PRECIPITATION

Experiment 11 in your laboratory involves EXCHANGE REACTIONS!

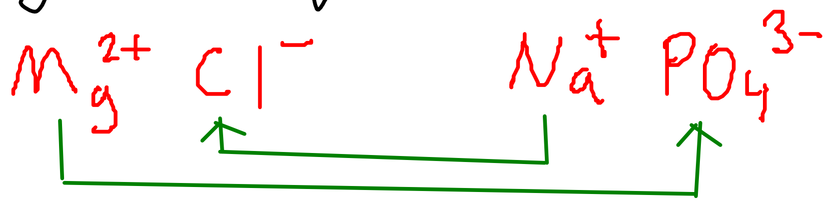
- Form an insoluble ionic compound

$MgCl_2(aq) + Na_3PO_4(aq) \rightarrow$???

Potential products:

$NaCl$

$Mg_3(PO_4)_2$



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

Remember, IONS exchange partners. That means that you need to write out the IONS, including their charges, and pair them up. The formulas of the products are controlled by the CHARGES of the IONS in the new compounds!

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

This compound does NOT dissolve in water. It is the DRIVING FORCE for this reaction!

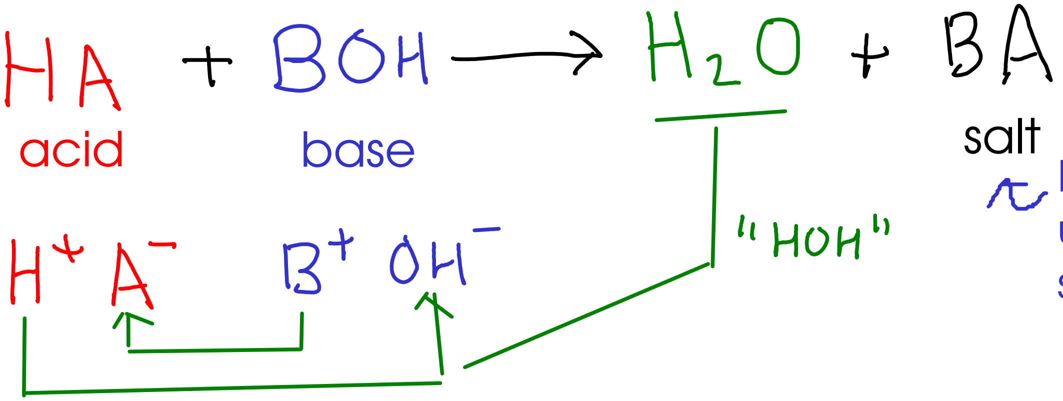
- Does a solid (insoluble) ionic compound form? Check DATA (p 172 in book)

* When writing exchange reactions, figure out the formulas of the products FIRST, and THEN balance the equation.

FORMATION OF STABLE MOLECULES

- 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"



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

Note: Ionic compounds are usually called "salts" - not just sodium chloride (table salt)

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

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!

Examples of acid-base chemistry:

When a neutralization reaction occurs, energy is released. There will be a temperature increase!

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

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

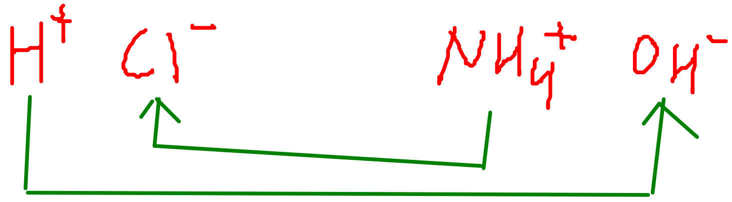
Potential products:

$\dfrac{H^+ \ OH^-}{H_2O}$ $\dfrac{Na^+ \ SO_4^{2-}}{Na_2SO_4}$

Why "neutralization"?

*The products of the reaction (water and a "salt") do not have any of the characteristic properties of acids and bases. These properties can be said to be "neutralized".

$HCl(aq) + NH_4OH(aq) \longrightarrow H_2O(l) + NH_4Cl(aq)$ ✓



H^+ Cl^- NH_4^+ OH^-

(see p172 for solubility chart)

DOUBLE REPLACEMENTS THAT FORM GASES

① Formation of hydrogen sulfide: H_2S

- need an ACID (source of hydrogen ion) and a SULFIDE

Observation: Odor
gas bubbles.

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

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

$$\frac{H^+ \; S^{2-} \\ H^+}{H_2S} \qquad \frac{Na^+ \; SO_4^{2-} \\ Na^+}{Na_2SO_4}$$

Hydrogen sulfide (common name) is a gas with a distinct rotten-egg smell.

② Formation of carbonic acid and carbon dioxide:

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

- to form carbonic acid by double replacement, you need a source of hydrogen ion (ACID) and a source of carbonate (can be CARBONATE or BICARBONATE)

CO_3^{2-} HCO_3^{-}

Example of a reactions that forms carbonic acid, then gas:

$$2HC_2H_3O_2(aq) + Na_2CO_3(aq) \longrightarrow 2Na\,C_2H_3O_2(aq) + \boxed{H_2CO_3}$$

H^+ $C_2H_3O_2^-$ Na^+ CO_3^{2-}

$$\frac{Na^+ \quad C_2H_3O_2^-}{NaC_2H_3O_2} \qquad \frac{\begin{array}{c}H^+ \quad CO_3^-\\ H^+\end{array}}{H_2CO_3}$$

... but carbonic acid
decomposes, and
we get GAS BUBBLES

$$\boxed{2HC_2H_3O_2(aq) + Na_2CO_3(aq) \longrightarrow 2NaC_2H_3O_2(aq) + H_2O(l) + CO_2(g)}$$

This is the overall process. We show carbon dioxide and water as products, since we want to show the reaction as it's actually observed -with carbonic acid broken down to water and (gaseous) carbon dioxide.

A few more double replacement / exchange examples:

See page 172 for a solubility chart

✓

$CaCl_2(aq) + 2\overset{*}{Ag}NO_3(aq) \longrightarrow 2\underline{AgCl(s)} + Ca(NO_3)_2(aq)$

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

PRECIPITATION of AgCl drives this reaction!

$H_3PO_4(aq) + 3NaOH(aq) \longrightarrow 3\underline{H_2O(l)} + Na_3PO_4(aq)$ ✓

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

Formation of WATER MOLECULES drives this reaction

... Detect this one by RELEASE OF HEAT!

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

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

NO REACTION occurs. There is no DRIVING FORCE for reaction, since both products are soluble ionic compounds. They exist as FREE IONS in solution, no different than before the "reaction".

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

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

CARBONIC ACIDdecomposes when formed to produce WATER and CARBON DIOXIDE gas!

$H_2CO_3 \rightarrow H_2O + CO_2$

$H_2SO_4(aq) + 2NaHCO_3(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$

* Transition metals DO NOT CHANGE CHARGE in exchange reactions!

✱ Reminder: Transition metals do not change charge during an exchange reaction!

$$Fe(NO_3)_3(aq) + 3NaOH(aq) \rightarrow 3NaNO_3(aq) + \underline{Fe(OH)_3(s)}$$ ✓

Fe^{3+} NO_3^- Na^+ OH^-

PRECIPITATION of solid iron(III) hydroxide drives this reaction!

$$2HCl(aq) + Pb(NO_3)_2(aq) \rightarrow \underline{PbCl_2(s)} + 2HNO_3(aq)$$ ✓

H^+ Cl^- Pb^{2+} NO_3^-

PRECIPITATION of solid lead(II) chloride drives this reaction.

Acids and bases can participate in precipitation reactions, too!

SINGLE REPLACEMENT REACTIONS

$$A + BC \longrightarrow AC + B$$

One element, usually a metal, replaces another element in a compound. This forms a new compound and leaves behind a new free element!

example: $\underset{0}{Cu}(s) + 2\,\underset{+1}{Ag}NO_3(aq) \longrightarrow \underset{+2}{Cu}(NO_3)_2(aq) + 2\,\underset{0}{Ag}(s)$

Copper loses electrons, goes from 0 charge to +2 charge!

Silver gains electrons, goes from +1 charge to 0 charge!

... but just because you combine an element and a compound doesn't mean that a reaction will occur. Some combinations react, some don't!

- Whether a reaction occurs depends on how easily the replacing and replaced elements lose electrons. An atom that loses electrons more easily will end up in IONIC form (in other words, in the compound). An atom that loses electrons less easily will end up as a free element.

- We say that an atom that loses electrons more easily that another is MORE ACTIVE than the other element. But how would you get information about ACTIVITY?

A single replacement reaction is an example of a reaction where ELECTRON TRANSFER is a driving force. Electron transfer reactions are generally called OXIDATION-REDUCTION reactions.

ACTIVITY SERIES

- comes from experiental data. It's a list of elements in order of their ACTIVITY - more active elements are higher in the series!

A sample activity series

Activity

Sodium Na^+

Magnesium Mg^{2+}

Very active metals will replace hydrogen in acids AND in water!

Aluminum Al^{3+}

Zinc Zn^{2+}

Iron Fe^{2+}

Lead Pb^{2+}

Metals more active than hydrogen will replace hydrogen in acids!

Hydrogen H^+

Copper Cu^{2+}

Silver Ag^+

Gold Au^{3+}

These metals are unreactive to most acids!