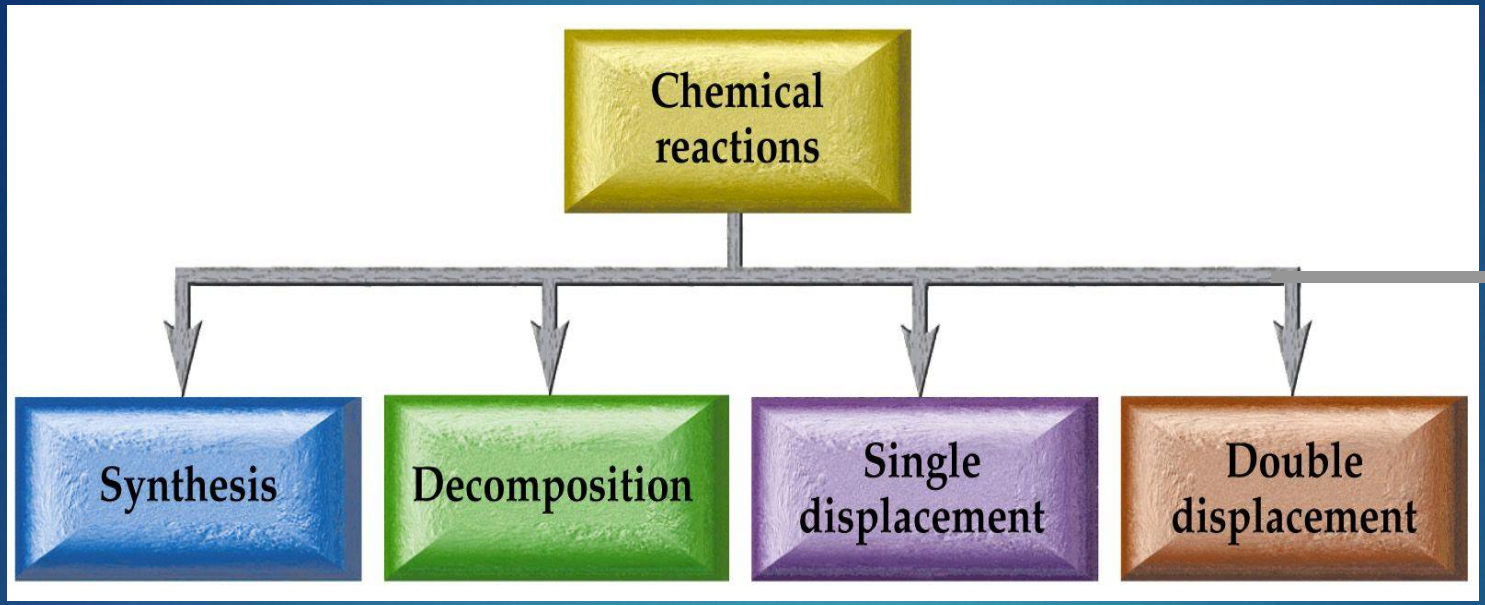
Chemical Reaction Types

Single replacement and Double replacement

Mr. Shields Regents Chemistry L11 L06

Reaction Types



Combustion

A+BC→AB+C

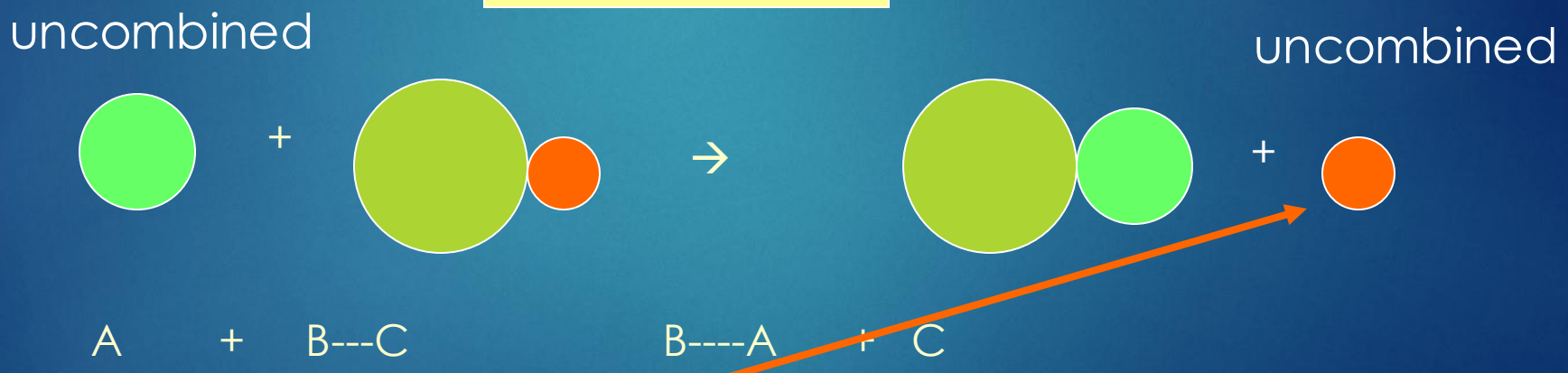
AX+BY→AY+BX

We've discussed Synthesis, Decomposition and Combustion.
Let's now look at Single and Double Replacement reactions.

Single Replacement

In a single replacement reaction an UNCOMBINED Element replaces one of the elements in a compound.

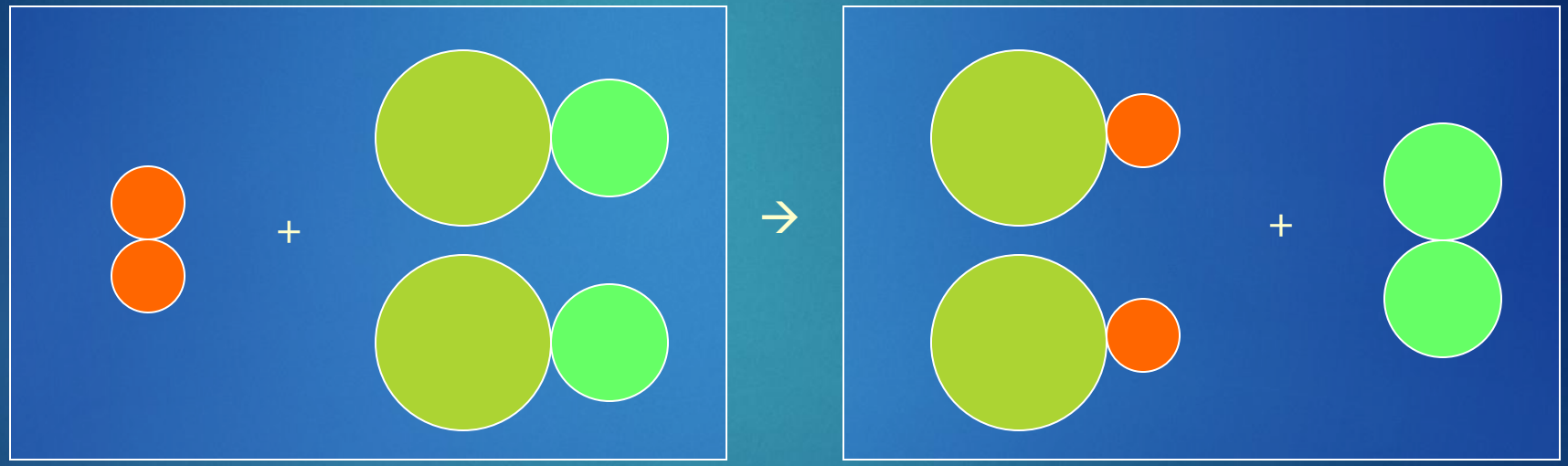
A+BC→AB+C



A replaces **C** and **C** becomes the uncombined element

Single Replacement

Typically the compounds involved in single replacement Reactions are ionic and occur in solution. For example…



Example:

Cl_2 + 2NaBr (aq) → 2NaCl (aq) + Br_2

Single Replacement

The reaction of Chlorine to replace Bromine is an example Of a NON-METAL REPLACING A NON-METAL

Cl_2 + 2NaBr (aq) → 2NaCl (aq) + Br_2

There are also single replacement reactions in which a METAL REPLACES ANOTHER METAL.

$2AgNO_3$ (aq) + Cu → $Cu(NO_3)_2$ (aq) + 2Ag

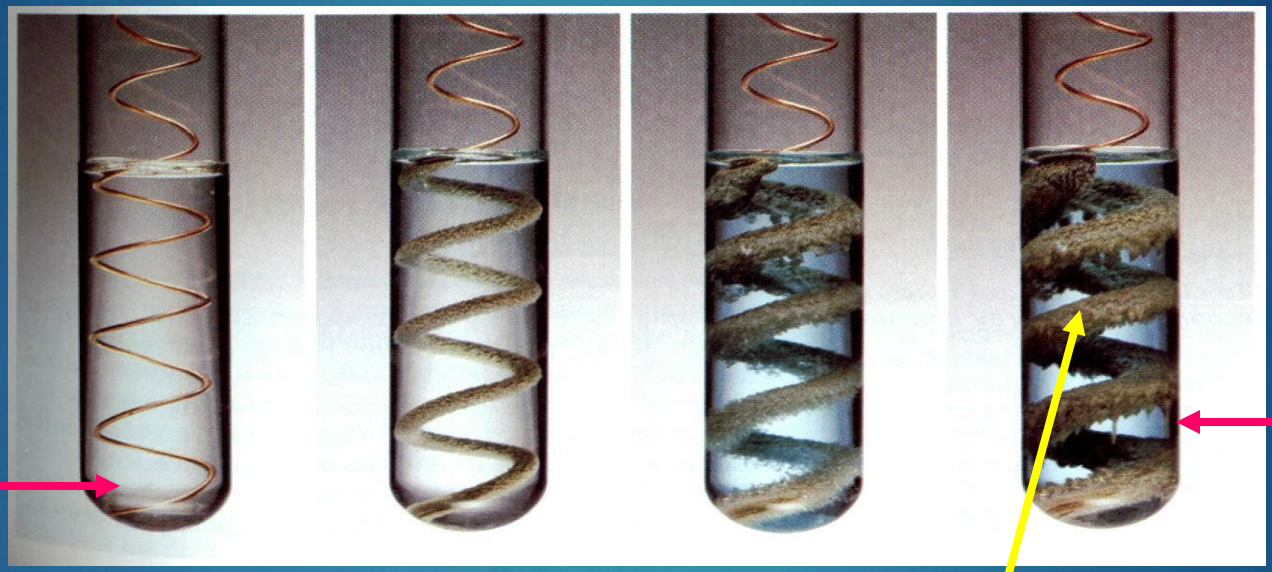
-In single replacement reactions:

- Metals will only replace metals
- Non-metals will only replace non-metals

Single Replacement

Let's look at what's happening in this reaction…

Clear $AgNO_3$ sol'n & Solid Cu Wire



Blue $Cu(NO_3)_2$ Sol'n & Solid Ag

$2AgNO_3\ (aq) + Cu\ (s) \rightarrow Cu(NO_3)_2\ (aq) + 2Ag\ (s)$

The silver in this reaction "precipitates" out of the solution

Single Replacement

In single replacement reactions:

- Metals replace metals

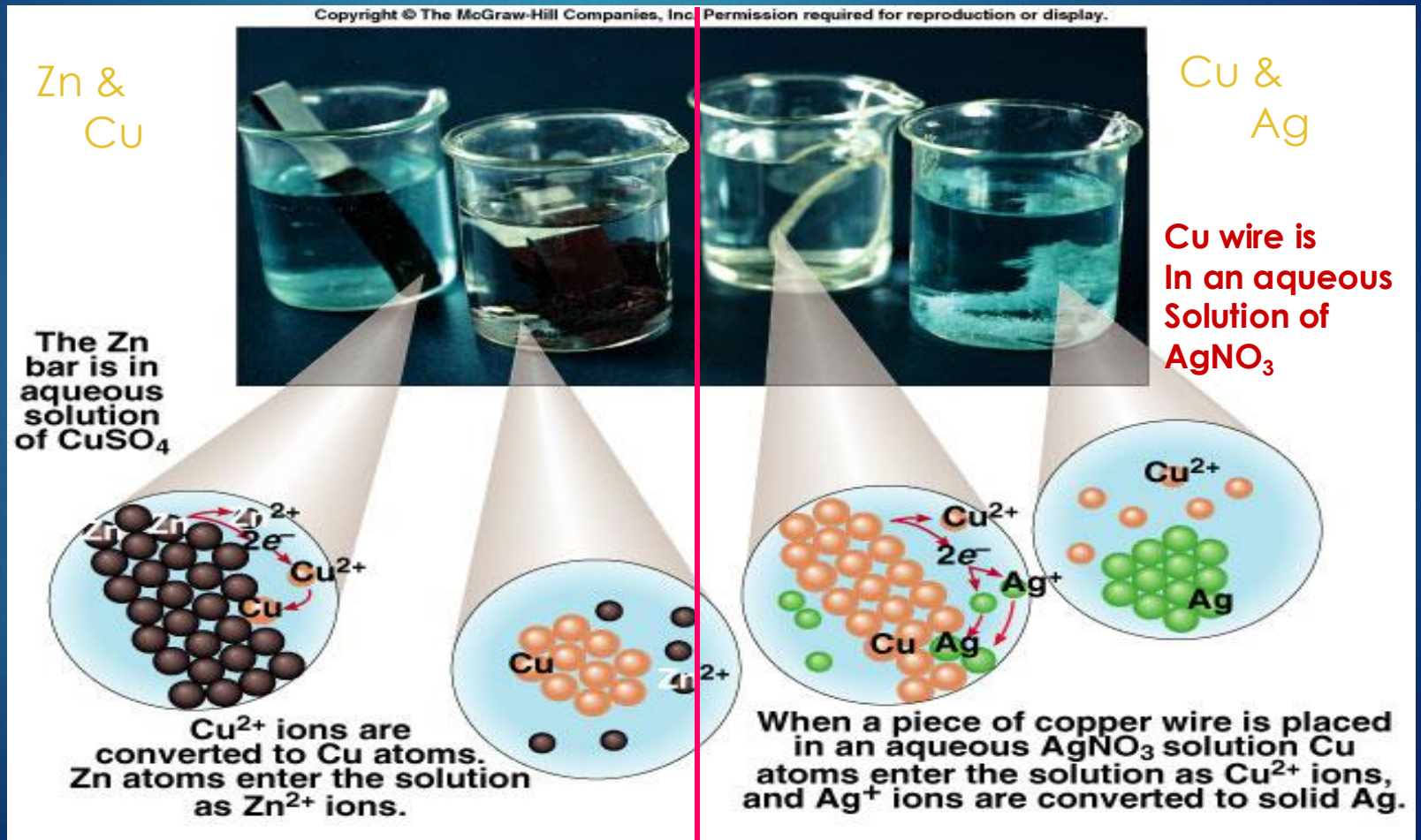
K Al Fe Cu

- Halogen Non-metals replace halogen non-metals

F_2 Cl_2 Br_2 I_2

We saw Copper can replace Ag but there are other Metals that will replace metals as well. For example Zinc will replace Cu in ionic compounds.

$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$



Activity Series

We know certain metals will replace other metals
And certain Non-metals will replace other non-metals.

But how can we determine which will replace which?

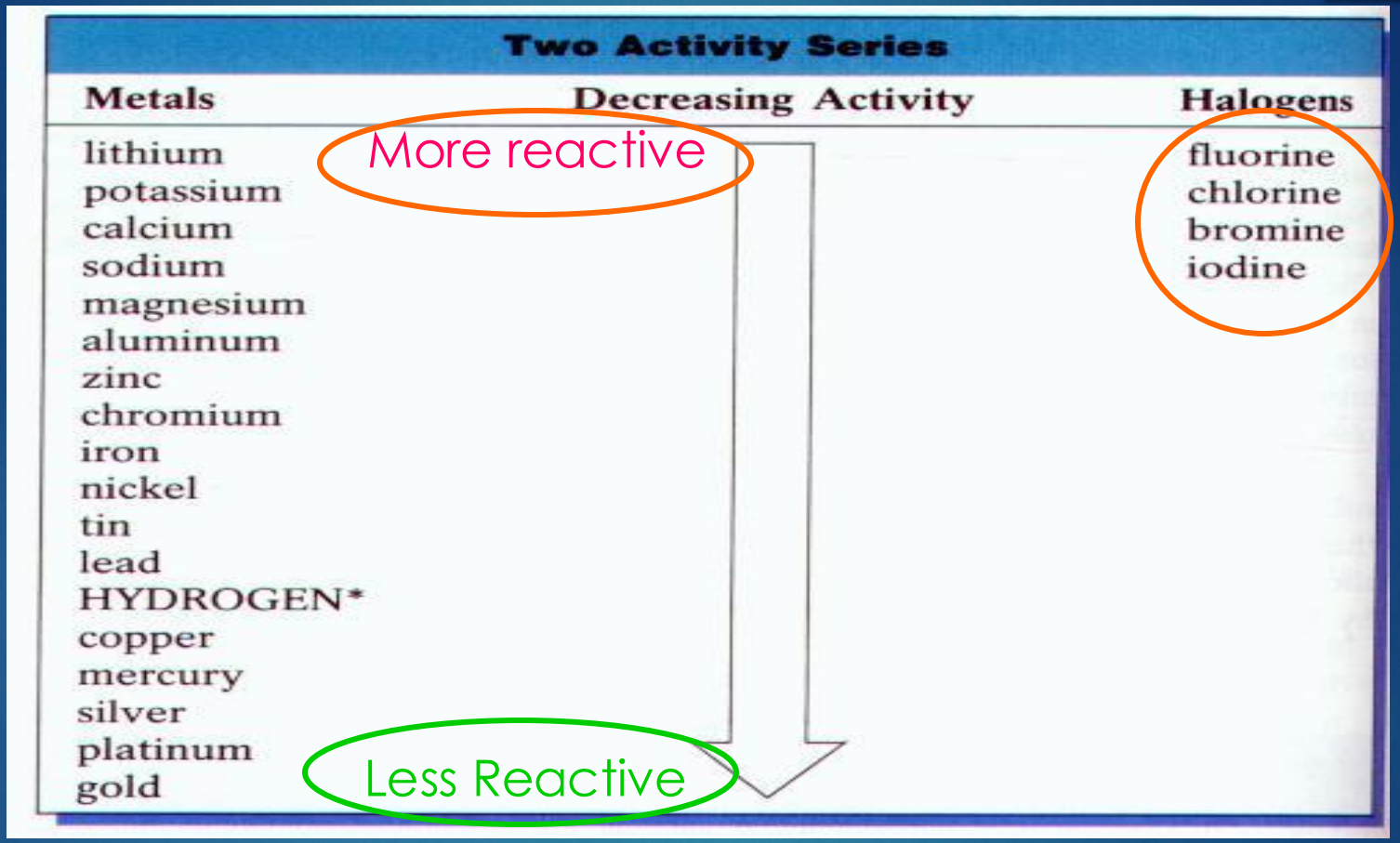
To make this determination you need to refer to

TABLE J

in your reference tables.

TABLE J IS KNOWN AS THE ACTIVITY SERIES

In the activity series the element higher on the list will Replace from a compound any element lower on the list.



For example: $Al\ (s) + Cr(NO_3)_3\ (aq) \rightarrow Al(NO_3)_3\ (aq) + Cr\ (s)$

or $3Cl_2\ (g) + 2AlI_3\ (aq) \rightarrow 2AlCl_3\ (aq) + 3I_2\ (s)$

So, how do you use it?

$$Fe_{(s)} + PbSO_{4\,(aq)} \rightarrow Pb_{(s)} + FeSO_{4(aq)}$$

Sodium	Na
Magnesium	Mg
Aluminum	Al
Zinc	Zn
Chromium	Cr
Iron	Fe
Cadmium	Cd
Cobalt	Co
Nickel	Ni
Tin	Sn
Lead	Pb

displaces H_2 gas fro

Fe is HIGHER so it can push Pb out of the way

So, how do you use it?

$Fe_{(s)} + NaNO_{3(aq)} \rightarrow NR$

Activity Series of Metals

Metal	Symbol	Reactivity
Lithium	Li	displaces H_2 gas from water,
Potassium	K	
Strontium	Sr	
Calcium	Ca	
Sodium	Na	
Magnesium	Mg	displ
Aluminum	Al	
Zinc	Zn	
Chromium	Cr	
Iron	Fe	displa nly and forms hydroxides
Cadmium	Cd	

Fe is LOWER so it can't push Na out of the way

The activity series also lists Hydrogen with the metals. Any Metal higher on the list than hydrogen will replace it from Either water or acid.

$2K + 2H_20 \rightarrow 2KOH + H_2$

$Ni + 2HCl \rightarrow NiCl_2 + H_2$

Replacing hydrogen from water is more difficult than Replacing hydrogen from acids. But, those metals higher Up the activity series will react with water more easily.

If the uncombined metal is below the combined metal (or hydrogen) it will not replace it from the compound and the reaction will NOT OCCUR !!

Try these

Will these reactions proceed as indicated?

1) $3Mg + 2Fe(NO_3)_3 \rightarrow 3Mg(NO_3)_2 + 2Fe$ — Yes

2) $Pb + Co(NO_3)_2 \rightarrow Pb(NO_3)_2 + Co$ — No

3) $Br_2 + 2KCl \rightarrow 2KBr + Cl_2$ — No

4) $2Au + 6HCl \rightarrow 2AuCl_3 + 3H_2$ — No

5) $Zn + 2HNO_3 \rightarrow Zn(NO_3)_2 + H_2$ — Yes

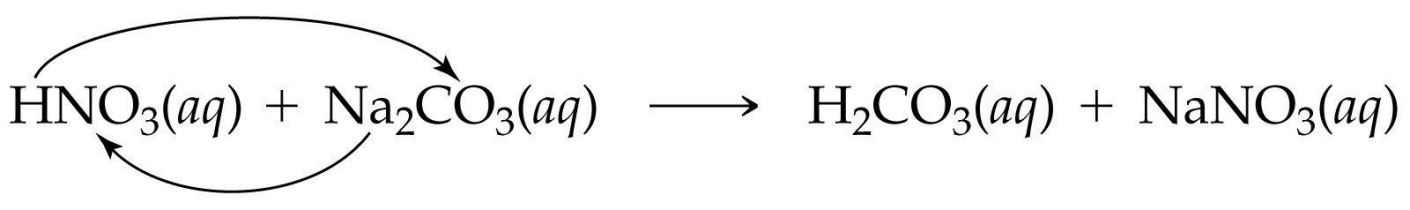
Notice in all these reactions a new compound and a free Element are formed

Double Replacement Reactions

As with single replacement reactions Double replacement Reactions take place with ionic compounds in solution.

In this case however, both reactants are compounds.

For example …

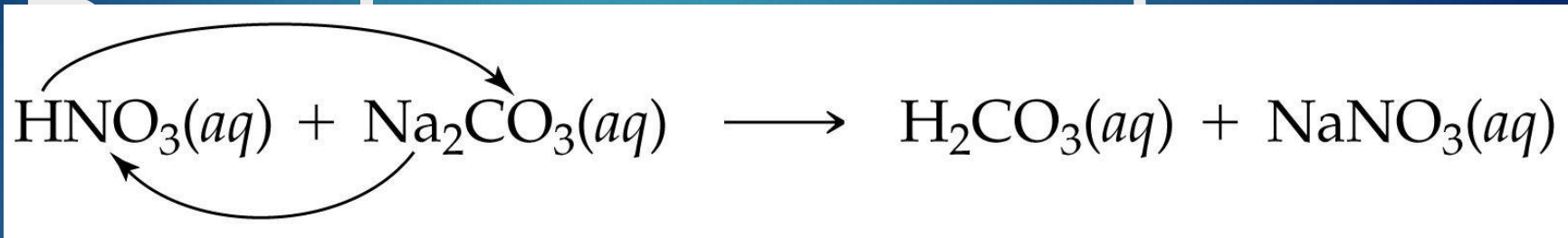


H replaces Na

Na replaces H

Double Replacement Reactions

These reactions occur in solution because the ions of the compounds must be able to move freely from one place to another



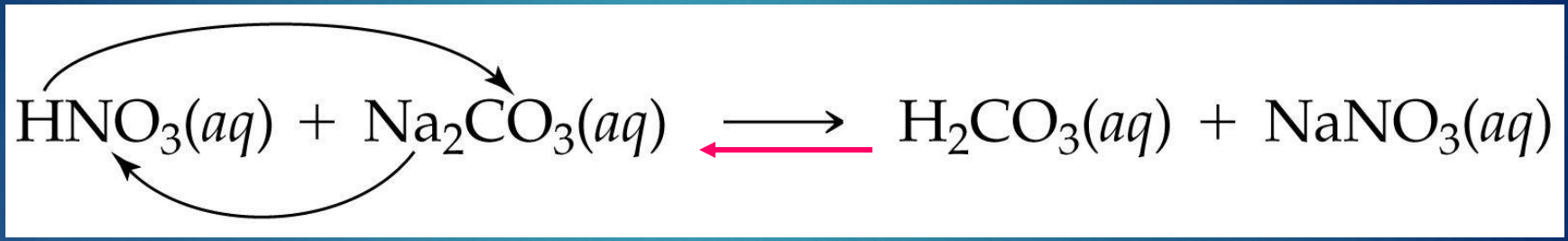
Since these compounds are all in sol'n we can write the equation a little differently showing all the ions present:

$H^+ + NO_3^- + 2Na^+ + CO_3^{-2} \rightarrow 2H^+ + CO_3^{-2} + Na^+ + NO_3^-$

This equation is known as a COMPLETE IONIC EQUATION

Double Replacement Reactions

Maybe you're wondering "if this reaction can occur as Indicated in solution why can't the reverse reaction Happen <u>just as easily</u>?"



In other words …

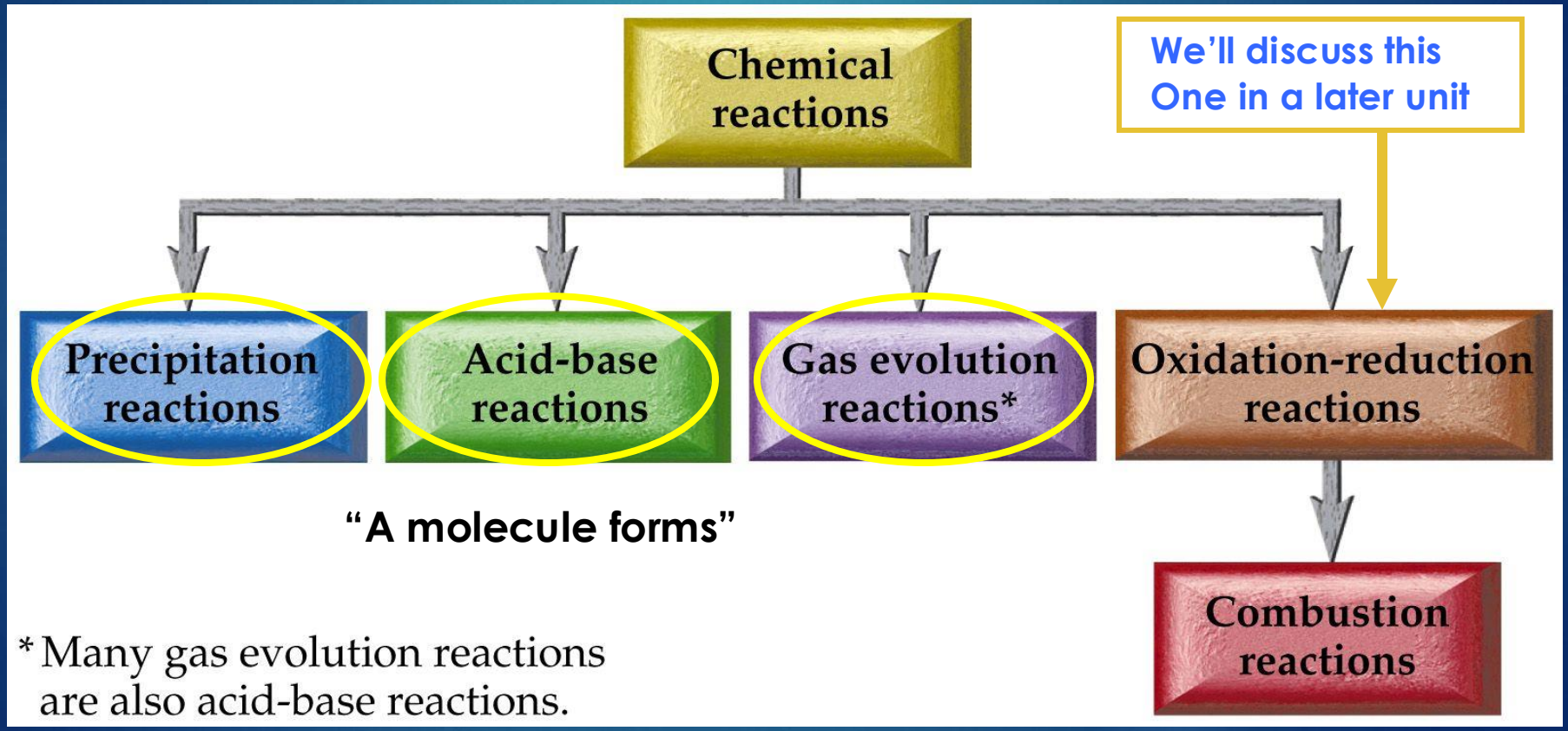
$2H^+ + CO_3^{-2} + Na^+ + NO_3^- \rightarrow H^+ + NO_3^- + 2Na^+ + CO_3^{-2}$

Well it can! So in order for these reactions to proceed Forward to <u>completion</u> something else <u>must occur</u>

The criteria necessary to drive double replacement reactions Forward to completion will be one of the following:

Reaction Start → Reaction Complete

Double Replacement

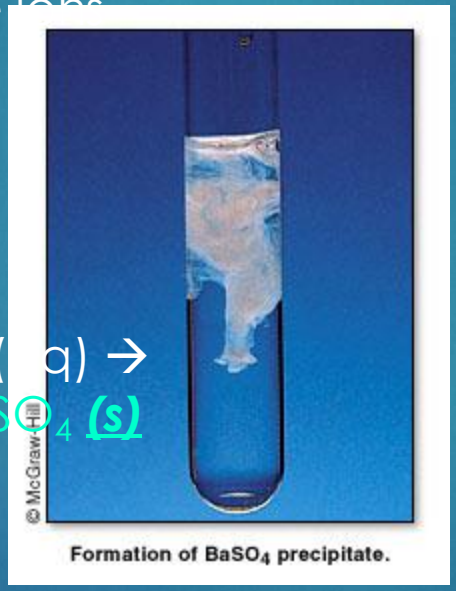


1- Precipitate forms

Some compounds are INSOLUABLE in water. Therefore,
In <u>double replacement</u> reactions the IONS of these
Insoluble compounds are no
Longer <u>free</u> and therefore can
<u>Not react</u> with other free ions

For example:

$Ba(NO_3)_2$ (aq) + $CuSO_4$ (aq) →
$Cu(NO_3)_2$ (aq) + $BaSO_4$ ***(s)***

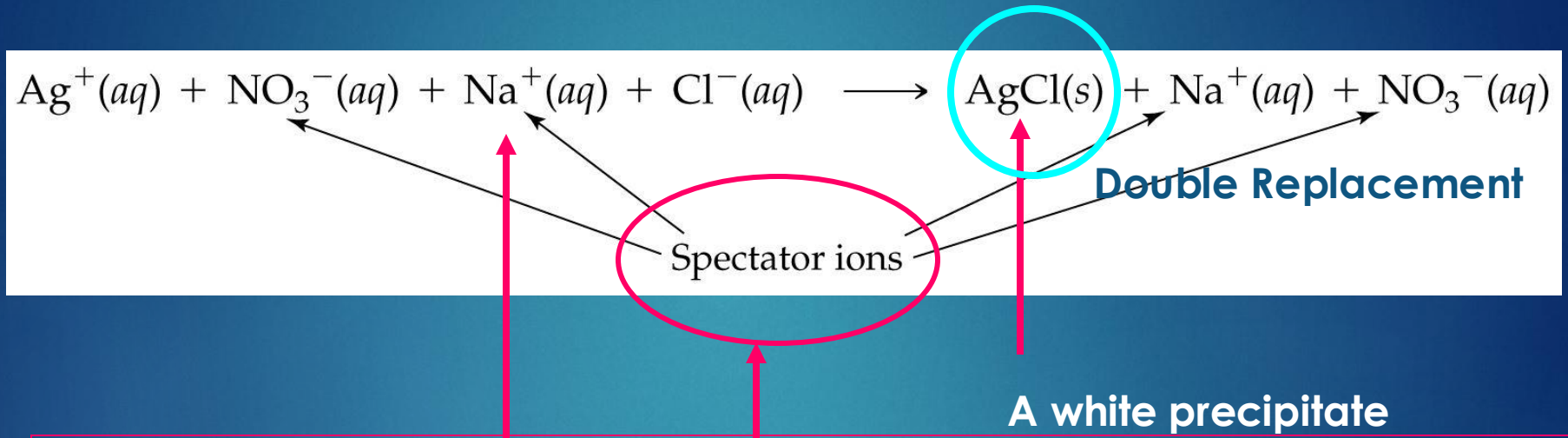


Formation of $BaSO_4$ precipitate.

A common precipitate

These insoluble compounds that are
Formed are known as **<u>PRECIPITATES</u>**

Another example of a common precipitate that forms in
This kind of reactions is AgCl



Ions in the Complete Ionic Equation that are not involved
In forcing the double replacement reaction to completion
Are known as SPECTATOR IONS. For example, the above
Equation can be rewritten as a NET IONIC EQUATION …

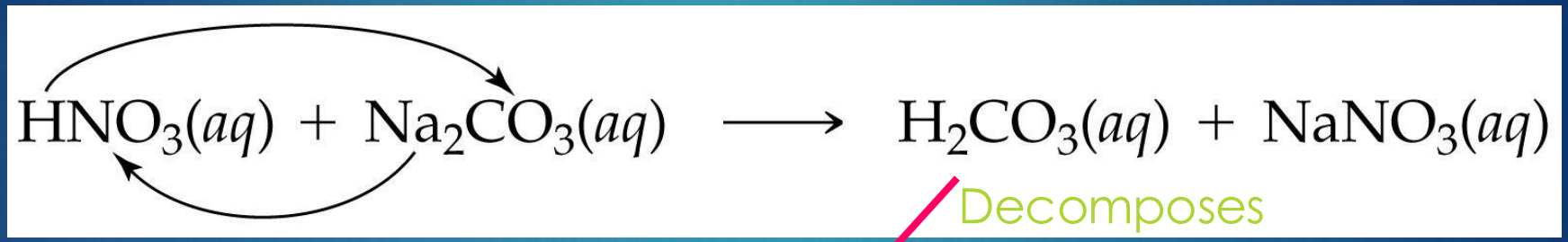
The only ions
Involved in
Driving the reaction to completion

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

Gas Evolution

The other type of double replacement reaction that goes To completion is one in which a gas is evolved.

For example …



$H_2CO_3 \rightarrow H_20 + CO_2$ (g)

Carbonic acid is the Acid that gives soda its fizz

Once the gas is evolved, the ions from which its generated Are no longer available. The rxn is driven to completion

Molecule formation

The last process we'll discuss that drives double replacement reactions to completion are reactions that Lead to the formation of molecules (i.e. covalently bonded Compounds like water)

Molecules can not ionize and thus once formed they are No longer available for replacement reactions.

Molecule formation

The most common example of molecule formation is ACID-BASE neutralization. In this type of double replacement Reaction WATER is the molecular compound that's formed

For example:

$HCl + KOH \rightarrow KCl + H_2O$

A "Molecule"

Acid Base A Salt Water

Complete ionic equation:

$H^+ + Cl^- + K^+ + OH^- \rightarrow K^+ + Cl^- + H_2O$

Net Ionic equation:

$H^+ + OH^- \rightarrow H_2O$

(the general equation for acid-base neutralizations)

Try these

Name the reaction type:

$CO_2 + H_2O \rightarrow H_2CO_3$ — Synthesis

$CaCO_3 \rightarrow CaO + CO_2$ — Decomp

$CH_4 + O2 \rightarrow CO_2 + H_20$ — Combustion

$Mg + ZnCl_2 \rightarrow MgCl_2 + Zn$ — Single Rep.

$MgSO_4\ (aq) + Ba(NO_3)_2\ (aq) \rightarrow BaSO_4\ (s) + Mg(NO_3)_2\ (aq)$ — Double Rep.

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2\ (g)$ — Single Rep.

$HCL + Ca(OH)_2 \rightarrow CaCl_2 + H_20$ — Double Rep.