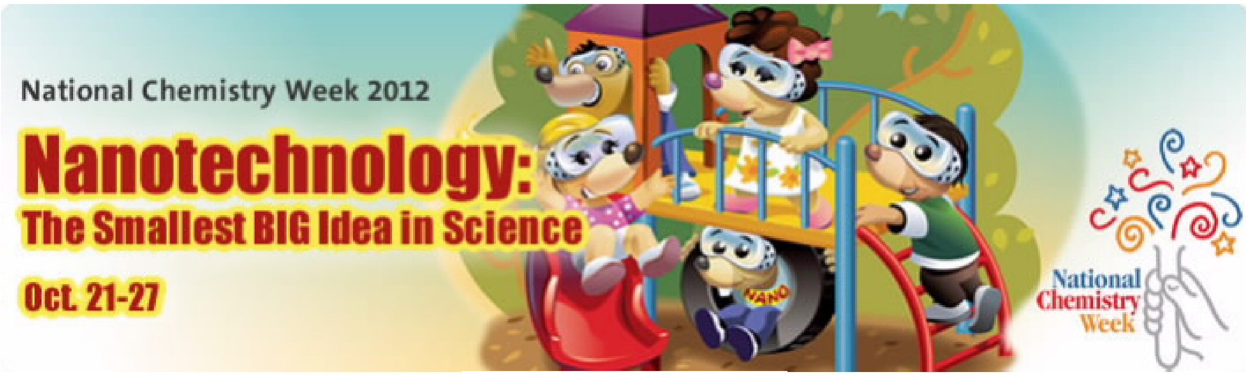

An Educational Hands-On Demonstration Program for Groups of 25 Students in Grades 2-5

Prepared by the

National Chemistry Week Planning Committee

of the

American Chemical Society Cleveland Section

for

National Chemistry Week 2012

Celebrating 25 Years of NCW

Overview

The delicious smell of baking cookies is actually small particles that are nanometers in size…one million times smaller than a grain of sand. When particles are very small they can look and act differently than when they are part of the bulk. In 6 experiments we will study the properties of nanometer-sized materials. What color is gold when it is broken into very small pieces? How can your raincoat keep you dry? 'Shrink your view' and explore the cool world of nanotechnology.

Note: After Sept. 14, 2012, please see our Cleveland Section web site (p. 4) for an Errata sheet.

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Acknowledgments

The National Chemistry Week (NCW) programs of the Cleveland Section of ACS began in 1994 with an idea to put together a scripted program that could be performed at any local school or library. This idea has expanded to become the centerpiece of the Cleveland Section's NCW activities. On several occasions it has received national recognition from the American Chemical Society, including the ChemLuminary Award for *Outstanding On-Going NCW Event*, awarded this year. In 2012, the Cleveland Section's volunteers will perform about 40 demonstrations at libraries, schools, and other public sites.

Our NCW efforts reach many students each year because of various sponsors who have donated money, materials and/or services to the Cleveland Section specifically for National Chemistry Week. We would like to especially thank our partners at the Cuyahoga County Public Library (CCPL) for creating flyers and providing the facilities for this program. The Lubrizol Corporation generously offered the time and expertise of its staff on the HydroBead experiment; we extend our thanks to them. We also extend our sincere thanks to John Carroll University for hosting GAK Day and our Dress Rehearsal, to NASA Glenn Research Center which printed this document, and to our Cleveland Section of ACS for its financial support.

Last and most important, we thank all the volunteers who donated their time and expertise. This library/school program and other NCW events are the result of the hard work of many dedicated and talented volunteers. It all starts with our local section NCW Planning Committee. The Committee recommends, tests, and reviews activities & experiments; writes a script including a story line to hold the attention of small children; collects supplies and materials; prepares the kits; recruits sponsors and volunteers; contacts libraries and schools; and schedules shows. Committee members include Betty Dabrowski, Bob Fowler, Lois Kuhns, Vince Opaskar, Margaret Pafford, Marcia Schiele, Shermila Singham and Natalie Zarlenga. Additional credit and thanks is given to the many GAK Day (**G**rand **A**ssembly of **K**its Day) volunteers including students from Baldwin Wallace, Case Western Reserve, Cleveland State and John Carroll universities who gave up a Saturday in September to help count, measure and assemble all of the necessary materials for our demonstration kits. A final thank you goes out to the dozens of dedicated chemistry professionals and scientists who lead the presentations and activities in schools, libraries, and other public locations. Without them there would be no Cleveland Section NCW program.

List of Experiments

How Experiment Write-ups are Organized

Each experiment's write-up is presented as follows:

Experiment Purpose & General Methodology: Background on the Experiment.

Introduce the Experiment: Suggestions for introducing the experiment to the students.

Performance Details: How to perform the Experiment in detail.

Conclusions: Suggested conclusions to draw from the Experiment.

Technical Information (for the Demonstrator): This information is background info to help you understand what we're trying to accomplish technically in the experiment. It certainly isn't intended that you give these technical details to the students.

Presentation Overview

This section describes the basic presentation technique used during the demonstrations. This is a guideline only as the technique may vary for some experiments. Make sure you follow the instructions given in each experiment. The program this year consists of 6 experiments.

- For most experiments your demonstration and the student's hands-on work are nearly simultaneous. You will lead them as they perform the experiment.
- Five experiments will be done by all students. There will be one experiment (#3) that is a group experiment to be shared by all or some of the students at the table; please encourage multiple students to assist when an experiment is done as a group at a table.

At the end of the day the students will be able to take home their memory wire; their nano sand (including the 50 ml vial); their treated piece of fabric; and a handout with a nanometer ruler, links to cool nano-related websites, to our electronic *Student Feedback* form (if they didn't fill out a hard copy at the end of the Program), and to our contests. The *Student Handout* also has a list of library books and experiments to do at home.

VOLUNTEERS

This year the NCW Committee will be videotaping the annual "Dress Rehearsal" demonstrations as they are presented at JCU. We hope that this video will be hosted on the Cuyahoga County Public Library's web site. We'll post the link to this video on the *Volunteers* page at our web site at http://www.csuohio.edu/sciences/dept/cleveland_acs/NCW/ as soon as we know. It will demonstrate this year's NCW program in detail and may be viewed by anyone interested in hosting our program. Alternately, this script provides enough detail for a teacher or parent to perform the presentation. The Cleveland ACS and NCW Committee do not require background checks on its volunteers nor do we require formal educational/teaching experience from all of its volunteers.

MAKE SURE TO FOLLOW ALL DIRECTIONS IN EXPERIMENTS

If experiments have special safety concerns due to the materials being used, they will be listed in the section for that experiment. Eye protection should be worn at all times by everyone, and students should be specifically told to not touch their eyes. If exposure should occur, flush with water and report the incident to the librarian and parent. We have used low concentrations of chemical solutions for safety purposes; they may be minor irritants at most. For skin contact, washing with soap and water will suffice; any coloration of the skin is temporary and will wash/wear off. Websites for where to obtain a Material Safety Data Sheet (MSDS) are listed in the appendix and also on our NCW website below.

For information about the American Chemical Society's NCW safety guidelines, visit www.acs.org/portal/Chemistry?PID=acsdisplay.html&DOC=ncw%5Csafetyguidelines.html.

Websites of Interest

Cleveland Section:
http://www.csuohio.edu/sciences/dept/cleveland_acs/NCW/

National American Chemical Society's "National Chemistry Week" website:
www.**acs**.org/ncw

To get the kids'-eye view of nanotechnology, you might want to look at a great video at:
http://www.youtube.com/watch?v=LFoC-uxRqCg

For your own overviews of nanotechnology today, we recommend
http://www.youtube.com/watch?v=CP6drnWiwT4&feature=relmfu

or

http://www.youtube.com/watch?v=S4CjZ-OkGDs&list=LPIBWS4oFfN0Y&index=1&feature=plcp

If you Google any of this year's topics (nanotechnology, ferrofluid, gold nanoparticles, magic sand, etc.), you'll find an usually large number of interesting articles and movies.

Note: At the time of this printing, the location of the video demonstrating this 2012 Nanotechnology Program had not yet been resolved. If and as soon as it resolved, we'll post the link to the video on our web site (first one, above) under the *Volunteers* tab.

Demonstration Check-Off List

Activities To Do Well Before the Day of the Demonstration	Completed?
Contact your library and ➢ **Verify the date and time of your 1-hour program** ➢ **Also schedule AT LEAST an hour <u>before</u> and an hour <u>after</u> your program for set-up and clean-up. Modify the setup time appropriately depending on how familiar you are with the materials in your kit and <u>if you will have an assistant</u>.**	❑
Read through this script to familiarize yourself with the experiments and verify that you have all the items as listed in the kit contents.	❑
<u>If you're using a pre-printed hard copy of the script, obtain the</u> **<u>Script Errata/Addendum Sheet</u>** ***<u>which will posted on our website.</u>***	❑
Please check your kit(s) upon receiving it. Vials and bottles containing solutions may have shifted during storage and transportation. Check for leakage; correct situations. Store vials and bottles in as upright a position as possible.	❑
Please do not store kits in an overly warm area (such as in a car on a hot day). The kit contains many vials and bottles containing solutions that may leak under pressure created by higher temperatures.	❑
Contact Bob Fowler at jrfowler@cox.net with any questions.	❑
Collect the materials you need to bring with you to the demonstration. This materials list is on page 9. The librarian may be able to provide some of the items, but you need to call to verify that—do **not** assume that the library has what you need.	❑
While not necessary, it's recommended that you to ask a friend to assist and/or contact the Head Children's Librarian well in advance and to request a student assistant or librarian to be your assistant. Having someone available to help set-up the room before the program and collect trash as the program progresses can help keep supplies organized. That person can also assist if multiple students need help with or have questions about the experiments.	❑
If you wish to add other experiments or demonstrations into your program, you must contact the Head Children's Librarian through your local librarian ahead of time to get approval. Be careful and think "safety first". Neither the NCW Committee nor the Cleveland ACS approves of any experiments added to your program, and you are responsible for your own actions.	❑

Activity To Do about ONE WEEK BEFORE your program	
Contact the Head Children's Librarian who is helping you to coordinate our program: ➢ VERIFY that they limited registration to 25 students. ➢ Ask the room to be arranged with 5 student experiment tables with 5 chairs each, an additional front table for the presenter and a small side table/area for literature, photo permission forms, and goggles. ➢ Ask for all the experiment tables to be covered with newspapers and for extra paper towels for each table. Otherwise take newspaper and do this during setup. ➢ Ask about availability of demonstration materials from the list of page 9 (ex. paper towels, newspaper). ➢ Ask about the availability of a hot water faucet or access to a microwave for heating water for Exp. #2. ➢ Ask if the librarian and/or an assistant will be available to assist with the program or inform them if you will also be bringing an assistant. ➢ Make sure that the room is available before and after the program for set up and clean up. **Set-up will take <u>approximately 1 hour</u>** if you do it yourself. When you call the librarian, **<u>make sure that the room will be available and that you can access it 1 hour before the start time</u>**. If the librarian and/or friend/student assistant are available to help with set-up, this will cut down the time. Invite the librarian and/or student assistant to stay for the entire program. (They might even offer to be an assistant if given the opportunity.)	❑
Activity To Do AT LEAST ONE DAY BEFORE the Demonstration	**Completed?**
Read over the experiments a few times and become familiar with them. Our program is designed for about one hour for someone who is comfortable with the script. Practicing your presentation is very helpful.	❑
Gather all the items needed for your presentation as provided in the materials list starting on page 9. Do NOT assume your librarian will supply any materials unless agreed upon in advance, and even then, call and verify he/she remembered your requests. Do NOT assume you can easily obtain water in the library; at some sites, faucets are close to the sink bottom and allow little room for easily filling bottles or cups.	❑
Check out water temperature issues for Experiment 2 and focus the beam on the Maglite for Experiment 4. See p. 12 for details.	

Activities To Do When You Get To The Library	Completed?
NOTE: Arrive at least 1 hour before show time to allow for introductions and set-up depending on how quickly you think you can perform the steps listed in the Experimental Set-up section. DO NOT assume that a librarian will be present to help you set up for the experiments.	❑
Introduce yourself to the Head Children's Librarian.	❑
Confirm that the tables and chairs are set up properly.	❑
Confirm that all tables are covered in newspaper.	❑
Obtain those supplies from the list on page 9 if provided by library.	❑
Optional: Ask the Head Children's Librarian or an assistant to take pictures when absolutely everyone is wearing goggles during the demonstration (subject to parents/guardians having given permission).	❑
Complete Demonstration Set-Up. See Experimental Set-Up: "Activities to Do On-Site Prior to Demonstration" starting on page 12. *Note: This set-up is estimated to take 60 minutes by one person.*	❑
Set-up note! If you follow the script as originally written, there are many cups and other items on the tables. Depending on the size of your tables, and the activity level of your students, you may choose to distribute fewer items originally. If so, then perhaps keep the remaining experiments' material at your presenter's table—on a tray if you have one by an assistant if you have one— and distribute these items throughout the program.	❑
Set up an 'Entrance' area table to allow space for goggle distribution and fitting by the parents, photo permission form signing, and (at the end of the program) distribution of literature .	❑
You may wish to set up an 'Exit' area table to allow space for end-of-program activities: goggle return and literature distribution.	❑
Activities To Do At the Start of The Demonstration	**Timing**
Ask the parent/guardian for permission to photograph the children for possible use on our website **and obtain their signatures to this effect**. If that permission is not obtained, make sure that that student is positioned in such a way in the room that they won't be included in the photographs, or do not take any photographs. It is advisable to seat students with photo permission at the same table.	❑
Hand out goggles and help adjust to the correct fit (if necessary). Tell the student to pull the air vents to the open position.	❑
Assess the number of students per table and adjust to 5 per table. Do not allow any student to sit alone at a table as some experiments require two people to perform.	❑

Activities To Do During The Demonstration		**Timing**
Welcome & Introduction		5 min
Experiment	***Type***	***Time (mins)***
1: How Big is a Nanometer?	Individual	10
2: Memory Wire	Individual	10
3: Ferrofluids	Group	5
4: Gold Nanoparticles	Individual/Demonstrator	10
5: HydroBead Coatings	Individual	10
6: Nano Sand	Individual	10
Revisit Experiment 3.	Group	5
Ask students to complete their *Student Feedback* forms	---	
Collect goggles and completed *Student Feedback* forms; remind students that they can take home their memory wire, paper clip, magic sand (including the 50-ml vial), and treated piece of fabric; hand out literature; remind the students to visit the websites on their handout; they should also visit the Section's web site if they want to complete the *Feedback Form* there; finally, thank the students for coming.		2 min. *Total Time: ~ 60 min*

Activities To Do Immediately After The Demonstration	**Completed?**
Clean up as indicated in the **Clean Up** section (p. 42).	❑
Give the mailing envelopes (with the reusable items and the photo permission forms) along with the box of student and adult goggles to the librarian for return to Julia Boxler via interlibrary mail. *(Those outside of the CCPL network can return items to your nearest CCPL branch for return to Julia Boxler-YTH. See www.cuyahogalibrary.org for branch listings.)* Please return all materials within two weeks of NCW.	❑
Give any leftover literature to the librarian *(CCPL library kits only).*	❑

Activities To Do Once You Get Home	**Completed?**
As soon as possible after returning home, please complete your *Feedback Form*. Go to our website at http://www.csuohio.edu/sciences/dept/cleveland_acs/NCW/, click on *Hands-on Programs* and follow the link. This information may be useful to other presenters who have not yet performed their 2012 presentation. Email photos to Bob Fowler at jrfowler@cox.net.	❑
Smile! You have just shared your joy of science and chemistry with children, possibly inspiring them to become great scientists, chemists, biologists ….	☺

Supplies Required for Demonstration

Items for Presenter to Provide (or to request in advance from the librarian — do not assume that the library will have these materials)

1. newspapers for covering 6 long tables with a few layers of paper (if none at site).
2. 1 large garbage bag for solid waste collection.
3. 1 bucket for liquid waste collection (optional if sink is within the demo room).
4. Pens for parents to fill out photo permission forms.
5. One large thermos for holding hot water. Fill this with boiling water before leaving home. **OR** Bring a 2-cup measuring cup suitable for microwaving. See p. 12.
6. 1 meat thermometer—optional--see p. 12.
7. 1 roll of paper towels.
8. Plastic tray(s) for arranging plastic cups on, filling same and then distributing.
9. It's a good idea to bring an extra gallon of water (Note: It may be difficult to transport water from library restrooms with shallow sinks or fountains with low spigots, so do NOT plan to use this method to obtain water unless you have investigated the water availability at your site.)
10. A vessel to pour tap water into cups. (Could be the measuring cup in *5*, above.)
11. 2 relatively large pairs of pliers and/or a slim screwdriver to pry/slide magnets apart. The magnets used in Exp. 3 are small, but very strong Neodymium magnets. We did our best on GAK Day to keep yours apart, but they do stick together mightily; unless you're very adroit at sliding one over another, you'll need more than finger power to get them apart.

Optional: IF you care to take pictures, bring a digital camera for taking photos. Make sure students' parents have given their permission for the children to be photographed on the ACS form and that the students and adults to be photographed are ALL wearing goggles. You might want to assign the photography chores to an assistant during the demonstration. It is better to have close ups of one or a few students to show what they are doing and their excitement.

Note: If you will be performing multiple demonstrations on the same day with the same goggles, you'll need to sanitize them between demonstrations (refer to p. 43 for more information). For this you'll need:

1. small quantity of household bleach
2. wash bin or bucket
3. old towels or cotton paper towels for drying (soft so as not to scratch the goggles)…**OR**…individual sanitizer wipes (soft so as not to scratch the goggles).

Items Provided by the Cleveland Section ACS:

General

1. 1 kit box containing materials for 6 Experiments and literature, most for distribution:
   a. 1 copy of this script.
   b. In 2-gallon plastic bag marked "X" find the following:
      i. 1 8x10 manila envelope addressed to *Julia Boxler – YTH* containing 25 copies of the *ACS Photo Permission* form.
      ii. 1 empty 10x15 manila envelope addressed to *Julia Boxler – YTH* for returning supplies.
      iii. 30 copies of *Celebrating Chemistry* (these may be outside the 2 gallon bag).

   Note: ***hang on to the 2 gallon plastic bag marked "X".*** It will be filled at the end of the program with the magnets, vials of ferrofluid, gold soln and gold nanoparticles and then put into the 10x15 manila envelope for return of these unopened vials.
2. 1 box of goggles (25-30 student & 2 adult sizes, addressed for return to *Julia Boxler - YTH*).

Sign-In: None for 2012. Perhaps to get the kids thinking, if they come early, you might ask them a question or two: What color do you think gold is when it's broken into teeny particles? Do you know of anything that bounces back into shape when you bend it? What is the smallest thing that you can see with your eyes? ☺

Materials by Experiment:

→ *Materials for each experiment are in numbered, 1- or 2-gallon plastic bags.*

Experiment 1: How Big is a Nanometer? (Individual Experiment)

1. 26 8 ½x11 sheets of plain copy paper
2. 6 10-ml vials marked "W" filled about ¾ full with tap water.
3. 25 copies of the *Student Feedback Form*
4. 25 copies of the *Student Handout* form

Experiment 2: Memory Wire (Individual Experiment)

1. 6 9-oz clear plastic cups marked "HW"
2. 6 9-oz clear plastic cups marked "E"
3. 26 3" lengths of memory wire
4. 26 golf pencils
5. 26 small paper clips

Experiment 3: Ferrofluids (Group Experiment)

1. 6 10-ml vials marked "F" containing a black liquid (ferrofluid).
2. 6 rectangular magnets. You may need to separate them and keep them apart. (During the experiment the magnets will be drawn to the fluid in the vials when held horizontally.) Please read the *Precautions* about these magnets on p. 26.

Experiment 4: Gold Nanoparticles (Individual Experiment)

1. 1 small Maglite flashlight.
2. 6 10-ml vials marked "G" containing a yellow liquid (gold solution).
3. 26 10-ml vials marked "N" containing a red liquid (nanoparticle gold).
4. 1 salt packet.

Experiment 5: HydroBead Coatings (Individual Experiment)

1. 6 small (2-4 oz) plastic portion cups marked "W" (for water).
2. 6 small (2-4 oz) plastic portion cups marked "C" (for chocolate).
3. 6 small (2-4 oz) plastic portion cups marked "K" (for ketchup).
4. 6 large packets of ketchup.
5. 1 can of chocolate syrup.
6. 26 3" square pieces of fabric, each with a small "x" on it, in a baggie marked "T" (for treated).
7. 26 3" square pieces of fabric in a baggie marked "U" (for untreated).
8. 78 beryl pipettes.
9. 52 paper towels.
10. 1 plastic spoon.
11. 1 bottle/can opener.

Experiment 6: Nano Sand (Individual Experiment)

- 26 50-ml vials marked "NS" containing about 20 g of blue or red nano ("magic") sand.
- 6 50-ml vials marked "S" filled with regular sand.
- 26 plastic spoons.
- 26 5-oz clear plastic cups marked "W" (for water).
- 26 5-oz clear plastic cups marked "D" (for decanting into later).
- 52 paper towels.

Activities Prior to Demonstration

A. At Home

There is concern for the temperature of the water used in Experiment 2. At the time of use it must be at least 95ºF to 100 ºF. This is required to transition the "memory wire" back to its straight shape. (Too much hotter and it becomes a safety issue; too much cooler and the memory wire won't transition, *i.e*., in our case, it won't straighten out.) We've found that the hottest possible tap water is sufficient. Have an assistant distribute hot tap water just before Exp. 2 while the kids are working on Exp. 1. Alternately, if you boil water at home and put it in your thermos, it'll likely be warm enough an hour and a half later to effect the transition. Or, if a microwave is available at the demo site, you could microwave lukewarm tap water for about 1 minute or less (at 1200 W) to get it to about 100ºF. We're using normal, clear plastic cups so that the kids can easily see the effect, so don't make the water super hot. We strongly suggest that you pick one method (depending perhaps on whether the library has a microwave and you have an assistant to use it), and try this method at home using a test piece of wire from your kit. Remember to allow an amount of time for your water to cool in a plastic cup equivalent to what you anticipate doing at the library.

Also, focus the beam on the Maglite (Exp. 4) as tightly as possible and test it to get the best Tyndall effect (p. 32) possible with one of the red gold nanoparticle suspension vials. A laser pointer would have been best for this purpose but was rejected because of safety concerns.

B. On-site

1. Verify room setup. (5 student tables with 5 chairs each, one presenter table, all covered with newspaper, each with paper towels, etc.) One additional table at room entrance.
2. Obtain any supplies requested from librarian (see page 9).
3. Please place the *ACS Celebrating Chemistry* fliers on the entry-table so that the kids can each take one at the end of the program (or place them there at the end of the program). You have 30 copies, so there should be more than enough to give the Librarian a few at the end of the Program.
4. Also on the entry-table place the *ACS Photo Permission* forms and some pens.

Place the goggles where they can easily be distributed. **IF** you plan to take photos during your presentation that we can use on the Cleveland NCW ACS website and/or for submission to National ACS for awards or annual reports, you MUST obtain a **signed** photo permission form for each and every person in the photo. Do NOT take photos of *anyone* without written approval. Also, ***everyone in any photo must be wearing goggles. ACS will (and has) disqualified us from receipt of awards if we submit photos in which even one person isn't wearing goggles.*** The kids will have a tendency to remove or slide their goggles up on the foreheads as the presentation progresses, so please check between photos.

Experimental Setup

Note: In the following the term "station" refers to each of the 5 places at all 5 student tables plus the demonstrator's table (i.e., 26 places total).

Experiment 1: How Big is a Nanometer? (Individual Experiment)

- At each station place the following:
    1. 1 8 ½ x 11 sheet of paper
    2. 1 *Student Handout*
    3. 1 *Student Feedback* form

- At the center of each table place the following:

    1. 1 10-ml vial marked "W" filled about ¾ full with tap water.

Experiment 2: Memory Wire (Individual Experiment)

- At the demonstrator's table place the following:
    1. The demonstrator's thermos filled with very hot tap or previously boiling water and/or a measuring cup suitable for microwaving or pouring.

- At the center of each table place the following:
    1. 1 clear plastic 9-oz cup marked "HW"
    2. 1 clear plastic 9-oz cup marked "E"

- At each station place the following:
    1. 1 3" length of memory wire
    2. 1 golf pencil
    3. 1 small paper clip

Experiment 3: Ferrofluids (Group Experiment)

- At the center of each table place the following:
    1. 1 10-ml vial marked "F" containing a black liquid.
    2. 1 rectangular magnet. Although small, these are powerful magnets. (See the *Precautions* on p. 26.) Take care to remove them one by one from the "sandwich" and to keep them separated from each other. It's very difficult to get them apart—you'll have to use the tools you brought if two or more of them touch and cling together. Keep the magnet away from the vial at this point.

Hang on to the plastic bags that the ferrofluid vials (Exp. 3) and both gold vials (Exp. 4) came in as well as the cardboard magnet dividers. You'll need them for returning these vials and magnets at the end of the Program.

Experiment 4: Gold Nanoparticles (Individual Experiment)

- At the demonstrator's table place the following:
  1. 1 small Maglite flashlight.
  2. 1 salt packet.

- At each station place the following:
  1. 1 10-ml vial marked "N" (nanoparticle gold) containing a red liquid. Remove the Parafilm from **only!** the Demonstrator's vial of red nanogold particle suspension marked N; make sure the cap is still tight and the vial is sitting upright in a stable position (i.e., not balanced on the fold of a piece of paper or similar). Do not remove the Parafilm from any vials at any of the student tables.

- At the center of each table place the following:
  1. 1 10-ml vial marked "G" containing a yellow liquid (gold solution).

Experiment 5: HydroBead Coatings (Individual Experiment)

- At the center of each table place the following:
  1. 3 small (2-4 oz) plastic portion cups marked "W", "K" and "C", respectively.
  2. Fill each cup marked "W" about ½ full with tap water.
  3. Empty the contents of the ketchup packet into each cup marked "K". Use the plastic spoon provided to assist in this.
  4. Using the can opener provided, open the can of chocolate syrup. Aliquot the contents evenly into the 6 cups marked "C", but no more than about ½--¾ full each. Please take the remainder home for your own use.

- At each station place the following:
  1. 1 3" square piece of fabric from the baggie marked "T" (for treated). Note that each treated fabric square has a small "x" on one corner.
  2. 1 3" square piece of fabric from the baggie marked "U" (for untreated)
  3. 3 beryl pipettes
  4. 2 paper towels

Experiment 6: Nano Sand (Individual Experiment)

- At each station place the following:
  1. 1 50 ml vial marked "NS" containing about 20 g of blue or red nano sand.
  2. 1 plastic spoon
  3. 1 5-oz clear plastic cup marked "W". Fill each about ¾ full with tap water.
  4. 1 5-oz clear plastic cup marked "D" (for decanting into later).
  5. 2 paper towels

- At the center of each table place the following:
  1. One of the 50 ml vials marked "S" filled with regular play sand.

Greet the Students (and Parents) Upon Their Arrival, Distribute Goggles, and Organize the Seating

1. If you plan to take pictures, ask the parents/guardians to give or withhold their permission for the student to be photographed via the ACS consent form. **Don't forget to obtain their signatures on the forms provided.**
2. Help the students or have the students' parents put on their goggles. Adjust the straps as necessary. (Note: These goggles are sanitized each year and prior to each demonstration.) Suggest that the students pull the air vents open for comfort while wearing the goggles.
3. Distribute the students 3-5 per table. (*Note*: You might want some librarian assistance with this: IF you plan to take photos and some of the parents have denied permission, you'll want to put all of the children who aren't going to be photographed at a separate table.)
4. If there are students who come early and are waiting, you might ask them a question or two: What color do you think gold is when it's broken into teeny particles? Do you know of anything that bounces back into shape when you bend it? What is the smallest thing that you can see with your eyes? We will ask questions like these during the program, and they can start thinking now.

Opening Discussion

Introduce the Items on the Tables:

- Tell the students that various items have been gathered for them on their table.
- Some of the items can be found around the house, but others are laboratory chemicals. Emphasize that students should NOT touch anything until instructed to do so. *Never taste or smell anything, as if they were in a laboratory!*
- Tell the students that some of our items today can stain clothes or hands if we're not careful. Mention to mom and dad that the chemicals can be washed off with soap and water if any hands get stained. We will also be good chemists and take the safety precaution of protecting our eyes with our goggles.
- Put on a pair of the adult-sized goggles. If you have an assistant, ask them to do the same. Verify that all students have goggles on. This is especially true this year because of the presence of the Neodymium Magnets in Exp. 2. See p. 26.

Introduce Yourself and the Program

- Introduce yourself as a chemist or chemist/science teacher/engineer (or state your interests in chemistry), and introduce the American Chemical Society as the largest organization in the world devoted to a single profession.
- Introduce National Chemistry Week—what it is and why we do it. *(Hint: it is a nationwide event put on by volunteers like you to let non-scientists know about chemistry and how it has improved our everyday life.)*
- Please tell the students that there are several other things they should be mindful of today:
  1. Please don't play with the magnet on your table and PLEASE don't touch them against another table's magnet. Don't get the magnet near credit cards or anyone who might have a medical device implanted in them. It could be very dangerous if you do!
  2. Please don't remove the plastic film covering the vials of black fluid marked "F", red fluid marked "N" or yellow fluid marked "G". Please don't remove that plastic film and PLEASE don't open these vials.
  3. Tell the students that we'd really like them to vote for the experiment they liked most in today's Program. At the end of the Program they're going to have a chance to vote on their favorite experiment and the one that they think taught them the most. They'll do this via the hardcopy *Student Feedback* form at their places. So tell them to remember what they like about each experiment. We'll give them a chance to make notes at the end of Exp. 1.
  4. Also tell them that they're going to receive a *Student Handout*. Tell them to make sure they get one and take it home because on it are lots of cool things they can do at home. **It also has our web site where they can go and vote online if they don't have time to fill out the hardcopy here today**.

Now let's have some fun!

Background for the Demonstrator (only)

Welcome to the fascinating world of nanotechnology! It's been 53 years since Richard Feynman gave his famous speech to the American Physical Society called *There's Plenty of Room at the Bottom*. In this 1959 presentation, Feynman offered his vision framing four key areas where nanotechnology might have a huge impact: information, imaging, materials, and machinery.

Some of us may remember the miniaturized submarine in which Raquel Welch travelled through a human body to zap a blood clot in the film *Fantastic Voyage* seven years later. Even though MEMS (micro-electro-mechanical) technology won't make it possible to reduce a complete submarine to such a small size (blood vessels range from 0.1 mm to 1-1.5 cm in diameter), scientists are actively studying the miniaturization of machinery to the nano scale. But today we're going to introduce our students to the unusual properties of some materials which exist at these small sizes. We'll see how sometimes nanotechnology is about designing new materials while other times it's about designing new structures that make old materials behave in new and different ways. You may want to look at the informative videos about these topics on p. 4.

When a "normal" material is reduced to a very, very small physical size, we enter the realm of *nanotechnology*. (1 nm = 10^{-9} m.) When a material's size is measured to nanometers, it's said to be on the *nanoscale*. Often when normal materials are reduced to these very, very tiny sizes, perhaps by the use of chemistry, non-normal "special properties" result because of something called "quantum confinement" of electrons. One finds that as size decreases to the nanoscale an increasingly overwhelming percentage of atoms occur at surfaces, edges and corners of lattices rather than in the interior volume. These effects alter physical properties and increase reactivity. For example, everyone knows that one of the things that makes gold so attractive is its beautiful golden yellow color. But chemists can now make nanoparticles of gold (3-13 nm) which are red! Or are they blue (~ 90 nm clusters)? We'll learn more about all this in our experiments.

Exciting new things are happening in the world of nanotechnology as scientists use the "special properties" that occur at the nanoscale. For example, red gold nanoparticles and inert nanoparticles coated with a nanolayer of gold are being used to detect and fight diseases in humans. Very tiny tubes called nanofibers are being used to increase the life and power of batteries. Nanomachines are poised to go where none have gone before. Examining our own DNA allows scientists to determine who we are and where we come from in a new science called *genetic fingerprinting*. Using nanotechnology scientists have created "restriction enzymes" which work like molecular scissors to cut DNA at defined sequences and reveal our origins and makeup. None of this was possible even a few years ago, but our students—as the scientists of tomorrow—will be able to share the excitement of using nanotechnology to study nanomaterials which may enhance our lifestyles and lengthen our lives.

But how exactly do we demonstrate nanotechnology to the students in a conference room setting since we won't be able to actually see any nanoparticles? In laboratories we use *high-resolution transmission electron microscopes* (HRTEM) and atomic force microscopes to see these particles, but we don't have one of these with us today. Instead, we'll learn about nanotechnology by observing some of these "special properties" in action.

Introduction to the Program for the Students

Have you read *The Magic School Bus* stories where the teacher Ms. Frizzle takes her kids on fantastic and imaginary field trips? In one story, they were able to learn about very small things inside the human body when they were shrunk down to the size of blood cells. Today, we will learn about very small things, too…even smaller than blood cells. We'll pretend to go on an imaginary trip along with our two chemistry professors, Millie and Avogadro. Professor Millie and Professor Avogadro want you to help them decide which experiments to use in another program for students your age. You can help them choose your favorite experiment and the experiment that helped you understand nanotechnoloy the most. In *The Magic School Bus*, remember the class pet is called Liz for lizard. Well our professors have interesting names, too. Millie is for "millimeter", a very small unit, about the size of the tip of your pencil. And Avogadro is a number usually referring to very small particles like atoms and molecules. Now we're talking small!! Atoms and molecules are measured in nanometers!

Our program today is called "*NANOTECHNOLOGY, the Smallest BIG Idea in Science*". We are going to study very small particles the size of nanometers. What's a nanometer? A nanometer is a unit of measure, like an inch or foot, but much smaller.

Have you smelled cookies baking? Mmmm. That smell is actually many teeny molecules that are less than a nanometer in size.

In our experiments today we will get a feel of just how small a nanometer is, and we will experiment with some metals that have been broken down into nanometer-sized particles. We'll look at how properties of things change when they are very small...properties like color. We will show how small particles can be used to make things in our world better for us….like how to make our clothes stay dry in the rain.

When we've finished with our experiments today you can let Professors Millie and Avogadro know which of the experiments you liked the best and that helped you understand chemistry the most. There is a handout in front of you and a pencil. You can write or draw things on the paper to help you remember, if you like. Then, at home, if you don't get a chance to fill out your *Feedback* form, there's a website to go to, to log into and let us know your favorite experiment. That web site and many other fun ones are listed on your *Handout*.

So sit back, enjoy the fun and let's learn about nanotechnology!

Experiment 1: How Big is a Nanometer? (Individual Experiment)

Experiment Purpose & General Methodology

The purpose of this experiment is to familiarize the students with the scale of nanotechnology.

Introduce the Experiment

Ask the students: What's the smallest thing you can SEE with your eyes?

Typical answers: A grain of sand. A piece of salt. A human hair. An ant.

Picture a grain of sand. Now picture something one million times smaller than that. That's a nanometer! It's hard to imagine, but we will do an experiment to help you picture how small that is. A teeny nanometer that is one million times smaller than a grain of sand is like the width of your front yard compared to the diameter of the entire earth.

[If kids ask: Are there some living things that are very small, like "bacteria"? Yes, one bacterium is very small, but only 20,000 times smaller than a grain of sand.]

What is smaller yet? What are the 'building blocks' of all matter? *Ans*: Atoms and molecules. An atom is ten million times smaller than a grain of sand.

[If kids ask: Can you see bacteria with a microscope? Yes. An atom? You can't 'see' anything smaller than the wavelength of light. So not with a regular light microscope. But computers can help you 'picture' an atom using electron beams or with the powerful atomic force microscopes.

Professors Millie and Avogadro suggest that we make something really small. What is one way to make something small? *Ans*.: You could take something BIG, and physically/mechanically grind it down, rip it apart, etc. (We will talk about other ways later.)

Performance Details

Tell the students to do the following:

1. Take the piece of paper at your place and fold it in half. Tear along the fold.
2. Now take one of the halves of paper, fold it again and again tear along that fold. Put the other half aside for making notes and for use in Experiment 4.
3. Continue tearing one half of each torn sheet into another torn half until the smallest possible piece has been obtained. **This should produce a small piece of paper still bigger than a grain of sand. That's still over 1 million nanometers wide!**
4. Ask the first student at the table to pick up the 10 ml vial filled about ¾ full with water and marked "W". Ask him/her to remove the parafilm and cap; then select his/her smallest piece of paper and put it into the vial. Pass the vial and cap to each student in turn so that each student can add their smallest piece of paper. **Don't spill it as you pass**

it down! Ask the last student to cap the vial and turn the top tightly. Have him/her shake it in an attempt to break apart some of the paper fibers.

5. After a few shakes, observe the water. **Has it become a little cloudy from the finer particles of paper? In the water the little pieces of paper have become even smaller as water breaks them apart and surrounds them. They are now much smaller than a grain of sand.**
6. Set the vial back in the middle of the table for use a little later.

Conclusions

- Tell the students to imagine that what they see in the vial is like tearing the smallest size of paper in half another 13 or 14 times to make it a million times smaller than before!
- Can they imagine how small the paper would be? That's about the size of particles at what scientists call the *nanoscale*.
- Scientists can make nanoparticles in a similar way: by mechanically grinding down big particles or physically or chemically breaking them part.
- This is the size of some of the materials we'll be working with (and learning about) in the following experiments.

Special Note:

Tell the students that the sheet in front of them has a picture of a hand holding a nanoruler on it. The width of your hand is about 100 million nanometers! Ask them to please vote for their favorite experiments either by completing the hard copy *Student Feedback* or by visiting our website at http://www.csuohio.edu/sciences/dept/cleveland_acs/NCW/. This website is listed on their handout. We will do 6 experiments today. To help you remember your favorite, there's a pencil that you can use to take notes on the half piece of paper left over.

Technical Information (for the Demonstrator):

We all know that a grain of salt is pretty small. How small is it? On average it's about 1 millimeter (~0.04 in.) in diameter. We often measure those small nanoparticles we've been talking about on something called the nanoscale which uses nanometers instead of millimeters. A nanometer is 1 millionth the size of a millimeter! So that grain of sand measures about 1 million nm across!

The diameter of a human hair (~ 10^{-2} mm or 10^{4} nm) is 100 times smaller than a grain of salt. You probably haven't seen a bacterium because you have to look through a microscope to do so, but it's about 20,000 times smaller than that grain of salt! Now think about an atom. Atoms are some of the most fundamental building blocks of material and are extremely small. In fact an atom (~0.1 nm) is about 10 million times smaller than a grain of salt.

Most students may be able to tear the paper into halves about 13 times. $(1/2)^{13} = 1 \times 10^{-4}$. If they were to tear it another 13 times you have $(1/2)^{26}$ or 1.5×10^{-8} or 14 more times for $(1/2)^{27}$ you have 7×10^{-9}—in the nano range.

Some relative sizes and measures:

- 1 mm = 10^6 nm
- 1 nm = 10^{-9} m.

- Grain of salt: ~ 1mm = 10^6 nm
- Typical bacteria: ~200 nm long.
- Human hair: ~10,000 nm in diameter.
- One piece of paper: ~100,000 nm thick.

- Atom: ~0.1 nm.
- Atoms in a molecule: ~0.15 nm apart.
- DNA double-helix: ~2 nm in diameter.
- Typical protein: ~10 nm long.
- Computer transistor (switch): ~100-200 nm wide.
- Young girl 1.2 m (4ft) tall: ~1200 million nm tall.

Experiment 2: Memory Wire (Individual Experiment)

Experiment Purpose & General Methodology

This experiment will demonstrate that scientists can make interesting materials because of changes at the atomic level. At the atomic and molecular level we are talking about nano-sized structures. Solid phase changes in metal alloys at this atomic level can result in interesting properties exhibited by the entire material. We will compare a "normal" metal wire (a paperclip) with a "memory wire". We will impose a straight shape on the paper clip, and we'll bend the memory wires into coils. When these two wires are immersed into hot water, the memory wire will assume its original shape (straight), while the paperclip won't: it will stay straight.

Introduce the Experiment

Tell the students the following:

The next experiment that Professors Millie and Avogadro want to explore with them begins with a special wire. When you bend wire what happens? Does it bend pretty well? Yes. Does it sometimes break, if you bend it a lot, back and forth? Yes. Does it bounce back like a rubber band? No.

Scientists have made some nanomaterials that act very differently from what you expect! Scientists have blended some metals together into what's called *alloys*…at the atomic level the atoms in these alloys are arranged in slightly different ways depending on their temperature. We are going to compare 2 metals: one is a "nanomaterial" called a "memory wire" and the other is a regular wire—a paperclip!

Note to the Demonstrator:

At the point where the kids are ready to immerse their wires, the water should be at 95ºF to 100ºF or slightly higher for a successful experiment. As you begin to discuss this experiment, have an assistant go to each table and fill the single 9 oz. plastic cup marked "HW" with the hot water from your thermos. (Note: we chose to use a plastic cup over a Styrofoam cup so that the wires could be viewed more easily. The water isn't hot enough to melt the cup.) **OR** Ask your assistant microwave the water for about 1 minute in a 1200 watt microwave. (Optional: you may use your meat thermometer you brought from home to check that the temperature is at least 100ºF. Our wire is designed to change phase from 95ºF to 100ºF—high enough so the wire isn't affected by body heat once it's curled.)

Performance Details

Tell the students to do the following:

1. Locate the 3" piece of memory wire, the paperclip, and the pencil on the table in front of them.

2. Straighten out the paperclip and sit it down.
3. Starting at blunt end of the pencil, hold one end of the "memory wire" against the pencil with one finger while wrapping it completely around the pencil to form a coil.
4. Now remove the coil from the pencil and sit it down for a second. Don't worry if it unravels just a bit.
5. Tell the students that this special "memory wire" exists in two different phases, just like two phases of water—ice and liquid water, except in the wire we're dealing with two solid phases.
6. Ask them how they can change ice (one phase of water) into liquid (a second phase of water). Ans: heat it.
7. Maybe we can do the same thing with the wires. Let's see what happens when we put these wires into hot water.
8. Tell the students to take turns to **CAREFULLY** drop both their wires into the cup of hot water, taking care not to put their fingers into the water.
9. Take a moment to look at your wires, but leave them in the cup for now. After our last experiment, Experiment 6, we will remove them (the water will be cooled down) and you can take them home (one memory wire and one paperclip per student).

Conclusions (Delay until after Exp. 6.)

Tell the students the following:

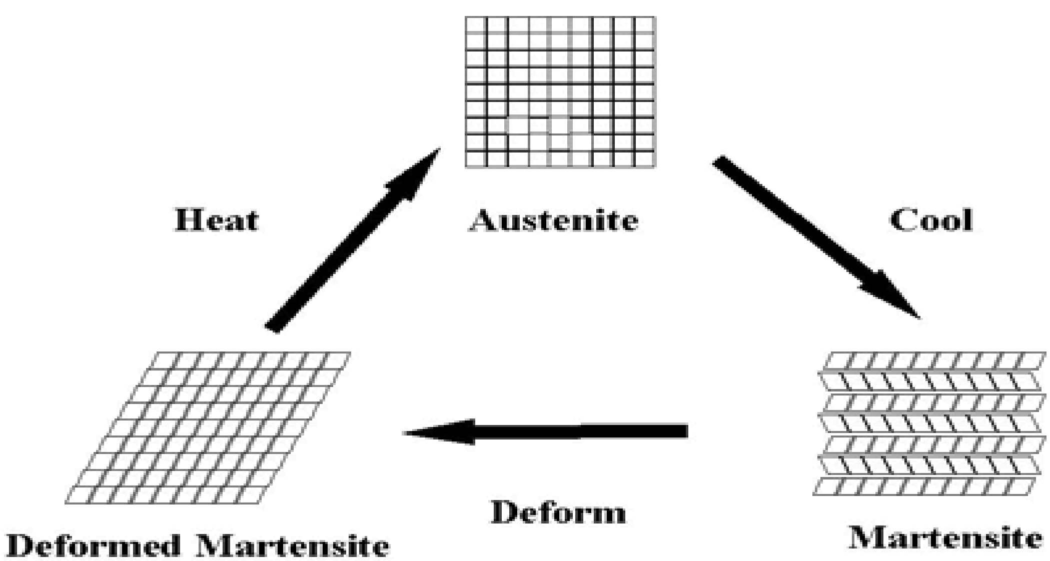
1. What happened to the wires? *Ans*: the "memory wire" returned to its original straight shape because it has a "memory", but the paperclips remained straight—they didn't return to their "normal" paper clip shape because they aren't made of a wire with a memory.
2. The "memory" metal is special. It is a blend, or alloy (like coins are a blend of metals) of nickel and titanium called Nitinol that was first made in the 1960's. It can be used in eyeglasses, in art, and in stents in blood vessels. It returns to its original shape when heated above a certain temperature. It can also be stretched a bit and then return to its original shape just like a rubber band.
3. Picture yourselves as atoms in a row holding hands. First stiffly hold hands, then stretch out, and pull back together. Now pretend to all lean in one direction, then another. This is a picture of what the atoms in the metal are doing.
4. The students make take their memory wires home with them (at the end of the program) and repeat the experiment there as often as they like with a parent's help…the handout in front of them will remind them how to do it.
5. Try to remember if this is your favorite experiment!

Technical Information (for the Demonstrator):

In 1965, the first of a series of metal alloys of nickel and titanium was produced by the Naval Ordnance Laboratory. These alloys are called Nitinol, for Nickel Titanium Naval Ordnance Laboratory. Many of the alloys have a rather remarkable property: they remember their shape. This "smart" property is the result of the substance's ability to undergo a phase change – a kind of atomic ballet in which atoms in the solid subtly shift their positions in response to a stimulus like a change in temperature or application of mechanical stress. These "memory wires" have been included in this series of experiments about nanotechnology because the phase change involves transitions at the atomic level.

NiTi alloys change from austenite to martensite upon cooling. The alloy can exist in either of two structures (solid phases) at room temperature, depending on the exact ratio of nickel to titanium atoms. The structure found above the temperature of the phase change possesses the high symmetry of a cube and is called austenite; the structure found below the temperature of the phase change is much less symmetric and is called martensite. In the martensite phase the material is very elastic, while in the austenite phase the material is comparatively rigid.

Nitinol can be "trained" to have a new shape by heating it into the austenite phase and then deforming it into the desired shape. As it cools to below the phase transition temperature, the material enters the martensite phase. In the martensite phase the shape can then be changed by mechanical stress: groups of atoms that were "leaning" in one direction will accommodate the mechanical stress by "leaning" in another direction, as allowed by the less symmetric structure. The sample will revert to the shape enforced upon it while it was in the martensite phase by returning it to the austenite phase through an increase in its temperature. (In our case, the wires were originally "set" into a straight shape by the manufacturer while heated into the austenite phase and then cooled below the phase transition temperature; they return to this straight shape after coiling them while in the martensitic phase and reheating back into the austenite phase.) The thermal energy acquired by the shape through heating it provides the energy the atoms need to return to their original positions and the sample to its original shape.



The transition from the martensite phase to the austenite phase is only dependent on temperature and stress, not time, as most phase changes are, as there is no diffusion involved. Similarly, the austenite structure receives its name from carbon steel alloys of a similar structure. It is the reversible, diffusionless transition between these two phases that results in special properties. While martensite can be formed from austenite by rapidly cooling carbon steel, this process is not reversible, so steel does not have shape-memory properties.

Many diverse applications have been developed for "memory metal" and other "smart" materials. These uses include eyeglass frames, coffee pot thermostats, electrical connectors, deicing system, heat pipes, clamps, and sculptures.

Research is underway on using shape memory alloys to deploy solar arrays and antennae on satellites and to control the balance on helicopter rotor blades. The biocompatibility of NiTi allows its use in many medical applications such as vascular stents, anchors for attaching tendons to bone, medical guidewires, medical guidepins, root canal files, bendable surgical tools, and devices for closing holes in the heart.

For more to do with Nitinol see:
https://nano-cemms.illinois.edu/media/content/teaching_mats/kits/nitinol/docs/nitinol--activity_guide--updated-pdf.pdf

Experiment 3: Ferrofluids (Group Experiment)

Please note the following:

The magnets used in this experiment are very strong Neodymium magnets. Certain prudent precautions must be taken with them:

Neodymium Magnet Precautions

1. Caution students to not put magnets into their mouths. They can be a choking hazard.
2. These are strong magnets and care must be taken to avoid personal injury and damage to the magnets. The students should not allow two magnets to come together. Little fingers can be severely pinched, and the magnets are difficult to separate once they're together.
3. The magnets are brittle, so never allow two of them to slam together. They could shatter and send metal shards flying all over. Eye protection must be worn!
4. Caution parents that these magnets can damage magnetic items such as credit cards, and electronic devices. The strong field of these magnets can interfere with the operation of pacemakers or similar medical devices.

Experiment Purpose & General Methodology

The purpose of this experiment is to further investigate the world of nanotechnology by showing that a metal like iron has very different properties when it is in small-particle (nano-size) form compared to its normal (bulk) form. Nanoparticles of iron can be "suspended" in a liquid and can cause the entire liquid-plus-solid-iron-particle (colloidal) mixture to respond to the magnetic field lines of a strong magnet.

Introduce the Experiment

Tell the students the following:

- In our first experiment we showed how you can make tiny nano particles using mechanical means—we used physical force to rip paper into tiny pieces and then we shook them in water to further break them apart. **In this experiment, we will see tiny particles of iron that have been made by chemical means.** Chemists can mix different liquids that react together and form new chemicals. The little iron particles we will be using here came from an iron-containing liquid that was chemically reacted (reduced) so tiny, solid iron particles were formed.
- **Small nano particles can look and act differently than if they were large particles.**
- Has anyone seen the cereal experiment where you can pull little iron filings out of an iron-fortified cereal slurry using a magnet? The iron particles we'll see today are much smaller than iron filings. They are nano-sized!
- Nano particles come in a variety of shapes and colors and can do interesting things.

- If you dropped an iron nail into water what would happen? It would sink. What about a flake of rust (which is iron oxide). It might float. What if the iron were in the form of really small particles? Would they float or sink? Would they be 'swimming' all around in the water?
- In this experiment we're going to show how magnetic nano particles of iron in this liquid can be pulled into interesting and delicate shapes and they can also reveal where a magnet's field lines are.

Performance Details

Tell the students to do the following:

1. As you do this experiment, try to remember if this will be your favorite; Professors Millie and Avogadro will want to know.
2. Have one student at each table locate the 10 ml vial with the black, gunky liquid marked "F" in front of them which consists of tiny nano particles of iron in mineral oil. They are moving randomly around in the oil, so it all looks black and liquidy. They are 'suspended': neither floating nor sinking. Ask a second student to find the rectangular magnet. Make sure they exercise care with the magnets as per the *Precautions* on p. 26.
3. Remind the students ***NOT TO OPEN THESE VIALS AND NOT TO UNDO OR FOOL WITH THE PARAFILM AT THE TOP OF THE VIALS.***
4. Hold the vial in a horizontal position and place the flat side of the magnet against the underside of the vial. The magnet should "stick" to the vial because the liquid inside is actually magnetic and is called a ferrofluid (ferro means 'iron'). The little magnetic iron nanoparticles cause this effect.
5. Don't shake the vial—try to hold it level and steady.
6. Pass the vial/magnet combination to each of the students in turn. If the students look carefully they'll begin to see "spikes" of iron particles inside the vial that look like tiny mountain peaks.
7. After a few more seconds the students should see black lines form on the inside walls of the vial. This is the iron particles, pulling the liquid along with them, lining up in the magnetic field caused by the magnet. The ferrofluid about 80-90% liquid carrier…so this is pretty amazing!
8. With time, the peaks will be more pronounced. Let the vials sit horizontally with the magnet on it, and we'll return to take a look after Experiment 6.

Conclusions (Delay until after Exp. 6.)

- As we have seen, nanoparticles demonstrate some really unusual "special properties".
- In this experiment we used suspended iron nanoparticles to show how field lines emanate or flow from a magnet.
- The small size of the nano particles allows the entire fluid they are in to respond to a magnet.
- Ferrofluids can be used as seals to keep out dust in computers.
- They are the magnetic solid materials in liquid form.

Technical Information (for the Demonstrator):

Ferrofluids are colloidal dispersions of extremely small ferromagnetic nanoparticles (diameter usually 10 nm or less) such as cobalt, nickel or iron, suspended in a hydrocarbon liquid by Brownian motion. They were invented by NASA in the 1960's for use as rotating shaft seals in satellites. The 10 nm particle size is small enough for thermal agitation to disperse them evenly within a carrier fluid, and for them to contribute to the overall magnetic response of the fluid. This is analogous to the way that the ions in an aqueous paramagnetic salt solution (such as an aqueous solution of copper(II) sulfate or manganese(II) chloride) make the solution paramagnetic.

The nano-sized iron particles are coated with a surfactant to prevent them from clumping together. When no magnetic field is present, a ferrofluid behaves and flows like a normal liquid. However, when a magnet or magnetic field is introduced, the ferrofluid is attracted to the field. Spikes then form along the magnetic field lines when the magnetic surface force exceeds the stabilizing effects of fluid weight and surface tension.

Ferrofluid, while lots of fun just to play with, has many practical applications as well. Since ferrofluid has low resistance to flow, it can function as a liquid O-ring seal, kept in place with permanent magnets. Ferrofluid seals prevent dust particles from working into disk drive mechanisms and crashing the drive head into the disk. Also, ferrofluids cool the coils of high-power, hi-fi speakers.

Experiment 4: Gold Nanoparticles (Individual/Demonstrator Experiment)

Experiment Purpose & General Methodology

In this experiment we'll demonstrate how the physical properties of a material can change when it is reduced to nano-size. We'll also simulate the use of nanoparticles to detect diseases.

Introduce the Experiment

Tell the students the following:

- The next experiment Professor Millie and Professor Avogadro want you to examine is rather colorful.
- Before we came here today some chemist friends of the two professors created gold nano particles using a method called a chemical reaction. Remember nano particles can be made mechanically or chemically, as well as other ways.
- In this experiment you'll see you'll see how **gold looks different when it is changed into nano particles.**
- When things are broken into nano particles, they can look or act differently.
- For example, you all know what normal hair is like. But when you have very tiny hairs they can be "sticky'…the little nano hairs on a gecko's feet help it stick to walls!
- Another example: do you remember sunscreen that stayed white on your skin because of the white metal oxides? When these are made into nano-particles they are transparent or clear.
- Some things that are very stable in their 'normal' state can be flammable when they are in their nano-particle state.
- Some things that can't dissolve in water when they are big particles can dissolve when they are small particles.
- Some things change color! What color is regular gold, like in a gold ring? Yellow! Gold! What color do you think nanoparticles of gold are? We'll soon see if you're right!
- We'll demonstrate a way to tell when small nanoparticles are "swimming" in a liquid--not floating on top or sinking or dissolved in it.
- Then, we'll see how gold nanoparticles can be used to detect when someone is sick with a serious disease.

Performance Details:

Tell the students to do the following:

1. Tell each student to find the 10-ml vial marked "N" containing a red liquid. The first student at each table should also get the vial marked "W" from Experiment 1 and the 10-ml vial marked "G" containing gold solution at the middle of the table. Remind the

students ***NOT TO OPEN ANY OF THESE VIALS AND NOT TO UNDO OR FOOL WITH THE PARAFILM AT THE TOP OF ANY OF THE VIALS.***

2. Ask the first student to hold the vial marked "G" up against the other half of the paper that wasn't torn up in Experiment 1. The liquid in the vial should look slightly yellow against the paper, and the solution should be clear. Can he/she observe this? This vial looks slightly yellow or golden in color because it contains a dilute salt of the "normal-sized" gold that we're used to seeing.
3. Ask the first student to observe the vial marked "W" in the same way. Does it look white and cloudy? That's because it's a suspension containing shredded paper which has started to dissociate in the water by now.
4. Now ask the each student to observe their vial marked "N" in the same way once again. It contains a suspension of **red** gold **nanoparticles**. Who guessed that nanoparticles of gold are RED?
5. Now ask the first student (only at this point) to compare the two vials marked "N" and "G" by holding them against the paper. Which of the vials has liquid which is absolutely clear and which is a little "cloudy"? *Ans*: the vial marked "G" (containing a solution of a gold salt) should be crystal clear while that marked "N" (containing the red gold nanoparticle suspension) should be slightly cloudy. The vial marked "W" (containing a slurry or solid suspension of paper particles) should be very cloudy (there should be no need to hold it up against the paper at this point).
6. Ask the first student to pass the vials marked "G" and "W" down the table to the other students so they can compare vials "G" and "N" like he/she did.
7. Looking at how cloudy something is can tell you whether the chemicals in it are dissolved or suspended. Rather than just using our eyes, we can examine the degree of cloudiness by a laboratory technique called the "Tyndall effect" which is light scattering by particles in a colloid or particles in a fine suspension. We're going to use a light beam to see if it's scattered by the liquid—we're going to shine a beam of light through the vials to see if we can see the beam of light in the liquid in the vial. If we can, the light has been "scattered" by solid particles suspended in the liquid; dissolved particles don't scatter the light beam. At this point the demonstrator should move from table to table with the highly focused maglite selecting a set of three of the vials (one "G", one "N" and one "W") at each table. (Note that there's only 1 vial marked "W" and one marked "G" at each table.) Show the students how you're shining the beam of light through each of the vials in turn starting with the one marked "G", then to the one marked "N" and finally to the one marked "W". Move the light up and down each vial to see this effect. It's a little difficult to see the scattered beam with the Maglite, but what do they see? If they look very closely it should be impossible to detect the light path in the liquid in the vial marked "G", while it should be more apparent in the vial marked "N" and very apparent in the vial marked "W".
8. Why is the path of light more apparent in the vial marked "W" than the one marked "G"? Ans: light is scattered by the presence of undissolved particles in the liquid. You can see that light is scattered by the small particles that are 'swimming' around in "W". These are the small pieces of paper from Experiment 1. If they were dissolved particles (like in vial "G"), you could not see them with the light beam at all.

9. Did the students see the light path passing through the liquid in the tube marked "N"? It's faint, but it's there, indicating that there are undissolved particles—gold nanoparticles—dispersed through the liquid. Being able to see the scattered beam in the liquid is one way we know that small, solid particles are present undissolved in the liquid.
10. Lastly, find the salt packet and your vial marked "N" at your Demonstrator's table. (**Note: only the Demonstrator will perform this step.**) Tear off one corner of the packet and carefully sit it on the table for a moment (try not to lose any salt). Now carefully remove the cap from the vial marked "N", and drop just a few grains of salt into the red liquid. Put the top back on the vial, close it tightly, shake it and show it to the students. What's happened? *Ans*: Adding salt makes the small red nanoparticles of gold cluster together to form bigger blue nanoparticles.
11. Tell the students that, unfortunately, they won't be able to take any of these vials home with them. (Demonstrator: **no exceptions to this no-take-home rule** because these materials are can be irritants and will turn your skin purple for a while.)

Conclusions

Tell the students the following:

- You have seen examples of how the physical properties of some materials can change as nano-sized particles of this material are created. In this case the change that's observed is the material's color. The red liquid in the vial marked "N" was actually a suspension of very tiny nano-sized clusters of gold atoms—each of these tiny clusters of gold atoms is maybe 10,000 times smaller than the width of one of your hairs! When gold particles become that small, peculiar things start to happen. In this case they absorb all but red light from visible light, so they look red. Who would have thought that gold could turn red just by making it very small?!
- The salt caused the very tiny red nanoparticles to cling together into slightly larger nanoparticles which reflect blue color! So gold can be red, gold or blue in color!
- They've also seen example of what chemists call solutions (vial marked "G"), colloidal suspensions (vial marked "N") and solid suspensions (vial marked "W"). Suspensions actually have tiny solid particles in them while the materials in solutions are completely dissolved—like sugar in water. One way to tell the difference is to see if the liquid scatters a light beam.
- The salt gives exactly the same effect that a blood sample from a diseased patient would, so the students have seen an example of how the exciting new science of nanotechnology is opening new methods for detecting and treating diseases. Who knows—perhaps some of our lives will be saved by nanotechnology. Now that's something worth studying!

Technical Information (for the Demonstrator):

For a great set of short background films about the nano scale, nano gold, its preparation and its properties, see http://www.accessnano.org/teaching-modules/gold.

The physical properties of an element, when it is reduced to nanometer size, can change dramatically. Gold is one of the densest elements known with an atomic radius of about 0.7 nm. A nugget of normal gold consists of a face centered cubic crystal with the majority its atoms in the interior of the mass. Its color is yellow, and pale yellow solutions of $HAuCl_4 \cdot 3H_2O$ can be prepared.

Stabilized colloidal gold suspensions consist of 10 to 100 nm nanoparticle clusters of 3 to 50,000 atoms of gold each. At ~ 5-13 nm the nanoparticles reflect red light; at~ 90 nm they reflect blue light.

Before the salt addition the gold atoms are suspended into 5-13 nm red nanoclusters that are stabilized by a "shell" of sodium citrate. The salt interferes with the citrate shell, resulting in the smaller red nanoclusters agglomerating together to form larger ones which causes the color to change to blue. This is not actually a blood sample from a diseased person, but the salt has the same effect as adding a diseased sample. If we had really added a protein from someone who had meningitis, for example, it would also have turned the red liquid blue as red nanoparticles couple together to form larger ones.

The red gold nanoparticles were created in a redox reaction of tetrachloraurate (also known as tetrachlorauric acid or tetrachlorauric (III) acid trihydrate), in which gold ions are reduced to atomic gold clusters. When heated and then treated with sodium citrate, this pale yellow tetrachloraurate solution turns first turns a deep purple and then into a ruby-red suspension. By adding the reductant, the atomic coagulation of the metal ions is halted and the result is a colloidal cluster enclosed by a ligand case. The reductant sodium citrate (also called trinatrium citrate dihydrate) not only reduces the gold but also acts as a dispersion medium to stabilize or "cap" the gold clusters that are created. If insufficient citrate is present, the solution will turn a milky yellow. If an excess of the citrate is added, the colloids will have a deep violet color, a result of colloids of a different size forming.

Those colloids (called "cloudiness" in the text) are detected by the Tyndall effect. This occurs when light is shined through a colloidal suspension: the light path can be seen in the liquid as visible light is scattered by suspended, microscopically (nanoscale in this case) small particles, the diameter of which is in the order of magnitude of the wavelength of visible light (400-800 nm). In contrast, when light is shined through a true solution of a solute in a solvent (no colloids present), the light passes through without being scattered, so the light path is not visible. Thus, in our case the light beam should be visible as it passes through the red nanogold colloidal suspension as well as through the dispersion of paper particles, but not visible as it passes through the solution of gold ions.

Colloidal gold was used by the ancient Romans to create stained glass windows and exotic drinking goblets. For example, the Lycurgus Cup (cf., http://master-mc.u-strasbg.fr/IMG/pdf/lycurgus.pdf) is a Roman glass cage cup now in the British Museum, made of a dichroic glass, which shows a different color depending on whether or not light is passing through it: red when lit from behind and green when lit from in front. It is the only complete Roman glass object made from this type of glass, and the one exhibiting the most impressive change in color; it has been described as "the most spectacular glass of the period, fittingly decorated, which we know to have existed". The dichroic effect is achieved by making the glass with tiny proportions of minutely ground gold and silver dust; the dust particles are approximately 70 nm in diameter.

The Lycurgus Cup in its red (left) and green (right) manifestations. Go to link above to see colors.

Gold particle nanotechnology may have the greatest impact in forensic science and the diagnosis of disease. If several drops of 0.5M NaCl solution are added to 25 ml of the red nanoparticle solution, a color change from red to blue takes place. This is known as the Plasmon Effect. This color change can be a useful diagnostic tool. Gold nanoparticles are also coupled together when a diseased protein is present, and the resulting, larger coupled nanoparticles reflect blue light. For example, the presence of the meningococcal bacteria (i.e., meningitis) can be detected by using gold nanoparticles to detect small amounts of the diseased protein as the introduction of a sample containing this protein will cause the red solution to turn blue. In the example in this experiment, salt had the identical end effect: it destroys the stabilizing effect of sodium citrate on the small red nanoclusters causing them to grow to about 90 nm so that the suspension become blue.

Nanotechnology is also actively being employed in new methods for the treatment of various forms of cancer. For example, gold nanoshells—tiny spheres of glass covered with a thin layer of gold—are being tested as a part of a new cancer therapy (cf., http://www.youtube.com/watch?v=VSObY7dlSaY&feature=relmfu). For an overview of developing cancer treatments using gold nanotechnology, see http://www.understandingnano.com/cancer-treatment-nanotechnology.html.

Experiment 5: Hydrobead Coatings (Individual Experiment)

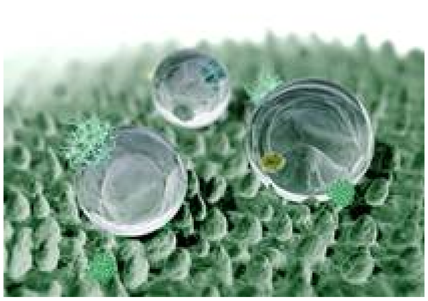
Experiment Purpose & General Methodology

In the experiment we'll see the amazing ability of nanotechnology to produce a coating that prevents liquids from penetrating into fabric.

Introduce the Experiment

Tell the students the following:

- Professors Avogadro and Millie want us to try this experiment for all you outdoor and sports fans.
- Using nanotechnology scientists have developed an amazing material that keeps you dry in the rain and protects your clothes from spills.
- We have a fabric that has been coated with a nano-structured polymer coating which enables water ("hydro") to "bead" up on the surface. We call this a HydroBead coating. Have you ever seen a drop of water rolling around on a waxy leaf…like a lotus leaf? (See the "lotus effect" in the figure on the left.)
- A nanocoating (one that is only a nanometer thick) can be sprayed onto a fabric to keep water and gooey liquids from penetrating into it. You will act as chemists to compare two pieces of fabric and determine which fabric has been treated and which has not.



Performance Details:

Tell the students to do the following:

1. Locate the two pieces of fabric on the table in front of them. One of these has been coated with the HydroBead material and the other has not. You can't tell which is which until you do an experiment to figure it out.
2. Also locate the three shared medicine cups marked "W" (containing water), "K" (containing ketchup) and "C" (containing chocolate syrup). If you look carefully, you'll also find three individual pipettes and two individual paper towels.
3. Put both paper towels down flat in front of you. Put one of the pieces of fabric on one of the paper towels, and the other on the other.
4. We're now going to use devices called pipettes. Explain that you need to pinch the bulb of the pipet to expel the air then put the tip under the surface of the water (or ketchup or syrup) before you let go of your pinch. Water will rise in the pipette rather quickly but the ketchup and syrup will take longer. **When pulling ketchup and chocolate syrup into a**

pipette, tell the students not to let go of the bulb when the liquid stops rising. (Otherwise, the liquids will simply collect in the bulb and be difficult to get out.) Instead, keep squeezing the bulb and immediately put the 6-8 drops of each liquid on each piece of fabric.

5. Select one of the pipettes, and fill it "one squeeze full" with ketchup as the shared cup is passed around. Now put a bead of 6-8 drops of ketchup near the top, left hand corner of each of the two pieces of fabric. You will be putting samples in three big drops across the top of each piece of fabric. **Don't move the piece of fabric until instructed to do so.**
6. Using a second pipette put 6-8 drops of chocolate syrup on the top center of each piece of fabric.
7. Now put 6-8 drops of water on the top, right hand corner of each piece of fabric using the last pipette.
8. We're going to start with the piece of fabric that doesn't have small "x" on it. Very carefully and very slowly pick up one top corner with each hand and raise the top of this piece of fabric up toward you until almost vertical so that the liquids start to run down the fabric and onto the paper towel.
9. Once the liquids have run down the first piece of fabric, repeat the process with the second piece of fabric that has the "x".
10. The liquids should have run right down one of two pieces without much penetration while they should have penetrated the other one as they ran down.
11. After the bulk of the liquids have rolled off the pieces of fabric and on to the paper towels, tell the students to examine the back sides of each piece of fabric.
12. Which piece of your fabric had the liquids run right down and off without penetrating through to the other side? That piece of fabric has the HydroBead coating (should be the one with the "x"). The liquids should have penetrated though the other piece of fabric which wasn't coated.
13. Wipe off the treated piece of fabric using the paper towel and set it aside. You can take this home with you. (We'll throw away the messy, untreated piece—you probably have lots of untreated, regular fabric, like rags, at home.)
14. Where do you think the term *HydroBead* might have come from? Hint: *Hydro* is a prefix that refers to water, so might *HydroBead* refer to a product that causes water to bead? Is this what happened on the treated fabric?

Conclusions

Tell the students the following:

- Have you ever dripped ketchup on your shirt? Your mom wouldn't be too happy about that, would she? Because it's hard to clean some stains.
- Suppose though, that your shirt had been sprayed with the HydroBead material like in our experiment. You could just wipe the ketchup off, and your mom would be happy!
- Same thing if you're caught out in the rain. Wouldn't you rather be wearing a coat that's been coated with the HydroBead material?
- This product of nanotechnology is available already, and if you Google it, you'll find it.

- Now that you have seen that nanocoatings on fabric can cause amazing properties like keeping things dry, can you think what other things nano coatings can do?
    - perhaps like make paint washable....or slippery, so graffiti can't stick to it.
    - perhaps make paint insulating, so you can just paint a wall and not use insulation to keep a room warm.
    - perhaps make fabric wrinkle-free.
    - perhaps make stove-tops self-cleaning.
    - maybe they can be used to coat things so they don't stick together in a clump.

Technical Information (for the Demonstrator):

Hydrobead coatings are based on nanotechnology and produce substances that are "superhydrophobic". The coatings have been designed to mimic some of the surfaces found in nature, like the lotus flower leaf or other plants (cf., http://www.youtube.com/watch?v=isiCOoFD3fc&feature=player_embedded). This "lotus effect" in materials science is the observed superhydrophobic and self-cleaning property found with lotus plants' leaves. In some Eastern cultures, the lotus plant is a symbol of purity. Although lotuses prefer to grow in muddy rivers and lakes, the leaves and flowers remain clean. Botanists who have studied lotus leaves have found that they have a natural cleaning mechanism.

Surfaces that have been coated with artificial HydroBead coatings will cause water to bead into a small droplet and roll off the surface without getting the surface wet. The coating can be applied to any surface that requires extreme water repellency, such as rain gear (umbrellas, canopies, ponchos), outdoor equipment (tents, tarps), fencing, roofs, or other surfaces subject to water wetting, degradation or corrosion. The superhydrophobic coating, *HydroBead*, is sold as a liquid that can be applied to surfaces by spray coating. The superhydrophobic spray is sold commercially in an aerosol can or as a liquid by the quart, gallon, or larger quantities.

Experiment 6: Nano Sand (Individual Experiment)

Experiment Purpose & General Methodology

- The hydrophobic properties of nano sand often sold under the name "Magic Sand" will be investigated.
- The experiment is done by each student and should take less than 5 minutes to complete.

Introduce the Experiment

Tell the students the following:

- Remember we started this program by talking about SAND and how a grain of sand is one of the smallest things we can see with our eyes? This is the last experiment Professors Millie and Avogadro want you to investigate today, so we'll also end with sand!
- Small grains of sand are normally attracted to water. But chemists have invented a chemical that can attach to the grains of sand, and make them repel water, just as the HydroBeads did in the experiment we just did. When this chemical attaches to the sand it forms a nanometer-thick coating, like the coating on the fabric. Note: when chemists make new chemicals like coatings, they are working with atoms and molecules. Chemists have been 'doing nanotechnology' for years and years!
- When we play at the beach, we build sandcastles and make sculptures from regular sand. Sand sinks in water, and, when mixed with a lot of water, it acts more like a liquid than a solid. In this experiment, you will compare how regular sand compares with the coated or "nano sand" or "magic sand," when put in water.
- Ask, "What do you think *hydrophobic* means?" Hint: Remember you learned what "hydro" means in the last experiment. It means water (as in fire hydrant or dehydrated). Do you know what the word "phobic" means? (fear of) You may know other phobias, like claustrophobia (fear of confined spaces) or arachnophobia (fear of spiders).
- When sand is hydrophobic is it nano or magic? Let's experiment with it and find out!

Performance Details

Tell the students to do the following:

- Locate the large cup marked "W" containing water in front of you.
- Open the 50 ml vial marked "NS" containing the nano sand.
- Locate your plastic spoon and fill it about ½ full with nano sand.
- **Slowly** sprinkle all of the nano sand from your spoon onto the surface of the water in the cup marked "W". Follow my example and slowly use this small amount of sand.
- What do you observe? The sand floats on top (in what's called a "raft") if only a little is put in.
- Now pick up the 50 ml vial marked "NS" and ***SLOWLY*** pour all of the nano sand from it into the cup and show how it makes shapes and will keep those shapes.

- Take the spoon and remove some of the sand from the water to show that it is still dry.
- Put the sand in the spoon back into the cup of water and decant (i.e., pour off the water while the sand remains at the bottom of the cup) as much of the water as possible from the cup marked "W" into the cup marked "D". The remaining sand is still dry but it might have a few water droplets clinging to it.
- You can repeat this process once or twice switching the cup functions as you go (the kids should love to do this!).
- When finished pouring the nano sand back and forth, <u>carefully</u> pour the almost-dry nano sand onto one of your paper towels. You can remove any clinging water droplets by folding the towel over the sand and pressing it.
- Tell each student to use their second paper towel to thoroughly dry their plastic spoon. Now place this same paper towel in front of them and flatten it out.
- Ask the first student to open the vial labeled "S" containing regular play sand.
- Pass this vial down the table. Each student in turn should carefully pour some play sand to fill their teaspoon over their second paper towel in case they spill any. Don't mix the two types of sand!
- Now repeat what you did with the nano sand using whichever cup marked "W" or "D" which now has the water. Do you see the difference between the two sands?
- Now <u>carefully</u> pick up the first paper towel with the <u>nano</u> sand (don't spill it!) and very <u>carefully</u> pour the nano sand back into the 50-ml vial marked "NS". (This sand and the 50 ml vial are theirs for the kids to keep.) Suggest that they use a buddy system to pour the nano sand back into the vials: one student holds a vial while the other pours. Cap this vial and you may take it and the nano sand home!
- Leave the regular sand in whichever cup for subsequent disposal.
- Your handout will remind you how to repeat this experiment at home. You can dry out the nano sand even more at home if you pour it out onto paper towels or old newspaper and let it sit overnight.

<u>Conclusions</u>

Tell the students the following:

- We all know that regular sand gets wet because you experience this when you go to the beach in the summer. It's *hydrophilic* ("water-loving"). Wet sand can stick to you and it can feel liquidy when put in water. Regular sand has atoms on its surfaces that are attracted to water.
- *Hydrophobic* ("water-fearing") nano sand is coated with a silicone compound that makes it repel water. The layer is only one nanometer thick, so the coated sand looks and feels like regular sand—but it behaves very differently. That is why the nanosand can be in water and still feel dry. What a difference nano makes changing sand from hydrophilic to hydrophobic!
- What other hydrophobic materials do you comes across in everyday life? *Ans*: raincoat, wax on car, oil, etc. You can remind them of the water-repelling fabric in the previous experiment.

Technical Information (for the Demonstrator):

Regular sand is mostly silicon dioxide that is formed in grains. The surface of the grains contains polar OH groups that are easily attracted to the polar OH bond of water. Therefore, beach sand is hydrophilic or water-loving.

Water wets or adheres to beach sand and flows freely between the grains. Sand is denser than water and sinks. Sand mixed with a lot of water acts more like a fluid than a solid. The sand/water mixture slides, slumps, and resists construction attempts.

The special nanosand used in this experiment is commercially known as *Magic Sand*™, *Astro Sand*™, or *Mystic Sand*™. The instructions that come with it suggest putting water in a large glass bowl and sprinkling in a small amount of nano sand. Instead of sinking, like beach sand, the nano sand will float and form a "sand raft". By sprinkling more and more nano sand onto the sand raft, the raft can be made to plunge to the bottom. The nano sand does not appear to be wet but to be surrounded by a silvery layer looking like plastic film. This silvery layer is the curved surface of a large air bubble that surrounds the nano sand.

Nano sand is ordinary beach sand that has been coated with the vapors of trimethylhydroxysilane, $(CH_3)_3SiOH$, the active ingredient in ScotchGuard™. When the grains of sand are exposed to the trimethylhydroxysilane, a chemical reaction takes place forming water and the bonding of the trimethysilane compound to the silica particles. A nanoscale hydrophobic coating on the grains of sand results. Following this treatment, the exterior of the sand grains sprout methyl groups that are insoluble in water or hydrophobic.

The nanosand is very attracted to nonpolar molecules such as oil and will appear "wet" with the oil. Hydrophobic means "scared of water", so a hydrophobic chemical is one that will not combine easily with water. Oil is a common example of a hydrophobic chemical. If you pour some oil in a cup of water, it will float on the surface. Nanosand behaves the same way; it will float on the surface of water, (but will eventually sink as more is added). The coating on the outside of the nanosand pushes the water away. Take the nanosand out of water and it is perfectly dry.

Return to Experiments 2 & 3

Before closing the session, ask the students to:

1. Return to Experiment 2 to observe its results. Go to each table and carefully pour (decant) the water from the 9 oz. plastic cup marked "HW" into the empty 9 oz. cup marked "E". It should be cool enough to hold by now, but exercise care nonetheless. Now pass the cup marked "HW" around to each student so they can remove one section of the memory wire and one paper clip each from this cup. Tell the students that they <u>can</u> take both wires home with them.

   Return to the **Conclusions** section on p. 23 and discuss these with the students.

2. Return to Experiment 3 to observe its results. Ask the students to *carefully* pass the vial/magnet combination around one more time. By this time, the formation of the sharp peaks of nanoparticles and the nanoparticles along the field lines should be well developed. They can use their pencil to draw what this peak-y shape looks like on their handout.

3. Return to the **Conclusions** section on p. 27 and discuss these with the students.

   <u>Tell the students that, unfortunately, they can't take the ferrofluid/vial home with them because of its potentially irritating nature.</u>

Closing Session

- Remind the students that Professors Millie and Avogadro need their help to determine which experiments to include in their student classes. So vote for your favorite experiment AND the experiment that helped you understand the idea of nano the most. Either use your golf pencil complete your *Student Feedback* form now or at home go to the web site listed on the front side of the handout. Click on *Hands-on Programs* to get to the electronic form.
- Tell them to click on *Contests!* on the same web site for information on how to enter our Chemistry and Poster Contests where each student receives a small token for entering and can win local and national cash prizes. You can also find us on-line by searching under "Cleveland" and "National Chemistry Week".
- Also tell them to make sure that they take home their handout with a list of library books and websites that tell more interesting things about nanotechnology.
- Tell the students that you hope they enjoyed our adventures with nanotechnology and that they've learned a lot. You can remind the students that nanoparticles can be created mechanically, chemically (through chemical reactions), by "building" up atoms and molecules, and by very creative means (such as putting scotch tape on the lead of a pencil).
- Tell them that they can take home their memory wire and paper clip, nano sand (including the 50-ml vial), and treated piece of fabric. Remember the handout has directions on how to redo these experiments.

Unfortunately, we can't allow the students to take home either of the vials containing the gold solution, gold nanoparticles or the ferrofluid because of their potentially irritating nature.

- Thank the students and parents for coming to this year's demonstration and learning about the chemistry of nanotechnology.
- Have the students come to the closing area to turn in their goggles and *Student Feedback* forms. Have them put their goggles back into the box and then give it to the librarian for return it to Julia Boxler at the main library.

Cleanup & Return Procedures

A. <u>Clean up for liquids</u>:

- Do not remove the fluids from <u>any</u> of the gold vials (except the blue one) or the ferrofluid vials. Please leave these intact (including the parafilm) and return them (see below).
- Dispose of the blue nano suspension into your bucket and pitch its vial.
- Dispose of the water from Exps. 1, 2 and 6 into your bucket.
- Pour the contents of your bucket into a toilet and flush.

B. <u>General clean up procedures for experiments</u>

- All solid waste can be placed into a regular trash bag.
- Check with the librarian if they are willing to take the trash; otherwise, please dispose of it with your own trash.

C. <u>Returns</u>

- Other than goggles, there are **<u>only</u>** 7 items we'd liked returned from the library programs:
    1. Any unused Memory Wire.
    2. All vials of nanogold labeled "G".
    3. All vials of nanogold labeled "N".
    4. All vials of ferrofluid labeled "F".
    5. The magnets (please try to keep the cardboard separators between them).
    6. larger manila envelope labeled "*<u>Julia Boxler YTH</u>*" (see immediately below).
    7. the smaller manila envelope labeled **"***<u>Julia Boxler YTH</u>* (see immediately below).

<u>Please do not return ANYTHING else beyond these 7 items</u>!

Please accept the Maglite flashlight as our thanks to you for taking your time to make some child's day.

- Place the signed *ACS Photo Permission* forms w/ a description of the photo to which it belongs into the smaller manila envelope labeled **"***<u>Julia Boxler YTH</u>*".
- Place the vials from Exps. 3 (6 ferrofluid) and 4 (25 red and 6 gold nanoparticle) back into the plastic bags they came from and then place these bags into the two-gallon sized plastic bag marked "X". <u>Discard the vial and the blue nanoparticle liquid created by the salt.</u> Please DO NOT open these vials—please leave the parafilm intact. Put the magnets from Exp. 3 into this larger manila envelope as well. Please do your best to return the magnets with the cardboard dividers between each of them. Please put any leftover memory wire into a sandwich bag and put this into the large manila envelope as well. Squeeze the excess air out of all the bags and close tightly. Put this 2 gallon bag marked "X" with the 37 10-ml vials, memory wire and magnets into the larger manila envelope labeled **"***<u>Julia Boxler YTH</u>*".

D. Goggles:

- If you are performing another demonstration for this year's National Chemistry Week, sanitize the goggles between demonstrations with a dilute bleach solution as instructed in the written directions found on the underside of the cover of the goggle container. Be sure to dry them with soft cloth or soft paper towels to prevent scratching. Please stack them into their box without twisting or crushing!
- If you are finished performing your demonstration(s) for this year, place the used goggles into their box. Please stack them without twisting or crushing! There is no need to clean them when you are through; our Planning Committee will clean them for the next year and/or for other programs.

E. Before you leave the library

- Return any items borrowed from the library.
- Give any leftover literature to the librarian. (You may save a copy for yourself though!)
- Give the two manila envelopes (containing completed forms and saved supplies) as well as the box of goggles to the Children's librarian with instructions to put it them in the interlibrary mail. (Or take to your nearest CCPL library branch.)

F. At Home (Feedback)

- There is no hardcopy *Demonstrator Feedback* form this year. Instead, **please** go to our website at http://www.csuohio.edu/sciences/dept/cleveland_acs/NCW/, click on the *Hands-on Programs* and follow the link to comment on today's program.
- If you took any photos to share, and have submitted signed permission forms to use them, please email them to Bob Fowler at jrfowler@cox.net. Please note that any photos that you care to share with us could end up on our web site and/or possibly with ACS if we choose to use your photo in one of award self-nominations.
- **Smile!** You may have expanded or even sparked scientific interest in a student today! ☺
  ☺ ☺ ☺ ☺ ☺

THANK YOU! …for your participation in our program this year.

We hope you will join us next year too. Planning of experiments and contests starts in late April. You don't have to be a teacher or scientist to join our Planning Committee; all you need is a desire to share science with students. Development of ideas and refinement of experiments goes on throughout the summer (a couple of hours every other week), donation gathering and shopping is in late summer, and kit assembly (about 40 of them needing a lot of volunteer hands) is on a Saturday in mid-September. It takes many, many volunteers to develop and put on all our programs. Even a little bit of help goes a long way. Contact us this year or next at jrfowler@cox.net if you (or a friend of yours) want to join in on the activities!

Appendix

A. Material Safety Data Sheets

MSDS sheets for all materials used in this year's program:

1. 1% gold solution: http://www.saltlakemetals.com/MSDS_Gold_Chloride.htm.
2. Nano gold solution: http://www.nanomaterialstore.com/au_msds.php
3. ferrofluid: http://ferrofluid.ferrotec.com/downloads/efhmsds.pdf
4. HydroBead: on our website at http://www.csuohio.edu/sciences/dept/cleveland_acs/NCW/. Click on "Hands-on Program".

B. Supply list for recreating these experiments including item substitutions

Material resources for reproducing the experiments for items not found in your local grocery/drug/hardware store:

1. **How Big is a Nanometer?** http://www.nanozone.org/nanoruler.pdf

2. **Memory Wire:** http://www.kelloggsresearchlabs.com/node/86. We worked through a very helpful individual named Joe at Kellogg's Research Labs (info@kelloggsresearchlabs.com). Joe worked with us "to tune the transition temperature to 95-100°F so that it doesn't respond to skin temperature". He also volunteered to cut the wire into 1040 3" long pieces for our immediate use.

3. **Ferrofluids:** We purchased our ferrofluid and Neodymium (NdFeB) magnets (type M34x12x18BL) from www.apexmagnets.com.

4. **Gold Nanoparticles:** Gold chloride solutions are available from www.SaltLakeMetals.com. We used 4 ml of the 1% solution to produce 1 L of red nanoparticle suspension. They even include the required quantity of sodium citrate.

5. **HydroBead Coatings:** The HydroBead coating is available from www.hyrdo-bead.com. We used Hydrobead-T.

6. **Nano Sand:** Nano (i.e., "magic") sand is available for Educational Innovations at http://www.teachersource.com/product/magic-sand/chemistry?gclid=CND1md7O_LECFQjZQgodRj8A-w

Thanks again!!!

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