DEMONSTRATION IDEAS FOR CLASSROOMS, WORKSHOPS, AND OUTREACH ACTIVIES

THE CENTER FOR SUSTAINABLE NANOTECHNOLOGY

The Center for Sustainable Nanotechnology

Congratulations! You are going to share your love of science with an awaiting audience. The mission of the Center for Sustainable Nanotechnology is to investigate the fundamental molecular mechanisms by which nanoparticles interact with biological systems. In addition to our blog, Sustainable Nano and other Education and Outreach initiatives, we value interactions with the public in classrooms, at museums, at fairs, nursing homes, or elsewhere. Here you will find a series of demonstration ideas that are meant to inspire, or guide, your science outreach activities. Every activity is modifiable, and you should aim to tailor the content to fall in line with the venue, age range, and educational status of your audience. If you try any of the following activities or have any that you would like to see added to this document, please send your thoughts and ideas to Miriam Krause, PhD.

The demonstrations listed below are intended for students in grades K-12. Where necessary, proper personal protective equipment (PPE) is also suggested for some of the demonstrations.

Look out for these symbols:

? Raising Questions: Have students answer specific questions based on their observations.

⚠ Take care: Be careful and consider the age and experience of the audience. Some steps may need to be taken care of by adults or older students.

Direct questions and ideas to:
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Singing Lemon Battery (15 minutes)

This hands-on lemon battery activity is based on an article published in the Journal of Chemical Education. This activity is also the basis of a blog post written by Alicia McGeachy entitled *Have You Ever Heard a Lemon Sing?*

Target Audience: Grades 3 – 12

Materials Needed:

Lemon (or Lemon Juice)	Singing Greeting Cards (or LED)
Aluminum Foil	Zn/Cu Metal Strips (or a Nail and a Penny)
Paper Tray/Bowl	Alligator Clips (2 for every two lemons)

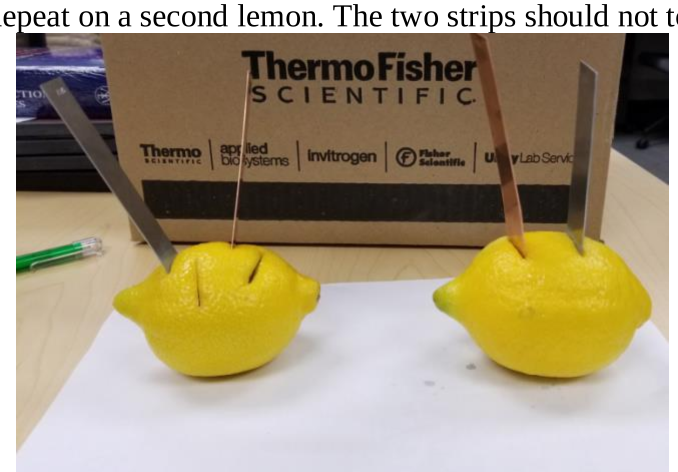
Metal strips and alligator clips can be purchases as a set from Indigo Instruments
Greeting cards (12 ct.) can be purchased from Amazon

PPE:

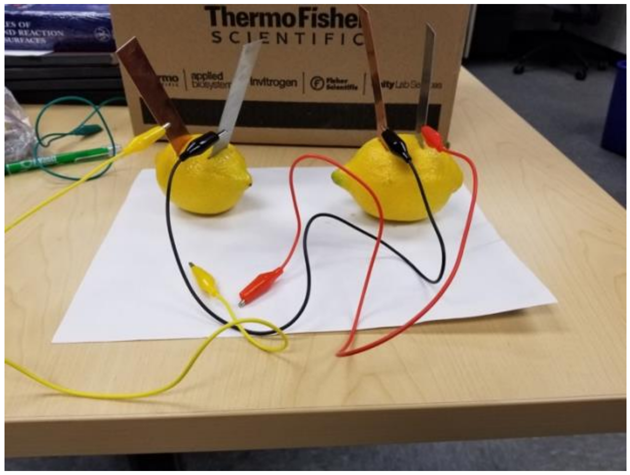
- Gloves (recommended)
- Safety Glasses (recommended)

Directions:

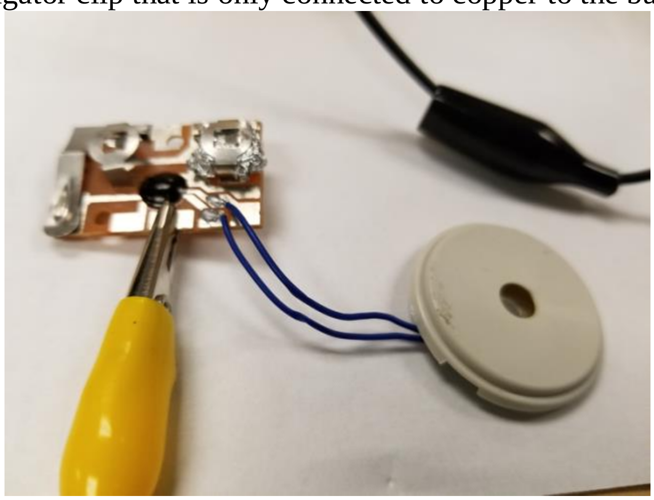
1. Place copper and zinc strips (or copper penny, pre-1982) in the lemon (you may need to cut two slits first, but usually the strips are sharp enough to pierce the lemon rind.) Repeat on a second lemon. The two strips should not touch



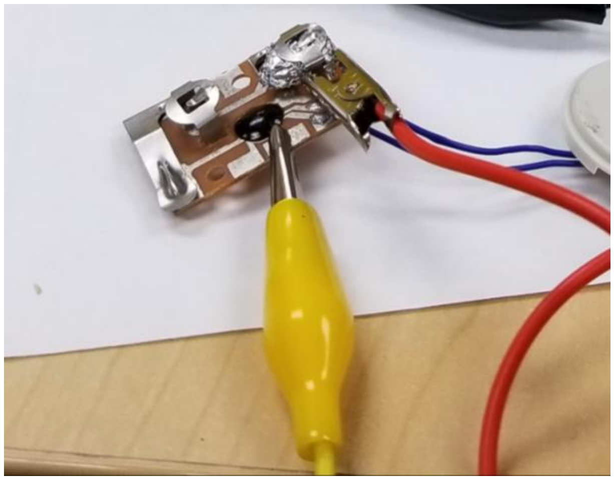
2. Connect the zinc and copper metal strips with alligator clip. (One alligator clip will be used to join the two lemons, one end on the copper in one lemon joined to the zinc strip in the second lemon. One end of the second alligator clip will be connected to the zinc and one end of the third wire will be connected to the copper



3. Carefully remove the circuit board and speakers from the card.
4. Remove both batteries from of the battery compartments.
5. Squeeze a small square of aluminum foil into a tight ball that is small enough to fit into one of the battery compartments and then insert into one of the battery compartments.
6. Connect the alligator clip that is only connected to copper to the base of the circuit board.



7. Connect the alligator clip that is only connected to zinc to the battery slot with foil inside.



Questions:

What happens if you move the copper and zinc strips closer together or further apart?

Does inserting another lemon (or a cup of lemon juice) change the quality of the song?

Tips:

- The article has a step-by-step procedure for performing the demonstration. It is important to note that the Cu strip needs to be connected to the battery compartment while the Zn strip needs to be connected directly to the base of the circuit board from the greeting card.
- Two or lemon batteries may need to be used in series to produce enough voltage to make the lemon "sing".
- The lemon can be replaced with a potato or an apple.
- To stop the card from playing remove the batteries or insert the paper strip between the metal wand and the base of the circuit board.
- For groups younger than the 3rd grade, this activity may be better as a demonstration instead of allowing the students to assemble the battery themselves.
- Works best with students working in pairs.
- Can be modified by having students compare two lemons to 1 lemon/1 cup of lemon juice, 2 cups of lemon juice, or more than two lemons.

Concepts Demonstrated: Redox Chemistry, Electrochemistry, Voltage, Nanobatteries, Series and Parallel Circuits, Nanotechnology, Sustainability, Acids,

Example Connections to Next Generation Science Standards:
Grades 3 – 6: 3-5-ETS1-2; MS-PS1.B;
Grades 9 – 12: HS-PS3.D/ HS-PS3-3; HS-ESS3-2;

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

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Heat Transfer: Nano vs. Macro Scale (20 minutes)

The concept of heat transfer is demonstrated using thermochromic paints. Thermochromic materials typically consisting of liquid crystals and leuco dyes, operate under a number of different mechanisms (ex. changes in molecular vs. crystal structure). This activity is based on a blog post about Heat Sensitive Color Changing Slime. This activity can be done as a demo or hands-on activity. If you're short on time, make a few batches of the heat sensitive slime ahead of time and distribute to students.

Target Audience: Grades 3 – 6

Materials Needed:

White School Glue	Water
Thermochromic Pigment	Liquid Starch
Food Coloring	Cups (for Mixing Slime)
Large Bowl (for mixing)	Wooden Tongue Suppressers (if hands-on)
Cold/Hot Pack (optional)	

Thermochromic Pigment, glue, and liquid starch can be purchased from Amazon.

Directions:

1. Decide on your color scheme for the slime. The color of thermochromic pigment will be the color of the slime when it is cold. Then pick an alternating color of food coloring for the hot color. Think color wheel neighbors to make the transition smooth. Example:
    - Blue pigment with yellow food coloring (Slime is teal and turns yellow when hot)
    - Red pigment with yellow food coloring (Slime is orangey red and turns yellow when hot)
    - Blue pigment with red food coloring (slime is purple and turns pink when hot)
2. Pour ***1/4 cup*** glue into a large bowl. Add ***1 tablespoon*** water and stir until combined. Add ***5 drops*** of food coloring and mix well. Then add ***3 teaspoons*** of thermochromic pigment and mix until uniformly distributed.
3. Add ***1/8 cup*** liquid starch and mix until thick and slimy. Then knead the slime with your hands and return to the starch mixture for another mixing making sure there is no unmixed glue. If slime is still sticky, add additional starch, a little bit at a time, and knead until not sticky anymore.
4. Store slime in a glass or plastic container with a lid for up to one week.

Tips:

- Before you get into presenting any chemical structures to show crosslinking, it might be a good idea to read this post on C&EN which discusses how this reaction has been incorrectly shown by nearly everyone for years.

- No liquid starch? Consider trying one of the three methods proposed here for making starch at home. Borax or Elmer's Magical Liquid Activator might also work here.

- May require more starch if it had been a few days since playing with it. Just pour a teaspoon or so on the slime and knead it again.

- You can use the same procedure to make heat-sensitive Play-Doh (check out info link above).

- Is this a hands-on activity? Distribute the ingredients into cups for individual/pairs of student(s). If the students are old enough (use your discretion or ask their teacher ahead of time), consider allowing them to measure things out themselves. Allow each student or pair of students to make their own slime.

- Slime can be customized by adding in small Styrofoam beads, glass beads, or glitter (use your discretion on ages).

- Slime time can work with students in grades K-2, check out this activity from Ann Arbor Hands-On Museum.

Concepts Demonstrated: Measurements, Heat, Heat Transfer, States of Matter, Polymer, Crosslinking, Light/Matter Interactions,

Example Connections to Next Generation Science Standards:
Grades 6-8: MS-PS3-4; MS-PS1-4; MS-PS1-2;
Grades 9-12:

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Matter of Size: Surface Area to Volume Ratio (~60 min.)

Increased surface area-to-volume ratio is one of the reasons nanomaterials demonstrate such unique properties when compared to their bulk counterparts. This activity is from a science snack activity on Exploratorium.

Target Audience: Middle or High School Students

Materials Needed:

Agar- agar powder	Scale
Graduated cylinder	Water
Whisk or Fork	Microwavable Bowl (cap. 500 mL)
Microwave	Oven Mitt
pH indicator	Ammonia
Silicone ice cube tray	Clear Plastic Ruler
Sharp Knife	Clear Container
Vinegar	Calculator
Pencil and paper	Spoon
White Paper (or plate)	Timers

To save time, you can purchase prepared agar cubes that come pre-mixed, pre-cut and loaded with phenolphthalein from Ward's Science. This set comes with 6 sets of cubes in three sizes (1, 2, and 3 cm)

Directions for Preparing Agar Cubes:

1. Measure out 1.6 g of agar-agar and 200 ml water. Mix them together with a whisk or fork in a large microwave-safe bowl.
2. Heat the solution in the microwave on high for 30 seconds. Remove to a heat-safe surface using a hot pad or oven mitts, stir, and return to the microwave for 30 seconds. Repeat this process until the mixture boils. (Keep your eye on it as it can boil over very easily!) When done, remove the container, and set it on a trivet or other heat-safe surface.
3. Choose ONE pH indictor to work with (*either bromothymol blue, phenolphthalein, or cabbage juice*) and add a few drops of it to the agar solution. *If you're using bromothymol blue*, add enough indicator so that the mixture turns blue. If it has a greenish hue, add ammonia a drop at a time until it is blue (see photo below). *If you're using phenolphthalein*, add enough indicator so that the mixture turns pale pink. Add ammonia drop by drop until the mixture turns (and remains) a bright pink color (see photo below).

4. Carefully pour the agar solution into silicone ice-cube molds or a small glass baking pan. Make sure the agar block(s) will be at least 3 cm deep when they solidify. If you don’t have enough solution, make more using the ratio of 0.8 g agar-agar powder to 100 ml water.

5. Let the agar cool until it solidifies (~1 hour). Remove the agar blocks from the molds or cut in the pan with a sharp knife to obtain two sets of cubes of three sizes: 1 x 1 x 1 cm, 2 x 2 x 2 cm, and 3 x 3 x 3 cm. *If you're using bromothymol blue*, you should have two sets of blue cubes. *If you're using phenolphthalein*, you should have two sets of pink cubes. The sets need to match in order to compare the color change later on in the Snack.

To Do and Notice

Place a few millileters of the pH indicator into a small container (*either bromothymol blue or phenolphthalein*). Using a dropper, add a few drops of vinegar. What do you notice? Is there a color change?

Fill a clear container with vinegar to a 3-cm depth. Place one agar cube of each size in the vinegar, making sure the blocks are submerged. The untreated blocks (one of each size) will be used for comparison. What do you think will happen to each cube?

Determine the surface area and volume of each cube. To find the surface area, multiply the length of a side of the cube by the width of a side of the cube. This will give you the area of one face of the cube. Multiply this number by 6 (the number of faces on a cube) to determine the total surface area. To find the volume, multiply the length of the cube by its width by its height. Then determine the surface-area-to-volume ratios by dividing the surface area by the volume for each cube.

? How will you know if hydrogen ions are moving into the cube? How long do you think it will take the hydrogen ions to diffuse fully into each of the cubes? Why? How would you be able to tell when the vinegar has fully penetrated the cube?

After 5 minutes, remove the cubes from the vinegar with a plastic spoon, and place them on white paper or on a white plate. Compare the treated cubes to the untreated cubes and observe any color changes.

? How much vinegar has been absorbed by each treated cube? One way to measure this is to calculate the *percentage* of the volume of the cube that has been penetrated by the vinegar. (Hint: It may be easier to first consider the volume that has not been penetrated by the vinegar—the portion that has not yet changed color.) Do you want to adjust any of your predictions for the diffusion times? What are your new predictions?

Carefully return all of the treated cubes to the vinegar. Continue checking the vinegar-soaked cubes every 5 minutes by removing them to determine the percentage of the cube that has been penetrated by the vinegar. Continue this process until the vinegar has fully penetrated the cubes. Make a note of the time when this occurs.

What do you notice about the percentage of penetration for each of the cubes at the different time intervals? What relationships do you notice between surface area, volume, surface-area-to-volume ratio, and percentage penetration? What does this say about diffusion as an object gets larger?

Tips:

- The agar cubes can be prepared ahead of time so that the students do not need to handle the sharp knives or pH indicators.

Concepts Demonstrated: Diffusion, pH, acids and bases, surface area, volume, surface area-to-volume ratio,

Example Connections to Next Generation Science Standards:

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Modeling Membranes: Demonstrating Properties of the Cell

The cellular membrane plays a critical role in maintaining the stability of the cell as well as regulating transport processes. Mammalian cell membranes are bilayer structures that are largely composed of phospholipids, proteins, and cholesterol. Phospholipids are *amphiphilic* meaning that they contain both hydro*phobic* and hydro*philic* groups. This property is similar to soap in that soap is also an amphiphile. The activity below is based on a science snack activity on Exploratorium.

Target Audience: Grades 6-8

Materials Needed:

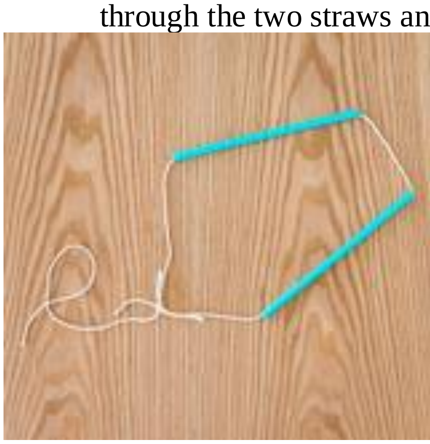
- Dish soap
- Glycerin
- Drinking straws
- Aluminum pan*
- Sharp Knife/Razor Blade
- Pen
- Rubbing Alcohol *(optional)*
- Water
- Cotton string
- Scissors
- Two film cans (can swap for 2-4" PVC)
- Black construction paper or Foam board
- Vegetable Oil *(optional)*

Film cans and cotton string (can also be purchased at hardware store) can be purchased from Amazon.

*Aluminum roasting pan or other similarly sized basin that is larger than the length of the straws.

Directions:

1. To make your bubble solution, mix dish soap and water in a ***1:10 ratio***, adding ***one tablespoon*** of glycerin to each gallon of solution. **Let the solution age at least overnight for the longest-lasting bubbles.**
2. Cut the bottoms off of the film cans using a sharp knife or a single-edge razor blade to pierce the side near the bottom then cut the bottom off using sharp scissors. Make sure that there are no rough edges.
3. Fill the roasting pan with the soap solution to a depth of at least 1 inch (2.5 cm).
4. Cut a piece of string that's approximately four times the length of the straw. Thread it through the two straws and tie the ends together to make a loop (see photo below).



5. Move the straws and string into the shape of a rectangle. This is your bubble frame (see photo below). Cut the excess string from the ends of the knot. Move the string through the straws so that the knot is hidden inside one of the straws.

6. To create a handle for the frame, cut another piece of string that's approximately three times the length of the straw. Thread the string through one of the straws and tie the ends together (see photos below).

To Do and Notice

This activity is easiest to do with at least two people. One person can make the soap film and hold the handle while the other person explores how the film behaves.

Shape the bubble frame into a rectangle. Holding the frame by the handle, immerse the entire frame into the bubble solution.

Lift the frame up by the handle until the bottom of the frame is slightly out of the bubble solution and the straws are parallel to the tabletop. You should have a rectangular soap film between the two straws. If there isn't any soap there, try immersing and lifting the frame again.

Hold the soap film in front of the black construction paper or other black material. Carefully observe the surface of the film. Blow gently on the film and watch what happens.

Repeat the first two steps if the bubble pops while you are completing the steps below.

Wet your finger in the bubble solution. Gently poke through the soap film with your finger. What happens? Can you move your finger around in the film? Now wet a non-soapy finger in plain water (or oil or alcohol) and poke it into the film. What happens?

Make a new film on the frame. Roll a film can or PVC tube section in the bubble solution to coat its surfaces. Grasp the film can near one end and remove it from the solution. If films have formed across the openings of the can, pop them. Insert one end of the film can through the soap film on the frame. If the film pops, make another and try again.

When you successfully insert a bubble-coated film can through the soap film, leave the can in this position and have your partner pass an object (such as a pen) through the openings of the can, from one side of the film to the other (see photo below). Can you move the film can around in the soap film?

Try putting a dry film can through the soap film. What do you notice?

Based on your observations, what conditions allow objects to pass through the soap film without popping it? What conditions cause the film to pop? Do you think the flexibility of the film influences its ability to resist popping? Why or why not?

For safety, consider cutting the canisters yourself ahead of the demonstration.

Tips:

- Make the soap solution at least 24 hours before the activity.
- Save time (and reduce safety concerns) by cutting the canisters beforehand.

Concepts Demonstrated: Cellular transport, biological membranes, non-polar, polar, hydrophobicity/hydrophilicity

Example Connections to Next Generation Science Standards:
Grades 6-8: MS-LS1-2 (LS1.A);

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Through the (Stained) Looking Glass

One of the most widely referenced examples of nanotechnology/nanomaterials is the Lycurgus cup. (Read about all the cool places where you can find nanoparticles in *Nanoparticles Are All Around Us*). This 4th century Roman artifact is made of a dichroic glass enabled by a colloidal suspension of gold and silver nanoparticles. To complement the historical reference, show students a suspension of gold and/or silver nanoparticles. In the activity described below, students will create their own stained glass windows as described in this NanoDays activity. Two other similarly themed activities include one where participants use nanogold/nanosilver solutions to make stained glass and another where students use crayons and waxpaper (younger children).

Target Audience: Grades 3-8

Materials Needed:
- Samples of nanogold glass/gold flakes
- Small pieces of tissue paper (assorted colors)
- Scissors
- Precut contact paper
- Strips of black paper

Gold sheets, tissue paper, and contact paper can be purchased from Amazon or dollar stores (except for gold sheets).

Directions:
1. Peel the backing off of one piece of contact paper.
2. Place pieces of colored tissue paper on the exposed adhesive side to create a design. Use the black construction paper strips to create a border.
3. Peel the backing off the other piece of contact paper and stick both adhesive sides together. Trim your artwork. You can even cut out a special shape.
4. Now hold your design up to the light or window. What do you notice?

Tips:
- Cut some tissue paper into random shapes.
- Pull back one corner of the contact paper ahead of time to help students/participants since peeling can sometimes be difficult.

Concepts Demonstrated: Nanoparticle; dichroism; colloidal suspensions; light; wavelength; absorption; reflection; light-matter interactions

Example Connections to Next Generation Science Standards:

Grades 3-5:

Grades 6-8:

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

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Ferrofluids (10 min.)

Ferrofluids are a colloidal suspension that contains nano-sized particles and becomes strongly polarized when exposed to a magnet. These nano-sized particles are typically composed of iron oxides like magnetite (both black sand and ferrofluid are made of magnetite). In this demonstration, students learn about the unique properties of ferrofluids, the prevalence of ferrofluids in everyday objects, and magnetism.

Target Audience: Grades 3-8; All Grades

Materials Needed: Ferrofluid Display Cell
Neodynium Magnet Wand
Bill-sized Paper
Ferrofluid Material Safety Data Sheet
Vial of Black Magnetic Sand
Dollar Bill
2 giant binder clips (black base)

Prefilled display cells can be purchased from Amazon (several models are available); Iron filings can be used to replace magnetic black sand. Iron filings can be purchased from Fisher Scientific.

Directions/Questions for Discussion:

1. Move magnet around next to the vial of black sand. Note observations.
2. Repeat with vial of ferrofluid. Compare and contrast with black magnetic sand.
3. Hold magnet near crisp dollar bill. What happens to the money?

Tips:

- Since this is a short demo, consider pairing with another activity or a few videos related to ferrofluids (maybe one with speakers)
- Great activity for a demo table where people are just passing by.

Example Connections to Next Generation Science Standards:

Grades 3-5: 3-PS2;
Grades 6-8: MS-PS2-3; MS-PS2-5

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Liquid Crystals (10 min.)

This activity is based on an activity outlined in a NanoDays activity. Liquid crystals are only partially ordered and exist between the solid and liquid phases. Liquid crystals are sensitive to changes in temperature and can shift to a liquid or crystal simply by tuning the temperature.

Target Audience: Age 4+

Materials Needed: Liquid crystal sheet, Paint brushes, Clear, square stickers, Vial of liquid crystal mixture, Printed cards with black squares, Self-laminating pouches

Liquid Crystal Sheets can be purchased from Teacher Source.

PPE/MSDS: Safety glasses

Directions:

To make your liquid crystal sensor:

1. Put a sticker over the black square of a card.
2. Use a paintbrush to spread a thin layer of liquid crystal mixture on top of the sticker.
3. Carefully place the card face down onto the clear side of a self-laminating pouch.
4. Remove the paper on the other side of the pouch and seal it.
5. Warm the card with your hands. ***Can you get the liquid crystal to change colors?***
6. Now cool it against a cool surface. ***What colors does it turn?***

Tips:

This activity is easily suitable to be combined with the thermoresponsive slime activity.

There are many great resources that can be useful to learn about how this activity, and liquid crystals, work.

Properties of Liquid Crystals
Liquid Crystals—How Do They Do That? Chemical Demo Kit

Another cool activity related to the temperature sensitive nature of liquid crystals is the liquid crystal thermometer activity linked here.

Example Connections to Next Generation Science Standards:

Grades 6-8: MS-PS1-1; MS-PS3-3; MS-PS3-4
Grades 9-12: HS-PS3-4

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Magic Sand (15 minutes)

Hydrophobic sand, or Magic sand, is a great example of a nanoscale phenomenon. Hydrophobicity is an important factor that can influence both the interactions between nanomaterials and biological systems and also the stability of nanoparticles in solution. In this activity, students learn about solubility, polarity, and some of the properties of hydrophobic materials. It might also be good to talk to students about the original intended use of magic sand: to clean up oil spills. From this lesson, students can also begin to briefly discuss environmental remediation which also ties in nicely to nanoscale solutions to solving environmental problems including oil spill cleanups. The activity below is from Teacher Source.

Target Audience: Grades 6-12

Materials Needed:

Magic Sand	250-500 mL glass beakers
Beach Sand	Water
Stir bar	Other liquids (oil, ethanol, soap, etc.)
Paper Towel/Coffee Filter	

Magic Sand can be purchased from Amazon or Teacher Source. Depending on the activity that you choose below, you may opt to only purchase some of these materials and not *all* of the ingredients. Mystic Sand can also be purchased from Flinn Scientific.

Directions

If you have limited time, this activity can be used as one of a few demonstrations instead of a classroom activity:

1. Add magic sand to a 500 mL beaker filled about ¾ of the way with water. You can use a stirring rod of your hand to mold the sand under the water.
2. This may work best for a small group demo or if students did this themselves: In a beaker filled with water gently, and slowly, sprinkle some sand on the top of the water's surface. The surface tension should allow the Magic Sand to float on top of the water without sinking. Keep sprinkling the san until a thick layer of sand is floating on top of the water.
    a. Gently push down on the sand until your finger breaks the surface of the water. Remove your finger from the beaker and it should be dry. Being too quick or aggressive in placing your finger into the Magic Sand layer may cause the sand to sink or clump up. If this happens, just pour more sand on the water surface.
    b. Use a water-filled pipet to add water dropwise onto the floating sand island. The water should form beads on the surface of the sand. After a sufficient amount of water is added, the sand will sink to the bottom of the beaker.

For classroom activities:

1. Pour some of your Magic Sand into a dry beaker. Describe the properties of the sand (shape, texture, etc.) How does Magic Sand compare to beach sand?
2. Fill a second beaker to about halfway with water. Quickly pour Magic Sand from the first beaker into the water all at once. How would you describe the shapes that are formed by the Magic Sand? How does the Magic Sand look (shiny or dull)?

Why do you think it looks the way it does? If possible, you a second pair of beakers to make a comparison to regular sand.

3. Using your finger, press the Magic Sand into different shapes against the side of the beaker.
4. Mix the Magic Sand in the beaker using a stirring rod. What do you notice? How does compare to mixing regular sand in a beaker of water?
5. Separate the Magic Sand from water by carefully pouring the beaker through a coffee filter or paper towel in a funnel. Is the sand captured in the filter wet or dry?

Tips:
Extend on the magic of this demonstration by exploring the behavior of magic sand in various types of liquids. For some hints on what other liquids to explore, check out this activity from Purdue.

Teacher source also has a great set of lesson ideas along with questions and worksheets to support this lesson. Additionally, they offer a series of ideas for follow up lessons.

Using oil or soap with your magic sand will cause the sand to irreversibly lose its hydrophobic properties.

Example Connections to Next Generation Science Standards:
Grades 6-8: MS-PS1-1
Grades 9-12: HS-PS2-6

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Extracting DNA from Strawberries (15 minutes)

In this experiment, based on one outlined on an activity from the National Human Genome Research Institute, students will extract DNA from strawberries. DNA itself is a nanoscale molecule that has given rise to a new class of nanotechnology, DNA nanotechnology. DNA is also being used to make nanomachines that can do real work in biological systems. Here, students will learn about DNA, genes, and learn some laboratory techniques. A great summary of this activity is also documented in the Scientific American.

Target Audience: High School/Advanced High School

Materials Needed:

- 1 re-sealable plastic bag
- 2 teaspoons of dish soap
- 2 clear plastic cups
- ½ cup of cold rubbing alcohol
- 1 teaspoon of salt
- 2 strawberries (fresh/frozen, no leaves
- ½ cup of hot water (~120 mL)
- 1 coffee filter
- 1 coffee stirrer

For this activity, students should work in pairs or groups of 3. Students will only use 2 teaspoons of the extraction liquid, so there may be room for them to share across groups. Instead of the plastic cups, students can also use plastic graduated beakers.

PPE: Gloves, safety glasses

Directions:

1. Put rubbing alcohol in freezer (or on ice)
2. Put the strawberries inside of the plastic bag and seal it shut. Make sure to remove all of the air.
3. Smash the strawberries until there are no longer any large strawberries clump remaining.
4. In one plastic cup, mix your extraction liquid: 2 teaspoons of detergent, 1 teaspoon of salt and ½ cup of water.
5. Add 2 teaspoons of the extraction liquid into the bag containing the strawberries and reseal the bag. Gently smash the strawberries a bit more but avoid making too many soap bubbles.
6. Place the coffee filter in the second plastic cup and pour the strawberry liquid into the filter. Gently squeeze the filter releasing the remaining liquid into the cup.
7. Pour down the side of the cup an equal amount of the cold rubbing alcohol as there is the extracted strawberry liquid. ***Do not mix or shake.***
8. You should notice the formation of a white cloudy substance (precipitate) at the top of the liquid. What do you think it is and why does it form when you add alcohol?
9. Tilt the cup and remove the white material from the cup using a plastic coffee stirrer or a wooden stick.

What's Happening? Students are physically (smashing) and chemically (extraction liquid) breaking the cells of the strawberry. The soap helps to break down the cellular membrane thereby releasing DNA into solution. The added salt makes the DNA clump together and separate out the proteins that are also being released. When the alcohol is added, the DNA is isolated form the rest of the strawberry's cellular content because the DNA is insoluble in alcohol.

Tips:

This activity can also be done with a banana or split peas.

If the students are advanced or if you are looking to adapt for AP Chemistry/Biology or Introductory Chemistry/Biology, you might consider pairing this activity with one outlined in a Journal of Chemical Education article.

Check out this cool virtual lab that students can use to extract DNA from human cells.

Concepts Demonstrated: Deoxyribonucleic acid, genetics, genes, extraction, precipitation, solubility,

Example Connections to Next Generation Science Standards: HS-LS1

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

The Center for Sustainable Nanotechnology

Nano Origami (5-10 min.)

When you think about origami you probably think about pretty, delicate paper animals or flowers. On the nanoscale, origami can be used to build things like electronic devices. Instead of paper, nanoscale origami can be made from composites or individual sheets of graphene. The way things are folded is an important engineering feature in nanotechnologies. Nanostructures are not easily replicated in classroom activities, but the activity described below is inspired by the many instances of nano-origami. Not to mention this is a great way to integrate art into STEM.

Target Audience: All ages.
Materials Needed: Colored Paper, Scissors
Paper can be purchased online from The Origami Paper Shop, Amazon, or Michael's.

There are so many origami plans that you can use with connections to nanotechnology. Here are a few examples:

Origami Butterflies
On our blog, we discussed how the wings of butterflies have inspired anti-counterfeit technology. But the wings of these mystifying creatures has also given scientists the inspiration that they needed to make optical communication faster and even for medical implants. After making the connection between origami and science, you can show students one of the cool videos that discusses nano-origami or scientists who have been inspired by origami and paper folding. Afterwards, make an origami butterfly with the instructions here.

Origami Penguins
Penguins also make use of nanoscale features to produce the color of their coats. While we often think of penguins in their completely formal black and white tuxedos, some penguins have brilliant blue feathers. This blue color is achieved by the bundled nano-fibers which scatter light in a unique way. After discussing how we see color, how scientists visualize nano-scale features, and, of course, connecting science and origami, you can use these instructions to make your own penguins.

Cool videos to accompany this activity:
Check out this cool Solar Panel Folding Challenge or Origami DNA activity.
Origami can bring us into the future: Inspiration for Scientists and Engineers
Cool video on NOVA discussing the origami revolution

Other Resources
Designing Origami for Performance and Manufacturing Scalability
There is an International Meeting on Origami in Science, Mathematics and Education

Concepts Demonstrated: Nanotechnology, intersection of science and art, Scale, Model, Materials inspired by nature.

Example Connections to Next Generation Science Standards: LS1-1,K-2-ETS1-2, HS-ETS1-2; HS-ETS1-3

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Nano Food Ideas

Nanotechnology has a lot of connections to food, food packaging, and sensors. On our Sustainable Nano blog we have written about how some nanoparticles are like chocolate chip cookies, how nanoparticles are keeping our food safe, and even how Nobel science can be explained through food. In the activity below, have your audience create some nano-inspired edible treats without the need for an oven.

Make sure you check to find out about any allergies before doing this activity.

No Bake Chocolate Chip Cookies (15 minutes) from Gemma's Bigger Bolder Baking

Ingredients Needed:
2 tablespoons of butter
1 teaspoon vanilla extract
½ cup brown sugar
3 tablespoons milk
½ teaspoon of salt
1 ½ cup of oat flour
½ chocolate chips
Other topping ideas: nuts, marshmallows, peanut butter.

Cooking Directions:
1. Line a cookie sheet with parchment paper, set aside.
2. In a large bowl, melt together the butter and brown sugar. This should take roughly 1 minute. Whisk together then add the milk and vanilla.
3. Once the wet ingredients are combined add in the oat flour, and salt, stirring until just incorporated. Once the dough has formed gently fold in the chocolate chips.
4. Using a cookie scoop or a tablespoon measure scoop 2 tablespoons of dough into your hand. Roll into a ball then place on the lined baking tray and press down into a ½- inch thick disc.
5. Repeat the process until you've used all of the cookie dough. Top with additional chocolate chips (optional).
6. Allow to set in the refrigerator for a minimum of 20 minutes.

Other ideas with food might be M&M chromatography or M&M dissolution experiments. Flinn Scientific offers a candy chromatography demo kit.

Gold Nanoparticle Synthesis and Gold Sensors for Food

Concepts Demonstrated: Models, scale, food science, nanoparticles, measurements

Example Connections to Next Generation Science Standards:

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Carbon Dot Synthesis

Carbon dots can be prepared from naturally-occurring chemicals such as citric acid or even food waste and are touted as the green alternative to quantum dots. Carbon dots are easy to make, relatively cheap, and have many potential applications. We have previously described our work with carbon dots in one of our public-friendly summaries for our Sustainable Nano. Also check out this great series of modules published by CSN members in *The Journal of Chemical Education*.

Target Audience: High School (Advanced Placement), First Year College

Materials Needed:
Based on Cruz reference
Citric Acid Anhydrous
50 mL beaker
Muffle furnace (or microwave)
3 in 1 Laser Pointer (laser diode, wavelength 630-650 nm; output <5mW)
Cuvette
UV-Vis Spectrophotometer

Based on CSN reference
Citric Acid
Ethylenediamine
Plastic or glass transfer pipettes
UV flashlight/ UV Source (needs to emit between 340-400 nm)
Conventional Kitchen Microwave

If you do not have the resources or time to make the carbon dots, consider purchasing your own carbon dots from Sigma Aldrich

The directions for formulating carbon dots can be found here. If there is not enough time to make the nanoparticles (45-60 min.), consider using some of the carbon dots available through the CSN.

Associated pre- and post-lab activities are outlined here.
Personal Protective Equipment: Gloves, goggles, lab coat.

Directions:
Based on Cruz Reference
1. Direct a red laser (630-650 nm) through the carbon nanodot solution and for comparison, direct a red laser through distilled water.
2. Expose the solution to a short wavelength UV lamp (365 nm).
3. If there is access to a UV-Vis spectrophotometer, dilute the carbon dot solution (1:50). Transfer the diluted carbon dot solution to a glass cuvette and acquire the absorption spectrum.

Based on CSN Reference
1. Weigh out 1.44 grams of citric acid and transfer it into a 100 mL beaker.

2. Add 5 mL of water to the beaker and add a stirring bar. Stir the solution on a magnetic stirring plate until the citric acid fully dissolves. If possible, have the stirring plate in a hood.
3. In a fume hood, measure out 0.5 mL (or 0.45 g) of ethylenediamine and add it to the beaker. SAFETY: Ethylenediamine reacts readily with air which will release toxic fumes. Do not inhale these fumes. It's also irritating to skin, so students should be careful when dealing with ethylenediamine. Gloves should be worn! Do all measurements and mixing in a hood as the reaction produces toxic fumes. The beaker can be taken out of the hood once no fumes are visible.
4. Let this solution stir for 20 minutes.
5. Remove the magnetic stirring bar from the beaker.
6. Place the beaker in a conventional microwave. Ensure that the power setting is at about a 30% power level/watts by using one of the lower "power" setting that's listed on many microwaves (we use 360 W, which is power level 4 on our microwave. Heat the solution at the selected power setting for 5 minutes; it should appear orange when taken out. Caution: the solution may be very hot.
7. Once cooled to room temperature, add 10 mL of water to the solid and stir the beaker to dissolve the compound.

Concepts Demonstrated: Models, scale, nanoparticles, measurements, light-matter interactions, Tyndall effect, synthesis, fluorescence

Example Connections to Next Generation Science Standards: MS-PS1-3

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Comparing the Structure of Diamond and Graphite

Carbon, like nanoparticles, are all around us. Differences in the atomic assembly of carbon atoms on the nanoscale can give rise to various types of nanoparticles including: carbon nanotubes, nanodiamond, graphene, or fullerenes just to name a few. Each of these materials can have different properties and collectively, these materials enable an entire range of technologies. In this activity, students can learn about some of the differences between bulk scale materials (diamond and graphite) and nanoscale carbon-based materials as well as, the way that atomic scale differences translate to structural differences in materials. Point students towards one of our posts on these structural differences or one of the many videos related to the topic like this one. The activity described below is from the National Teacher Training Institute.

Target Audience: Grades 8-12
Materials Needed: (per group of 4 students)

If using GeoMags or Magnetix
52 magnetic bars
24 steel balls

If using Marshmallow/Candies
52 toothpicks
32 large (stale) marshmallows/candies

Alternatives to Magnetix include Goobi sets, or stale marshmallow (or dots candies) and toothpicks. To complement the activity, show students a pre-built model of fullerene or carbon nanotubes which can be constructed using 4 or more of the same set used for fullerenes.

The accompanying student lab sheet can turn this into a more comprehensive classroom activity.

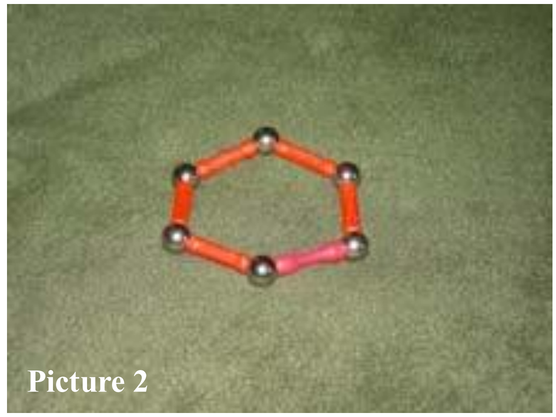
Directions:

1. Divide the materials evenly among the members of your group. Each member should be able to build one carbon octahedron or one carbon chain ring.

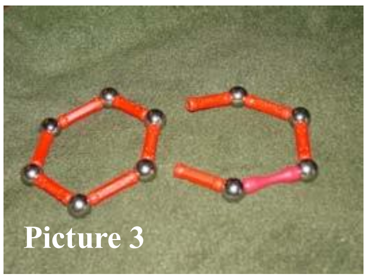
2. Build a carbon chain by alternating a ball (the carbon atom) and a bar magnet so that you have a long chain of ball-bar-ball-bar-ball-bar-ball-bar-ball-bar-ball-bar. (Picture 1) Here the ball represents carbon atoms while the bar represents the bond between atoms.

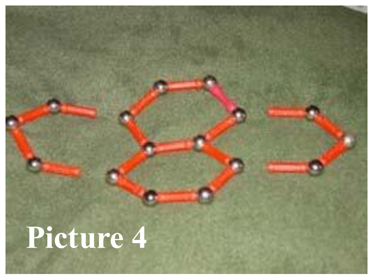
3. Carefully bend the long chain around to connect the two ends making a carbon ring structure. (Picture 2)

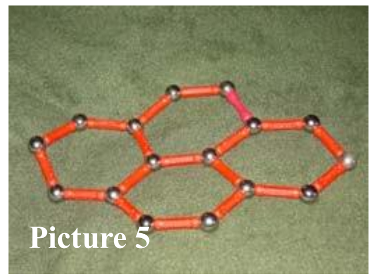

Picture 1


Picture 2

4. Join the rings together. You will have to remove bars and balls and make a sheet-like structure. (This is the basic structure of the mineral graphite.) (Pictures 3-5)


Picture 3

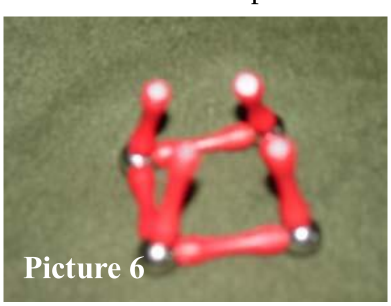

Picture 4

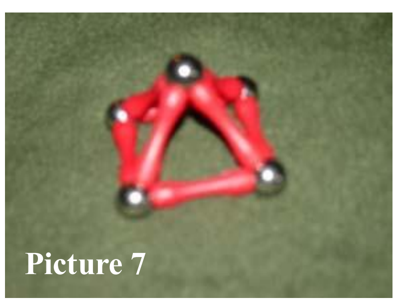

Picture 5

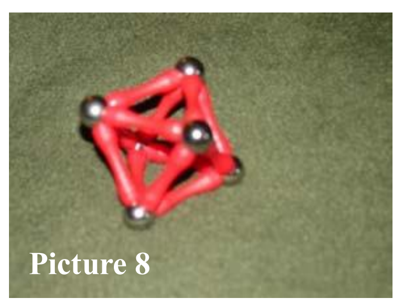
5. Carefully pick up the ringed sheet structure. Is it the structure stiff? Are the bonds easy to reshape without breaking any bonds? Stack several sheets on top of each other to see how they are found in nature. The "weak bonds" between the sheets allow them to slide past or break away from each other.

6. Dismantle your sheet and make sure that everyone has at least 6 balls and 12 magnets. You are going to form a new set of structures called octahedrons. First make a square using four bars for the sides and a ball at each corner. Now attach one bar straight up from each corner (Picture 6). Move the upright bar ends in toward each other and join them together with one ball (Picture 7). You should now have something that looks like a four-sided (square-based) pyramid.

7. Carefully turn your pyramid over so that you can repeat the addition of four bars and one ball to this side of the base. When you have completed adding the last ball to the structure it should look like picture 8. This is an octahedron.

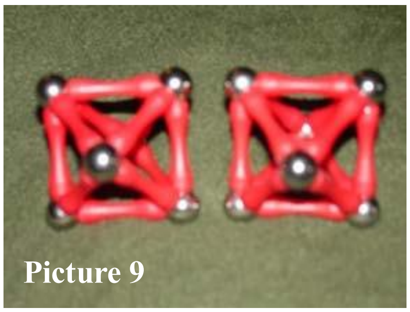

Picture 6

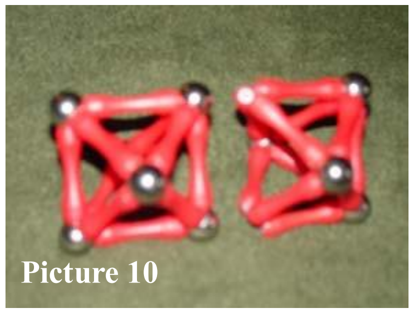

Picture 7

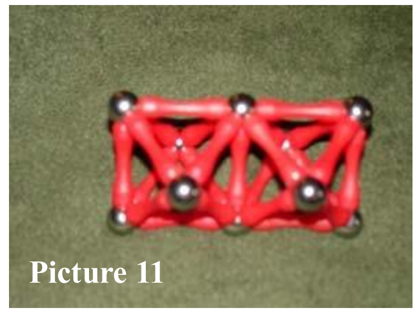

Picture 8

8. Pick up your octahedron and gently tug on any ball to see what happens. Try pulling gently on two balls at the same time.

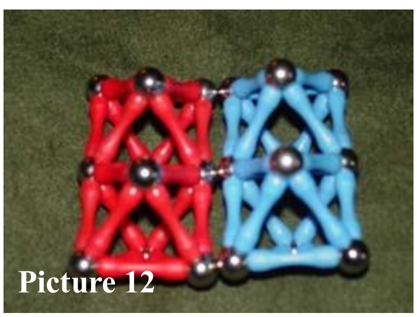
9. You are now ready to join octahedrons to start a chain. Pair up with a member of your group and place your octahedrons side by side so that any two corners touch two corners of the octahedron next to it. Notice that you have too many balls and bars to allow the easy joining of the two octahedra. Carefully remove the two balls and the connecting bar from one side of the square on one octahedron. (see picture 10) Now place the two octahedral together to form a chained structure. (See picture 11)

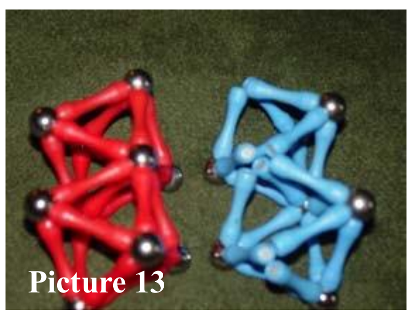

Picture 9


Picture 10


Picture 11

10. Repeat the joining process to join single chain side by side with another single chain. This will make a square double chained structure. See pictures 12,13, and 14. How does the relative strength of the bonds in this new structure and bendability compare to the sheet like structure that you built earlier?

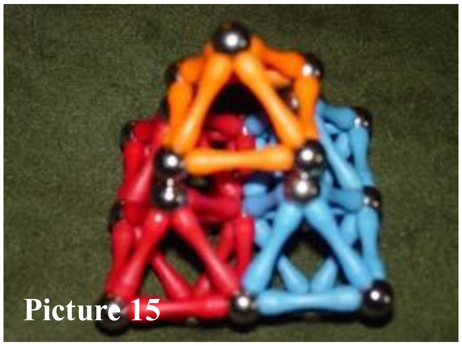

Picture 12

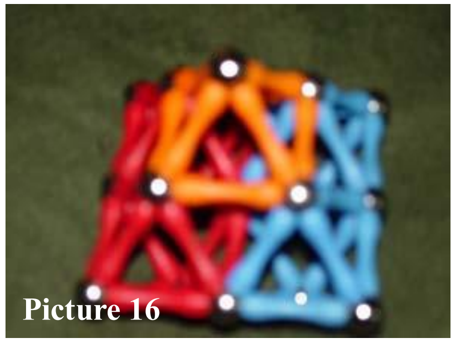

Picture 13

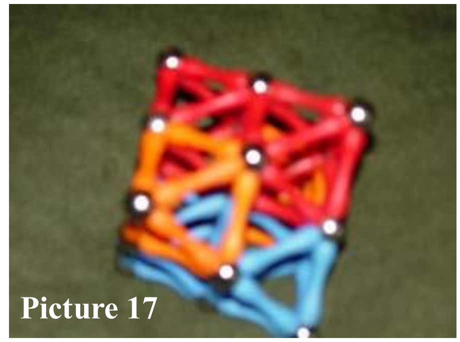

Picture 14

11. Join with two other students from another group. They will each be adding their single octahedron to your square double chain, by using the four atoms on the top as the square base of their octahedron. See pictures 15 and 16. Repeat this process on the bottom of the base double chain. See picture 17.

You have now created the smallest network solid. (A diamond is a network solid!)


Picture 15


Picture 16


Picture 17

Concepts Demonstrated: scale, atom, atomic structure, model, allotropes, bonding, structure-function relationship, network solid

Example Connections to Next Generation Science Standards:
Grades 6-8: MS-PS1-1; MS-PS1-3
Grades 9-12: HS-PS1-3; HS-PS1-4; HS-PS2-6

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

The Center for Sustainable Nanotechnology

Light Can Do Way More Than Bend

Our blog post on the properties of light is one of the most popular posts on Sustainable Nano. The ways that light interacts with matter are magical and mystifying. In this series of demonstrations, students will first learn about total internal reflection. This process is just one of many that can occur and is sometimes a useful property for spectroscopists. Here, students learn about light trapping which is useful for designing and improving the effectiveness of solar cells.

Target Audience: Grades 9-12
Materials Needed:
Light beam viewing tank (or similar product)
Opaque white tank insert
Stirring Rod
Water
Powdered Milk (or another scattering agent)

Directions:

1. Fill the tank about half way with water.
2. Shine the laser across the length of the viewing tank into the water and note any observations.
3. Add a small amount of powdered milk and mix.
4. Shine the laser through the water again (along the length of the viewing tank) and note any observations.
5. Shine the light into the tank at an angle over the top of the tank so that the light passes first through the air above the water and then through the water. Note any observations about the path of the light

Additional options for exploring total internal reflection, scattering, and refraction are outlined in this reference from Arbor Scientific.

Sample post-lab questions are provided by Arbor Scientific.
Related Materials:

- Ghost Crystal Activity Kit to teach students about refractive index.
- Other uses for light beam viewing tank
- Refraction and Total Internal Reflection (check out this cool related video)

Concepts Demonstrated: Models, scale, colloids, measurements, light-matter interactions, scattering, nanotechnology,

Example Connections to Next Generation Science Standards: HS-ETS1-1; HS-ETS1-2; HS-ETS1-3; HS-ESS3-2; HS-ESS3-4; HS-LS2-7

Have you tried this experiment? Tell us about it on our Ask the Scientists Page!

Other Kits for Designing your Own Demonstrations.

At University of Wisconsin-Madison, there are some pre-assembled kits available for use from the Institute for Chemical Education.

Physics and Physical Science

1. Optics Discovery Kit from Edmond Optics for Classroom Demonstrations and Activities
2. Determining Electric Charge with a Sensor
3. Absorption Spectroscopy

Biology

1. Building Blocks of Life
2. Understanding the Human Genome (HS)
3. Genetic Simulation (MS)

Environmental Sciences

1. Cleaning Up with Iron
2. Oil Spill Cleanup Demo Kit

Miscellaneous

1. Gold Nanoparticle Synthesis

Other Resources for Designing Demos

Check out this blog from Teacher Source where they share demonstration ideas along with lesson ideas.

Optics4Kids has a ton of activities (grouped by age) that teach the audience all about the properties of light and the way that light interacts with matter.

NanoYou has a ton of activities that make connections between nanomaterials/nanotechnology and everyday life.