A Crystal Lab

Strand	Nomenclature, Chemical Formulas, and Reactions	
Topic	Investigating bonding, nomenclature, and formula writing	
Primary SOL	CH.3	The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include d) bonding types.
Related SOL	CH.1	The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include a) designated laboratory techniques; b) safe use of chemicals and equipment; c) proper response to emergency situations.

Background Information

Copper sulfate pentahydrate will grow beautiful blue rhombic crystals. The quality of the crystals greatly depends on the quality of the copper sulfate compound used. If you have crystalline reagent grade cupric sulfate, you will get first-rate crystals. Try to avoid using powered copper sulfate, as it does not produce very good results. Students can get great results using copper sulfate purchased from hardware or lawn-care stores.

Students can change the rate at which the solution evaporates by covering it or leaving it uncovered in order to see how this affects the size of the crystals.

Potassium aluminum sulfate (alum) will grow clear hexagonal crystals, and sodium chloride will grow clear cubic crystals. Potassium aluminum sulfate can be purchased at the grocery store. The silver crystals are really beautiful and are amazing to watch under the stereoscope because they look like shiny silver trees.

The following background information is essential to the understanding of this activity:

> The behavior of substances in the solid state is governed mainly by the way in which the atoms, ions, or molecules of the substance are arranged and the forces that hold them together.
>
> These experiments deal only with ionic and metallic crystalline solids. Each of these is distinguished by the kinds of particles that make up the three-dimensional structure of the solid. If the structure has a regular pattern, then the solid is described as “crystalline.” A familiar example would be sodium chloride (NaCl), in which sodium ions and chloride ions alternate in an extended structure known as a “crystal lattice.” In this structure, each ion occupies a point in space called a “lattice point.” This is an example of an ionic crystalline solid since ions are the structural unit. Any crystalline solid would exhibit a similar orderly arrangement of particles. Some solids, however, do not have such organization on the molecular level. Substances such as glass are really super-cooled liquids or amorphous solids

because they lack a definite crystal-lattice organization. In this experiment, we are concerned only with crystalline solids.

Ionic crystals are, of course, composed of ions. These are held tightly in place in the crystal lattice by strong electrostatic forces because of the opposite charges of the ions. These very strong forces contribute to high melting points. Although the ions are charged, they cannot move in the solid; hence, these crystals in their solid form do not conduct electricity. However, when melted, most of the attractions in the lattice structure have been overcome, and molten ionic compounds conduct electricity very well since the charged ions are now free to move. Many ionic compounds also dissolve in water. The amount that dissolves is completely separated into ions and thus makes a solution which is a good conductor of electricity.

Ionic crystals get larger by adding layers of ions on the outside of the base structure. Sometimes a "seed crystal" is added to form this base. Crystals can be grown from a solution of a substance dissolved in a liquid; when the liquid evaporates, the dissolved substance joins together in a crystal structure. The more slowly the liquid cools and evaporates, the larger and more pure the crystal structure will be.

Metallic crystals consist of metal cations positioned at the lattice points of the crystal. The valence electrons are given up to a common "sea" of electrons that flows freely throughout the metal cations. This property in metallic bonding makes most metals malleable. Metals are excellent conductors of electricity because of all the mobile electrons. This conductivity exists in both the solid and liquid state.

Supersaturated solutions are highly unstable solutions in which a saturated solution has been forced to hold more of a dissolved substance than it should be able to hold at that temperature. Supersaturated solutions are formed by quickly and carefully cooling saturated solutions. The crystals will not form unless the solution is jarred or a "seed crystal" is introduced. Once the crystallization process starts, it continues rapidly until all of the solution is crystallized.

The test tube should feel warm during the crystallization process. Crystallization is an exothermic process that gives off heat energy. When bonds form, energy is released in the form of heat. The crystal-lattice structure is more stable and lower in energy than the solution, so by forming the crystal lattice, the compound increases its stability and decreases its potential energy.

Sodium thiosulfate is a hydrated compound that contains water molecules bonded to the lattice structure. When heated, the water molecules are removed, and the remaining substance dissolves in the water. This makes it easy to make a supersaturated solution of sodium thiosulfate.

Materials

- Distilled water
- Beaker
- Burner
- Filter paper
- Safety goggles
- Watch glasses

- Stereoscope
- Sodium chloride ($NaCl$)
- Copper(II) sulfate pentahydrate ($CuSO_4 \bullet 5\ H_2O$)
- Potassium aluminum sulfate [$KAl(SO_4)_2$]
- Copper wire
- Aluminum wire
- *M* silver nitrate ($AgNO_3$) solution
- *M* copper(II) nitrate [$Cu(NO_3)_2$] solution
- Sodium thiosulfate ($Na_2S_2O_3 \bullet 5\ H_2O$) crystals
- Test tube
- Utility clamp
- Cold running water
- Window facing bright sunshine or other good light source

Vocabulary

anion, cation, compound, crystals, evaporation, ionic, lattice points, metallic, particle, pattern, saturated, seed crystal, solution, stereoscope, supersaturated

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. Explain to students that they will be dealing with only ionic and metallic crystalline substances in this experiment. Each of these is distinguished by the kinds of particles that make up the three-dimensional structure of the solid. If the structure has a regular pattern, then the solid is described as "crystalline." Ionic crystals are, of course, composed of both cations and anions. Metallic crystals consist of only metal cations positioned at the lattice points of the crystal.

Procedure

Experiment 1: Ionic Crystal Formation

1. Place approximately 50 mL of distilled water in a clean beaker, and begin heating. Be sure to keep the water below boiling temperature.
2. Slowly add solid sodium chloride, and allow it to dissolve while stirring.
3. Continue to add the salt until no more will dissolve and a small amount of undissolved solid remains in the bottom of the beaker. This is now a saturated solution.
4. Filter the hot solution into a clean, dry beaker, and cover with a watch glass, leaving a small opening for evaporation to take place.
5. Set the beaker aside, and do not disturb it until the crystals have completely formed.
6. When the crystals have completely formed, observe their structure under the stereoscope.
7. Repeat the above procedure with copper(II) sulfate pentahydrate and again with potassium aluminum sulfate.

Experiment 2: Metallic Crystal Formation

1. Place a small piece of clean copper wire on a watch glass, and place under the stereoscope.

2. Use a plastic pipette to add a small amount of silver nitrate solution ($AgNO_3$) to the copper metal, and observe the growth of silver (Ag) crystals. The reaction is expressed as 2 AgNO3 + Cu → $Cu(NO_3)_2$ + 2 Ag. *CAUTION! $AgNO_3$ causes skin discoloration.*
3. Observe the growth of the metal crystals under the stereoscope.
4. Repeat the above procedure with aluminum wire and a copper(II) nitrate [Cu(NO3)2] solution. The reaction is expressed as 3 $Cu(NO_3)_2$ + 2 Al → 2 $Al(NO_3)_3$ + 3 Cu.

Experiment 3: Supersaturated Solution Crystal Formation

1. Fill a large, clean test tube slightly more than half full with sodium thiosulfate ($Na_2S_2O_3 \bullet 5 H_2O$) crystals. Sodium thiosulfate is a hydrated crystal: it contains water molecules chemically bonded to the crystal-lattice structure.
2. Using a utility clamp, heat the test tube containing the sodium thiosulfate. As you heat the substance, the water will come out of the crystals, and then the rest of the substance will dissolve in the water. Heat the test tube until all of the crystals dissolve.
3. When the solution begins to boil, heat it *gently* so it will not shoot out of the test tube. *CAUTION! Do not point the test tube at anyone, including yourself.* Boil the solution for a few seconds to rinse any remaining crystals from the upper part of the test tube; then turn off the burner.
4. At this point, you will have a saturated solution. Hold the test tube of hot liquid very still under cold running water, or place it in a beaker of cold water. Do not shake or stir the solution. Do not let any water run into the solution, as this would dilute it. Cool the liquid for several minutes, and then slowly remove the test tube from the running water or water bath. Wait about 10 seconds. If the test tube still feels warm, cool it a little longer; if it feels cool, stop cooling it.
5. By cooling the saturated solution rapidly and carefully, you have created a supersaturated solution. The cooled solution actually contains more solid than it should contain at that temperature. This is a very unstable solution, and it will not stay supersaturated very long. It can be easily changed by dropping in a seed crystal of the solid.
6. Place the test tube of cool liquid in a bright window or near a good light. Be careful not to shake or disturb the solution at this point. Drop a single crystal of sodium thiosulfate into the liquid in the test tube, and observe what happens. Feel the sides of the test tube for the release of heat energy as the crystal-lattice structure forms.
7. Repeat this process several times with the same test tube and contents. Each time, you create a more supersaturated solution, and crystallization will occur more rapidly.
8. Clean up your test tube as directed by your instructor. (You may have to throw it away.)

Observations and Conclusions

1. Observe your crystals under the stereoscope, and draw the crystal structures you see.
2. Describe the differences and similarities between the ionic and metallic crystals you have made.

Assessment

- **Journal/Writing Prompts**
  - Research the actual crystalline geometry for the crystals you grew, and describe and explain any differences between the lab-grown crystals and the expected geometry.
- **Other**
  - Role-play the formation of ionic compounds. Have students become metal and nonmetal atoms, using sticky notes to show valence electrons and signs around students' necks to indicate which atoms they are. "Metal" students remove the sticky note electrons and place them appropriately on the "nonmetal" students and then move next to each other to show the formation of an ionic compound.

Extensions and Connections (for all students)

- Challenge students to grow larger and more complex crystals. There is more information on the Internet about crystal-growing projects. Have them research a crystal they would like to work on further, and encourage them to experiment with different crystal-growing techniques.
- Invite a geologist to bring in samples and describe crystal formation in minerals.

Strategies for Differentiation

- Videotape each experiment for students to review as needed.
- Have students take digital photos of the crystal structures formed in each experiment.
- Have students use a draw/paint program to draw the crystal structures seen through stereoscope.
- Have students use a digital microscope to view the crystals on a computer monitor; save the images.
- Have students demonstrate ionic model formation, using poker chips to represent the valence electrons and construction paper squares labeled with metal and nonmetal atomic symbols. Have students manipulate the poker chips to show the loss of electrons by the metal atom(s), the gain of electrons by the nonmetal atom(s), and the subsequent electrostatic attraction to form an ionic bond.
- Provide a two-column sorting chart labeled ionic and metallic. Have students place pictures of the crystals into the correct column.
- Provide a Venn diagram template for students to show the similarities/differences between ionic/metallic crystals.