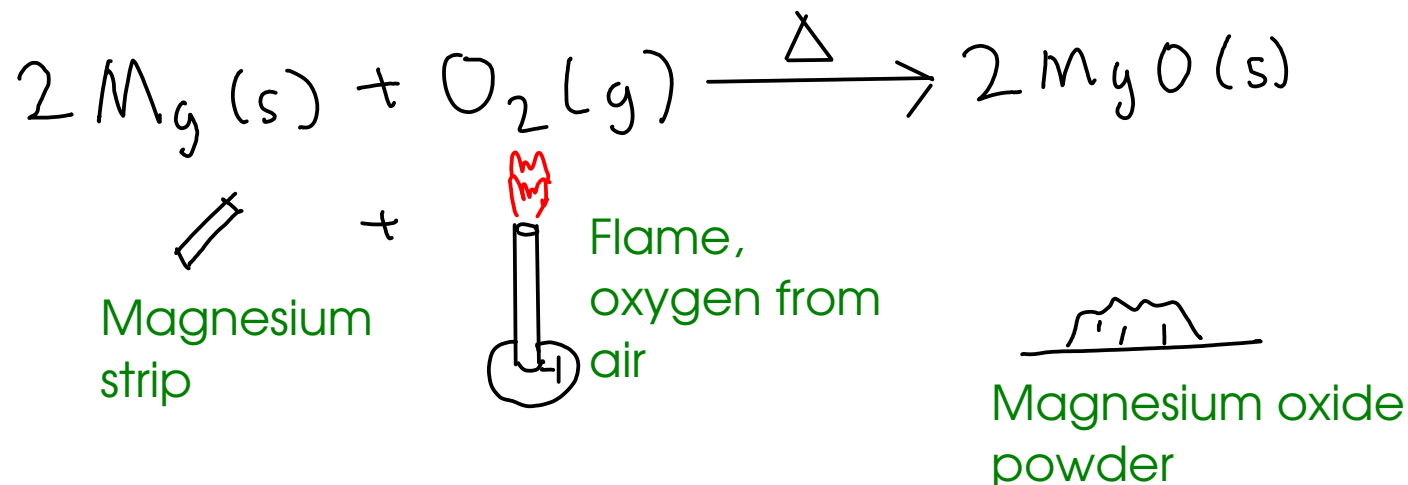


## CONCEPT OF LIMITING REACTANT

- When does a chemical reaction STOP?



- When does this reaction stop? When burned in open air, this reaction stops when all the MAGNESIUM STRIP is gone. We say that the magnesium is LIMITING.

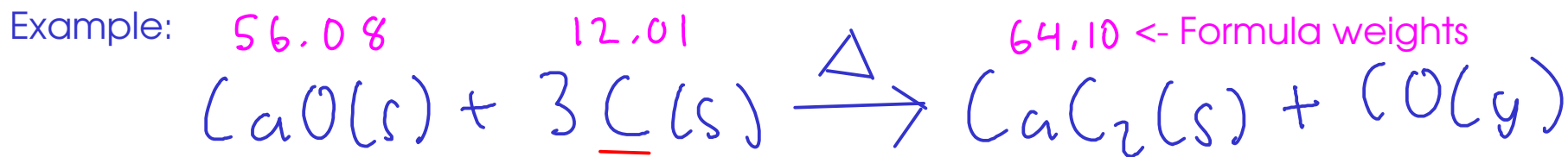
- This reaction is controlled by the amount of available magnesium

- At the end of a chemical reaction, the LIMITING REACTANT will be completely consumed but there may be amount of OTHER reactants remaining. We do chemical calculations in part to minimize these "leftovers".

These are often called "excess" reactants, or reactants present "in excess"

## LIMITING REACTANT CALCULATIONS

- To find the limiting reactant, calculate how much product would be produced from ALL given reactants. Whichever produces the SMALLEST amount of product is the limiting reactant, and the smallest amount of product is the actual amount of product produced.



If you start with 100. g of each reactant, how much calcium carbide would be produced?

---


$$\text{CaO: } 56.08 \text{ g CaO} = \text{mol CaO} \quad | \quad \text{mol CaO} = \text{mol CaC}_2 \quad | \quad 64.10 \text{ g CaC}_2 = \text{mol CaC}_2$$

$$100. \text{ g CaO} \times \frac{\text{mol CaO}}{56.08 \text{ g CaO}} \times \frac{\text{mol CaC}_2}{\text{mol CaO}} \times \frac{64.10 \text{ g CaC}_2}{\text{mol CaC}_2} = 114 \text{ g CaC}_2$$

---


$$\text{C: } 12.01 \text{ g C} = \text{mol C} \quad | \quad 3 \text{ mol C} = \text{mol CaC}_2 \quad | \quad 64.10 \text{ g CaC}_2 = \text{mol CaC}_2$$

$$100. \text{ g C} \times \frac{\text{mol C}}{12.01 \text{ g C}} \times \frac{\text{mol CaC}_2}{3 \text{ mol C}} \times \frac{64.10 \text{ g CaC}_2}{\text{mol CaC}_2} = 178 \text{ g CaC}_2$$

114 grams of calcium carbide can be produced by this reaction. At that point, all of the CaO has been consumed and the reaction must stop - since there's nothing left for the C to react with! We say that CaO is LIMITING, and C is present IN EXCESS.

## PERCENT YIELD

- Chemical reactions do not always go to completion! Things may happen that prevent the conversion of reactants to the desired/expected product!

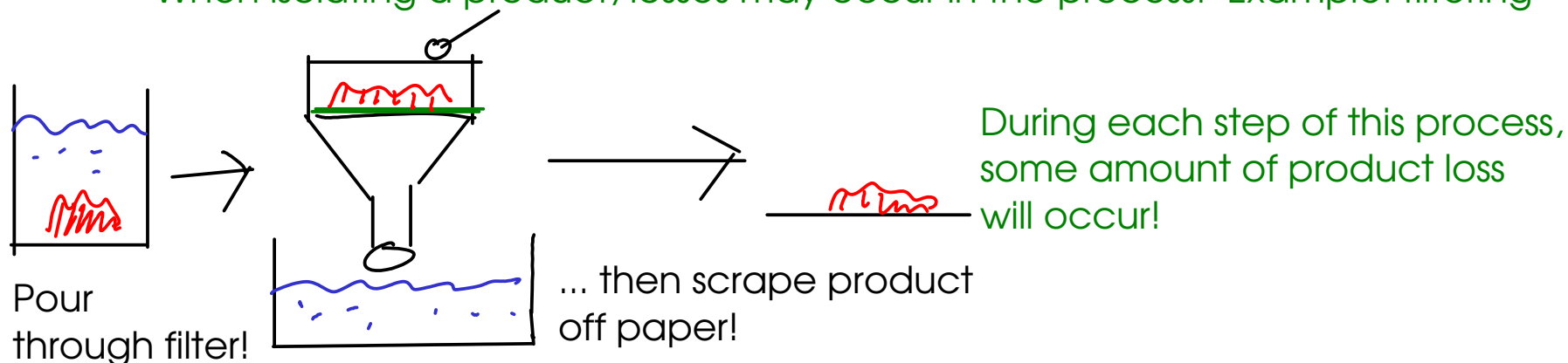
### ① SIDE REACTIONS:



... so in a low-oxygen environment, you may produce less carbon dioxide than expected!

### ② TRANSFER AND OTHER LOSSES

- When isolating a product, losses may occur in the process. Example: filtering



### ③ EQUILIBRIUM

- Reactions may reach an equilibrium between products and reactants. We'll talk more about this in CHM 111. The net result is that the reaction will appear to stop before all reactants have been consumed!

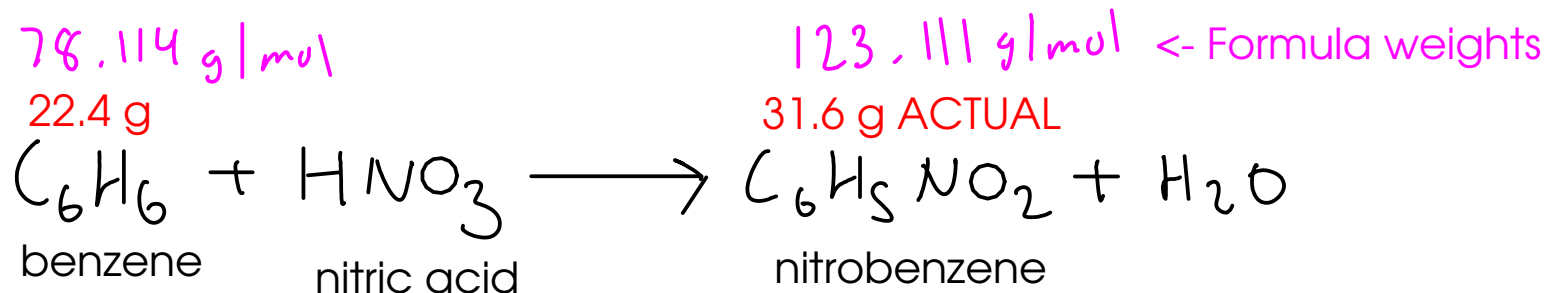
- All of these factors cause a chemical reaction to produce LESS product than calculated. For many reactions, this difference isn't significant. But for others, we need to report the PERCENT YIELD.

$$\text{PERCENT YIELD} = \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}} \times 100\%$$

↙ Determined EXPERIMENTALLY!

↑ Calculated based on the limiting reactant. (The chemical calculations you've done up to now have been theoretical yields!)

... the percent yield of a reaction can never be greater than 100% due to conservation of mass! If you determine that a percent yield is greater than 100%, then you've made a mistake somewhere - either in a calculation or in the experiment itself!



22.4 grams of benzene are reacted with excess nitric acid. If 31.6 grams of nitrobenzene are collected from the reaction, what is the percent yield?

To calculate percent yield, we need to know both the THEORETICAL YIELD and the ACTUAL YIELD. The ACTUAL YIELD is given already (31.6 g nitrobenzene). We need to calculate THEORETICAL YIELD based on the amount of starting material (22.4 g benzene).

$$78.114 \text{ g C}_6\text{H}_6 = \text{mol C}_6\text{H}_6 \quad | \quad \text{mol C}_6\text{H}_6 = \text{mol C}_6\text{H}_5\text{NO}_2 \quad | \quad 123.111 \text{ g C}_6\text{H}_5\text{NO}_2 = \text{mol C}_6\text{H}_5\text{NO}_2$$

$$\begin{aligned}
 22.4 \text{ g C}_6\text{H}_6 & \times \frac{\text{mol C}_6\text{H}_6}{78.114 \text{ g C}_6\text{H}_6} \times \frac{\text{mol C}_6\text{H}_5\text{NO}_2}{\text{mol C}_6\text{H}_6} \times \frac{123.111 \text{ g C}_6\text{H}_5\text{NO}_2}{\text{mol C}_6\text{H}_5\text{NO}_2} = \\
 & = 35.3 \text{ g C}_6\text{H}_5\text{NO}_2
 \end{aligned}$$

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theor. yield}} \times 100\% = \frac{31.6 \text{ g}}{35.3 \text{ g}} \times 100\% = \boxed{89.5\%}$$

## Electrolytes and Ionic Theory

- electrolytes: substances that dissolve in water to form charge-carrying solutions

\* Electrolytes form ions in solution - (ions that are mobile are able to carry charge!). These IONS can interact with one another and undergo certain kinds of chemistry!

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### IONIC THEORY

- the idea that certain compounds DISSOCIATE in water to form free IONS

### Strong vs weak?

- If an electrolyte COMPLETELY IONIZES in water, it's said to be STRONG

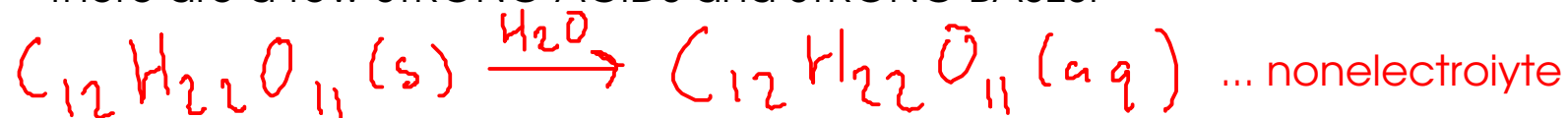
- If an electrolyte only PARTIALLY IONIZES in water, it's said to be WEAK

- Both kinds of electrolyte undergo similar kinds of chemistry.

What kinds of compounds are electrolytes?

### MOLECULAR COMPOUNDS

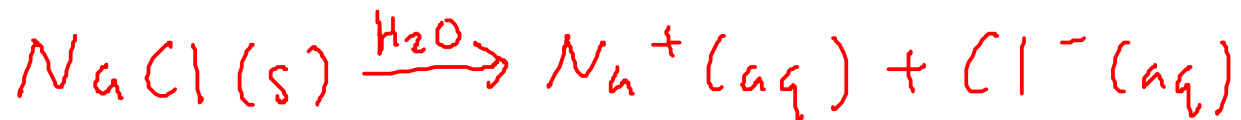
- Most molecular compounds are NONELECTROLYTES - they don't ionize in water
- ACIDS and BASES will ionize in water. Most of these are WEAK ELECTROLYTES, but there are a few STRONG ACIDS and STRONG BASES.



... acetic acid (electrolyte)

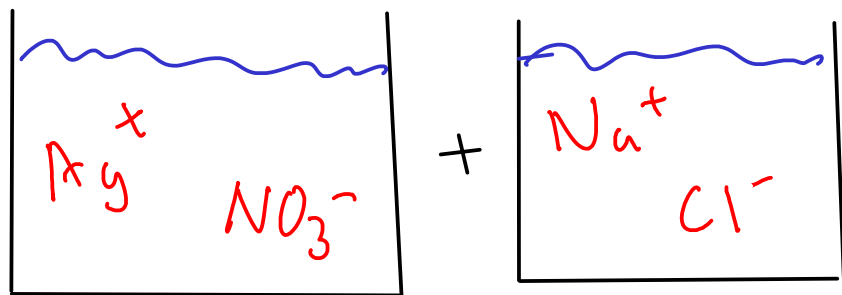
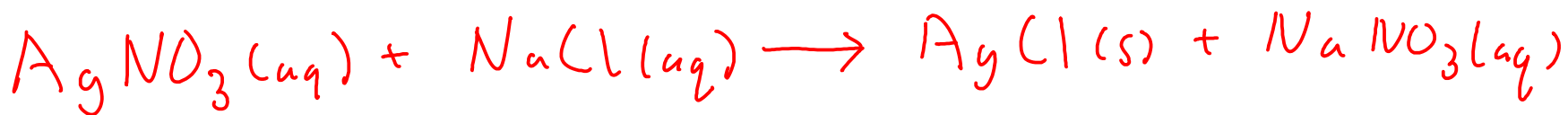
### IONIC COMPOUNDS

- SOLUBLE ionic compounds are STRONG ELECTROLYTES - they completely ionize in water.
- Not all ionic compounds are water soluble, however!

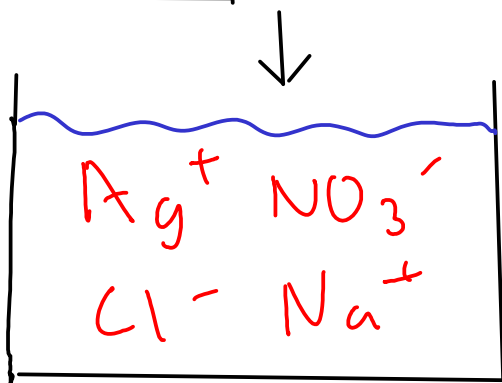


112 - What good is ionic theory?

- provides an easy-to-understand MECHANISM for certain kinds of chemical reactions.
  - "Exchange" reactions. (a.k.a "double replacement" reactions)



These free ions mix and can interact with each other!



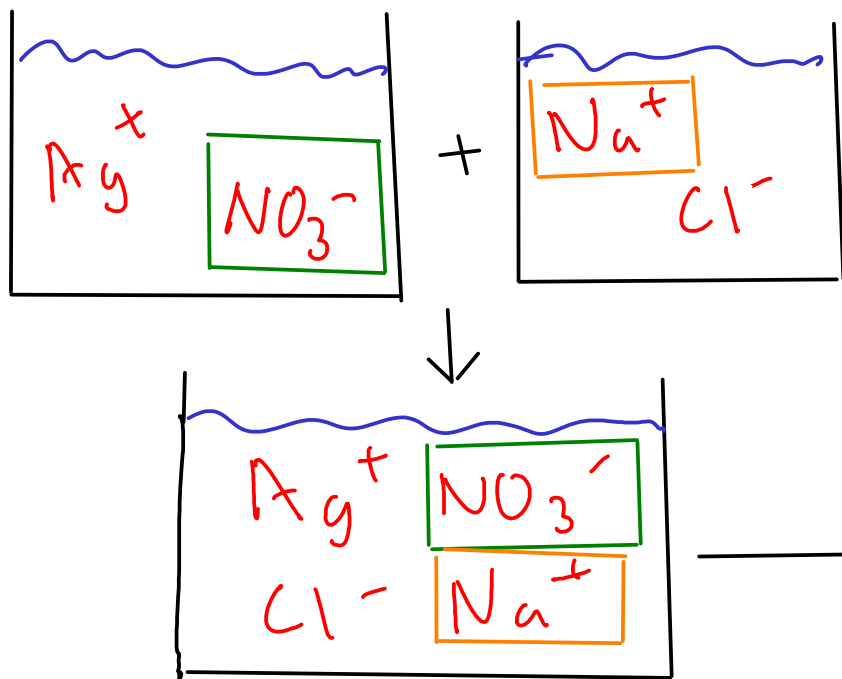
"ion soup"!



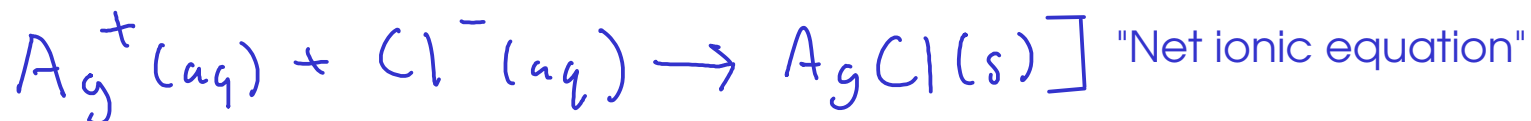
Insoluble  $\text{AgCl}$  falls out of solution as it is formed - "precipitation"



Looking a bit more closely...



The nitrate and sodium ions do not really participate in this reaction. They start and end in exactly the same state. We call them "SPECTATOR IONS".



(The net ionic equation shows only ions and substances that change during the course of the reaction!)

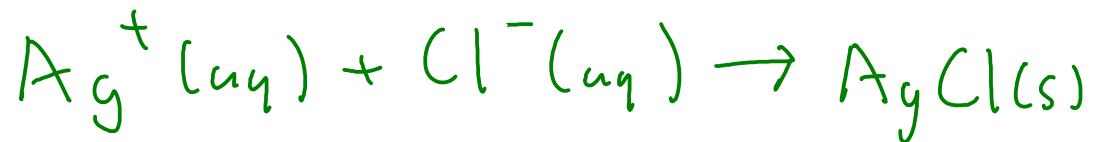
- The net ionic equation tells us that any source of aqueous silver and chloride ions will exhibit this same chemistry, not just silver nitrate and sodium chloride!

## 114 A bit more about molecular, ionic, and net ionic equations

- molecular equations: Represent all substances (even ionic substances) as if they were molecules. Include spectator ions, and do not show charges on ions. Traditional chemical equations.

- ionic equations: Show all free ions - including spectators - in a chemical reaction. Molecules and WEAK electrolytes are shown as molecules. STRONG electrolytes (like HCl) are shown as ions. Ions that are part of undissolved ionic compounds are shown as molecules.

- NET ionic equation: An ionic equation that leaves out spectator ions. Intended to show only things that actually change in a reaction.



\* You can get from the complete ionic equation to the net ionic equation by crossing out the spectator ions on both sides.

## "Undissolved ionic compounds":

How can I tell if an ionic compound dissolves in water?

- consult experimental data: "solubility rules"!

A few of the "rules"...

- Compounds that contain a Group IA cation (or ammonium) are soluble
- Nitrates and acetates are soluble
- Carbonates, phosphates, and hydroxides tend to be insoluble

See p 129 9<sup>th</sup> edition (10<sup>th</sup> ed: p131)

... or see the web site for a solubility chart.



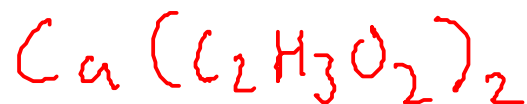
#8 - hydroxides generally insoluble, except Group IA, ammonium, calcium, strontium, barium

Conclusion: iron(III) hydroxide is insoluble.



#3 - Iodides usually dissolve, exceptions are silver, mercury, lead

Conclusion: silver(I) iodide is INSOLUBLE



#2 - acetates are soluble, no common exceptions.

Conclusion: calcium acetate is soluble.



#5 - Most carbonates are insoluble

Conclusion - barium carbonate is insoluble.

## Exchange Chemistry

- Three kinds of exchange chemistry.

① PRECIPITATION

← Formation of IONIC SOLID

② ACID/BASE or NEUTRALIZATION

③ GAS FORMATION (formation of unstable molecules)

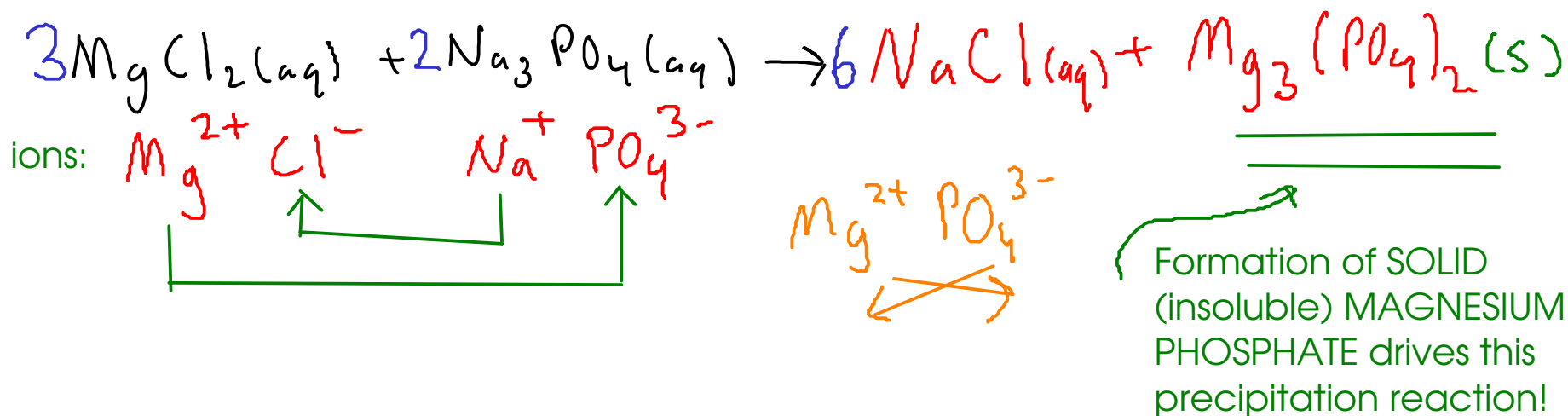
↪ SOME (but not all) reactions that form gases  
are examples of exchange chemistry.

Formation of  
MOLECULES!

Just because you mix together two ionic compounds does NOT mean that a reaction will occur. You need a DRIVING FORCE for a reaction.

## PRECIPITATION REACTIONS

- driving force is the formation of an insoluble ionic compound.



When you're trying to complete a precipitation reaction:

- ① Write the IONS that form when the reactants are dissolved.
- ② Make NEW compounds by pairing up cations with anions. Don't forget that the positive and negative charges must balance each other out!
- ③ Use the solubility rules to determine the PHASE of each new compound - solid or aqueous.
- ④ Balance the overall equation.