The Science of Snowflakes

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Subject: Earth Science, Engineering
Level: Middle School
Standards: *New York State- Intermediate Science* *(www.emsc.nysed.gov/ciai/)*
Standard 1- Analysis, Inquiry and Design
Standard 4- The Physical Setting
Standard 6- Interconnectedness: Common Themes
Standard 7- Interdisciplinary Problem Solving
Schedule: Five to six 40-minute class periods

Objectives:

Learn about states of matter, classification, and properties of crystals

Students will:

- Catch snowflakes and classify them by shape and structure
- Grow a crystal in a jar
- Design an experiment that will show if the growth of the crystal changes if grown under different conditions
- Design a "mini-hut" to preserve the crystal structure of ice
- Reflect on scientific process and discuss concepts that were learned

Vocabulary:

Matter
Atom
Crystal
Volume
Density
Ion

Materials:

For Each Student:
Activity Sheet 1: *Thinking About Snowflakes*
Activity Sheet 2: *The States of Matter*
Activity Sheet 3: *Temperature of Substances*
Activity Sheet 4: *Let's Classify Snowflakes*
Activity Sheet 5: *Properties of Crystals*
Activity Sheet 6: *Grow a Snowflake in a Jar*
Activity Sheet 7: *Experiment Template*
Activity Sheet 8: *Design a Mini-Hut*
Box with a lid
Can of "Crystal Clear" spray
Glass microscope slides
String
Wide mouth jar
White pipe cleaners
Blue food coloring (optional)
Boiling water*
Borax
For Each Pair:
Microscope*

*Provided by the teacher

Safety:

Blue food coloring can stain clothing. If it is used, use caution when handling it.

Science Content:

Snow Crystals:
When cloud temperature is at freezing or below and the clouds are moisture filled, snow crystals form. The ice crystals form on dust particles as the water vapor condenses and partially melted crystals cling together to form snowflakes. It is said that no two snowflakes are the same, but they can be classified into types of crystals. All snow crystals have six sides. The six-sided shape of the ice crystal is because of the shape and bonding of the water molecules. Basically there are 6 different types of snow crystals: needles, columns, plates, columns capped with plates, dendrites and stars. The type of crystals depends on the amount of humidity and temperature present when they are forming. That's why when it's very cold and snowing, the flakes are small, and when it's closer to 32 degrees Fahrenheit the flakes are larger.

Crystals: What Are They and What Holds Them Together

Introduction

Crystals have changed the world a lot. Crystals occur widely in nature and they are used a great deal in modern technology. Crystals are everywhere. The purpose of designing a unit on "Crystals What Are They and What Holds Them Together" is to help students learn about crystals and their structure.
The unit will deal with what is a crystal, the three states of matter: their properties, structure, ions and salts, and crystal growth.

What Is Matter?

Matter is what the world is made of. All materials consist of matter. All matter has its own set of properties or characteristics. Some properties of matter such as color, size, and shape can be observed easily; other properties cannot be observed quite so easily. Properties that can be determined without changing the substance into a new kind of substance are called physical properties. Changes that do not produce a new kind of substance are called physical changes. During a physical change, the physical properties of a substance are altered, but the substance remains the same kind of matter.

Two Basic Properties: Mass and Volume

Mass is the most important physical property of matter in an object. The kilogram is the basic unit of mass in the metric system. For example, there is more matter in a large pool than in a child's play pool. So a large pool has more mass than a child's play pool. To measure small units of mass, we use the gram. One kilogram is equal to 1000 grams. Volume is another important property of matter. Volume is the amount of space an object takes up. Volume is expressed in units called liters (1), milliliters (ml) and cubic centimeters (cm^3). One liter is equivalent to 1000 cubic centimeters.
Using the two physical properties of mass and volume, you can define matter as anything that has mass and volume.

Density

Density is the mass per unit volume of a substance. The following formula can be used to find the density of an object. Density is mass/volume. Mass is usually expressed in grams, and volume in milliliters or cubic centimeters. Thus density is g/ml or g/cm^3. So we can compute the density of a 1-centimeter cube taken from the planet Mars with a mass of 3.96 grams. The average density of mass would be: Density=3.96g (mass)/1 cm^3 (volume) =3.96 g/cm^3. The density of water is 1g/cm^3, while the density of gold is 19.32g/cm^3.

The Three States of Matter

On the earth, matter can exist in three states. The states of matter are solid, liquid, and gas. A solid has a definite shape. A liquid takes on the shape of its container. A gas does not have a definite volume or a definite shape. A gas fills all the space in a container, regardless of the shape or the size.

Most materials can take any of the three forms, with no change in their chemical composition. Steam, water, and ice are common names for the three forms taken by a single material.

The best way to picture the difference in the states of matter is to think about water which can be changed into a solid by freezing it to produce ice, melting it to produce a liquid, and heating it to produce a vapor or gas.

In order to understand the states of matter, you must know something about molecules. The different substances that exist are made up of small particles. A molecule is the smallest part of any substance that still has all of the properties of that substance. The behavior of solids, liquids, and gases can be explained in terms of the arrangement and movement of molecules.

In the solid, atoms are close together. They vibrate but cannot move past one another. In the liquid the atoms are almost as closely packed as in the solid, but they can move past one another. In the gas the atoms are widely separated, and can move almost independently.

What Are Crystals?

Sometimes when a mineral is forming in the earth's crust, it grows into a particular geometric shape. The shape of a crystal results from the way the atoms or molecules of a mineral come together as the mineral is forming. So, each mineral has its own crystal shape. This solid body has a characteristic internal structure and is enclosed by symmetrically arranged plane surfaces, intersecting at definite and characteristic angles. Fashioned snowflakes, flawless diamonds with glittering facets, the almost perfect cubes of salt grains are all fine examples of crystals bodies with a pattern of flat surfaces that meet at definite angles. The universe is full of almost all nonliving substances in the solid state form crystals. Crystals are ice, snow, sugar, salt and sulfur; in metals like gold, silver, copper, iron and mercury; in precious stone like zircon, emerald, topaz, ruby, and sapphire.

A specific crystal is a collection of fundamental building blocks with atoms and molecules arranged in a unique and always repeated regular space arrangement. Nature has grown crystals over a long span of geological time. The smooth, hard surfaces of a crystal are not shaped by the tools of man.

The Inner Structure

The external differences between crystals are based on differences in internal structure. The particles of matter within a crystal are arranged in a framework called a crystal lattice. There are four types of structural units in crystal lattices. They are small molecules, giant molecules, ions or electrically charged molecules and atoms.

Crystals Made Up Of Small Molecules

In substances like ice, iodine and solid carbon dioxide or dry ice, the structural units of the crystal lattice are small molecules. These are held together by rather weak electrical forces. There is much space between the molecules and the crystals are light in weight. That is why ice is lighter than liquid water, though both substances are built up of the very same water molecules. It is important to know that ice is unique because if ice would sink, life in the ocean would be at stake. Fish and other aquatic life will freeze. Usually, crystals in which small molecules are the structural units have low melting points; they are good insulators and are relatively soft. In some cases the bonds between the molecules are so weak that the solid will change into a gas without first becoming a liquid. This is what happens in the case of dry ice which is solid carbon dioxide.

Crystals Made Up Of Giant Molecules

Some crystals consist of giant molecules. These may be built up in one, two, or three dimensions. Asbestos is a good example of a substance that forms one dimensional giant molecule. The asbestos giant molecule consists of a long chain of atoms; this accounts for the fibrous structure of the mineral. The molecules are set side by side; they are linked together by weak forces of attraction.

The giant molecules of graphite, made up entirely of carbon atoms, are two-dimensional; they are joined together in flat hexagonal plates which lie parallel to each other. See figure 4. The bonds between layers are weak in comparison with those within the hexagons; hence one layer slips easily over the one beneath it. That is why graphite is one of the best lubricants known.

The diamond is a giant molecule built up in three dimensions. Diamond consists exclusively of carbon atoms. Each atom is bonded to four neighboring atoms, which are grouped about it at equal distances. See figure 5, for example, the carbon atom A is bonded to carbon atom B, C, D, and E. B, C, D, and E are each bonded to other atoms in the same way. Since the distances between the atoms in this type of giant molecule are equal, the bonds are of equal strength. The result is a very rigid formation. The diamond is the hardest substance known and it is very difficult to cleave or split it. It has a high melting point; is a good insulator and is transparent.

Crystals Made Up Of Ions

In salts, the unit making up the crystal is an ion, an electrically charged molecule or atom. Each atom has a nucleus or central core made up chiefly of protons, each with a positive electrical charge, and neutrons, which have no charge. Around this central core revolve the electrons, each of which has a negative charge. Normally the charge of an atom is neutral; which means that there will be as many negative charges as there are positive charges. If an atom loses an electron, it has one excess positive charge; it becomes a positive ion. If an atom gains an electron, it has one excess negative charge; it becomes a negative ion. Look at what happens when sodium, normally a metal, and chlorine, normally a gas react to form the solid called sodium chloride, NaCl, which is table salt. Each sodium atom transfers an electron to a chlorine atom. The sodium atom becomes a positive ion since it now has an excess positive charge. Each chlorine atom acquires a single excess negative charge; it is now a negative ion.

Ions with unlike charges attract each other, the chlorine ions will attract the sodium ions; but will hold off the other chlorine ions since ions with like charges repel each other. As a result of the attraction between the oppositely charged particles, each chlorine ion will surround itself with six sodium ions; each sodium ion will surround itself with six chlorine ions. This pattern will be repeated throughout the crystal. Substances that have the ionic type of lattice have moderate insulating properties and high melting points. They are hard, but they can be split along definite lines.

Crystals Made Up of Electrically Neutral Atoms

In metals, the atom is the structural unit in the formation of a crystal. The atoms may be thought of as spheres having the same diameter and packed together as closely as possible. To illustrate one arrangement, let us imagine that fifteen billiard balls are racked up to form the base, or foundation layer. See figure 8. Six more are set on top of the first layer of balls; then another ball is placed on the second layer. This shows the closest packing possible in a cube. Iron, lead, gold, silver, and aluminum assume this kind of pattern. There are several other arrangements of atoms in metallic crystal lattices. Lattices of this kind are opaque; they have moderate harness; they have high melting points; they are the best conductors of heat and electricity. These qualities make metals very useful.

The Internal Structure of a Crystal Affects Its Properties

The variation in internal structure shown by different crystals has a direct bearing upon their properties. Different crystals have different lines of cleavage, which are lines along which they split most readily. They conduct heat at different rates. They react differently to magnetic and electrical forces. A few crystals, like those of the mineral Iceland spar, allow only light waves that vibrate in parallel planes to pass through them. This effect is called plane polarized light. For example, try to pass a knife blade between the pages of a closed book. This will be possible only if the knife blade is held parallel to the pages. The book in this case would correspond to the Iceland spar crystal; the knife would correspond to one of the parallel planes in which the light would vibrate.

If a light is allowed to pass through a selected crystal of quartz, the plane of polarized light is twisted to the plane to the same angle to the left. Crystals of the first type are called right-handed, those of the second type, left handed.

The fact that different crystals will rotate the plane of polarized light in different directions forms a reliable means of identifying certain substances. For example, sugars in solution will rotate the planes of light through different angles; the angle of rotation will identify each sugar in question.

Preparation:

Day One

1. Photocopy print materials (*Activity Sheets 1-8*).
2. Distribute materials evenly to each student.

Day Two

1. Leave the box with spray can and glass slides outdoors overnight to maintain the same temperature as the falling snow.
2. Set up workstations with microscopes.

Day Three

1. Boil water.

Classroom Procedure:

Day One

Engage (Time: 40 mins)

Discuss the properties of snow crystals and matter outlined in 'Science Content' with the students. Discuss terminology. Tell students they will be working on three activities: 1) Classifying Snowflakes and Identifying Properties of Crystals, 2) Growing a Snowflake in a Jar, and 3) Designing a Mini-Hut that would keep the crystal structure. Distribute all print materials (Activity Sheets 1-8) to each student. Allow students time to fill out Activity Sheets 1, 2, and 3 based on the information discussed on the properties of snow crystals and matter. Allow time for questions on what they learned.

Day Two

Explore (Time: 40 mins)

Students should collect all their necessary materials and handouts. Review the properties of crystals with the students. Students should begin working Activity Sheet 4: Let's Classify Snowflakes. (Note: Students will have to complete this assignment on Day 3).

While waiting for the plastic to harden, students may move on to Activity Sheet 5: Properties of Crystals, and complete the chart. If student have time, they should begin reading through Activity Sheet 6: Grow a Crystal in a Jar.

Day Three

Explore (Time: 40 mins)

Students should collect all their necessary materials and handouts. Students should continue working Activity 4: Let's Classify a Snowflake, and complete the Observations and Conclusions portion of this activity. Assist as necessary. After they have completed Activity 4, students may start or continue working on Activity Sheet 6: Grow a Crystal in a Jar. (Note: This activity will be completed during the following class period.)

Students must leave their snowflake in the borax solution overnight. They should set this activity aside and begin reading through Activity Sheet 8: Design a Mini-Hut.

Allow students to take their ‘snowflakes’ home or keep them in the classroom for display purposes. Students should clean up and/or dispose of any unused materials. Review and discuss the implications of the day’s experiments.

Day Four

Explore (Time: 40 mins)

Students should collect all their necessary materials and handouts. Following the instructions from Activity Sheet 6, students should work towards completing this assignment. The Observations and Conclusions portion of this activity should be filled out before proceeding to the activity.

During a discussion session, work on Activity Sheet 7: Experiment Template, with the entire class. Ask students to think of ways the growth of the crystal can change under different conditions.

Day Five

Explore (Time: 40 mins)

Ask students to finish any activities not yet completed. Students may work in pairs for Activity Sheet 8: Design a Mini-Hut. They will have two days to complete this activity. Explain to the students that on the second day, they will compete for the title best “mini-hut” and/or “mini-sauna”. Allow the students to work on this activity for the remainder of the class period. Make sure students complete the assignment so that the following class time can be devoted to the competition. Allow time for discussion and overview of the day’s activities.

Day Six

Explore (Time: 25 mins)

Students should gather their “mini-hut” and “mini-sauna”. If they have not yet completed the experiment write-up portion of the activity, they should do so before the competition begins. Make sure each group enters a “mini-hut” and “mini-sauna” into the competition. Explain the rules and begin the competition.

Explain (Time: 15 mins)

Discuss the winning designs for the “mini-hut” and “mini-sauna” and why they were so effective. Have students present the strengths and weaknesses of their designs. Allow time for a discussion of each activity and answer any other questions the students may have. Discuss Supplemental Information if time allows.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain
1	Shows leadership in the discussion and offers creative ideas reflecting a good understanding of crystals.	Completes work accurately while providing an explanation for what is observed.	Provides an in-depth explanation of findings. Fills out worksheet clearly.
2	Participates in the brainstorm and shows an understanding of crystals.	Completes work accurately.	Provides clear explanation of findings. Fills out worksheet clearly.
3	Contributes to the brainstorm, but shows little understanding of crystals.	Makes some mistakes with the procedure.	Provides a limited explanation of findings. Fills out some of the worksheet.
4	Does not participate in brainstorm. Shows no understanding of crystals.	Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out worksheet.

Extension Activities:

More Snow Science Activities

1. Make a snow gauge.
   Take an old clear plastic soda pop bottle and cut off the top half. Mark the outside in centimeters or inches with a permanent laundry marker and place it outside in a place where it can collect the falling snow.
2. Measure how much melted snow it takes to make water.
   Collect some snow in a container and record the level of snow on the container. Let the snow melt. How much water is there? Are you surprised at the difference?
3. Make your own glacier.
   Fill a bowl with snow and bring it inside to partially thaw, and then add more snow on top. Keep doing this all winter long. You will then have the "layers" of ice and snow like a glacier.

Supplemental Information:

Frozen crystals of all shapes and sizes float down and accumulate. The white fields resemble diamonds glittering in the sun. Wilson 'Snowflake' Bentley took over 6,000 photographs of individual flakes between the early 1880's and his death in 1931. No two were alike.

Some snowflakes resemble Dorian columns; some look like oak leaves; some are shaped like dinner plates; and thousands are almost perfectly symmetrical six-armed intricate snowflakes that look like frozen lace.

Scientists believe dust and bacteria blown off plants and thrown into the air by ocean waves produce rain and snow. In a lab, Russell Schnell (U of CO) produced snowflakes by injecting bacteria into a cloud chamber. The experimental clouds immediately turned into snow. The bacteria, *Pseudomonas syringae* and *Erwinia herbicola,* contain a molecule that attracts water. After one ice crystal forms, it splinters. Each fragment serves as a seed for another ice crystal. The snowflake's six-sided shape comes from the hexagonal lattice structure of an ice molecule.

Ice crystals are extremely sensitive to a variety of conditions, including temperature, air currents, and humidity. A crystal needs atmospheric conditions of 5 F. to grow. These six-sided hexagonal crystals are shaped in the high clouds; needle or flat six-sided crystals are shaped in the middle height clouds; and a wide variety of six-sided shapes are formed in the low clouds. The colder the temperature, the ice crystal tips are

sharper. At warmer temperatures, the ice crystals grow slower and smoother, resulting in less intricate shapes. The growing branch-like protrusions are called dendrites. Differences in the macroclimate on each side of the ice crystal produce the asymmetrical shapes.

ICE

by: Judi Manning

Ice exhibits itself as the gentle tiny frost flowers we see sparkling on a sunlit window, to towering icebergs. It can range in color from clear too as blue as the sky. Standing near a frozen lake you can occasionally hear a crack as it zips from shore to shore. Icicles have a melodious sound as they break away from their bases. Large blocks of ice falling from the house make a thudding sound. Out cross-country skiing, the trees creak and groan under the weight of the ice in a gentle breeze.

The U.S. Army Corps of Regions Research and Engineering Laboratory (CRREL) is studying ice to unlock its secrets. They hope to help people better cope with wintertime and to take advantage of the world's vast frozen resources.

Water expands as it freezes and is lighter than water. Water can take three forms:

(1) Gas — heated, its molecules bump and bounce forming a vapor
(2) Liquid — cooled, its molecules move slowly and glide around one another to give liquid water its smooth flow
(3) Solid — chilled below 32^0F, its molecules slow even more and form ice crystals

The amount of impurities deposited along the edges of the ice crystal form different types of ice:

- **Frazil ice:** Surface water in a swiftly flowing stream is cooled below 0 C and forms crystals. These crystals move downstream and to quieter water, mix with warmer layers beneath it, and produce a spongy mass of crystals. They freeze into thick slabs, and are responsible for ice jams.
- **Anchor ice:** Surface ice that forms around stream bed rocks when the nights are cool enough. The ice detaches from the rocks when warmed by the sun and rise to the stream's surface.
- **Snow ice:** Formed by heavy snow that sinks surface ice and freezes into a white slab
- **Columnar ice:** Long vertical crystals that are exposed when the outer layer of frozen water decays.
- **Icebergs:** Portions of glaciers that break off and become free-floating. They may reach a height of 300-500 feet above the sea's surface, with 90% of the iceberg below the water line. North Atlantic icebergs all come from the Great Greenland Ice Sheet and have been found 2,000 miles from their origin.
- **Glaciers** are large sheets of compacted snow that move around the land. In 1930, Alaska's Black Rapids Glacier moved 250 feet per day.

Seawater, because of its salt content, freezes at a lower temperature than fresh water. Sea ice is softer and weaker because the salt is forced out and pools in pockets.

Ice makes potholes in pavement that are put together with low budgets. Ground water freezes then expands, weakening the pavement overhead.

Unexpected cold snaps can be lethal on some species and if it interrupts migration. In unusual cold snaps, the male pheasant's long tail feathers can freeze to the ground and the bird will starve. Fine snow blown by the wind can clog the nasal passages of quail and grouse, suffocating them. Thick ice coating berries, buds and seeds makes them inaccessible for birds to eat.

Safety:

- Use caution when using blue food coloring as it can stain clothing.