Igneous Rocks: Crystallization and Cooling Rate

Author(s): Diane Pflug
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Performance Indicator 3.1: *Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.*

3.1b Minerals are formed inorganically by the process of crystallization as a result of specific environmental conditions. These include:
- Cooling and solidification of magma
- Rearrangement of atoms in existing minerals subjected to conditions of high temperature and pressure.

3.1c Rocks are usually composed of one or more minerals.
- Rocks are classified by their origin, mineral content, and texture.
- Conditions that existed when a rock formed can be inferred from the rock's mineral content and texture.

Objectives:

- Describe the internal arrangement of atoms or molecules in a crystalline structure such as a mineral
- Observe and discuss how temperature affects crystal size in an igneous rock
- Compare crystalline patterns of different substances
- Investigate how conditions in the environment affect crystal formation
- Justify that macroscopic properties are linked to the crystalline structure

Vocabulary:

Atom
Molecule
Crystal
Crystal lattice/ Crystal structure/ Crystalline
Crystallization
Extrusive igneous rock
Intrusive igneous rock
Grain size
Glassy
Fine
Coarse
Non-crystalline
Polycrystalline
Single Crystal

Safety:

Salol is slightly toxic if ingested. MSDS: http://www.sciencestuff.com/msds/C2247.html

Materials:

Part 1:
Random set of objects (tri-colored pasta, Trix cereal, marbles, etc.)

Part 2:
Salol (phenyl salicylate)
Test tube/ boiling tube
250ml beaker
6 microscope slides
Stirring rod
Safety goggles
Hot plate
Access to a freezer or ice
Forceps
Microscope/Hand lens/Magnifying glass

Part 3:
Borax, alum, epsom salt (any substance that crystallizes and is not flammable)
Microscopes
Slides and coverslips
Hotplate
Forceps

Part 4:
Extrusive igneous rock samples (Ex: obsidian, pumice, scoria)
Intrusive igneous rock samples (Ex: granite, rhyolite, gabbro, basalt)

Description:

Have you ever wanted to teach about crystals but didn't want to waste precious classroom time waiting for sugar to crystallize? This series of activities allows students to observe the crystallization process instantly underneath a microscope. Students will investigate how temperature affects crystallization, and apply their conclusions to igneous rock formation. Students will be able to directly link how the environment on Earth affects the cooling process and visible properties of igneous rocks.

Science Content for the Teacher:

Key Ideas

1. A mineral is a solid substance that has a crystalline structure.
2. A crystalline material has a structure that is a regular order (arrangement) of atoms or molecules in a substance.
3. Crystals or materials with crystalline patterns can form when a material, such as magma, solidifies and cools in a particular way so that the atoms or molecules form a pattern.
4. Temperature affects crystal size. The quicker a substance cools, the smaller the crystals will form because the molecules within that substance have a shorter time to arrange into a fixed, ordered pattern.
5. Igneous rocks form from the process of solidification, but not all igneous rocks have crystals. The environment in which they form on Earth determines the crystal size. Igneous rocks that cool on Earth's surface are extrusive and do not have a crystalline structure because they cool quickly.

Common Student Misconceptions

1. Students often misidentify sedimentary rocks as igneous because they mistake sediments for crystals.
2. Students mistakenly conclude that if a rock doesn't have visible crystals, then it is non-crystalline, which is not necessarily true. For example, rocks such as halite or minerals such as calcite are crystalline, even though you can't see the individual crystals.
3. (If microscopes are used): Students may not be able to use a microscope. If so, ensure to teach the basics before implementing microscope in lesson.

Preparation:

1. Gather random set of objects (tri-colored pasta, Trix cereal, marbles, etc)
2. Put microscope slides in the freezer the night before (for Part 2)
3. Prepare slides of crystalline substances (for Part 3)
4. Gather and organize igneous rock samples (for Part 4)

Classroom Procedure:

Engage (10 minutes)

Part 1: What's a pattern?
Give each pair of students a set of objects that have variations in color (For example, tri-colored pasta, Trix cereal, marbles, etc. Use what's cheap and available to you!). Tell each pair of students to make as many patterns with the objects they are given and have them keep a record of how many patterns they come up with.

Show a picture of a Diamond and Graphite. Discuss the differences of these two objects. Discuss with students how different materials have different patterns, and reference the activity they completed in the beginning of class. Then show the structure of Diamond and Graphite to show the different patterns of carbon, and this is why they have different properties. (http://www.enmu.edu/services/museums/miles-mineral/diamond.shtml)

Explain how the patterns that are found in different materials are called crystal structures. Review some common materials that have crystal structures, and potentially have students brainstorm as a class.

Question: How do carbon atoms "choose" to make the pattern of diamond or graphite?

The purpose of the activities today is not only to investigate crystal structure, but how conditions in our environment affect the crystal structures that form.

Explore (25 minutes)

Part 2: How can temperature affect crystal size?

Students will manipulate temperature conditions to affect the crystal size of Salol. By completing this experiment, students will be able to make the connection between crystal size and cooling rate.

Source: The following is adapted from an activity found on Earthlearningidea entitled "Why do igneous rocks have different crystal sizes? Simulating crystallisation from a melt at different rates of cooling," http://www.earthlearningidea.com. This activity was originally based on ESTA's 'Magma -Introducing Igneous Processes' in 'The Science of the Earth 11-14' series. It is also incorporated into the workshop titled 'The Dynamic rock cycle', Earth Science Education Unit, http://www.earthscienceeducation.com

Teacher Actions
Distribute handouts to students. Set aside materials for student groups.

Procedure for Students

1. Melt some Salol in a water bath. Set the temperature so it will just melt the Salol, around 45°C. Do not overheat or it will not work.
2. Use a stirring rod put a few drops of the melted Salol on the middle of a cold slide. Cover it with another cold slide.
3. Observe the results with a hand lens or a microscope. Record observations.
4. Repeat Step 2 with slides at room temperature and slides that have been warmed.

Note: The changes in temperature don't affect crystal structure (the pattern that forms), but rather affects the actual size of the crystals themselves. On every slide, the salol is still salol; while the size of individual crystal grains changes, the identity of crystal stays the same because the same pattern is observed on every slide.

Explore (15 minutes):

Part 3: Do all materials have the same crystal structure?

Students will be able to observe crystals formed from other materials so they can compare the crystalline pattern formed by Salol to other substances. Students should be able to explain that different substances have different crystalline patterns. They should also be able to make the connection between the arrangement of a substances molecules/ atoms determines its actual crystalline pattern.

Teacher Actions

Teacher can prepare slides of different materials ahead of time for safety purposes. Anything that crystallizes can be observed under the microscope. Some suggestions are:

- Epsom salt
- Alum
- Borax
- Anything that crystallizes can be observed under the microscope. Just be sure it isn't flammable so it will not catch fire when you heat it up.

How to Prepare Slides

1. Place the substance on one end of a glass slide. You only need a small amount.
2. Put the glass slide on a hot plate so that it is half on the hot plate and half hanging off.
3. As soon as the substance becomes a liquid, remove the glass slide with forceps.
4. Put a coverslip (or additional slide) on the slide.

Procedure for Students

Students view the prepared slides underneath the microscope and determine if it is the same substance as Salol based on the crystallization pattern that forms. Students should be able to justify their reasoning, and relate it back to the atoms and molecules in the substances.

Explore (20 minutes)

Part 4: How do environmental conditions affect crystallization?

For a more inquiry based approach, give students the set of igneous rock samples you have picked out. Remind them that all igneous rocks form from magma. Ask why they all look different if they all come from magma, and ask them what other visible characteristics they could use to help separate them into 2 groups. Students may have several different classifications. Guide students to observe the different sizes of crystals, and even push them to use a ruler to measure different crystal sizes in the samples.

Explain (10 minutes)

Using the Rock Cycle, discuss with students how igneous rocks form from magma. Depending on where the magma cools determines the relative size of the crystals in the igneous rock.

Extrusive Igneous Samples: obsidian, pumice, scoria
Extrusive igneous rocks form on Earth's surface once the magma has exited the volcano. These samples will tend to be noncrystalline because they cooled so quickly. Since it cooled so quickly, there was not enough time for the atoms or molecules to organize into a regular, crystalline pattern. Igneous rocks that are noncrystalline can also be glassy.

Intrusive igneous rock samples: granite, rhyolite, gabbro, basalt
Igneous rocks form below Earth's surface where pockets of magma get trapped. Since the inside of the Earth is very hot, it takes a longer time for the magma to cool, resulting in bigger crystals. Since it cooled so slowly, there was enough time for the atoms or molecules to arrange themselves in a regular, crystalline pattern and form the visible crystals in the rocks. Igneous rocks with bigger sizes crystals have a coarse grained texture. Igneous rocks with smaller crystals have a fine grained texture.

Extension Ideas

- Build on knowledge of crystalline structures by introducing models of crystal lattice structures, including isometric, hexagonal, tetragonal, orthorhombic, monoclinic, and triclinic patterns. Also, show students different minerals with different types of cleavage and fracture patterns. Discuss how the particular pattern of atoms and molecules in the crystal lattice structure determines of cleavage of fracture observed in a mineral.
- Show students evidence for crystal lattice structures by showing them X-ray diffraction patterns.

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 an in depth understanding of chemical reactions and titration.	Completes work accurately while providing an explanation for what is observed. Works very will with partner.	Provides and in-depth explanation of findings. Fills out worksheet clearly.
2	Participates in the demo and shows an understanding of chemical reactions and titration.	Completes work accurately and works cooperatively with partner.	Provides clear explanation of findings. Fills out worksheet clearly.
3	Contributes to the discussion, but shows little understanding of reactions or titration.	Works cooperatively with partner, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Fills out some of the worksheet.
4	Does not participate in discussion. Shows no understanding of reactions or titration.	Has trouble working with partner. Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out worksheet.

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http://newyorkscienceteacher.com/sci/files/download.php?id=967&file=Crystallog.pdf
Videos and lesson of Salol crystallization
http://www.earthscienceeducation.com/resources/index.htm,
http://www.earthlearningidea.com/
NASA Microscope observation of crystal growth
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Microscopic_Observation.html