ROUND 5

Formation of a Gas

Common gases formed in metathesis reactions are listed in the table below.

	Common Gases
H_2S	Any sulfide (salt of S^{2-}) plus any acid form $H_2S(g)$ and a salt.
CO_2	Any carbonate (salt of CO_3^{2-}) plus any acid form $CO_2(g)$, HOH and a salt.
SO_2	Any sulfite (salt of SO_3^{2-}) plus any acid form $SO_2(g)$, HOH and a salt.
NH_3	Any ammonium salt (salt of NH_4^+) plus any soluble strong hydroxide react upon heating to form $NH_3(g)$, HOH and a salt.

Reactions that produce three of the gases (CO_2, SO_2, and NH_3) involve the initial formation of a substance that breaks down to give the gas and HOH.

Example 1. The reaction of Na_2SO_3 and HCl produces H_2SO_3:

$$Na_2SO_3(aq) + 2HCl(aq) \longrightarrow H_2SO_3(aq) + 2NaCl(aq)$$

Bubbling is observed in this reaction because the H_2SO_3 (sulfurous acid) is unstable and immediately decomposes to give HOH and SO_2 gas:

$$H_2SO_3 \longrightarrow HOH(l) + SO_2(g)$$

The molecular equation for the complete reaction, therefore, is:

$$Na_2SO_3(aq) + 2HCl(aq) \longrightarrow HOH(l) + SO_2(g) + 2NaCl(aq)$$

Example 2. A typical reaction of a carbonate and an acid is:

$$K_2CO_3(aq) + 2HNO_3(aq) \longrightarrow HOH(l) + CO_2(g) + 2KNO_3(aq)$$

Bubbling is also observed in this reaction. Theoretically H_2CO_3, carbonic acid, is formed, but the acid is unstable and immediately decomposes to form carbon dioxide gas and water according to the following equation:

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

Example 3. Ammonium salts and soluble bases react as follows (particularly when the solution is warmed):

$$NH_4Cl(aq) + NaOH(aq) \longrightarrow NH_3(g) + HOH(l) + NaCl(aq)$$

The odor of ammonia gas is noted and moist blue litmus paper held near the mouth of the container will turn blue. Theoretically NH_4OH, ammonium hydroxide, is produced (also known as ammonia water). The compound is unstable and decomposes into ammonia gas and water:

$$NH_4OH(aq) \longrightarrow NH_3(g) + HOH(l)$$

Example 4. The odor of rotten eggs and bubbling are noted when an acid is added to a sulfide. A typical reaction producing hydrogen sulfide gas is:

$$FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$$

Helpful Tip: Be aware of reactions involving the formation of carbon dioxide, sulfur dioxide, ammonia, and hydrogen sulfide gases on the AP Chemistry Examination. Over the years these reactions have appeared many, many times. Know these four gases and how they are produced!

Exercise 9–2: Predict and balance the following metathesis reactions. Use the abbreviations (s), (l), (g), and (aq) for the reactants and products. All reactants are aqueous unless otherwise stated.

1. ammonium sulfate and potassium hydroxide are mixed together

2. ammonium sulfide is reacted with hydrochloric acid

3. cobalt(II) chloride is combined with silver nitrate

4. solid calcium carbonate is reacted with sulfuric acid

5. potassium sulfite is reacted with hydrobromic acid

6. potassium sulfide is reacted with nitric acid

7. ammonium iodide + magnesium sulfate

8. solid titanium(IV) carbonate + hydrochloric acid

9. solid calcium sulfite + acetic acid

10. strontium hydroxide + ammonium sulfide