# 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 $HCO_3^-$

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

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.

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

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

Other molecules of interest:

$H_2SO_3$: sulfurous acid - React an ACID with a SULFITE

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

$H_2S$: 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:

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

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

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

This reaction is driven by formation of SOLID AgCl. (Precipitation)

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

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

This reaction is driven by the formation of WATER MOLECULES (neutralization)

$$KCl(aq) + NaNO_3(aq) \rightarrow \cancel{NaCl(aq) + KNO_3(aq)}$$ NO REACTION

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

Sodium chloride and potassium nitrate are both soluble ionic compounds. So, there are none of our three possible driving forces here, and NO REACTION.

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

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

$$H_2CO_3 \rightarrow H_2O + CO_2$$

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

This reaction is driven by formation of carbonic acid and its decomposition into water and carbon dioxide gas.

# OXIDATION / REDUCTION CHEMISTRY

- Exchange reactions involve ions pairing up, but the ions themseves are not formed in exchange reactions. Exchanges start with pre-existing ions.

... but the ions have to be produced somehow - through a chemistry that involves the transfer of electrons.

- oxidation / reduction chemistry ("redox" chemistry) involves transfer of electrons and can make ions.

$$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s)$$

Elemental, metallic aluminum. Uncharged! $Al^0$

Aluminum cation $Al^{3+}$

These are called "half-reactions"

$$Al \rightarrow Al^{3+} + 3e^-$$

electron

oxidation: loss of electrons

$$Br_2 + 2e^- \rightarrow 2Br^-$$

reduction: gain of electrons

- oxidation and reduction always occur together. In other words, we can't just make free electrons using oxidation without giving them somewhere to go.
- Many of the types of reactions that we learned about in previous courses are redox reactions!
  - COMBINATIONS (often but not always redox)
  - DECOMPOSITIONS (often redox)
  - SINGLE REPLACEMENT (always redox)

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

$$Cu \rightarrow Cu^{2+} + 2e^- \quad \text{oxidation}$$

$$2Ag^+ + 2e^- \rightarrow 2Ag(s) \quad \text{reduction}$$

net ionic $\rightarrow$ $Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

  - COMBUSTION

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$2Mg(s) \rightarrow 2Mg^{2+} + 4e^- \quad \text{oxidation}$$

$$O_2(g) + 4e^- \rightarrow 2O^{2-} \quad \text{reduction}$$