XYZ Lab: Observing & Questioning

Discussion: Chemists are constantly seeking answers to questions about the composition and properties of matter and how they can change it to benefit mankind. The more we learn about nature and how it works, the more specific our questions can become. In this lab, you will observe some changes in matter having an unknown composition, then list some specific questions you would like answered to gain more understanding about the changes. You will also try to identify any barriers that prevent you from understanding the changes you see in this experiment.

Problem: Can you clearly describe several changes in matter and ask specific questions that will help you to understand what has occurred?

Procedure:

Prepare a data table in your lab journal, following the sample format below:

Procedure	Observation(s)
1.	

Record at least one observation after each procedure step. The substances are only identified as "X, Y and Z". Therefore, you need to treat them as if they are poisonous or corrosive. Avoid skin contact, do not inhale any fumes, and rinse spills with plenty of water. Goggles *must* be worn during this experiment.

1. Obtain one small, level spoonful of the crystals labeled "X" and place them in a clean, dry 50 or 100 mL beaker. Describe their appearance and properties.
2. Measure 15 mL of the liquid labeled "Y" in a graduated cylinder. Describe its appearance and properties.
3. Add the liquid "Y" to the beaker containing the crystals "X". Do not stir. Observe the results for about 3 minutes.
4. Use a stirring rod to stir the mixture until the crystals completely dissolve.
5. Obtain a piece of metal foil, approximately 2 cm x 2 cm.
6. Loosely crumble the foil and place it in the beaker with the dissolved "X" crystals. If the foil floats, use a stirring rod to press it down into the liquid. After the reaction stops, decant the liquid down the drain, rinse any solids with water, then throw the solids in the trash. Wash the beaker with water.
7. Obtain 15 mL of the liquid labeled "Z" and place it in a clean 50 or 100 mL beaker.
8. Obtain a second piece of the metal foil, crumple it, then add it to the "Z". Allow the reaction enough time to go to completion. Rinse and wash the beaker, as described in step 6.
9. Obtain another 15 mL of the liquid labeled "Z" and place it in a clean 50 or 100 mL beaker. Add a small level spoonful of the crystals "X", then stir to dissolve.
10. Obtain a third piece of the metal foil, crumple it, then add it to the beaker with the "X" and "Z". Allow the reaction enough time to go to completion. Rinse and wash the beaker, as described in step 6.
11. Place another 15 mL of the liquid labeled "Y" into a clean 50 or 100 mL beaker. Obtain a fourth piece of the metal foil, crumple it, then add it to the beaker with the "Y". Observe the results for about 3 minutes, then rinse and wash the beaker, as described in step 6.

Results:

1. Complete the data table summarizing the procedure steps and listing your observations.

2. Write at least 10 questions (requiring more than yes or no responses) that you would like answered about this experiment in order to help you understand the changes that occurred.

Conclusions: Write answers for as many of your questions as you can. Describe major barriers that prevent you from discussing and understanding all of the changes you saw in this lab.

Materials for X, Y, Z Lab

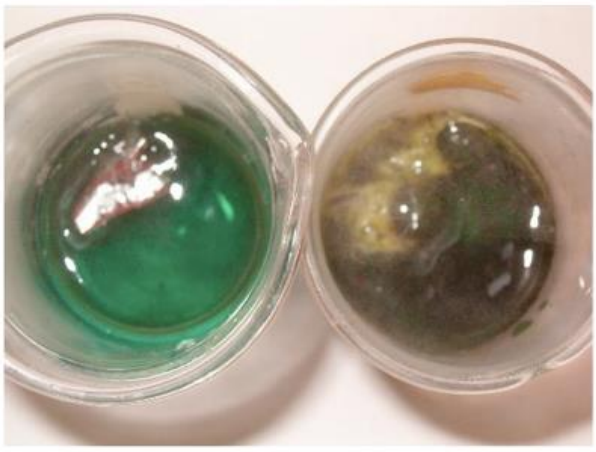
Solid X

Liquids Y and Z

Mixture of Liquid Y and Solid X with no stirring

on left: Mix of Liquid Y and Solid X, with stirring
on right: Mix of Liquid Z & Solid X, with stirring

on left: Metal with Liquid Y & Solid X
on right: Metal with Liquid Z & Solid X

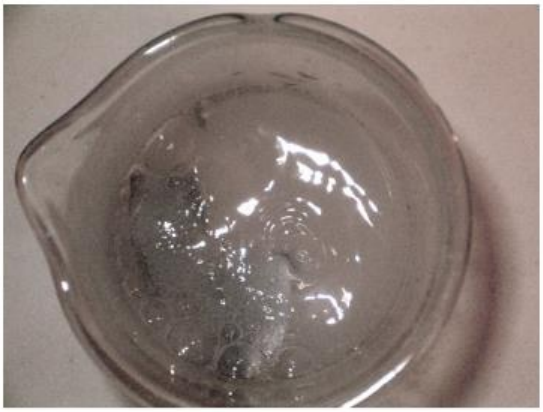


Metal with Liquid Y & Solid X after 1 minute

Metal with Liquid Y & Solid X after 3 minutes and metal dipped in solution, then removed

Metal with Liquid Z after 2 minutes

Metal with Liquid Z after 3 minutes



Metal with Liquid Y after 5 minutes

Teacher Notes: This experiment is designed to provide students with evidence of physical and chemical changes that can be used to describe matter. Without being given the identity and chemical make-up of the substances, the students are limited to relating the observed properties to things which they may be familiar with, such as specific odors like ammonia or reactions similar to rusting of metals. This provides a pathway for the teacher to present chemical names and formulas as a means of describing the changes that occur.

Substance X is a green solid called copper (II) chloride dihydrate, with the chemical formula $CuCl_2 \bullet 2H_2O$. Substance Y is water and Substance Z is an aqueous solution of 4 molar hydrochloric acid, HCl. Both liquids are clear and colorless, but students may detect a slight chlorine odor from the HCl. The metal foil is common, household aluminum foil, which is a flexible foil with a shiny, silver color.

When Liquid Y and Solid X are combined without stirring, the solid $CuCl_2 \bullet 2H_2O$ begins to dissolve and separate into the ions of Cu^{2+} and Cl^{1-}. The Cu^{2+} acts as a Lewis acid to bond to six water molecules in a dilute solution to form a complex ion structure, $[Cu(H_2O)_6]^{2+}$, that is blue in color. When the mixture is stirred, more of the $CuCl_2 \bullet 2H_2O$ dissolves causing the concentration of the Cl^{1-} to increase. The chloride ions replace the water molecules to form the green-colored complex ion, $[CuCl_4]^{2-}$. When Solid X is dissolved in Liquid Z, hydrochloric acid, there is an abundance of excess chloride ions, therefore only the green-colored $[CuCl_4]^{2-}$ is formed.

When aluminum foil is added to mixture the mixture of Solid X with either Liquid Y or Liquid Z, a single replacement reaction occurs where the aluminum dissolves and metallic copper is formed. The aluminum metal is oxidized and the copper ions are reduced. Since this reaction occurs very rapidly, the crystal structure of the metallic copper is not well defined. This makes the Cu appear as a reddish-orange, fluffy solid, rather than being shiny, like a new penny. Some students will confuse this copper solid with rust being formed, which is actually iron (III) oxide, Fe_2O_3.

The Cu^{2+} ions will also form a complex ion with available hydroxide ions in water, forming $[Cu(OH)_4]^{2-}$. This will create an excess amount of H^+, that makes the mixture of Liquid Y and Solid X an acidic solution with a pH ~ 2. When Solid X is mixed with Liquid Z, the pH ~ 0 due to the 4 M HCl. Both of these situations cause a second reaction with the aluminum foil, which is the replacement of H^+ ions in an acid to form hydrogen gas bubbles. The reaction with Liquid Z is much more vigorous due to greater acidity of the as indicated by the lower pH value.

When the aluminum foil is placed in Liquid Z alone, the reaction takes several minutes until bubbles of hydrogen gas begin to form. This is due to the fact that aluminum metal reacts with oxygen from the air to form a tough oxide coating that protects it from further reaction (oxidation). The chloride ions in the hydrochloric acid can remove the oxide coating to expose fresh aluminum metal, which then begins to react with the acid. The rate of bubbling will begin to increase rapidly and heat is released during this exothermic reaction. The beaker will feel warm to the touch.

The chemical equations for the reactions that occur are listed below.

aluminum + copper (II) chloride $\rightarrow$ aluminum chloride + copper

$$2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$$

net ionic equation: $2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$

aluminum + hydrochloric acid $\rightarrow$ aluminum chloride + hydrogen gas

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$$

net ionic equation: $2Al + 6H^+ \rightarrow 2Al^{3+} + 3H_2$