Purpose

The purpose of this experiment is to observe chemical reactions of common household substances.

Learning Objectives

Make and record observations of chemical reactions of known substances.

Identify common chemicals by comparing observations of chemical reactions with those of known substances.

Laboratory Skills

Light and adjust a Bunsen burner properly.

Make and record observations.

Equipment

- 150 mL beaker
- Bunsen burner and hose
- Six 3 in. test tubes
- Spatula
- Three medicine droppers
- Test tube rack
- Red and blue litmus paper
- Test tube clamp

Chemicals

- Household ammonia
- Household chlorine bleach
- Baking soda
- Vinegar
- Table salt
- Chalk
- Epsom salts
- Mineral oil
- Chemical fertilizer
- NaI
- $(NH_4)_2CO_3$
- 18.0 M H_2SO_4
- 1.0 M NH_4Cl
- 8.0 M NaOH
- 3.0 M HNO_3
- $Ba(OH)_2$ (sat. soln.)
- 0.1 M $AgNO_3$
- 0.2 M $BaCl_2$
- 2.0 M HCl
- Solid unknown containing: $CO_3{}^{2-}$, Cl^-, $SO_4{}^-$, or I^- ion

Introduction

One important aspect of chemistry is the identification of substances. The identification of minerals for example, fool's gold as opposed to genuine gold, was and still is of great importance to prospectors. The rapid identification of a toxic substance ingested by an infant may be the determining factor in saving the child's life. Substances are identified by the use of instruments, by reactions characteristic of the substance, or both.

A reaction that is characteristic of a substance is frequently referred to as a ***test***. For example, you may test for oxygen with a glowing splint; if the splint bursts into flame, oxygen is probably present. You test for chloride ions by adding silver nitrate to an acidified solution. The formation of a white precipitate suggests the presence of chloride ions. Because other substances may yield a white precipitate under these conditions, one can "confirm" the presence of chloride ions by observing that this precipitate dissolves in ammonium hydroxide while the other white precipitates do not. This last step is known as a **confirmatory test**. Commonly, in order to test for an ion present in an unknown solution, two experiments need to be performed. The first test is a test to give a clue of the possible ion present in the unknown solution, and the second is a confirmatory test. Determining the identity of a substance is referred to as **qualitative analysis**. Determining the amount of a substance is **quantitative analysis**.

In this experiment, students will perform tests on or with substances they are likely to encounter in everyday life, such as table salt, bleach, smelling salts, and baking soda. While you may not think of these as chemicals, they most certainly are. Their chemical names are sodium chloride, chlorine, ammonium carbonate, and sodium bicarbonate, respectively.

After observing some reactions of these household chemicals, students will partially identify an unknown. The task will be to determine whether the substance contains the carbonate (CO_3^{2-}), chloride (Cl^-), sulfate (SO_4^{2-}), or iodide (I^-) ion.

Ammonia, NH_3

Ammonium salts are converted to ammonia, $\mathbf{NH_3}$, by the action of strong bases. Thus, it is possible to test for the ammonium ion, $\mathbf{NH_4^+}$, by adding the strong base, sodium hydroxide, **NaOH**. A reaction can be detected by the familiar odor of ammonia,NH_3, or by using red litmus paper.

The net ionic reaction is given in Reaction CL.1:

$$NH_4^+(aq) + OH^-(aq) \rightleftharpoons NH_3(aq) + H_2O(l) \qquad \text{(Reaction CL.1)}$$

Most ammonium salts are stable, which is why it is necessary to add sodium hydroxide to the ammonium chloride solution to detect the ammonia using litmus. However, $(NH_4)_2CO_3$ is quite unstable and decomposes to ammonia and carbon dioxide as seen in reaction CL.2:

$$(NH_4)_2CO_3(s) \xrightarrow{\Delta} 2\,NH_3(g) + CO_2(g) + H_2O(g) \qquad \text{(Reaction CL.2)}$$

Household sources of ammonia include smelling salts, which contain ammonium carbonate and many different types of household cleaning solutions, especially those used to clean glass and kitchen counters.

Carbonate Ion, CO_3^{2-}

Substances that contain the carbonate ion, CO_3^{2-}, react with acids to liberate carbon dioxide, CO_2, which is a colorless and odorless gas. Carbon dioxide is released from baking soda by acids, such as those found in lemon juice and buttermilk, and forms bubbles in the cake batter that expand in the hot over, causing a cake to rise. Acids release H^+ in aqueous solution, so the reaction of carbon dioxide with acids is written as shown in Reaction CL.3:

$$NaHCO_3(s) + H^+ \longrightarrow CO_2(g) + H_2O(l) + Na^+(aq) \qquad \text{(Reaction CL.3)}$$

A **confirmatory test** for CO_2 is to allow it to react with $Ba(OH)_2$, barium hydroxide, solution. A white precipitate of $BaCO_3$, barium carbonate, is produced (reaction CL.4):

$$CO_2(g) + Ba(OH)_2(aq) \longrightarrow BaCO_3(s) + H_2O(l) \qquad \text{(Reaction CL.4)}$$

Many substances, such as eggshells, oyster shells, limestone, and washing soda all contain the carbonate ion. A closely related ion, bicarbonate, HCO_3^-, that also reacts with acids to produce carbon dioxide, is found in baking soda and baking powder.

Chloride Ion, Cl^-

Chloride salts react with concentrated sulfuric acid to liberate hydrogen chloride, which is a pungent and colorless gas that turns moist blue litmus red (Reaction CL.5:

$$2\,Cl^-(aq) + H_2SO_4(aq) \longrightarrow 2\,HCl(g) + SO_4^{2-}(aq) \qquad \text{(Reaction CL.5)}$$

This reaction will occur whether the substance is $BaCl_2$, KCl, or $ZnCl_2$; the only requirement is that the salt be a chloride. For KCl, the complete equation is shown in reaction CL.6:

$$KCl(s) + H_2SO_4(aq) \longrightarrow 2\,HCl(g) + K_2SO_4(aq) \qquad \text{(Reaction CL.6)}$$

The **confirmatory test** for chloride ion is a well-known characteristic reaction of the chloride ion with silver nitrate to form silver chloride, AgCl, which is a white, *insoluble* substance (reaction CL.7):

$$Cl^{-}(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + NO_3{}^{-}(aq) \qquad \text{(Reaction CL.7)}$$

Chloride ions can be found in table salt and road salt.

Sulfate Ion, $SO_4{}^{2-}$

The following tests are characteristic of the sulfate ion, $SO_4{}^{2-}$.

Barium sulfate is a white insoluble substance that forms when barium chloride is added to a solution of any soluble sulfate salt, such as Epsom salts, as seen in Reaction CL.8:

$$SO_4{}^{2-}(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + 2\,Cl^{-}(aq) \qquad \text{(Reaction CL.8)}$$

Barium chloride solution is then used as a confirmatory test for sulfate ion.

Sulfate ions can be found in Epsom salts, $MgSO_4 \cdot 7\,H_2O$, which are used as a laxative and also in a soaking solution for tired, aching feet.

Iodide Ion, I^{-}

Iodide ion can be converted to elemental iodine by reacting with chlorine gas (Reaction CL.9).

$$Cl_2(aq) + 2\,I^{-}(aq) \longrightarrow I_2(aq) + 2\,Cl^{-}(aq) \qquad \text{(Reaction CL.9)}$$

Iodine gives a reddish-brown color to water; it is more soluble in mineral oil than in water, and it imparts a violet color to mineral oil. Thus, chlorine can be used to identify iodide salts.

Elemental chlorine behaves very differently than chloride ions. Elemental chlorine is a pale yellow-green, highly toxic gas and, thus, is inappropriate for use in an introductory chemistry experiment. Fortunately, commercial bleach, which is a 5% solution of sodium hypochlorite, NaOCl in water, can be used in place of elemental chlorine.

Another way to identify iodide ions uses concentrated sulfuric acid. Solid iodide salts react with concentrated sulfuric acid by turning dark brown and emitting a gas that, when exposed to moist air, appears violet. Pure solid iodine is known to form a violet vapor.

An additional characteristic reaction of iodides is that they form pale-yellow precipitates when treated with silver nitrate solution, shown in reaction CL.10:

$$I^{-}(aq) + AgNO_3(aq) \longrightarrow AgI(aq) + NO_3{}^{-}(aq) \qquad \text{(Reaction CL.10)}$$

Silver nitrate solution is then used as a confirmatory test for iodide ion.

Iodine, an important nutrient, can be found in seafood and dairy products, as well as iodized salt.

Sodium Ion, Na^+

Sodium ions are ubiquitous (found everywhere). The presence of sodium ions can be easily detected because sodium ions emit a characteristic yellow color in a flame. When salted water boils over on a gas stove, the temporary yellow flame color is due to sodium ions. The yellow flames of a campfire indicate the presence of sodium ions in the wood.

Unknown Ion or Ions

Your solid unknown contains **one** of the following ions: carbonate, chloride, sulfate, or iodide. Table CL.1 summarizes the behavior of these ions toward H_2SO_4.

Table CL.1: Reaction of Solid Salts with H_2SO_4

Ion	Reaction	Confirmatory Test
CO_3^{2-}	Colorless, odorless gas, CO_2, evolved	Barium hydroxide solution
Cl^-	Colorless, pungent gas, HCl, evolved, which turns blue litmus red	Silver nitrate solution
SO_4^{2-}	No observable reaction	Barium chloride solution
I^-	Violet or red-brown vapors of I_2 formed	Silver nitrate solution

Procedure

Safety Precautions

Even though household chemicals may appear innocuous, you should **never** mix them. Innocuous chemicals when combined may produce noxious gases, explosions or other hazardous reactions.

CAUTION: Concentrated sulfuric acid, H_2SO_4, causes severe burns. Do not get it on your skin. If you come in contact with it, immediately wash the area with copious amounts of cool water (10 -15 min).

CAUTION: Bleach contains sodium hypochlorite, NaOCl, which is a skin irritant. Avoid direct contact with your skin and eyes.

A. Household Ammonia, NH_4OH

1. Obtain ~1 mL of household ammonia in a 150 mL beaker.
    - Hold a dry piece of red litmus paper over the beaker, being careful not to touch the paper with the sides of the beaker or the solution. Record your observations on the Report Sheet.
    - Repeat the operation using a piece of red litmus paper that has been moistened with tap water. Record your observations about household ammonia and litmus paper on the Report Sheet.

2. Place ~1 mL of 1.0 M NH_4Cl, ammonium chloride, in a test tube.
    - Hold a moist piece of red litmus in the mouth of the tube. Record your observations about NH_4Cl and litmus.
    - Now add about 1 mL of 8.0 M NaOH and repeat the test. If the litmus paper does not change color, gently warm the test tube, but do not boil the solution. Record your observations about NH_4Cl, NaOH and litmus paper.

    > Do not allow the litmus paper to touch the sides of the tube because it may come in contact with NaOH, which will turn the litmus paper blue.

3. Test fertilizer for the presence of ammonia by placing an amount about the size of a pea, in a test tube.
    - add 1 mL of 8.0 M NaOH and test as above using moist litmus paper. Record your observations.
    - Does the fertilizer contain ammonium salts? Record your answer.

4. Hold a moist piece of red litmus over the mouth of an open jar of ammonium carbonate ($(NH_4)_2CO_3$).
    - Record your observations about ammonium carbonate and litmus paper on the Report Sheet.
    - Carefully fan your hand over the jar and see if you can detect a familiar odor. Record your observations.

CAUTION:

Do not place any sample being tested for odor directly under your nose. Instead, waft the air above the sample toward you.

5. Place the chemicals used in the designated waste receptacles.

B. Baking Soda, $NaHCO_3$

1. Place in a small, dry test tube an amount of solid baking soda about the size of a small pea.
    - Add 1 or 2 drops of concentrated H_2SO_4.
    - Record your observations about baking soda and H_2SO_4.

2. Repeat the above procedure using vinegar instead of the sulfuric acid. Record your observations about vinegar and baking soda.

3. Place a small piece of chalk in a dry test tube.
    - Add a few drops of 2.0 M HCl. Record your observation.
    - Test the escaping gas for CO_2 by carefully holding a drop of $Ba(OH)_2$, suspended from the tip of a medicine dropper or a wire loop, a short distance into the mouth of the test tube.
    - Record your observation.
    - Clouding of the drop is due to the formation of $BaCO_3$ and indicates the presence of carbonate ion. Does chalk contain carbonate ion? Record your answer on the Report Sheet.

    Breathing on the drop will cause it to cloud, because your breath contains CO_2 .

4. Place the chemicals used in the designated waste receptacles.

C. Table Salt, NaCl

1. Place in a small, dry test tube an amount of sodium chloride about the size of a small pea.
   - Add 1 or 2 drops of concentrated H_2SO_4.
   - Hold a piece of moistened blue litmus paper over the test tube, being careful not to touch the paper with the sides of the test tube or the solution. Record your observations about NaCl andH_2SO_4 on the Report Sheet.
   - On the Report Sheet, complete and balance the equation $NaCl(s) + H_2SO_4(aq) \longrightarrow\ ?$

2. Place a small amount (about the size of a pea) of NaCl in a small test tube.
   - add 15 drops of DI water and 1 drop of 3.0 M HNO_3.
   - Then add 3 or 4 drops of 0.1 M $AgNO_3$ and mix the contents. Record your observations about NaCl and 0.1 M $AgNO_3$ on the Report Sheet.

3. Could you have replaced the DI water with tap water for this test? Record your answer on the Report Sheet.

4. Confirm your answer by testing tap water for chloride ions:
   - Add 1 drop of 3.0 M HNO_3 to about 2 mL of tap water
   - Add 3 drops of 0.1 M $AgNO_3$. Record your observations?
   - Does this test indicate the presence of chloride ions in tap water? Record your answer on the Report Sheet.

5. Your lab instructor will demonstrate the presence of sodium ions by placing drops of a solution of NaCl or holding NaCl crystals in a flame. Record your observations on the Report Sheet.

6. Place the chemicals used in the designated waste receptacles.

D. Epsom Salts, $MgSO_4 \cdot 7\,H_2O$

1. Place a small quantity of Epsom salts in a small, dry test tube.
   - Add 1 or 2 drops of 18.0 M H_2SO_4 and record your observations.
   - Note (and record!) the difference in the behavior of this substance toward sulfuric acid compared with the behavior of baking soda toward sulfuric acid.

2. Place some Epsom salts (an amount the size of a small pea) in a small test tube and dissolve it in 1 mL of DI water.
   - Add 1 drop of 3.0 M HNO_3, then 1 or 2 drops of 0.2 M $BaCl_2$.
   - Record your observations about Epsom salts and $BaCl_2$ on the Report Sheet.

3. Place the chemicals used in the designated waste receptacles.

E. Bleach, NaOCl

1. In a small test tube, dissolve a small amount (about the size of a pea) of sodium iodide, NaI, in 1 mL of DI water.
   - Add 5 drops of bleach and note the color.
   - Then add several drops of mineral oil, shake, and allow the layers to separate, which takes about 20 sec.
   - Record your observations about bleach and NaI on the Report Sheet.

   > Mineral oil is less dense than water. Thus, the mineral oil layer is the top layer.

2. Dissolve a small amount of sodium iodide in 1 mL of DI water.
   - First add a drop of 3.0 M HNO_3 and then add 3 or 4 drops of 0.1 M $AgNO_3$ solution.
   - Record your observations about NaI and $AgNO_3$ on the Report Sheet.
   - Balance and complete the equation.

3. Place a small amount (about the size of a pea) of sodium iodide in a small, dry test tube and carry it to the hood.
   - *Carefully, while under the hood,* add 1 or 2 drops of 18.0 M H_2SO_4.
   - Record your observations about NaI and H_2SO_4 on the Report Sheet.

4. Place the chemicals used in the designated waste receptacles.

F. Unknown

Your solid unknown will contain only one of the following ions: carbonate, chloride, sulfate, or iodide. Table CL.1 summarizes the behavior of these ions toward H_2SO_4

1. Place a small amount of your unknown (save some for further tests) in a small, dry test tube.
   - Carefully add a drop of 18.0 M (concentrated) H_2SO_4.
   - Record your observations and the identity of the unknown ion on the Report Sheet.

2. Confirm the identity of the unknown. Carry out the appropriate confirmatory test and record your observations on the Report Sheet.

3. Place the chemicals used in the designated waste receptacles.

Name: ______________________________

Section: __________ Date: ______________

A. Household Ammonia, NH_4OH

Effect of household ammonia on dry litmus paper ______________________________

Effect of household ammonia on moist litmus paper ______________________________

Effect of NH_4Cl on litmus paper ______________________________

Effect of NH_4Cl + NaOH on litmus paper ______________________________

Effect of fertilizer + NaOH on litmus paper ______________________________

Do fertilizers contain ammonium salts? Yes ____________ No ____________

Effect of smelling salts on litmus paper ______________________________

Odor of smelling ______________________________

What do smelling-salts contain? ______________________________

B. Baking Soda, $NaHCO_3$

Effect of sulfuric acid on baking soda ______________________________

Effect of vinegar on baking soda ______________________________

chalk + HCl ______________________________

Appearance of $Ba(OH)_2$ drop ______________________________

Does chalk carbonate ion? Yes ____________ No ____________

C. Table Salt, NaCl

Effect of H_2SO_4 on table salt ______

$H_2SO_4(aq) + 2\,NaCl(s) \longrightarrow$? ______

Effect of $AgNO_3(aq)$ on table salt solution ______

Could tap water replace DI water? ______

______

Effect of $AgNO_3(aq)$ on tap water ______

Chloride ions in tap water: Yes ______ No ______

Salt in flame ______

. D. Epsom Salts, $MgSO_4 \cdot 7\,H_2O$

Effect of H_2SO_4 on Epsom salts ______

Compare effects of H_2SO_4 on Epsom salts versus baking soda. ______

______

$BaCl_2$ + Epsom salts ______

E. Bleach

Effect of bleach on NaI(aq) ______

Effect of $AgNO_3(aq)$ on NaI(*aq*) ______

$AgNO_3(aq) + NaI(aq) \longrightarrow$ ______

Effect of H_2SO_4 on NaI(*aq*) ______

F. Unknown

*Unknown #*______________________________

Effect of H_2SO_4 on unknown(*aq*) ____

Unknown ion____________________________

Confirmatory test__________________________

Results of confirmatory test) ____