Exchange Chemistry

- Three kinds of exchange chemistry.

1. PRECIPITATION

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.

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.

$$3MgCl_2(aq) + 2Na_3PO_4(aq) \rightarrow 6NaCl(aq) + Mg_3(PO_4)_2(s)$$

ions: Mg^{2+} Cl^- Na^+ PO_4^{3-}

Potential products: $NaCl$, $Mg_3(PO_4)_2$

The DRIVING FORCE of this reaction is the formation of INSOLUBLE magnesium phosphate!

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.

$MgCl_2(aq) + NaC_2H_3O_2(aq) \rightarrow$ NO REACTION!*

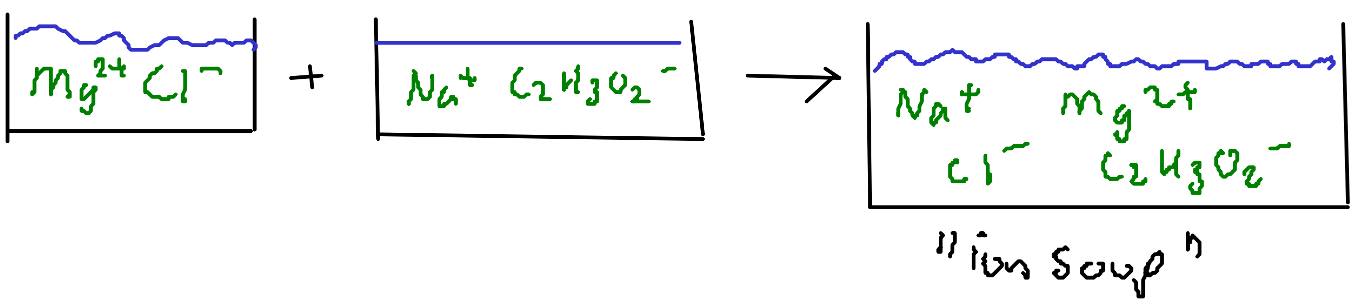
ions: Mg^{2+} Cl^- Na^+ $C_2H_3O_2^-$

"exchange"

$Mg(C_2H_3O_2)_2$ ... dissolves in water

$NaCl$ ... dissolves in water

So, no solid forms here. All possible combinations of these four ions result in compounds that dissolve readily in water.



NO CHANGE, therefore NO DRIVING FORCE, and NO REACTION

*We will learn about other driving forces than the formation of solid, but these driving forces do not apply to this reaction

ACID/BASE REACTIONS (also called NEUTRALIZATION REACTIONS)

- There are several stable molecules that may be formed in double replacement reactions, but the most common is WATER!

- Double replacement reactions that form water are also called "neutralizations"

$$HA + BOH \longrightarrow H_2O + BA$$

acid | base | salt

salt ⇐ ionic compound

$H^+ \; A^-$ $B^+ \; OH^-$

"HOH"

* To make water (H_2O), you need a source of hydrogen ion (H^+) and hydroxide ion (OH^-)

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(\ell)$$

This is the NET IONIC EQUATION for many neutralizations

... assumes you're reacting STRONG acid with STRONG base!

ACIDS

- compounds that release hydrogen ion (H^+), when dissolved in water.

Properties of acids:

- Corrosive: React with most metals to give off hydrogen gas
- Cause chemical burns on contact
- Taste sour (like citrus - citric acid!)
- Changes litmus indicator to RED

BASES

- Substances that release hydroxide ion (OH^-) when dissolved in water

Properties of bases:

- Caustic: Attack and dissolve organic matter (think lye, which is NaOH)
- Cause skin/eye damage on contact
- Taste bitter
- changes litmus indicator to BLUE

Due to the dissolving action of base on your skin, bases will feel "slippery". The base ITSELF is not particularly slippery, but what's left of your skin IS!

ACID/BASE or NEUTRALIZATION reactions continued

- the driving force of these reactions is the formation of water molecules.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$ Net ionic equation

From the acid (H⁺) — From the base (OH⁻)

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

ions: H^+ SO_4^{2-} Na^+ OH^-

H_2O

Potential products: Na_2SO_4, H_2O

- How can this reaction be detected?
  - pH detector (indicator paper, etc.)
  - do the products have similar chemical properties to the reactants?
  - release of heat!

... formation of water is usually accompanied by a release of heat

GAS FORMATION / OTHER MOLECULES

- There are a few other molecules that can be made with exchange-type chemistry.
- Most of these molecules are unstable and can break apart to form gases.

- Formation of a weak acid:
    - The formation of ANY weak acid in an exchange-type reaction can be a driving force.
    - Some weak acids are unstable and can break apart into gas molecules.

$$H_2CO_3(aq) \longrightarrow H_2O(l) + \boxed{CO_2(g)}$$

Gas bubbles can leave solution!

... but how would you form carbonic acid in an exchange-type reaction?

acid + carbonate CO_3^{2-}

OR

acid + bicarbonate HCO_3^-

$$H_2SO_4(aq) + 2\,NaHCO_3(aq) \rightarrow 2\,H_2CO_3(aq) + Na_2SO_4(aq)$$

Ions: H^+ SO_4^{2-} Na^+ HCO_3^-

Formation of carbonic acid drives the reaction ... BUT ...

$$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2H_2CO_3(aq)$$

H^+ SO_4^{2-} Na^+ HCO_3^-

... but when we mix sulfuric acid and sodium bicarbonate, we observe BUBBLES. We need to write an equation that agrees with our observations. We know that carbonic acid decomposes, so we go ahead and put that into our equation.

$$H_2CO_3(aq) \longrightarrow H_2O(\ell) + CO_2(g)$$

$$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell) + 2CO_2(g)$$

Other molecules of interest:

H_2SO_3: sulfurous acid - React an ACID with a SULFITE

$$H_2SO_3(aq) \rightarrow H_2O(\ell) + SO_2(g)$$

H_2S: hydrogen sulfide (gas) - React an ACID with a SULFIDE

$$H_2SO_4(aq) + Na_2S(aq) \rightarrow Na_2SO_4(aq) + H_2S(g)$$

A few more exchange examples:

$$CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow 2AgCl(s) + Ca(NO_3)_2(aq)$$

Ca^{2+} Cl^- Ag^+ NO_3^-

* Transition metals DO NOT change their charge in exchange reactions!

Formation of SOLID AgCl drives this PRECIPITATION reaction!

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

H^+ PO_4^{3-} Na^+ OH^-

Formation of liquid water drives this NEUTRALIZATION reaction. Detect by release of HEAT.

$$KCl(aq) + NaNO_3(aq) \longrightarrow \text{~~}KNO_3(aq) + NaCl(aq)\text{~~}$$ NO REACTION

K^+ Cl^- Na^+ NO_3^-

Both 'products' are water-soluble ionic compounds -present in water as free ions. Since this is the same state they were in BEFORE the 'reaction', we conclude that there is NO DRIVING FORCE and NO REACTION!

$$H_2SO_4(aq) + Na_2CO_3(aq) \longrightarrow H_2CO_3(aq) + Na_2SO_4(aq)$$

H^+ SO_4^{2-} Na^+ CO_3^{2-}

$$H_2CO_3 \rightarrow H_2O + CO_2$$

$$H_2SO_4(aq) + Na_2CO_3(aq) \longrightarrow H_2O(l) + CO_2(g) + Na_2SO_4(aq)$$

Formation of and decomposiion of carbonic acid drives this reaction! We will observe FIZZ.