

Exploring Crystallization and Color of Nanocrystals

**Overview:**

In this lesson we will expand on previous discussion of materials properties of crystals to learn about how crystals form (nucleation and growth). This topic will be related to how materials behave differently in bulk vs. at nanoscale. Additionally, students will explore the differences between mixing light and color (pigment) and discuss how we can make white light in TVs and LEDs using the properties of nanocrystals.

**Essential Question:**

1. How do crystals form?
2. How small is “nano” and how do crystals at nanoscale behave differently from the bulk?
3. What is the difference between *light* and *color,* and how can we take advantage of these differences to make useful things with *nano-science?*

**Vocabulary:**

Crystals: solid material made of atoms or molecules in a highly ordered arrangement

Nucleation: atoms or molecules self organize to form a new phase/structure

Nano-scale: dimension on the order of 1-100 nm (compare football stadium to tennis ball)

Absorb: light is taken in by material

Reflect: light is not taken in by material, and instead reaches our eyes

Emit: excited materials relax and give off light

**Background:**

Materials on the nanoscale behave very differently from bulk materials. We will focus on bulk vs nanoscale crystals, their growth, and their unique properties. The main concepts students should take away are (1) crystals (bulk and nanoscale) grow by a process called nucleation, where a single crystal causes atoms and/or molecules around it to self organize into a regularly repeating pattern making a larger crystal; (2) that nanocrystals interact with light to produce pure colors; and (3) that the difference between light and color is that the source of light light is emission, while the source of color is absorption and reflection.

**Research Connection:**

Nucleation and growth are important concepts in understanding the synthesis of nanomaterials and their mechanism of growth.

**NGSS Standards:**

|  |  |
| --- | --- |
| Standard Number | Standard text |
| 5-PS1-4. | Conduct an investigation to determine whether the mixing of two or more substances results in new substances. |

**I. Crystal formation by nucleation and growth**

*\*NOTE: If travel is required for the lesson, the accompanying demonstration is challenging due to how readily a supersaturated solution of sodium acetate crystallizes as well as the required temperature changes (requires heating and cooling). In the case that transporting the solution is impossible, show the video of nucleation and growth from a supersaturated solution and then show the “egg geodes” (prepared ahead of time) as an example of crystals grown by this method.*

*Video:* [*https://www.youtube.com/watch?v=HnSg2cl09PI*](https://www.youtube.com/watch?v=HnSg2cl09PI)

**Materials:**

3 cups white vinegar, 3 tbsp baking soda, ziploc bags, cooking pot

**Procedure:**

Start by reviewing with the students what crystals are (recurring patterns in a structure). Talk about some examples of crystals/crystal structure we see in our daily life such as gems, snowflakes, table sugar, and salt. (Colorful egg geodes may be prepared beforehand to show around the class: <https://www.kiwico.com/diy/Science-Projects-for-Kids/3/project/Egg-Geodes/2591>)

Crystals form in *supersaturated* solutions.

Useful video: <https://www.youtube.com/watch?v=d55JCDEv-UQ>

Hands on Activity to see nucleation in action:

To be made beforehand and distributed to students:

From Water and Sodium Acetate:

<https://www.sciencecompany.com/How-To-Make-Instant-Hot-Ice.aspx>

From White Vinegar and Baking Soda:

<https://www.thoughtco.com/hot-ice-or-sodium-acetate-607822>

Students will drop a piece of the crystal into the ziploc bag containing supersaturated solution. This crystal will activate the supersaturated solution and become the nucleus for growth.

**Discussion:**

1. How do crystals grow? Comment on the different sizes and shapes as the reaction proceeds.

* Video of the reaction can be found here: <https://www.youtube.com/watch?v=HnSg2cl09PI>

**II. Materials in bulk vs. at nanoscale**

**Materials:**

gold nanoparticles in a vial, blue laser pointer, quantum dot samples in vials (red/green emitting)

**Procedure:**

* **Handout** with a diagram demonstrating nanoscale (attached in the back).

Talk about bulk (macro) versus the nanoscale. How things change.

* **Show** Gold vs gold nanocrystals
* Powerpoint TEM images of nanocrystals
* All the crystals are the same size! All the nuclei form at once.
* **Video** of QD synthesis:<https://www.youtube.com/watch?v=MLJJkztIWfg>

Show QD-TVs. Property that we’re focused on is their ability to absorb and emit light.

* What is light absorption and emission? Visible color wheel with wavelengths and/or spectrum.
* Explain that size of nanocrystal dictates color of absorption/emission.
* **Show** vials of QDs with laser pointers.
* These TVs use a combination of red, blue, and green emitters to generate white light.

**Discussion:**

1. How do the properties of crystals change from bulk to nanoscale?

**III. Mixing light vs. mixing colors (applications of nanocrystals)**

**Materials:**

red/green/blue/yellow glow sticks, poster paint/kids washable paint, popsicle sticks, cups.

**Procedure:**

* Mix red, green, blue paint = brown

Paint *absorbs* and *reflects* light

* Mix red, green, blue glow sticks = white

<http://cdn.teachersource.com/downloads/lesson_pdf/SS-6.pdf>

Glow sticks have chemicals that *emit* light

* **Show** deconstructed QD TV
* **Show** light convergence demo (WCS kit)
* Coloring activity to compare light vs. color and record the results.

**Discussion:**

1. What is the difference between light and color?

How small is a nanometer?

