3(s)} \rightarrow N_{2\ (g)} + 3\ I_{2\ (s)}$

3. Single Replacement Reactions

- **Single Replacement Reactions** occur when one element replaces another in a compound.
- A metal can replace a metal (+) **OR** a nonmetal can replace a nonmetal (-).
- **element + compound → product + product**

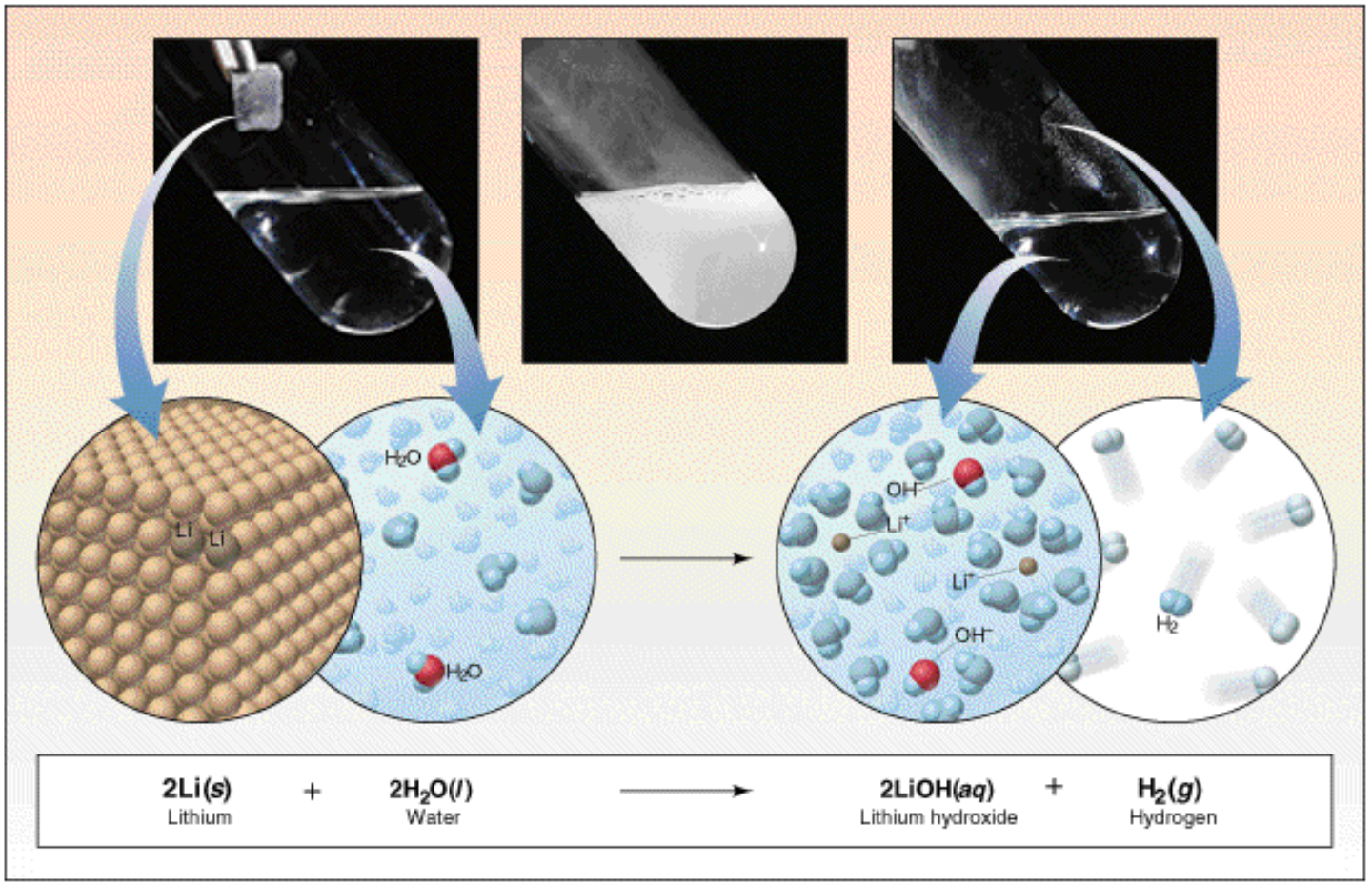
  A + BC → AC + B (if A is a metal) **OR**

  A + BC → BA + C (if A is a nonmetal)

  (remember the cation always goes first!)

When H_2O splits into ions, it splits into H^+ and OH^- (not H+ and O^{-2} !!)

Single Replacement Reaction Ex



Single Replacement Reactions

- Write and balance the following single replacement reaction equation:
- Zinc metal reacts with aqueous hydrochloric acid

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_2 + H_{2(g)}$$

Note: Zinc replaces the hydrogen ion in the reaction

Single Replacement Reactions

- Sodium chloride solid reacts with fluorine gas

$$2\,NaCl_{(s)} + F_{2(g)} \rightarrow 2\,NaF_{(s)} + Cl_{2(g)}$$

Note that fluorine replaces chlorine in the compound

- Aluminum metal reacts with aqueous copper (II) nitrate

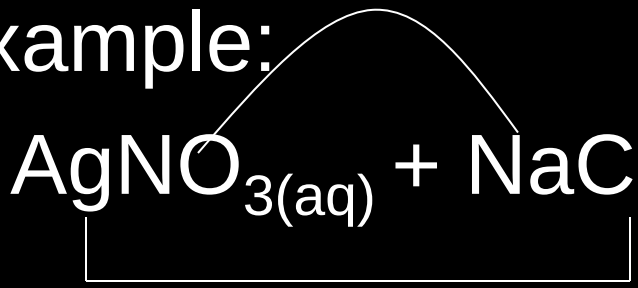
$$2\,Al_{(s)} + 3\,Cu(NO_3)_{2(aq)} \rightarrow 3\,Cu_{(s)} + 2\,Al(NO_3)_{3(aq)}$$

4. Double Replacement Reactions

- **Double Replacement Reactions** occur when a metal replaces a metal in a compound and a nonmetal replaces a nonmetal in a compound
- **Compound + compound → product + product**
- AB + CD → AD + CB

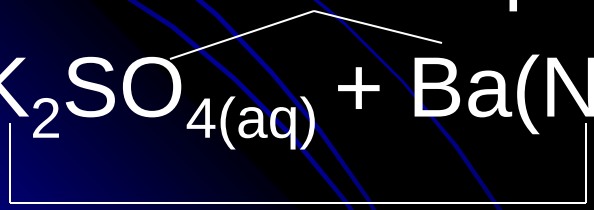
Double Replacement Reactions

- Think about it like “foil”ing in algebra, first and last ions go together + inside ions go together
- Example:



$$AgNO_{3(aq)} + NaCl_{(s)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

- Another example:



$$K_2SO_{4(aq)} + Ba(NO_3)_{2(aq)} \rightarrow 2\ KNO_{3(aq)} + BaSO_{4(s)}$$

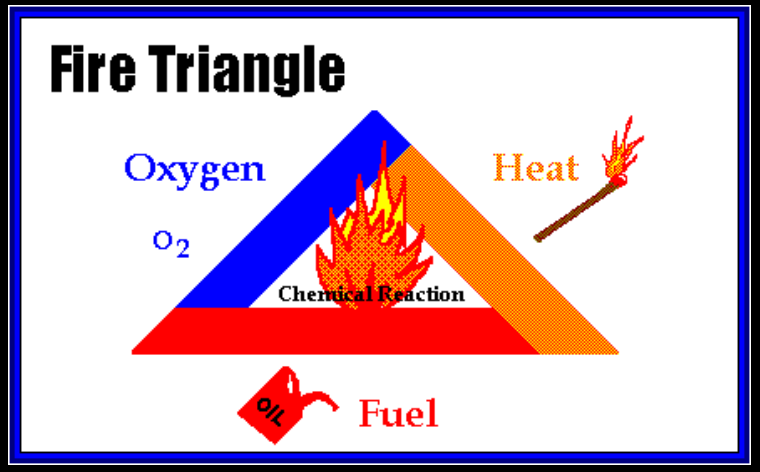
Practice

- Predict the products. Balance the equation

1. $HCl_{(aq)} + AgNO_{3(aq)} \rightarrow HNO_{3(aq)} + AgCl_{(s)}$
2. $CaCl_{2(aq)} + Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + NaCl_{(aq)}$
3. $Pb(NO_3)_{2(aq)} + BaCl_{2(aq)} \rightarrow PbCl_{2(s)} + Ba(NO_3)_{2(aq)}$
4. $FeCl_{3(aq)} + NaOH_{(aq)} \rightarrow Fe(OH)_{3(s)} + NaCl_{(aq)}$
5. $H_2SO_{4(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + Na_2SO_{4(aq)}$
6. $KOH_{(aq)} + CuSO_{4(aq)} \rightarrow K_2SO_{4(aq)} + Cu(OH)_{2(s)}$

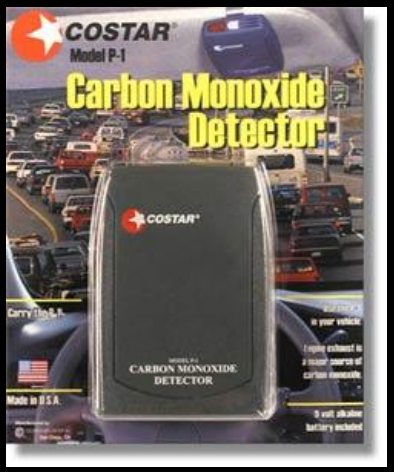
5. Combustion Reactions

- **Combustion reactions** occur when a hydrocarbon reacts with oxygen gas.
- This is also called burning!!! In order to burn something you need the 3 things in the “fire triangle”:
  1) A Fuel (hydrocarbon)
  2) Oxygen to burn it with
  3) Something to ignite the reaction (spark)



Combustion Reactions

- In general:
  $C_xH_y + O_2 \rightarrow CO_2 + H_2O$
- Products in combustion are ALWAYS carbon dioxide and water. (although incomplete burning does cause some by-products like carbon monoxide)
- Combustion is used to heat homes and run automobiles (octane, as in gasoline, is C_8H_{18})

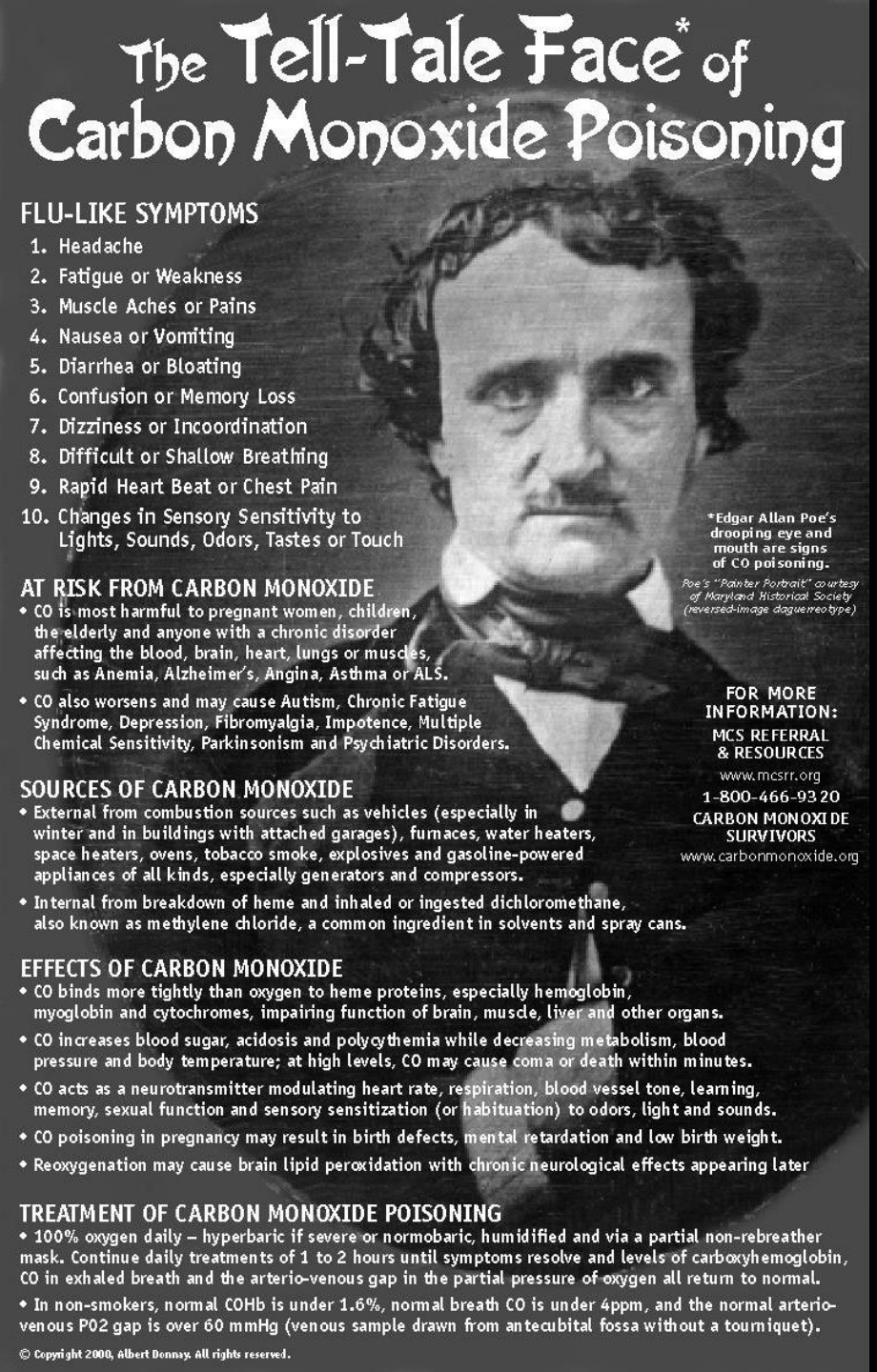


Carbon monoxide, an invisible gas, can be deadly.

The Tell-Tale Face* of Carbon Monoxide Poisoning

FLU-LIKE SYMPTOMS

1. Headache
2. Fatigue or Weakness
3. Muscle Aches or Pains
4. Nausea or Vomiting
5. Diarrhea or Bloating
6. Confusion or Memory Loss
7. Dizziness or Incoordination
8. Difficult or Shallow Breathing
9. Rapid Heart Beat or Chest Pain
10. Changes in Sensory Sensitivity to Lights, Sounds, Odors, Tastes or Touch



*Edgar Allan Poe's drooping eye and mouth are signs of CO poisoning.

Poe's "Painter Portrait" courtesy of Maryland Historical Society (reversed-image daguerreotype)

AT RISK FROM CARBON MONOXIDE

- CO is most harmful to pregnant women, children, the elderly and anyone with a chronic disorder affecting the blood, brain, heart, lungs or muscles, such as Anemia, Alzheimer's, Angina, Asthma or ALS.
- CO also worsens and may cause Autism, Chronic Fatigue Syndrome, Depression, Fibromyalgia, Impotence, Multiple Chemical Sensitivity, Parkinsonism and Psychiatric Disorders.

FOR MORE INFORMATION:
MCS REFERRAL & RESOURCES
www.mcsrr.org
1-800-466-9320
CARBON MONOXIDE SURVIVORS
www.carbonmonoxide.org

SOURCES OF CARBON MONOXIDE

- External from combustion sources such as vehicles (especially in winter and in buildings with attached garages), furnaces, water heaters, space heaters, ovens, tobacco smoke, explosives and gasoline-powered appliances of all kinds, especially generators and compressors.
- Internal from breakdown of heme and inhaled or ingested dichloromethane, also known as methylene chloride, a common ingredient in solvents and spray cans.

EFFECTS OF CARBON MONOXIDE

- CO binds more tightly than oxygen to heme proteins, especially hemoglobin, myoglobin and cytochromes, impairing function of brain, muscle, liver and other organs.
- CO increases blood sugar, acidosis and polycythemia while decreasing metabolism, blood pressure and body temperature; at high levels, CO may cause coma or death within minutes.
- CO acts as a neurotransmitter modulating heart rate, respiration, blood vessel tone, learning, memory, sexual function and sensory sensitization (or habituation) to odors, light and sounds.
- CO poisoning in pregnancy may result in birth defects, mental retardation and low birth weight.
- Reoxygenation may cause brain lipid peroxidation with chronic neurological effects appearing later

TREATMENT OF CARBON MONOXIDE POISONING

- 100% oxygen daily – hyperbaric if severe or normobaric, humidified and via a partial non-rebreather mask. Continue daily treatments of 1 to 2 hours until symptoms resolve and levels of carboxyhemoglobin, CO in exhaled breath and the arterio-venous gap in the partial pressure of oxygen all return to normal.
- In non-smokers, normal COHb is under 1.6%, normal breath CO is under 4ppm, and the normal arterio-venous P02 gap is over 60 mmHg (venous sample drawn from antecubital fossa without a tourniquet).

Combustion Reactions

Edgar Allen Poe's drooping eyes and mouth are potential signs of CO poisoning.

Combustion

- Example
  - $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$
- Write the products and balance the following combustion reaction:
  - $2C_{10}H_{22} + 31O_2 \rightarrow 20CO_2 + 22H_2O$

Mixed Practice

- State the type, predict the products, and balance the following reactions:

1. $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$
2. $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$
3. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
4. $Cs + Br_2 \rightarrow CsBr$
5. $FeCO_3 \rightarrow FeO + CO_2$

Total Ionic Equations

- Once you write the molecular equation (synthesis, decomposition, etc.), you should check for reactants and products that are soluble or insoluble.
- We usually assume the reaction is in water
- We can use a solubility table to tell us what compounds dissolve in water.
- If the compound is soluble (does dissolve in water), then splits the compound into its component ions
- If the compound is insoluble (does NOT dissolve in water), then it remains as a compound

Total Ionic Equations

Molecular Equation:

$K_2CrO_4 + Pb(NO_3)_2 \rightarrow PbCrO_4 + 2\ KNO_3$

Soluble Soluble Insoluble Soluble

Total Ionic Equation:

$2\ K^+ + CrO_4^{-2} + Pb^{+2} + 2\ NO_3^- \rightarrow$

$PbCrO_4\ (s) + 2\ K^+ + 2\ NO_3^-$

Net Ionic Equations

- These are the same as total ionic equations, but you should cancel out ions that appear on BOTH sides of the equation

Total Ionic Equation:

$2\ K^{+} + CrO_4^{-2} + Pb^{+2} + 2\ NO_3^{-} \rightarrow PbCrO_4\ (s) + 2\ K^{+} + 2\ NO_3^{-}$

Net Ionic Equation:

$CrO_4^{-2} + Pb^{+2} \rightarrow PbCrO_4\ (s)$

Net Ionic Equations

- Try this one! Write the molecular, total ionic, and net ionic equations for this reaction: Silver nitrate reacts with Lead (II) Chloride in hot water.

$AgNO_3 + PbCl_2 \rightarrow$

Molecular:

$2\ AgNO_3 + PbCl_2 \rightarrow 2\ AgCl + Pb(NO_3)_2$

Total Ionic:

$2\ Ag^+ + 2\ NO_3^- + Pb^{+2} + 2\ Cl^- \rightarrow 2\ AgCl\ (s) + Pb^{+2} + 2\ NO_3^-$

Net Ionic:

$Ag^+ + Cl^- \rightarrow AgCl\ (s)$