EXPERIMENT
6

Observations of Chemical Reactions

INTRODUCTION

In the previous experiments, measurements of weights and volumes were made and recorded. Lab 4 involved observations about the behavior of compounds in solution; compounds can be classified as ionic or covalent, depending on whether the species that make up the compounds are, respectively, ions or molecules.
Ionic compounds can be further classified as acids, bases, or salts. Acids are compounds that produce H^+ ions in solution. Three common acids are HCl (hydrochloric acid), H_2SO_4 (sulfuric acid), and HNO_3 (nitric acid). Bases are compounds that produce OH^- ions in solution. Two common bases are NaOH (sodium hydroxide) and KOH (potassium hydroxide). Salts are ionic compounds that do not contain H^+ or OH^-, such as NaCl, $MgCO_3$, or Na_2SO_4.
This experiment deals mainly with solutions of salts and the chemical reactions that occur when different salt solutions are mixed. When solutions containing ions from different soluble salts are mixed together, the ions may react to form different substances. That is, one set of substances, called the reactants, is changed into substances with different properties, called the products. A reaction may be represented by a chemical equation, which is usually written in the form

$$\text{reactants} \rightarrow \text{products}$$

The reactants are shown on the left, the products on the right, and the arrow is used to indicate the direction of chemical change. Only species that actually change are usually written in a chemical equation. Reactants and products may be characterized by physically observable quantities such as color, odor, and state of matter (solid, liquid, or gas). Careful observation of these properties often allows deductions to be made about the identity of a chemical compound and the ions present in a sample.
The reactions of seven anions and one cation are to be studied in this experiment. The anions are carbonate (CO_3^{2-}), sulfate (SO_4^{2-}), chloride (Cl^-), iodide (I^-), acetate ($C_2H_3O_2^-$), nitrate (NO_3^-) and chromate (CrO_4^{2-}). The cation is copper II (Cu^{2+}). It is important to learn the names, chemical symbols, and charges on these ions. Correct chemical equations describing the reactions of the ions must also be learned. These chemical reactions are described below.

Carbonate, CO_3^{2-}

Carbonate, CO_3^{2-}, is found in such compounds as sodium carbonate, Na_2CO_3, which is soluble, and calcium carbonate, $CaCO_3$, which is insoluble. If an acid solution (containing H^+) is mixed with a carbonate, either in a solid compound or in solution, carbon dioxide gas, CO_2, will be given off. The equation for the reaction of Na_2CO_3 with HCl can be written

$$Na_2CO_3 + 2\,HCl \rightarrow CO_2 + H_2O + 2\,NaCl$$

Another form of this equation (called the *complete ionic equation*) indicates the species that are actually present in solution.

$$2\,Na^+ + CO_3^{2-} + 2\,H^+ + 2\,Cl^- \rightarrow 4\,CO_2 + H_2O + 2\,Na^+ + 2\,Cl^-$$

Since balanced chemical equations indicate only substances that change, this equation simplifies to

$$CO_3^{2-} + 2\ H^+ \rightarrow CO_2 + H_2O$$

This simplified equation is called a *net ionic equation*. The evolution of CO_2 gas is visible as tiny bubbles.

Sulfate, SO_4^{2-}

Sulfate, SO_4^{2-}, is found in compounds such as Na_2SO_4. If a solution containing Ba^{2+} ions from a compound such as $BaCl_2$ is added to a solution containing SO_4^{2-} ions, an insoluble solid called a *precipitate* forms. This may be represented by the equation

$$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4(s).$$

Chloride, Cl^-

Chloride, Cl^-, is found in compounds such as NaCl. If a solution containing Ag^+ from a soluble compound such as $AgNO_3$ is added to a solution containing Cl^-, a precipitate of silver chloride forms.

$$Ag^+ + Cl^- \rightarrow AgCl(s)$$

This precipitate will dissolve when ammonia, NH_3, is added to it. The AgCl reacts with the NH_3 to form another ion, $Ag(NH_3)_2^+$.

$$AgCl(s) + 2\ NH_3 \rightarrow Ag(NH_3)_2^+ + Cl^-$$

$Ag(NH_3)_2^+$ is called a *complex ion*. Complex ions are composed of a metal ion and one or more molecules or negative ions.

Iodide, I^-

Iodide, I^-, from a soluble compound, such as KI, also forms a precipitate when it is mixed with a solution containing Ag^+ ion.

$$Ag^+ + I^- \rightarrow AgI(s)$$

Silver iodide, unlike silver chloride, is not soluble in ammonia, NH_3.

Acetate, $C_2H_3O_2$

Acetate is found in compounds such as $NaC_2H_3O_2$. If a solution containing $C_2H_3O_2^-$ is mixed with an acid solution, such as HCl or HNO_3, the H^+ from the acid reacts with the $C_2H_3O_2^-$ to form acetic acid. Acetic acid solution is the chemical name for vinegar and can be identified by its smell.

$$H^+ + C_2H_3O_2^- \rightarrow HC_2H_3O_2$$

Nitrate, NO_3^-

Nitrate is found in compounds such as KNO_3. When Fe^{2+} in solution from a source such as $FeSO_4$ is mixed with NO_3^- in solution, a characteristic brown ring forms. The chemistry involved in this process is complicated and cannot be represented by a simple chemical equation.

Chromate, CrO_4^{2-}

Chromate is found in compounds such as K_2CrO_4. If a solution containing CrO_4^{2-} is mixed with a solution containing Pb^{2+} ions from a compound such as $Pb(NO_3)_2$, a precipitate of lead chromate forms.

$$Pb^{2+} + CrO_4^{2-} \rightarrow PbCrO_4(s)$$

Copper II, Cu^{2+}

Copper (II) ion is found in such compounds as $CuSO_4$. If a solution containing Cu^{2+} is mixed with ammonia, NH_3, a complex ion containing Cu^{2+} and four NH_3 molecules forms.

$$Cu^{2+} + 4\ NH_3 \rightarrow Cu(NH_3)_4^{2+}$$

RELEVANT PROBLEMS FROM THE TEXT (Chang, 10e): Example 4.2, Problems 4.21, 4.22

PROCEDURE

NOTE: Students often experience difficulty distinguishing between true solutions and precipitates suspended in solution. When recording data, be sure to distinguish between a true solution (which can be seen through even though it may be intensely colored) and a precipitate suspended in solution (which makes the solution cloudy and difficult to see through). If a "solution" looks cloudy, a solid has formed.

Carbonate, CO_3^{2-}

1. Add a small amount of solid calcium carbonate, $CaCO_3$, to a small test tube. Add 15 to 20 drops of 6M HCl. Observe and record the result.
2. Place 15 to 20 drops of 1M Na_2CO_3 in a separate small test tube. Slowly add 15 to 20 drops of 6M HCl. Observe and record the result.

Sulfate, SO_4^{2-}

3. Place 15 to 20 drops of 0.1M Na_2SO_4 in a test tube. Add about 5 drops of 0.5M $BaCl_2$ and stir the solution. Observe and record the result.

Chloride, Cl^-

4. Place 15 to 20 drops of 0.1M NaCl in a test tube. Add 1–2 drops of 6M HNO_3 and 5 drops of 0.1M $AgNO_3$. Stir the solution. Observe and record the result.
5. To the **same** test tube, add 6M NH_3 dropwise (i.e., drop by drop), and stir until a change occurs. Record the result.

Iodide, I^-

6. Place 15 to 20 drops of 0.1M KI in a test tube and add a few drops of 0.1M $AgNO_3$. Observe and record the result.
7. To the same test tube, add 20 drops of 6M NH_3 and stir. Record the result.

Acetate, $C_2H_3O_2^-$

8. Place 15 to 20 drops of 1M $NaC_2H_3O_2$ in a test tube. Add 15 to 20 drops of 3M H_2SO_4 and stir. Carefully note any odor. Record the result.

Nitrate, NO_3^-

9. Place 30 to 40 drops of 0.1 M KNO_3 in a test tube and add 1 to 2 drops of **3M** H_2SO_4. Add 15 to 20 drops of saturated $FeSO_4$. Hold the test tube at a 45° angle and slowly pour 15 to 20 drops of **concentrated** H_2SO_4 (not 3M!) down the side of the test tube. Do not mix the solutions. A brown ring between the two liquid layers indicates the presence of NO_3^- (It may take a few minutes for the reaction to occur). Observe and record the result.

Chromate, CrO_4^{2-}

10. Place 15 to 20 drops of 0.1M K_2CrO_4 in a test tube. Add 15 to 20 drops of 0.1M $Pb(NO_3)_2$ and stir. Observe and record the result.

Copper (II), Cu^{2+}

11. Place 15 to 20 drops of 0.1M $CuSO_4$ in a test tube. Add 15 to 20 drops of 6M NH_3. Record the result.

OBSERVATIONS OF CHEMICAL REACTIONS

Name: ________________________

Section: ________________________

DATA

Record the observation(s) that indicate the presence of each anion. Give both **color** and **state of matter**.

CO_3^{2-}: (Step 1)

before addition of H^+: ____

after addition of H^+: ____

(Step 2)

before addition of H^+: ____

after addition of H^+: ____

SO_4^{2-}: (Step 3)

before addition of $BaCl_2$: ____

after addition of $BaCl_2$: ____

Cl^-: (Step 4)

before addition of $AgNO_3$: ____

after addition of $AgNO_3$: ____

(Step 5)

after addition of NH_3: ____

I^-: (Step 6)

before addition of $AgNO_3$: ____

after addition of $AgNO_3$: ____

(Step 7)

after addition of NH_3: ____

$C_2H_3O_2$: (Step 8)

before addition of H_2SO_4: ____

after addition of H_2SO_4: ____

NO_3^-: (Step 9)

before addition of conc. H_2SO_4: ____

after addition of conc. H_2SO_4: ____

CrO_4^{2-}: (Step 10)

before addition of $Pb(NO_3)_2$: ____

after addition of $Pb(NO_3)_2$: ____

Cu^{2+}: (Step 11)

before addition of NH_3: ____

after addition of NH_3: ____

RESULTS

Write the molecular equation, the **complete ionic equation,** and the **net** ionic equation for the reaction that occurs in each test (if there is no reaction, write "no reaction." Be sure your equations are balanced.

CO_3^{2-}: (Step 1) Molecular: ____

Complete: ____

Net: ____

CO_3^{2-}: (Step 2) Molecular: ____

Complete: ____

Net: ____

SO_4^{2-}: (Step 3) Molecular: ____

Complete: ____

Net: ____

Cl^-: (Step 4) Molecular: ____

Complete: ____

Net:____

(Step 5) Molecular: ____

Complete: ____

Net:____

I^-: (Step 6) Molecular: ____

Complete: ____

Net:____

(Step 7) Molecular: ____

Complete: ____

Net:____

$C_2H_3O_2^-$: (Step 8) Molecular: ____

Complete: ____

Net:____

CrO_4^{2-}: (Step 10) Molecular: ____

Complete: ____

Net:____

Cu^{2+}: (Step 11) Molecular: ____

Complete: ____

Net:____