Seeing Structure in Solids

Overview

This activity is designed to let students experience solids close-up using a USB microscope. Students will be surprised to discover that little granules of salt and sugar are crystals, and that grains of sand look like miniature versions of rocks (which they are). If we had much stronger microscopes, we would even be able to see the crystal structures of the sand particles.

Theory

Most solids have a crystal structure composed of molecules bonded together in an orderly three-dimensional pattern. Solids maintain their crystal structure even as the size of the material gets smaller and smaller. Think of different sizes of sugar: sugar cubes, granulated sugar, and powdered sugar. The cubes contain many sugar crystals. When you examine granulated sugar with the USB microscope, you will see the signature elongated crystals with slanted ends. Individual powdered sugar pieces are so small that the USB microscope in the kit can't detect them. Scientists have used x-rays to determine that powdered sugar does have the same crystal structure as what you observe in granulated sugar; the crystals are just much smaller.

Doing the activity

Necessary materials:

- laptop computer
- Celestron USB Digital Microscope
- samples of salt, sugar, sand
- Petri dish
- dark pieces of paper or fabric to put under the petri dish to create contrast with the samples (optional, but recommended)

Preparation before class: You will be using a Celestron USB digital microscope and your computer for this activity. It's one of the most exciting and inexpensive tools we've found to view solids, and we think that you and your students will love it! Directions and software are included in the kit for Windows OS. If you are using a Mac, connect the USB cable to the USB port on your computer, then open the Photo Booth application (you can open this program from the Applications folder in Finder, or search for it by pressing command + space bar to bring up Spotlight). Before you work with your students, practice positioning and focusing the microscope over a solid. Photo Booth can take snapshots or a short video of what you are examining, so the class can review it later. Connect your computer to a projector or smartboard so the whole class can discover what a close-up view of solids reveals. (If you are at a 1:1 school, you may want to consider searching for funding to acquire a classroom set of USB microscopes — basic models are generally less expensive than dissecting microscopes, and have a wide range of uses.) What you find may be quite surprising!

An image of multiple salt crystals viewed through a USB microscope. The crystals have a clear cubic structure, and are all roughly the same size (there is some variation).

Salt

Ask students what they think table salt will look like when viewed through the microscope. If your students previously did the "Building Blocks" activity, they may suggest that they will see crystals or cubes. Sprinkle some salt into the Petri dish, and place the dish on a dark surface to improve the contrast for viewing. Encourage your students to share

An image of salt crystals formed after the evaporation of salty water, taken through a USB microscope. The crystals still have a clear cubic structure (and layers seem to be visible in some crystals), but now there is quite a bit of variation in size: The largest crystal is perhaps 10× as wide as the smallest visible crystal.

observations and discuss their findings. You may want to review the model of salt and the composition of salt molecules: A salt molecule is made of two different atoms, and the molecules form a crystal structure as they stick (bond) together.

You may also want to dissolve some salt in water and ask the students what they think will happen when all the water evaporates. Will there be anything left at all? What will happen to the salt? Once students can see that the salt stays behind in the container and re-forms into crystals, ask students to hypothesize why these crystals have the same shape as the crystals they started with. (The crystal structure is determined by how the molecules fit together, and the salt molecules have the same structure both before and after being dissolved in water. However, you may find more size variation in the crystals now.) We did this in a dark measuring cup and took a snapshot of our findings (at left).

Sugar

Ask your students to predict what sugar crystals will look like when viewed through the microscope, then investigate using the granulated sugar sample. Encourage your students to comment on the images and discuss. Students may be surprised to see that sugar granules have a crystal shape that is different from the salt crystal shape. Sugar molecules, which are composed of three different types of atoms (carbon, oxygen, and hydrogen), are organized in a repeating pattern that forms a crystal structure that is elongated and has slanted ends.

An image of sugar crystals viewed through a USB microscope. The sugar crystals tend to be more variable in size and more elongated than the salt crystals; they have a rectangular prism structure, and many have a pointed end.

Students often wonder what powdered sugar might look like under a microscope. This is a great idea for an investigation, but unfortunately, our USB microscope cannot detect the crystal structure of powdered sugar — the crystals are just too small. However, scientists have used x-rays to determine that it indeed has the same crystal structure as the granulated sugar. You may want to dissolve sugar in water and let the water evaporate. What would the sugar crystals look like? We haven't tried this yet, so please let us know how it turns out!

Sand

Now that they've seen two examples of crystals under a microscope, ask your students to predict what sand will look like under the microscope. Your students will most likely be surprised by the view! The *States of Matter* kit includes sand from two different locations: Lake Michigan and the Cache la Poudre River in Colorado. Ask students to observe similarities and differences between the two types of sand.

An image of sand from Lake Michigan viewed through a USB microscope. The sand grains are mostly clear and colorless, white, or yellowish. Most grains are relatively smooth and small, but there is some variation.

The sand from Lake Michigan is composed mostly of quartz, although you may notice a few pieces of shells as well. The sand particles have smooth edges and look quite similar in size to one another. This may be due to erosion over time from wind, water, and ice.

An image of sand from the Cache la Poudre River viewed through a USB microscope. These sand grains are also mostly clear and colorless, white, or yellowish, but they appear quite pointy and rough. There is a great deal of variation in size.

The sand from the Cache la Poudre River looks significantly different from the Lake Michigan sand when examined using the USB microscope. Although, just like the Lake Michigan sand, Cache La Poudre sand is composed mostly of quartz, notice the variation in particle size, and also the jagged edges. Discuss ideas about why the samples look so different. Let students touch a sample of sand from each location. Do the two types of sand feel different to the touch?

Sand along a river, lake, or ocean can be quite different, as the sand is a collection of materials (rocks, crystals, and shells) from the surrounding area. Variation among sands from different locations also arises from the hardness of the materials and the process and intensity of erosion. The sand on the island of Cozumel, Mexico is quite white, a bit rough on the feet, and made mostly of shells. In Hawaii, there are black sand beaches due to rocks and ash from volcanoes. (If you want to bring sand or other samples back from vacation for further exploration, make sure to check local ordinances first — we've been told that it's illegal to remove sand from Hawaii, for example.)

Have students find additional natural items on school grounds, or anything they want to investigate in the classroom, to examine under the microscope. Remind them that all of these solids are formed by molecules sticking (bonding) together.

Extension: Borax "snowflake"

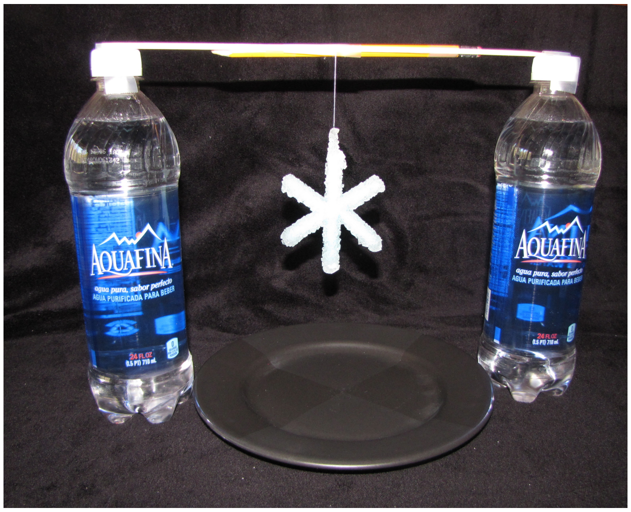
After examining salt crystals and more, students most likely will enjoy growing crystals. Instructions for this type of activity are widely available online. We tried some, and got the best results from this Borax Crystal Snowflake recipe: https://www.thoughtco.com/grow-a-borax-crystal-snowflake-602199. The materials are easy to find, and students can start the process on one day and see the results the next.

SAFETY NOTE: *Borax can cause skin, eye, and airway irritation, and can be toxic if ingested. Avoid breathing borax dust, use gloves and eye protection, and have students wash their hands with soap after working with borax. Students with damaged skin should not handle borax. Ensure that students do not consume any borax.* ***If a student consumes a substantial quantity of borax (about a gram or more), get medical help right away.***

Extension materials:

- borax*
- boiling water
- a wide mouthed container, such as a plastic canister
- white pipe cleaners
- scissors
- sewing thread
- pencils
- tape
- food coloring (optional)

*Borax is available in the laundry sections of most grocery stores. Make sure you get powdered borax, not a soap that contains borax.



A borax crystal "snowflake" suspended from a pencil between two bottles of water. The "snowflake" has a vertical arm and two cross-arms angled about 45˚ above and below the horizontal. The arms are all about the same size, and are covered in small, spiky white crystals.

As you do this activity, have a class discussion about what's happening to the borax molecules. What are they doing in the liquid state, and what are they doing as they become a solid? The liquid water molecules in the boiling water have more energy and can move a little farther apart. Even though they are still touching each other, they can move around and glide past other molecules. The borax molecules also absorb energy from the boiling water and dissolve in the water. As the borax solution cools, the liquid water molecules have less energy and move more closely together. The dissolved borax molecules also have less energy as they cool off, and some molecules start moving back into the less-energetic crystal structure and start collecting on the sides of the container and the pipe cleaners in the solution. Students will be thrilled with this liquid to solid transformation!

Summing up

As students experience solids close-up using tools such as microscopes, they discover a tiny world of crystals and more. This helps them understand that there are many very, very small particles (atoms and molecules) which make up all matter. It is also a step towards understanding what is happening at a molecular level during phase changes.

For more information

Little Shop of Physics: https://www.lsop.colostate.edu

Colorado State University College of Natural Sciences: https://www.natsci.colostate.edu