Five reaction types & predicting products using solubility tables/activity series

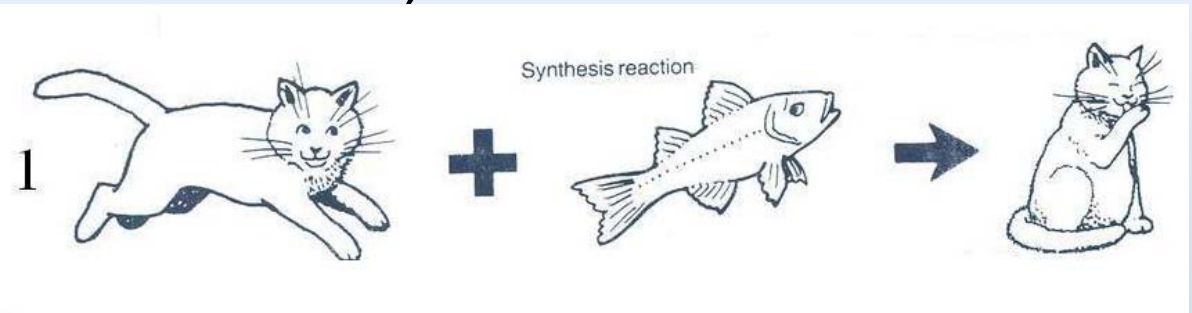
Unit 06, Chemistry Themed

Five reaction types

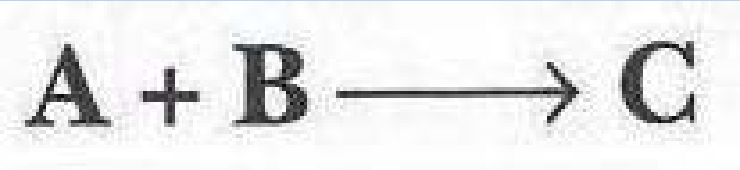
- Helps to understand and remember reactions by classifying them
- Chemists have five common reaction types:

1. Synthesis
2. Decomposition
3. Combustion
4. Single replacement
5. Double replacement

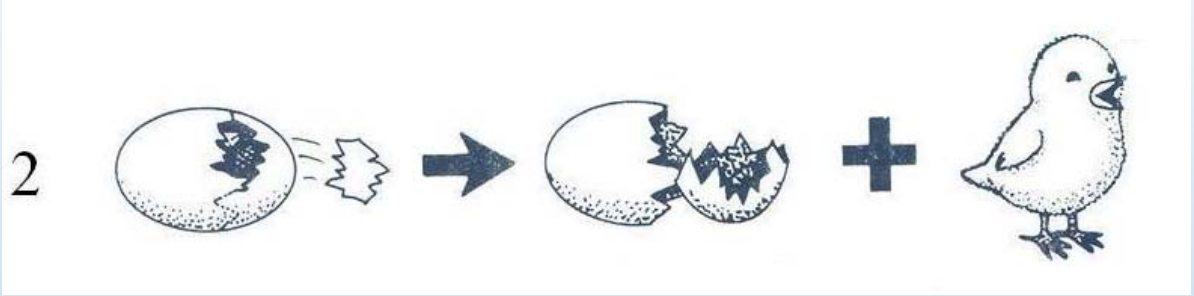
Synthesis reaction, aka: Combination



- A synthesis reaction is when you take multiple reactants to form a single product.
- 2 Mg(s) + O_2(g) → 2 MgO(s)



Decomposition reaction



- The opposite of a synthesis reaction is a decomposition reaction
- A decomposition reaction is when you take a single reactant to create multiple products
- $2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$

Combustion reaction

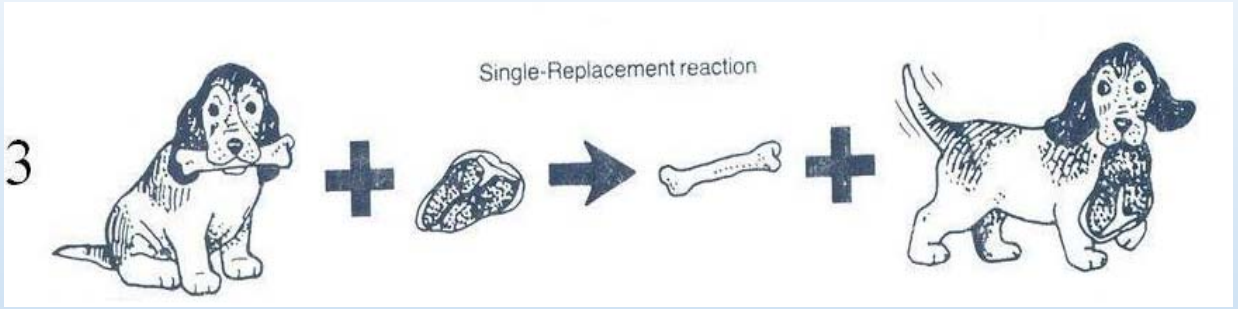
Combustion Reaction (burning wax, etc.)

Fuel + oxygen makes carbon dioxide and water

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

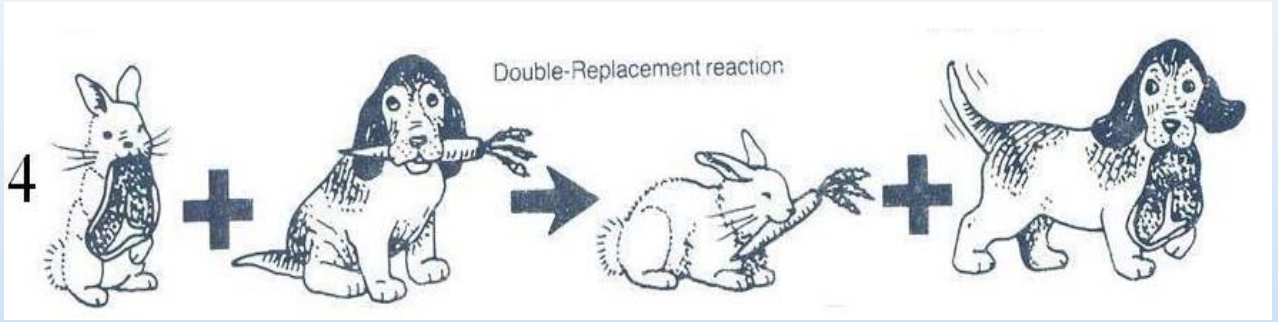
- A combustion reaction is very specific, we don't need algebra to symbolize it, because it doesn't vary
- In this class, our combustion reactions will be hydrocarbons burning (reacting with) oxygen
- $2\ C_{20}H_{42}(s) + 61\ O_2(g) \rightarrow 40\ CO_2(g) + 42\ H_2O(l)$

Single replacement reaction



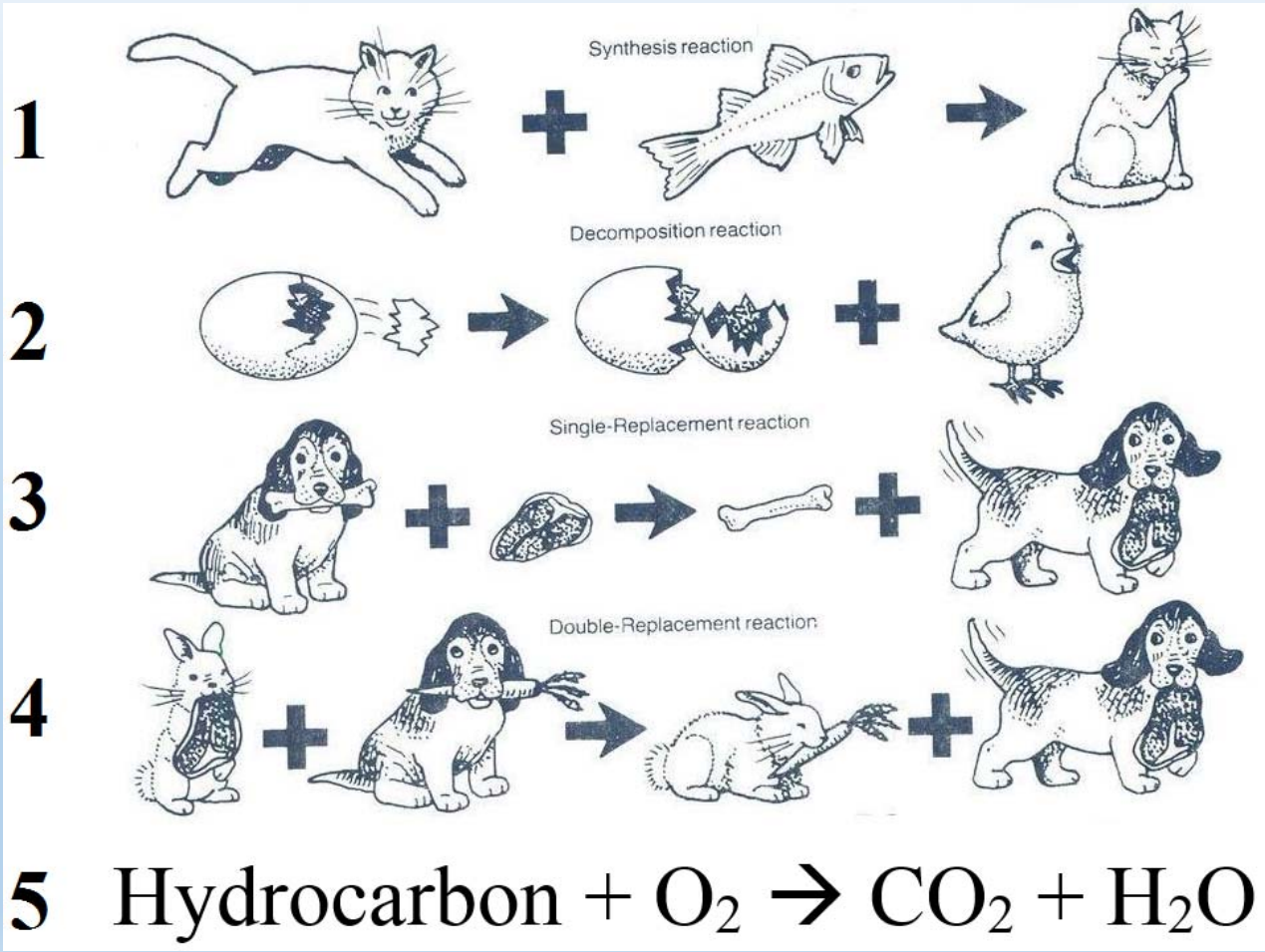
- Many redox reactions are single replacement. It's kind of about when you have a better choice. Reactivity series help us predict what is a "better choice"….more reactive
- $Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

Double replacement reaction



- Double replacement reactions are about where you "swap" dance partners. Bunny's not really happy with the steak and dog's not crazy about his carrot…maybe we can make a deal!
- $Pb(NO_3)_2(aq) + 2\ KI(aq) \rightarrow 2\ KNO_3(aq) + PbI_2(s)$

5 Reaction types - Summary



Predicting Products

- Don't forget to balance and include states of matter
- Use characteristics of five reaction types and follow patterns
- Examples:
- Just one reactant → must be decomposition
- See two reactants? Here are the questions to ask:
  - Are both reactants ionic compounds*? Consider double replacement.
  - Is one reactant an ionic compound and the other a metal or halogen? Consider single replacement
  - Is one reactant oxygen and the other a hydrocarbon (just H and C)? It's a combustion reaction
  - Doesn't fit these? Consider synthesis

* Or an acid reacting with a base…details to follow

Predicting Products - Examples

- Use these questions to determine which reaction type
  - Just one reactant → must be decomposition
  - Are both reactants ionic compounds? Consider double replacement.
  - Is one reactant an ionic compound and the other a metal or halogen? Consider single replacement
  - Is one reactant oxygen and the other a hydrocarbon (just H and C)? It's a combustion reaction
  - Doesn't fit these? Consider synthesis

1. $Ag\ (s) + Cl_2\ (g) \rightarrow AgCl_3\ (s)$
2. $KCl\ (aq) + ZnSO_4\ (aq) \rightarrow K_2SO_4\ (aq) + ZnCl_2\ (aq)$
3. $Cu\ (s) + ZnO\ (s) \rightarrow Cu_2O_3\ (s) + Zn\ (s)$
4. $C_2H_6\ (g) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (l)$
5. $H_2O_2\ (aq) \rightarrow O_2\ (g) + H_2O\ (l)$

How would I know the states of matter?

- Follow these guidelines
  - Is it an element? Look for black (solid), red (gas), blue (liquid) on periodic table (posted in room)
  - Common sense for a few (water is a liquid, CO_2 is a gas)
  - Ionic compounds are solids (crystalline solids) , except if soluble in water (then (aq) for aqueous). You learn and get to use a solubility table this unit
  - Something else? (hydrocarbons, etc.), we need to tell you (read wording of problem carefully; it might be there)

1. $Ag\ (s) + Cl_2\ (g) \rightarrow AgCl_3\ (s)$
2. $KCl\ (aq) + ZnSO_4\ (aq) \rightarrow K_2SO_4\ (aq) + ZnCl_2\ (aq)$
3. $Cu\ (s) + ZnO\ (s) \rightarrow Cu_2O_3\ (s) + Zn\ (s)$
4. $C_2H_6\ (g) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (l)$
5. $H_2O_2\ (aq) \rightarrow O_2\ (g) + H_2O\ (l)$

Check for understanding

- Potassium is exposed to oxygen in a dry environment and the two react. Write out a complete, balanced reaction including states of matter.

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$4\ K\ (s) + O_2\ (g) \rightarrow 2\ K_2O\ (s)$

- How do you know this?
- First, you need to recognize that oxygen is part of the 7-up → O_2
- Seconds, elemental potassium is NOT part of the 7-up → K
- Use previous knowledge of ionic compounds → K_2O
- Look up states of matter for oxygen and potassium on periodic table
- You don't need a solubility table for state of matter for K_2O . Ionic compounds are crystalline solids (dry, can't be aqueous)

Activity Series – predict single replacement reactions

- Single replacement reactions take place when a more reactive partner becomes available
- Example 1: If tin is added to a solution of barium chloride, will a reaction take place?
  - Solution: Activity series says Ba is more reactive than Sn. Chloride ions are already with the more reactive partner. No reaction takes place.
- Example 2: If tin is added to a solution of copper (II) chloride, will a reaction take place?
  - Solution: Activity series says Sn is more reactive than Cu. Chloride ions are presented with a more reactive partner. Chloride ions will combine with Sn rather than Cu. This (redox) reaction takes place.

Activity of Metals

Li
Rb
K
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Ni
Sn
Pb
H_2
Sb
Bi
Cu
Hg
Ag
Pt
Au

Activity Series – predict single replacement reactions (halogen example)

- Example 3: If fluorine gas us bubble through a copper (II) chloride solution, will a reaction take place?
  - Solution: Activity series says F is more reactive than Cl. Copper ions are not already with the more reactive partner. Reaction takes place.

Activity of Non-metal halogens

F_2
Cl_2
Br_2
I_2

Predict a single replacement reaction

- If the following reaction takes place, predict products and write a complete, balanced chemical equation.
- Zinc metal is added to a solution of Iron (III) sulfate. Determine if this reaction will take place and if so, follow above instructions.

Solution

- Zinc is more reactive than iron, so the sulfate ions will combine with Zinc when given this choice. Zinc sulfate will therefore be a product and iron will be reduced to iron metal (redox).

$Fe_2(SO_4)_3$ (aq) + 3 Zn (s) → 2 Fe (s) + 3 $ZnSO_4$ (aq)

States of matter: *reactants states were described, since Fe was reduced in reaction, it's solid (not a cation), you would need to look up zinc sulfate in a solubility table to be sure it's soluble (aq)*

Activity of Metals

Li
Rb
K
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Ni
Sn
Pb
H_2
Sb
Bi
Cu
Hg
Ag
Pt
Au

Solubility table

- Table Serves two functions:

1. Does a double replacement reaction take place?
2. Is an ionic compound soluble in water? ((aq) means it IS soluble)

Solubility Table is just a list (look-up table) of cations and anions

	$C_2H_3O_2^-$	AsO_4^{3-}	Br^-	CO_3^{2-}	Cl^-	CrO_4^{2-}	OH^-	I^-	NO_3^-	$C_2O_4^{2-}$	O^{2-}	PO_4^{3-}	SO_4^{2-}	S^{2-}	SO_3^{2-}
Group I & NH_4^+	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)
Al^{3+}	(aq)	(s)	(aq)	-----	(aq)	-----	(s)	(aq)	(aq)	-----	(s)	(s)	(aq)	d	-----
Ba^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(aq)	(aq)	(aq)	(s)	(aq)	(s)	(s)	d	(s)
Bi^{3+}	-----	(aq)	d	(s)	d	-----	(s)	(s)	d	(s)	(s)	(aq)	d	(s)	-----
Ca^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(aq)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	d	(s)
$Co^{2+}, Ni^{2+}, Cu^{2+}$	(aq)	(s)	(aq)	(s)	(aq)	(s)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)
Fe^{2+}	(aq)	(s)	(aq)	(s)	(aq)	-----	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)
Fe^{3+}	(s)	(s)	(aq)	-----	(aq)	-----	(s)	-----	(aq)	(aq)	(s)	(s)	(aq)	(s)	-----
Pb^{2+}	(aq)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(aq)	(s)	(s)	(s)	(s)	(s)	(s)
Mg^{2+}	(aq)	d	(aq)	(s)	(aq)	(aq)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	d	(aq)
Hg^{2+}	(aq)	(s)	(s)	(s)	(aq)	(aq)	(s)	(s)	(aq)	(s)	(s)	(s)	d	(s)	-----
Ag^+	(aq)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(aq)	(s)	(s)	(s)	(s)	(s)	(s)
Zn^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)

Solubility table

- (aq) means that cation/anion combination dissolves in water
- (s) means that combination is insoluble in water (a solid precipitate forms) – This is a chemical change – a reaction!
- (d) or ----- are results we won't deal with

	$C_2H_3O_2^-$	AsO_4^{3-}	Br^-	CO_3^{2-}	Cl^-	CrO_4^{2-}	OH^-	I^-	NO_3^-	$C_2O_4^{2-}$	O^{2-}	PO_4^{3-}	SO_4^{2-}	S^{2-}	SO_3^{2-}
Group I & NH_4^+	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)
Al^{3+}	(aq)	(s)	(aq)	-----	(aq)	-----	(s)	(aq)	(aq)	-----	(s)	(s)	(aq)	d	-----
Ba^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(aq)	(aq)	(aq)	(s)	(aq)	(s)	(s)	d	(s)
Bi^{3+}	-----	(aq)	d	(s)	d	-----	(s)	(s)	d	(s)	(s)	(aq)	d	(s)	-----
Ca^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(aq)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	d	(s)
$Co^{2+}, Ni^{2+}, Cu^{2+}$	(aq)	(s)	(aq)	(s)	(aq)	(s)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)
Fe^{2+}	(aq)	(s)	(aq)	(s)	(aq)	-----	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)
Fe^{3+}	(s)	(s)	(aq)	-----	(aq)	-----	(s)	-----	(aq)	(aq)	(s)	(s)	(aq)	(s)	-----
Pb^{2+}	(aq)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(aq)	(s)	(s)	(s)	(s)	(s)	(s)
Mg^{2+}	(aq)	d	(aq)	(s)	(aq)	(aq)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	d	(aq)
Hg^{2+}	(aq)	(s)	(s)	(s)	(aq)	(aq)	(s)	(s)	(aq)	(s)	(s)	(s)	d	(s)	-----
Ag^+	(aq)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(aq)	(s)	(s)	(s)	(s)	(s)	(s)
Zn^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)

Solubility table – check for understanding

- Will barium chloride dissolve in water?

Yes. (aq) means this combination is soluble

- Is Iron III phosphate soluble in water?

No. (s) means this combination is insoluble (not soluble)

	$C_2H_3O_2^-$	AsO_4^{3-}	Br^-	CO_3^{2-}	Cl^-	CrO_4^{2-}	OH^-	I^-	NO_3^-	$C_2O_4^{2-}$	O^{2-}	PO_4^{3-}	SO_4^{2-}	S^{2-}	SO_3^{2-}
Group I & NH_4^+	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)	(aq)
Al^{3+}	(aq)	(s)	(aq)	-----	(aq)	-----	(s)	(aq)	(aq)	-----	(s)	(s)	(aq)	d	-----
Ba^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(aq)	(aq)	(aq)	(s)	(aq)	(s)	(s)	d	(s)
Bi^{3+}	-----	(aq)	d	(s)	d	-----	(s)	(s)	d	(s)	(s)	(aq)	d	(s)	-----
Ca^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(aq)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	d	(s)
Co^{2+}, Ni^{2+}, Cu^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)
Fe^{2+}	(aq)	(s)	(aq)	(s)	(aq)	-----	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)
Fe^{3+}	(s)	(s)	(aq)	-----	(aq)	-----	(s)	-----	(aq)	(aq)	(s)	(s)	(aq)	(s)	-----
Pb^{2+}	(aq)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(aq)	(s)	(s)	(s)	(s)	(s)	(s)
Mg^{2+}	(aq)	d	(aq)	(s)	(aq)	(aq)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	d	(aq)
Hg^{2+}	(aq)	(s)	(s)	(s)	(aq)	(aq)	(s)	(s)	(aq)	(s)	(s)	(s)	d	(s)	-----
Ag^+	(aq)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(aq)	(s)	(s)	(s)	(s)	(s)	(s)
Zn^{2+}	(aq)	(s)	(aq)	(s)	(aq)	(s)	(s)	(aq)	(aq)	(s)	(s)	(s)	(aq)	(s)	(s)

Will a double replacement reaction take place?

- D.R. reactions take place if either of two conditions are met
- A solid is formed (from two aqueous solutions) – SOLUBILITY TABLE, BABY!
  - Use D.R. to find two possible products
  - Check if either product makes a solid
  - If either possible product makes a solid, then reaction takes place
  - If both possible products are aqueous, no reaction takes place
- Water is made
  - One reactant is an acid (formula begins with H) and one is a base (formula ends in OH)
  - The H combines with the OH to make HOH (water)
- If neither of these conditions are met, you're just mixing up ions

Double replacement reaction - examples

- Will a solution of barium chloride react with aluminum sulfate?

Yes. Barium sulfate is a solid (precipitates to bottom on reaction vessel)

$3\ BaCl_2\ (aq) + Al_2(SO_4)_3\ (aq) \rightarrow 3\ BaSO_4\ (s) + 2\ AlCl_3\ (aq)$

ALL of these states of matter come from solubility table

- Will H_3PO_4 react with sodium hydroxide?

Yes. Acids and bases always react and are always aqueous

$H_3PO_4\ (aq) + 3\ NaOH\ (aq) \rightarrow H_2O\ (l) + Na_3PO_4\ (aq)$

- Will calcium iodide react with magnesium sulfate?

Look up both potential products: calcium sulfate and magnesium iodide. Both are aqueous according to table. **No reaction** takes place.