# DOUBLE REPLACEMENTS THAT FORM GASES

1. Formation of hydrogen sulfide: $H_2S$

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

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

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

$H^+$ $S^{2-}$ | $H_2S$
$H^+$

$Na^+$ $SO_4^{2-}$ | $Na_2SO_4$
$Na^+$

Gas with rotten-egg odor!
Observation: Odor and visible gas bubbles

2. Formation of carbonic acid and carbon dioxide:

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

- 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: The "baking soda volcano"!

VINEGAR

BAKING SODA

$2HC_2H_3O_2(aq) + Na_2CO_3(aq) \longrightarrow 2NaC_2H_3O_2(aq) + H_2CO_3$

$H^+$ $C_2H_3O_2^-$ $Na^+$ $CO_3^{2-}$ $NaC_2H_3O_2$ $H_2CO_3$

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

$$2HC_2H_3O_2(aq) + Na_2CO_3(aq) \longrightarrow 2NaC_2H_3O_2(aq) + H_2O(\ell) + CO_2(g)$$

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 170 for a solubility chart

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

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

In exchange reactions, transition metal ions DO NOT change charge!

PRECIPITATION of silver(I) chloride drives this reaction!

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

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

Formation of WATER is the driving force for this reaction (a NEUTRALIZATION)

$KCl(aq) + NaNO_3(aq) \rightarrow$ ~~$NaCl(aq) + KNO_3(aq)$~~

NO REACTION

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

NO REACTION occurs. There's no driving force. In other words, (1) NO SOLID FORMS (2) NO STABLE MOLECULE - WATER - FORMS (3) NO UNSTABLE MOLECULE - CARBONIC ACID - FORMS. So we're left with "ion soup"!

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

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

Carbonic acid is UNSTABLE and DECOMPOSES to form water and carbon dioxide. The release of carbon dioxide drives this reaction.

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

$Fe(NO_3)_3(aq) + 3\,NaOH(aq) \rightarrow 3\,NaNO_3(aq) + Fe(OH)_3(s)$

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

Formation of insoluble (the book uses the term "slightly soluble") iron(III) hydroxide drives this reaction. This is a PRECIPITATION!

$2\,HCl(aq) + Pb(NO_3)_2(aq) \rightarrow 2\,HNO_3(aq) + PbCl_2(s)$

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

Formation of insoluble lead(II) chloride drives this reaction. This is another PRECIPITATION!