Piezoelectric Effect of a Rochelle Salt Crystal Investigation

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Activity Summary

The Kawasaki lab focuses on investigating the conductive, magnetic, and elastic properties of crystal materials. The specific research project we worked on involves making new crystalline materials using a technique called molecular beam epitaxy (atomic spray painting). Crystals produced are evaluated for purity and structural symmetry after growth. Our lab activity models this research by having students investigate what factors influence crystal growth and formation. Students will also try to optimize Rochelle salt crystal purity and piezoelectricity, which is similar to the general process done in our research lab. Variables students are encouraged to investigate include crystal doping (adding an impurity), changes to temperature during crystallization, different amounts of solute in the crystal-forming solution, and modifications to the filtration or crystal seeding procedure.

Audience

Lalitha Murali - 6-8th grade (Science)

Nick Bonde - 10-12th Grade (Chemistry and Environmental Science)

Time Frame

Set-up: 30 minutes

Activity: Pre-lab 20 minutes, Lab 30 minutes, Post-Lab (must be next day) 15 minutes

Clean-up: Lab 10 minutes, Post-Lab 5 minutes

Objective(s)

After completing the activity, participants will be able to:

Background:

1. Model the basic lattice structure of crystals.
2. Identify the types of crystal structures.

Lab Activity:

3. Design an investigation that tests factors that influence Rochelle crystal growth and their piezoelectric properties.
4. Apply the concept of crystal formation to specific applications in everyday life.

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Standards Addressed:
6-8 NGSS

Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support.

MS-ETS1-1 Engineering Design (6-8)
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2 Engineering Design (6-8)
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3 Engineering Design (6-8)
Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4 Engineering Design (6-8)
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Engineering Principles: http://www.nap.edu/openbook.php?record_id=13165&page=203

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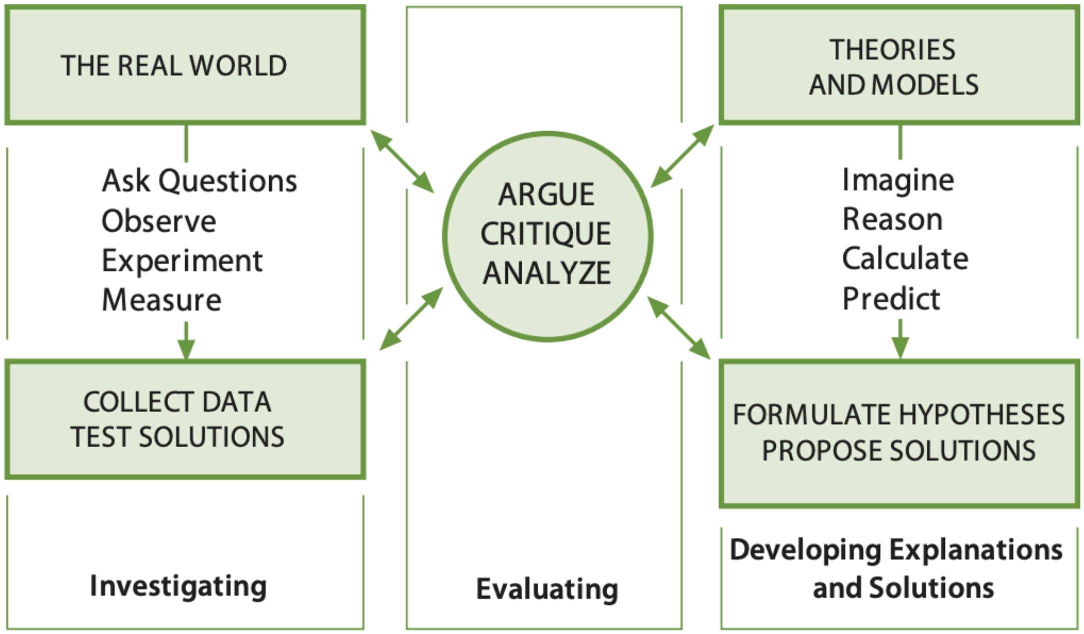

FIGURE 3-1 The three spheres of activity for scientists and engineers.

Chemistry/Environmental: (9-12)

- **HS-PS1-1 Matter and its Interactions -** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

- **HS-PS2-6 Motion and Stability: Forces and Interactions -** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Engineering principles (9-12)

- **HS-ETS1-1 -** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

- **HS-ETS1-3 -** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Science Practices and Skills

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- Plan & Carry Out Investigations
- Analyze & Interpret Data
- Construct Explanations & Design Solutions

Activity Materials

- Cream of tartar (large bag)
- Sodium Carbonate
- Beakers (2 per group)
- Clear plastic cups (3 per group)
- Coffee Filters (3 per group)
- Hot Plate (1 per group)
- Scale (1 per group)
- Stir rod (1 per group)
- Multimeter (1 per group)
- Wires with clips (2 per group)
- Light intensity probe (Optional: 1 per class)
- Clamp (1 per group)
- Aluminum foil (Small sheet per group)
- Paper towel (1 roll per class)
- 1 marble
- 1 quartz
- 1 sugar crystal (rock candy)
- 1 Rochelle salt crystal (1 per group)
- 1 pencil
- 1 lab notebook and pencil per student
- Piezoelectric transducer (1 per group

Safety

- Goggles must be worn since hot chemicals are in use.
- Chemicals are non-toxic but can be irritating in large quantities when they come in contact with the eyes.
- Hotplates and hot liquids are involved - Hot pads must be used.
- Gloves if necessary as the ingredients are non-toxic.

Activity Instructions

Set-up:

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1. Day 1- The best procedure requires Rochelle salt to be made ahead of time or available from a supplier like Flinn. The procedure involving 80g of cream of tartar and 40 g of sodium carbonate can be done in real-time by the students on Day 2.
2. Day 2 - Each group will need the following materials at their lab stations: Two Beakers, a hot plate, Rochelle Salt, a stir rod, weigh boat, balance, and distilled water
3. Day 3 - Each group will need the following materials at their lab stations: Clamp, voltmeter, Aluminum foil, paper towel, pencil, and Rochelle crystal from Day 2.

Introduction (20 min)

- Rochelle salt (Sodium Potassium Tartrate Tetrahydrate) is an example of a crystalline solid with piezoelectric and conductive properties. Piezoelectricity is the process of converting mechanical energy into electrical energy. Piezoelectricity crystals like Rochelle Salts can be applied to a variety of different technologies including generators, microphones, speakers, motors, sensors, and more.

- **Pre-Lab Discussion Questions:**
  What is a crystal?
  What conditions are needed for crystals to form?
  What are three factors that affect crystal growth and purity?

- **Key Concepts**:
  - Crystal structure and lattice model
  - Crystal formation
  - Solutions - Solute vs Solvent
  - Supersaturated solutions
  - Seeding and Crystal Growth Procedures
  - Properties of crystalline solids
  - Phase changes (prerequisite)

The Next Part of the Activity - Crystal Growth - Day 2 (45 minutes)

1. Bring 100 mL of distilled water to a boil on a hot plate.
2. Add 80 g of potassium bitartrate (cream of tartar) to the boiling mixture and stir slowly for 1 minute.
3. Slowly add 10g of sodium carbonate and stir until the solution stops bubbling.
4. Repeat Step 3 three more times (adds 40 g of sodium carbonate total).
5. Turn the hot plate off. Leave the solution on the hot plate as it cools. The solution should become clearer.
6. Filter the solution using filter paper and a funnel.

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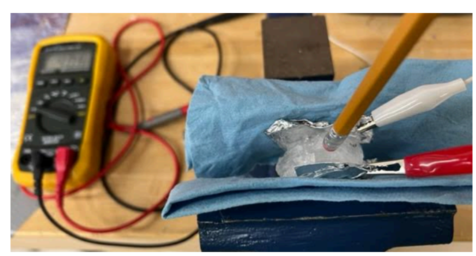
7. Once cooled, move the solution to a plastic cup and let it sit overnight.

The Third Part of the Activity (45 min)

Crystal Properties Tests - Day 3 (45 minutes)

1. Select your best single crystal from your "control" and "test" containers. These crystals should be roughly the same shape and size (if possible).
2. Measure the **mass** of your crystal
    a. Gently dry the crystal off with a paper towel.
    b. Once the crystal is dry, collect and record a mass reading.
3. Measure the **Light Reflection Intensity** for each of your samples and record in the table below.
    a. Place your "control" crystal sample on the dot under the light intensity probe. Do not move the light intensity probe to ensure consistent readings between groups. Record the measurement.
    b. Place your "test" crystal sample on the dot under the light intensity probe. Do not move the light intensity probe to ensure consistent readings between groups. Record the measurement.
4. Measure the **Piezoelectricity** produced by your crystal samples.
    a. Obtain two small pieces of paper towel, two small squares of aluminum foil, your Rochelle crystal, a voltmeter, and a clamp.
    b. Wrap the paper towels on each side of the clamp.
    c. Place a piece of aluminum foil on each side of the Rochelle salt crystal and **lightly** clamp it together. The two pieces of aluminum foil should **not** be touching each other. Your Rochelle salt can easily break in this step, so make sure to tighten the clamp only enough to secure the crystal.



    d. Attached each side of the voltmeter onto each piece of aluminum foil using the gator clip wires.
    e. The completed setup should look like the one pictured to the right.

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f. Record the initial voltage reading. Wait for your teacher to come around to tap your sample (uniformly) with a pencil. This will be the final voltage reading.
g. Repeat for all the following samples: marble, quartz sample, sugar crystal, transducer

Evidence Data Table:

Crystal Sample	Mass (g)	Light Reflection Intensity (lux)	Piezoelectricity (mV)	
Rochelle Salt			Initial:	Final:
Marble			Initial	Final:
Sugar			Initial:	Final:
Quartz			Initial:	Final:
Transducer			Initial:	Final:

Conclusion (30 min)

- Students submit a lab summary of their results, including the analysis questions' answers. They will also answer the three self-reflection questions.

Assessment
Students will be evaluated based on their lab notebook, crystal samples, and self-reflection.

Self-reflection:

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1. What did you think you did well during this project?
2. What new skills or knowledge did you learn by doing this project?
3. If you worked with other students on this project, describe that experience and how you think it went

Analysis Questions:

1. Many minerals grow from a liquid. Describe the primary steps required for a mineral to grow from solution.
2. What causes crystal growth?
3. Why is crystal growth important?
4. What is your favorite crystal? Why?
5. What are some factors that affect crystal growth?
6. What could be some futuristic and technological inventions that you can think of with crystal growth?

Background:

Crystallization is critical to diverse areas of science and technology. There are many ways to grow crystals, such as from supersaturated solutions, liquids of pure substances or mixtures that do not change their composition when melting, chemical vapor deposition, etc.

Scientific Explanation:

When we dissolve solids in water, the solution becomes stronger. We can make a saturated solution by adding more solute to the solvent. A saturated state occurs when you cannot dissolve any more solute in the solvent. Hot water can dissolve more solvents than cold water. If the solvent is left to cool down and the water evaporates, the solute molecules begin to link up and grow into crystals. A crystal is a solid material with atoms and molecules that are arranged in a consistent repeating pattern.

Students can make crystals using a variety of materials like borax, Alum, sugar, salt, Epsom salt (Magnesium sulfate), baking soda, Rochelle salt, copper sulfate, and potassium ferricyanide.

Crystals are formed because of evaporation. Temperature and humidity are two things that affect the rate of evaporation. Students can design their own experiments to see how different

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temperatures and humidity levels affect the rate of crystal growth and the size of the crystals. They can also test the rate at which their solution is cooled. If they make a solution with boiling water or hot water, what would happen? Will the crystals grow better if it is allowed to come to room temperature slowly or if it is cooled in the refrigerator?

Supplemental Materials

1. TEACHER COPY - Piezoelectric Effect of Rochelle Salt Crystals
2. STUDENT COPY - Piezoelectric Effect of Rochelle Salt Crystals

Email to Matthew Stilwell at mstilwell@wisc.edu

References

TED-Ed. (2017, June 20). How to squeeze electricity out of crystals - Ashwini Bharathula [Informational Video]. Youtube. https://www.youtube.com/watch?v=YEJ2qryXcIQ

TED-Ed. (2019, June 18). How do crystals work? - Graham Baird [Informational Video]. Youtube. https://www.youtube.com/watch?v=PgSRAsgrKm

Additional References

How to squeeze electricity out of crystals - Ashwini Bharathula

How do crystals work? - Graham Baird

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