NanoDemos

The activities described below are short demonstrations designed to teach students of any age about nanotechnology principles. They can be used individually or in conjunction with each other. Most of the materials can be purchased through www.teachersource.com.

Learning Objectives

- To understand that properties (physical, chemical, and biological) are different at the nanoscale than they are at the macro scale
- To understand how the properties of nanoscale materials are used in various applications
- To understand how natural nanoscale phenomena can be replicated or mimicked to advance technology
- To understand how nanotechnology integrates biology, chemistry, physics, electronics, environmental sciences, engineering, etc.

Washington EALR Alignment

9-12 APPA	Science affects society and cultures by influencing the way many people think about themselves, others, and the environment. Society also affects science by its prevailing views about what is important to study and by deciding what research will be funded.
9-11 PS1H	Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces.
9-11 PS2G	Chemical reactions change the arrangement of atoms in the molecules of substances. Chemical reactions release or acquire energy from their surroundings and result in the formation of new substances.
9-11 PS2H	Solutions are mixtures in which particles of one substance are evenly distributed through another substance. Liquids are limited in the amount of dissolved solid or gas that they can contain. Aqueous solutions can be described by relative quantities of the dissolved substances and acidity or alkalinity (pH).
9-11 PS2I	The rate of a physical or chemical change may be affected by factors such as temperature, surface area, and pressure.
9-11 PS3D	Waves (including sound, seismic, light, and water waves) transfer energy when they interact with matter. Waves can have different wavelengths, frequencies, and amplitudes, and travel at different speeds.

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Oregon Content Standards Alignment

H.2 P.1 Explain how chemical reactions result from the making and breaking of bonds in a process that absorbs or releases energy. Explain how different factors can affect the rate of a chemical reaction.

H.2 P.2 Explain how physical and chemical changes demonstrate the law of conservation of mass.

H.2 P.4 Apply the laws of motion and gravitation to describe the interaction of forces acting on an object and the resultant motion.

H.3 P.5 Explain how technological problems and advances create a demand for new scientific knowledge and how new knowledge enables the creation of new technologies.

H.4 D.5 Describe how new technologies enable new lines of scientific inquiry and are largely responsible for changes in how people live and work.

Idaho Content Standards Alignment

8 – 9 Physical Science, 8 – 9 Earth Science, 9 – 10 Biology

1.2.1 Use observations and data as evidence on which to base scientific explanations.

1.2.3 Develop scientific explanations based on knowledge, logic and analysis.

5.2.1 Explain how science advances technology.

5.2.2 Explain how technology advances science.

5.2.3 Explain how science and technology are pursued for different purposes.

8 – 9 Physical Science, 8 – 9 Earth Science, 9 – 10 Biology

9-10.B.5.1.1 Analyze environmental issues such as water and air quality, hazardous waste, forest health, and agricultural production.

11 – 12 Chemistry

11-12.C.1.3.7 Interpret how the presence of solute particles affect the properties of a solution and be able to do calculations involving colligative properties.

11-12.C.2.1.2 Predict the polarity of chemical bonds using electronegativity.

11-12.C.2.1.3 Predict physical properties of compounds based upon the attractive forces between atoms and molecules.

11-12.C.2.1.4 Distinguish and classify all matter into appropriate categories.

11-12.C.2.4.3 Describe the relationship between the structure of atoms and light absorption and emission.

11-12.C.2.5.3 Describe the factors that influence the rates of chemical reactions.

11-12.C.5.1.1 Demonstrate the ability to work safely and effectively in a chemistry laboratory.

11-12.C.5.2.1 Assess the role of chemistry in enabling technological advances.

11-12.C.5.3.1 Evaluate the role of chemistry in energy and environmental issues.

Size and Scale

Background

Due to their size, nanoparticles exhibit a number of size dependent properties. These unique biological, chemical, and optical properties can then be used to create new materials that take advantage of these changes. As you decrease the size of a material, you increase the surface area.

The tea cup and alka seltzer surface area activities are solely designed to demonstrate how size affects the forces acting on objects and how reactive a material is, respectively. In the tea cup demonstration students will explore how gravity, surface tension, and mass are connected. Because of the smaller mass of water held in the dollhouse tea cup, there is less gravitational force (Force = mass x gravity) allowing surface tension to hold the water in the cup while turned upside down. The alka seltzer demonstration explores how with the same mass of material smaller particles are more reactive because of their increase in surface area.

Although the thin film and ferrofluid demonstrations also show how size and scale affect optical properties and the magnetic forces, they are also valuable tools for discussing how nanoscale materials are used – see background information and applications for more information.

Materials

Tea Cups - Forces

- Dollhouse cup **(included)**
- Large cup
- Water
- Bowl or large container
- Food or water coloring (optional)

Surface Area

- Alka Seltzer **(included)**
- Two small measuring cups
- Two 50 mL graduated cylinders
- Large beaker
- Water
- Waste container
- Food or water coloring (optional)

Pre-Lab Set-up

Tea Cup

Fill a bowl or large container with water. If desired, food or water coloring can be used to color the water. This makes it easier to see the water in the dollhouse tea cup, but does not affect the demonstration.

Surface Area

Fill a large container with water. If desired, food or water coloring can be used to color the water. This makes it easier to see the reactions, but does not affect the demonstration. Label a waste container.

Size and Scale

Tea Cups

What do you think will happen if you fill up a cup with water then turn it upside down?

1. Fill the large and small teacups with water.

2. What do you predict will happen when you turn over the large cup? The small cup?

3. Turn both cups upside down over the tub of water. See what happens and record your observations.

   Large Cup –

   Small Cup –

   What force causes what you observed in the large cup to occur?

   What force causes what you observed in the small tea cup to occur?

   Why do you think the force that dominates the small cup overcomes the force that causes what occurs in the large cup?

Size and Scale

Alka Seltzer

1. Make sure both graduated cylinders are dry.

2. Measure 20 mL of water in each of the two small measuring cups.

3. Take one tablet of antacid and break it in half (two pieces – they do not have to be equal in size). Place them in one of the graduated cylinders.

4. Break another tablet into as many small pieces as you can. Place the pieces into the second graduated cylinder.

5. At the exact same time, add 20 mL of water to each graduated cylinder. Record what happens below.

    Small pieces –

    Large pieces -

    Why do you think the antacid reacted in such a way?

    Which sample, the smaller pieces or the larger pieces, would you rather take if you needed antacid to settle your stomach right away?

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Thin Films

Background

Using nail polish and water, a thin film can be made that shows the difference between nail polish at the macroscale (as in when it is put on a nail) and a thin film of nail polish, which is only a few microns thick. When you drop a small amount of nail polish on water, the drop spreads out into a thin coating on the top of the water. This film can then be lifted off the top of the water using black acetate or construction paper. Although not nano in size, the thin film formed shows how scale changes the properties of a material as well as the optical properties that nanomaterials have that make them useful in the field of photonics. The film that results shows how the thickness of the film, which is not uniform, dictates what color of light is reflected.

Applications

- Bubbles and oil slicks demonstrate this same phenomenon
- In nature, many butterflies, beetles, and bird feathers exhibit colors based on light's interaction with their nano or microscale features
- Similar to the effect on CDs and DVDs

Vocabulary

- Interference fringes
- Photonics
- Thin films

Materials

- Acetate paper or black construction paper **(included)**
- Clear nail polish **(included)**
- Colored nail polish (optional)
- Food or water coloring (optional)
- Dish or waxed paper plate
- Water

Pre-Lab Set-up

Fill the container about halfway with water. If desired, food or water coloring can be used to color the water. This makes it easier to see the thin film on top of the water, but does not affect the demonstration. Label the clear nail polish, polish 1. Label a colored nail polish, polish 2.

Thin Films: Nail Polish

In this demonstration you will be able to observe properties of nail polish at the macro and micro scale.

What color is the nail polish labeled polish 1?

What do you think will happen when one drop of polish 1 is dropped into the container of water?

1. With the brush from the bottle, pick up some polish from the bottle labeled polish 1.
2. Drop <u>ONE small bead</u> of nail polish from the brush onto the water. (If needed, just touch the drop of polish to the surface of the water.)
3. Take a black square of paper and slide it carefully in the water without disturbing the layer of nail polish so that it lays flat underneath the layer of nail polish.
4. With two hands, carefully lift the square to catch as much of the film as possible, draining off excess water. Do not let the film slide off the square. Let the film and square dry.

How is the nail polish in the bottle similar to the nail polish on the square?

How are they different?

What do you think you will observe if you repeat this procedure with polish 2?

Repeat steps 1 through 4 above with the polish in the bottle labeled polish 2.

What do you observe happen with polish 2?

Have you seen anything act similarly to the nail polish? Explain.

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Magic Sand

Background

Magic sand is a material that is made by adding a hydrophobic or non-polar nanolayer to the surface of grains of sand. Oil, like the magic sand, is non-polar. Water molecules are polar. Because like attracts like, oil molecules are attracted to magic sand whereas water molecules are not. This material was originally developed to aid in the cleanup of oil spills as it would absorb oil making the material heavier. The sand would then sink to the bottom of the body of water where it could be dredged. In reality, this process was too expensive to be used for cleaning oil spills. Another property of magic sand is that it does not freeze since it does not absorb water. This is useful to ensure the safety of pipelines and oil fixtures buried underground in northern regions where there is permafrost. The hydrophobic sand surrounds the pipes and then is usually surrounded by regular sand. If the pipes surrounded by the magic sand leak, the oil should be absorbed by the magic sand and is less likely to enter into the surrounding ground water.

Applications

- Magic sand shows the hydrophobic nanoscale properties of many natural materials such as lotus and nasturtium leaves, which also contain a hydrophobic nanolayer coating.
- These biological advantages have been imitated by humans in products like magic sand, stain resistant clothing, and car wax.

Vocabulary

- Hydrophobic
- Hydrophilic
- Polar
- Non-polar

Materials

- Magic sand **(included)**
- Regular sand
- At least four clear cups
- Water

Pre-Lab Set-up

Label 2 cups sample A. Label 2 cups sample B. In one of the cups labeled sample A pour a small amount of magic sand. Fill the other cup labeled sample A about ¾ full with water. In one of the cups labeled sample B pour a small amount of regular sand. Fill the other cup labeled sample B about ¾ full with water.

Magic Sand

In front of you are two different sands, sample A and sample B. Throughout the following steps, do not mix the sands together. Gently sprinkle a very small amount of each type of sand into the respectively labeled cup of water so that there is a layer of sand on the top of the water.

What do you think will happen if you very gently push down on each layer of sand with your finger?

Very gently push down on each layer of sand with your finger.

What do you observe happening with sample A?

What do you observe happening with sample B?

Thinking about how the two samples reacted, what do you think might happen when you quickly pour both sands into the respective cups?

Quickly pour some of each type of sand into the cups in which you sprinkled the respective type of sand.

What do you observe with sample A?

What do you observe with sample B?

What do you think will happen when you pour the water out of each sample and back into the respectively labeled cup?

Pour the water out of each container.

What happened?

Swirl both samples of sand.

How does the small amount of water left in sample A react?

How does the small amount of water left in sample B react?

What do you think causes the difference between the two sands?

Can you think of a uses for this product? What about other products with the same properties?

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Memory Wire

Background

Nitinol, Nickel Titanium Naval Ordnance Laboratory, is an alloy that was discovered in the 1961 and is named after the elements in the alloy and the laboratory where it was discovered. Nitinol is just one of many alloys and polymers that have shape memory properties. Shape memory materials are materials in which all of the atoms in the material move at once to a certain crystalline structure. In other materials, crystal shapes are changed in small areas when heated and not throughout the entire structure, therefore showing no change in overall shape of the material. Nitinol, when at room temperature, can be bent or shaped in a way that disrupts the crystalline structure of the material. When the material is placed in near boiling water or exposed to an electrical current, the atoms begin to move back to the original crystalline structure. While Nitinol is triggered back to the original crystalline structure by temperature or electrical current, polymers and other shape memory alloys are being made that return to a shape when exposed to different wavelengths of light.

The shape that shape memory alloys make when heated can be changed by slowing heating the alloy just below the temperature at which the crystal structure changes.

Applications

- Medical and dental applications
- Airplanes
- Glasses frames
- Rubber Bands

Vocabulary

- Alloy
- Crystalline structure
- Polymer

Materials

- Memory Wire **(included)**
- Hot Plate
- Water
- Non memory wire such as copper, aluminum (paperclip),
- Tongs
- Large beaker or other glassware
- Goggles

Pre-lab Set-up

Fill a large beaker or other glassware container about ¾ full of water. Using a hot plate, heat the water until it is close to boiling. Once the water is near boiling, turn the heat down to low.

Memory Wire

Safety: Safety goggles should be worn at all times. Use care around the hot plate.

Bend the three sample materials into different shapes. It is very important that you do not tie the metal into a knot.

What do you think will happen to each sample when you drop it in the hot water?

Sample 1

Sample 2

Sample 3

Situate yourself so you can observe the water from the side of the beaker (not from above it). Being mindful of the hot plate, drop Sample 1 into the hot water. Using the tongs, remove the metal from the water right away. What do you observe?

Sample 1

Repeat this with the remaining samples.

Sample 2

Sample 3

Why do you think what you observed happened?

There are a number of other metals and plastics that exhibit the same shape memory properties. What products do you think could benefit from being made from similar materials?

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Liquid Crystals

Background

Liquid crystals are materials that display properties of both a liquid and a solid. They move like a liquid, but have a crystal structure like a solid. The liquid crystals in this lab are thermotropic meaning that they change phases due to a change in temperature. Each of the three sheets of liquid crystals used in this lab has a different temperature range in which that phase change occurs. Liquid crystals are composed of nanoscale structures that, when combined in a sheet, demonstrate how what we see on the macroscale is affected by properties at the nanoscale. As the crystals change temperature, the crystal structure changes shape. This shape change causes birefringence in which the waves of light passing through the material are out of phase with each other. This causes the color change that can be seen and is similar to the color change seen in thin films.

Applications

- Liquid Crystal Displays – TVs, cell phone screens, computers
- Thermometers
- Optical Imaging
- Possible cancer fighting applications

Vocabulary

- Birefringence
- Thermotropic

Materials

- Three different temperature range liquid crystal sheets
    - 20-25 °C **(included)**
    - 25-30 °C **(included)**
    - 30-35 °C **(included)**
- Ice
- Boiling Water – Steam

Pre-Lab Set-up

Fill a large beaker or other glassware container about ¾ full of water. Using a hot plate, heat the water until it is close to boiling. Once the water is near boiling, turn the heat down to low. Make sure you have enough ice packs or ice to stay cold during the entire duration of the lab. On the back of the sheets, remove the temperature labels and re-label the three liquid crystal sheets – Sample 1, Sample 2, and Sample 3.

Liquid Crystals

Liquid crystals act both as a liquid and a solid. They flow like a liquid, but remain in a somewhat organized (crystal) state like a solid.

There are three liquid crystal sheets. One side of each sheet is white in color and labeled as Sample 1, Sample 2, or Sample 3.

1. Have one person place their hand directly on a table, desk, or other flat surface for about 30 seconds.
2. Paying careful attention to the placement of your hand, quickly remove your hand and place one of the sample sheets with the white side down on the table directly over where your hand was.

   What do you observe occur with sample 1?

3. Repeat this with the other two samples. How do they react?

   Sample 2 –

   Sample 3 –

Using the sheet that most easily reacts to your hand, with as little pressure as possible place your hand on the sheet for 1 sec, 10 sec, and then 30 seconds.

Does time affect the reaction of the liquid crystals?

Now try this while exerting a good amount of pressure on the liquid crystals for 1 second and then again for 10 and 30 seconds.

Does pressure affect the reaction of the liquid crystals?

What do you think makes this sheet react? What do you think might make the others have a similar reaction?

Try a number of different objects to see if they cause reaction in each of the three liquid crystal sheets. Place each sheet on the following objects with the white side of the sheets down so you are able to observe what happens.

Ice –

Steam –

What do you think is happening to the liquid crystals to affect their color?

What technologies that you use everyday use liquid crystals?

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