Table of Contents

Nanoscale Materials and Their Properties

The ***Student Handbook-Teacher Version*** is to accompany the NanoLeap chemistry module *Nanoscale Materials and Their Properties*. This guide includes relevant background, set-up instructions, and answer keys.

Pages that correspond to student handbook pages are labeled at the top of each page. This numbering system will help to keep both you and your students on the correct page of their student handbook as you progress through the lessons.

Using the Fact Sheets, Activities, and Problem Sheets

Students should refer to the **Fact Sheet** that is pertinent to the lesson on the slide number indicated at the top of the Fact sheet and in the lesson script. The fact sheet format is used so that this information is available for student reference without the need for extensive note taking. However, we have included some empty note-taking space on many of the fact sheets. The information in these fact sheets may be used as additional background detail and discussion during the PowerPoint questioning sessions and as students complete the final assessment assignment.

Activities are typically hands-on lessons and may require preparation of materials. Refer to the teacher guide for each activity for a list of required materials and set up instructions. Answer keys to student questions are also found in the teacher guide section.

Problem sheets require students to answer questions about a problem posed and to come to a conclusion for their answer. Some may require mathematical computations and students are allowed to use calculators when necessary. The answer key will follow each problem sheet in this teacher version of the student handbook.

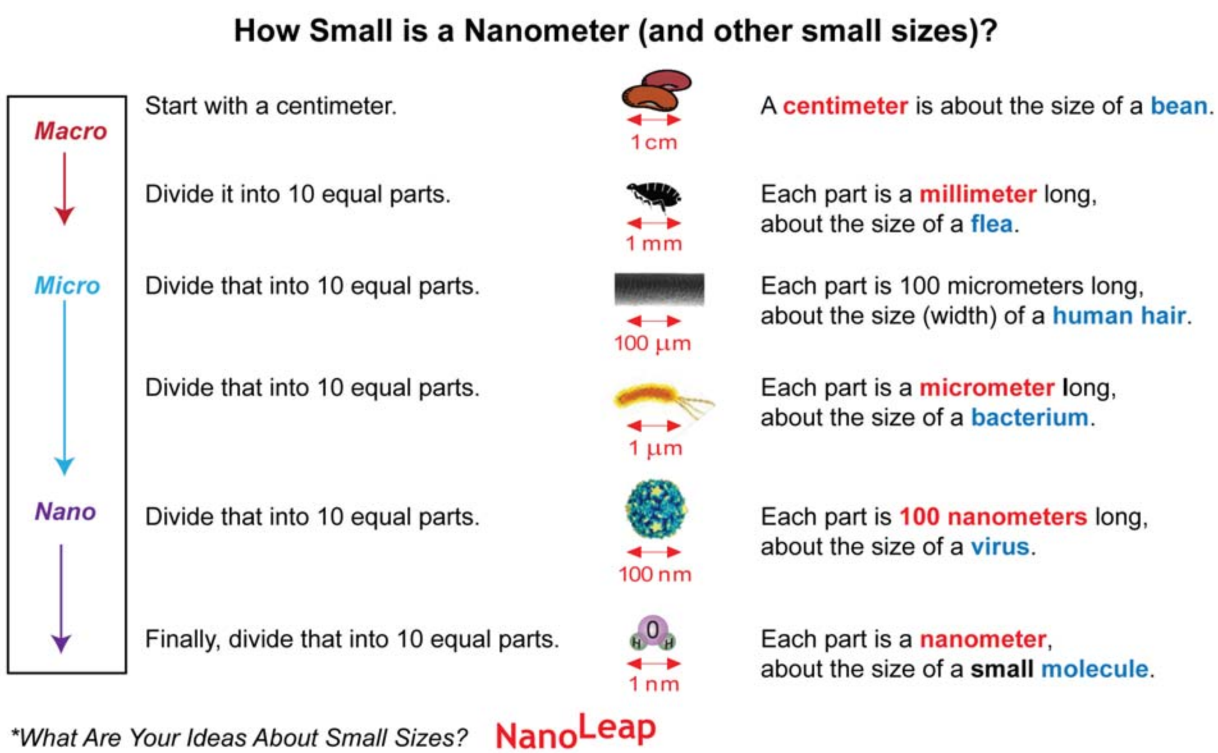
K-W-L
(Student Handbook, Page 3)

What I **Know** About Nanoscale Science and Technology	What I **Want** to Know About Nanoscale Science and Technology	What I **Learned** About Nanoscale Science and Technology

Teacher Guide Unit 1: Nanoscience: What Is It?
Lesson 1.1 What is Nanoscience
Fact Sheet 1–Common SI Prefixes
(Student Handbook, Page 4)

Nano–Its Place in the Prefix Hierarchy
The prefix nano, and its related size in the prefix hierarchy, is basic to the understanding of the meaning of terminology like nanoscience, nanotechnology, and nanoparticles. If your chemistry texts, wall charts, or the measurement background of your curriculum, do not include the nano- prefix, use a copy of the chart below to help students understand the position of this prefix in the hierarchy. You may make a transparency of this chart, which is reproduced for student use in Fact Sheet 1–Common SI Prefixes.

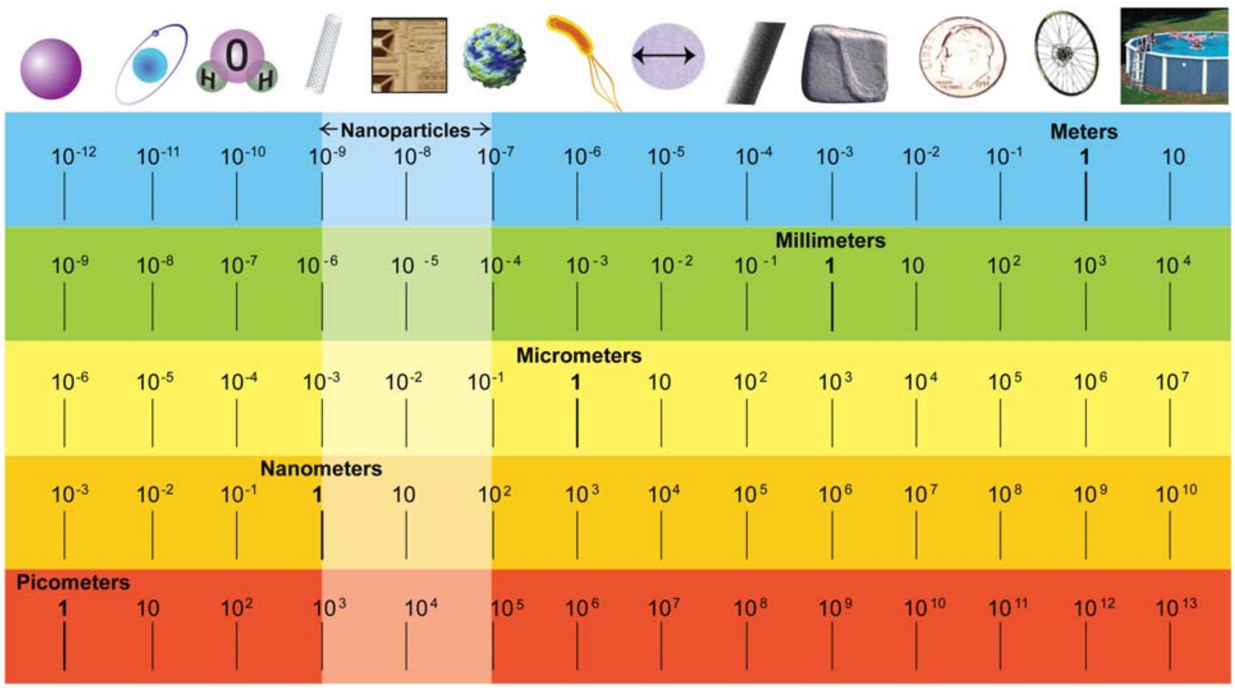
Prefix	Abbreviation	Size related to meter
deci-	d	1 decimeter (dm) = 10^{-1} meter
centi-	c	1 centimeter (cm) = 10^{-2} meter
milli-	m	1 millimeter (mm) = 10^{-3} meter
micro-	µ	1 micrometer (µm) = 10^{-6} meter
nano-	**n**	**1 nanometer (nm) = 10^{-9} meter**
pico-	p	1 picometer (pm) = 10^{-12} meter



Student Version: Problem Sheet 1–On the Nanoscale

(Student Handbook, Page 5–6)

Slide 4 Questions



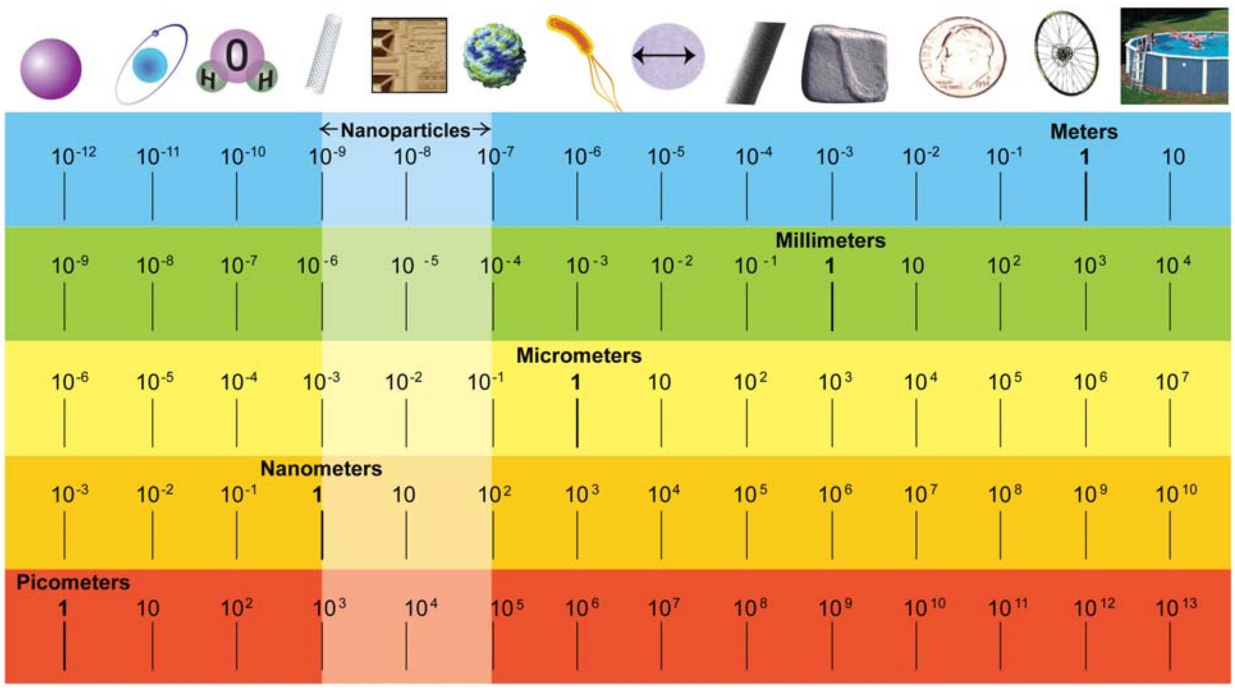
1. Locate and note the objects visible to the human eye on the size line.
2. Note where the white rectangle representing the size of **nanoparticles** is found on this size line. One dimension of an AVERAGE-SIZED nanoparticle measures is about 10 nm. How large is a bicycle tire measured in nanometers? ___________________________________
3. How many times larger than AVERAGE-SIZED nanoparticles is a bicycle tire? ___________
4. How many times larger than the LARGEST nanoparticles is a bicycle tire? _______________
5. How many times larger is a human hair than the largest nanoparticle? ____________________
6. If the gray rectangle represents the size of nanoparticles on this size line, what is the relative size of the hydrogen atom as compared to that of the smallest nanoparticles? ______________
7. How many times larger are nanoparticles than a water molecule? _________________

NanoLeap

Answer Key: Problem Sheet 1 – On the Nanoscale

In this activity, students relate the size of atoms and ions to the size of nanoparticles using a labeled size line.

One of the more important concepts that students should understand is that nanostructures and nanoparticles are just a little larger than individual atoms and small molecules. (Note the position of the rectangle showing the size range of nanoparticles relative to the size range of atoms.)



Answer Key: Problem Sheet 1–On the Nanoscale

1. Locate and note the objects visible to the human eye on the size line. **On the far right; hair, salt, dime, tire, pool**

2. Note where the white rectangle representing the size of **nanoparticles** is found on this size line. One dimension of an AVERAGE-SIZED nanoparticle measures is about 10 nm. How large is a bicycle tire measured in nanometers? **10^9 nm**

3. How many times larger than AVERAGE-SIZED nanoparticles is a bicycle tire? **10^8**

4. How many times larger than the LARGEST nanoparticles is a bicycle tire? **10^7**

5. How many times larger is a human hair than the largest nanoparticle? **10^3**

6. If the gray rectangle represents the size of nanoparticles on this size line, what is the relative size of the hydrogen atom as compared to that of the smallest nanoparticles? **10 x smaller**

7. How many times larger are nanoparticles than a water molecule? **10 x**

Student Version: Activity 1–What are Your Ideas about Small Sizes?
(Student Handbook, Pages 6–8)

Purpose:
In this activity, you will classify very small objects by size to better understand sizes on the nanoscale.

Procedure

1. Go to http://www.mcrel.org/nanoleap/multimedia/index.asp. Choose "Nanoscale Me" from the Interactives column.

2. Click on "Sort Meters" on the menu at the bottom of the page for the first set of images. Predict the correct order of the images as determined by their width (diameter). Note: mousing over any image will display the name of the object. Record your prediction in the "Prediction" column of the data table. Also record the instrument used and the dominant force as indicated at the bottom of the screen for each image sort.

3. Click on the next set, "Sort Millimeters" on the menu. Complete the next set of predictions. Repeat for each image sort through the "Sort Picometers."

4. Work in small groups and compare your predicted order. Try to come to agreement (if possible) on the best order from largest to smallest for each image sort. Record any changes in the "Predictions" column.

5. Go back to each image sort (i.e., "Sort Meters") and click and drag the objects to the empty boxes below in the order predicted. Record the correct order in the "Actual" column of the data table. Note any discrepancies between your predicted and actual order. Repeat for each image sort.

6. Answer the discussion questions on the last page of the activity.

7. View the "Exploring Scale" section of the *NanoScale Me* interactive. These objects are compared on the same scale.

8. Complete the "Sort All" as a review.

Data Table:
Arrange the images of Image Sort #1 in order of actual **width**. Record the names of the objects from the **largest to smallest** object. Repeat for each image sort.

Image Sort #1 (Meter Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		
2		
3		
4		

Smallest in Actual Width

Write down the instruments typically used at this scale:

Image Sort #2 (Millimeter Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		
2		
3		
4		

Smallest in Actual Width

Write down the instruments typically used at this scale:

Image Sort #3 (Micrometer Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		
2		
3		
4		

Smallest in Actual Width

Write down the instruments typically used at this scale:

Image Sort #4 (Nanometer Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		
2		
3		
4		

Smallest in Actual Width

Write down the instruments typically used at this scale:

Image Sort #5 (Picometer Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		
2		
3		
4		

Smallest in Actual Width

Write down the instruments typically used at this scale:

POWERS OF TEN

Directions:

1. Type the following Web site address:
   http://microcosm.web.cern.ch/microcosm/p10/english/welcome.html
2. Click "What Is a Power of Ten?" and read info.
   a. When are powers of 10 used? ______________________
   b. Write 10^3 as a whole number __________
   c. Write 10^{-3} as a whole number __________
3. Click "Start" link at bottom of page.
4. As you click through the different powers of 10 (both + & -); answer the following questions:
   a. What can you observe at 10^9m?

   b. What can you observe at 10^{-9}m?

   c. On the (+) scale, between what powers of 10 does the view not change? Why do you think this is?

   d. On the (-) scale, between what powers of 10 does the view not change? Why do you think this is?

nanoreisen – ADVENTURES BEYOND THE DECIMAL

1. Type the following Web site address: http:www.nanoreisen.de/
2. Click on the "English Version" link, then click on the pulsating suit case.
3. Navigate through all of the following routes
   - Ego-Trip - Bit-Land Route - Bright-Spot Route
4. When you get to the atomic level, describe the motion of the atom.

5. For the following powers of 10; copy down the stage name for the *Ego-Trip* and provide a brief description of what you are observing.

SIZE	STAGE	DESCRIPTION
1^0 Meter = 1m		
10^{-2} Meter = 1cm		
10^{-3} Meter = 1mm		
10^{-6} Meter= 1µm		
10^{-9} Meter = 1nm		
10^{-12} Meter = 1pm		
10^{-15} Meter = 1fm		

Discussion Questions

a) Which Image Sort set was the easiest for you to put in order? Why?

b) Which was the most difficult? Why?

c) How do nanoparticles compare with cells in size?

d) How do nanoparticles compare with atoms and molecules in size?

Teacher Guide
Activity 1 – What are Your Ideas about Small Sizes?

Background:
This activity guides high school students as they begin to think about size and scale from macro to micro to nano. It builds on research by Tretter[1] et al. (2006) on conceptual boundaries and the concepts of scale of scientific phenomena by student and expert groups. This research noted that students need to mentally manipulate new units like a nanometer in order to make sense of the numbers used during a comparison. In addition, Tretter discovered that high school students had difficulty ranking microscopic objects compared with gifted students or experts, who distinguished small sized objects by grouping them into distinct landmarks such as small macroscopic items, microscopic, many atoms (nanoscale), and the size of an atom. This activity will provide students with an opportunity to use new landmarks as they compare images of very small objects.

Preparation of Materials

<u>For each student (or each group of students)</u>
- one computer per student or pair of students
- internet access to the online *NanoScale Me* interactive at http://www.mcrel.org/nanoleap/multimedia/index.asp
- Optional: one classroom computer connected to an LCD projector for classroom discussion and display of the interactive
- Test to make sure the interactive works on the computers to be used by students.

Optional: The Power of Ten Web sites can be used to help students develop understanding of the meaning of powers of ten.
http://www.nanoreisen.de/
http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.html
http://microcosm.web.cern.ch/microcosm/p10/english/welcome.html

Procedure

1. Begin by asking students to name some objects that are smaller than a penny. Then ask them to identify which of those objects would be considered microscopic (unable to be seen with the unaided eye). Explain that in this activity, they will have some new experiences in classifying and ordering very small objects to better understand the size of objects in the nanoscale. If necessary, review the size line from Problem Sheet 1–*On the Nanoscale.*

2. Ask students to open the online *NanoScale Me* interactive by going to http://www.mcrel.org/nanoleap/multimedia/index.asp and selecting "Nanoscale Me" from the Inteactives Column.

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[1] Tretter, T. R., Jones, M.G., & Minogue, J. (2006) Accuracy of scale conceptions in science: Mental maneuverings across many orders of spatial magnitude. *Journal of Research in Science Teaching, 43*(10), 1061–1085.

3. Click on “Sort Meters” on the menu at the bottom of the page for the first set of images. Students should predict the correct order of the images as determined by their width (diameter). Note: mousing over any image will display the name of the object. Students should record their prediction in the “Prediction” column of the data table. Students also need to record the instrument used and the dominant force as indicated at the bottom of the page for each image sort.

4. Click on the next set, “Sort Millimeters” on the menu. Students should complete their next set of predictions. Repeat for each image sort through the “Sort Picometers.”

5. After students complete their individual predictions, students should work in small groups of three students. Have them compare their data tables and come to agreement (if possible) on the best order from largest to smallest for each image sort. Circulate around the classroom and encourage students to discuss any disagreements and to write down arguments in support of their answers. Any changes to their predicted order may be recorded in the “Predictions” column.

6. Now students should come back to each image sort (i.e., “Sort Meters”) and click and drag the objects to the empty boxes below in the order they predicted. Note that the interactive will only allow the objects to be placed in the correct order. Once the students have the objects placed in the boxes in order they should record the correct order in the “Actual” column of their data table. They can note any discrepancies between their predicted and actual order. Repeat for each image sort.

7. Once the whole group has finished recording the actual order of objects, ask them to discuss the questions on the last page of the activity and record their responses.

8. View the “Exploring Scale” section of the *NanoScale Me* interactive. Discuss with students that often images placed side-by-side are not to scale. “Exploring Scale” shows these objects comparably on the same scale.

9. Lastly, students may individually (or in groups) complete the “Sort All” as a review.

NOTE: This activity may be completed individually by students (or in pairs), each on their own computer, or, it may be adapted as a class activity with one computer displaying the interactive on an LCD projector. Prior to dragging the images into the boxes and recording the actual order, the teacher may want to encourage class discussion about the group predictions after step 5.

Answer Key: Activity 1–What are Your Ideas about Small Sizes?

Purpose:
In this activity, you will classify very small objects by size to better understand sizes on the nanoscale.

Procedure

1. Go to http://www.mcrel.org/nanoleap/multimedia/index.asp. Choose "Nanoscale Me" from the Interactives column.

2. Click on "Sort Meters" on the menu at the bottom of the page for the first set of images. Predict the correct order of the images as determined by their width (diameter). Note: Mousing over any image will display the name of the object. Record your prediction in the "Prediction" column of the data table. Also record the instrument used as indicated at bottom of the page for each image sort.

3. Click on the next set, "Sort Millimeters" on the menu. Complete the next set of predictions. Repeat for each image sort through the "Sort Picometers."

4. Work in small groups and compare your predicted order. Try to come to agreement (if possible) on the best order from largest to smallest for each image sort. Write down ideas to support answers for which there is disagreement. Record any changes in the "Predictions" column.

5. Go back to each image sort (i.e., "Sort Meters") and click and drag the objects to the empty boxes beneath in the order predicted. Record the correct order in the "Actual" column of the data table. Note any discrepancies between your predicted and actual order. Repeat for each image sort.

6. Answer the discussion questions on the last page of the activity.

7. View the "Exploring Scale" section of the *NanoScale Me* interactive. These objects are compared on the same scale.

8. Complete the "Sort All" as a review.

Data Table:
Arrange the images of Image Sort #1 in order of actual **width**. Record the names of the objects from the **largest to smallest** object. Repeat for each image sort.

Image Sort #1 (Meter Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		**Leaning Tower of Pisa**
2		**Swimming Pool**
3		**Bicycle Wheel**
4		**Ant**

Smallest in Actual Width

Instruments: **Eyes**

Image Sort #2 (Millimeter Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		**Dime**
2		**Ant**
3		**Grain of Salt**
4		**Human Hair**

Smallest in Actual Width

Instruments: **Eyes and Hands**

Image Sort #3 (Micrometer Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		**Human Hair**
2		**White Blood Cell**
3		**Bacterium**
4		**Virus**

Smallest in Actual Width

Instruments: **Optical Microscope**

Image Sort #4 (Nanometer Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		**Virus**
2		**Microchip**
3		**Protein Chain**
4		**DNA Helix**

Smallest in Actual Width

Instruments: **Electron and Atomic Force Microscope**

Image Sort #5 (Picometer Range)
Largest in Actual Width

	Write Image Names Below	
	Predicted Order	**Actual Order**
1		**Buckyball**
2		**Water Molecule**
3		**Hydrogen Atom**
4		**Atom Nucleus**

Smallest in Actual Width

Instruments: **Atomic Force or Electron Microscope for objects ~100 picometers or larger**

POWERS OF TEN ANSWERS

Directions:

1. Type the following Web site address:
   http://microcosm.web.cern.ch/microcosm/p10/english/welcome.html
2. Click "What Is a Power of Ten?" and read info.
   a. When are powers of 10 used? *it is useful shorthand for very large or small numbers*
   b. Express 10^3 as a whole number *1000*
   c. Express 10^{-3} as a whole number *0.001 or* $\frac{1}{1000}$
3. Click "Start" link at bottom of page.
4. As you click through the different powers of 10 (both + & -); answer the following questions:
   a. What can you observe at 10^9m? *the moon orbits around the Earth*
   b. What can you observe at 10^{-9}m? *DNA is a long chain made of sets of nucleic acids*
   c. On the (+) scale, between what powers of 10 does the view not change? b*ecause they are the same size*
   Why do you think this is? *Answers will vary.*
   d. On the (-) scale, between what powers of 10 does the view not change? Why do you think this is? b*ecause they are the same size*

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ANSWERS WILL VARY DEPENDING ON THE ROUTE THE STUDENTS TAKE

6. Type the following Web site address: http:www.nanoreisen.de/
7. Click on the "English Version" link, then click on the pulsating suit case.
8. Navigate through all of the following routes:
   - Ego-Trip - Bit-Land Route - Bright-Spot Route

9. When you get to the atomic level, describe the motion of the atom.

10. For the following powers of 10; copy down the stage name for the *Ego-Trip* and provide a brief description of what you are observing.

SIZE	STAGE	DESCRIPTION
1^0 Meter = 1m		
10^{-2} Meter = 1cm		
10^{-3} Meter = 1mm		
10^{-6} Meter= 1µm		
10^{-9} Meter = 1nm		
10^{-12} Meter = 1pm		
10^{-15} Meter = 1fm		

Discussion Questions

a) Which Image Sort set was the easiest for you to put in order? Why?
Student response–Ask students to provide an explanation for their answer

b) Which was the most difficult? Why?
Student response–Ask students to provide an explanation for their answers

c) How do nanoparticles compare with cells in size?
A cell is about 1000 times larger than a 10nm nanoparticle.

d) How do nanoparticles compare with atoms and molecules in size?
Nanoparticles are larger than atoms and molecules. They are about 100x larger on average.

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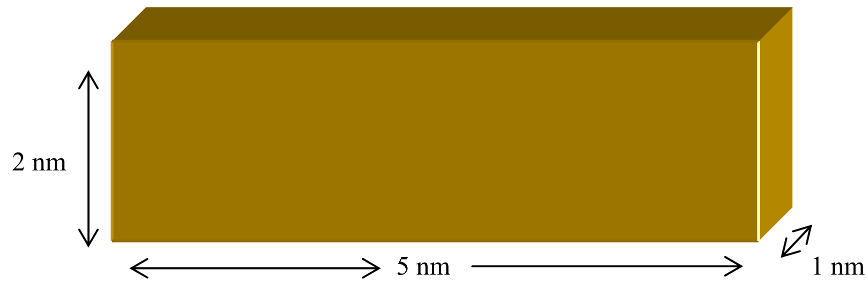
Lesson 1.2 What Makes Nanoscience so Different?
Student Version: Problem Sheet 2–Nanoparticle Calculations
(Student Handbook, Page 11)

Nanoparticle



1. How many atoms with a radius of 5×10^{-2} nanometers might fit on one 5 nm edge of this simulated nanoparticle? Show your work or explain how you arrived at your answer.

2. How many atoms with a radius of 5×10^{-2} nanometers could this nanoparticle contain? Show your work or explain how you arrived at your answer.

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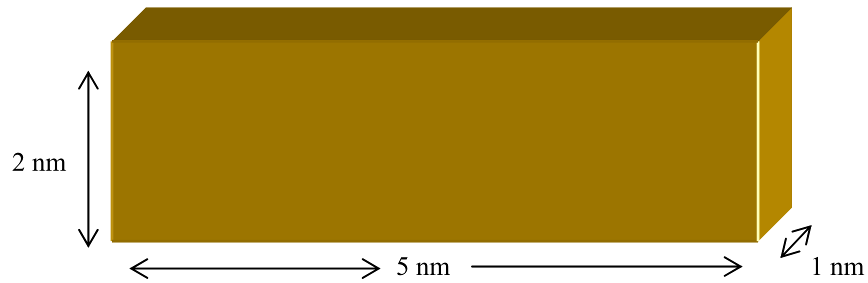
Nanoscience: What Is It?

Answer Key: Problem Sheet 2–Nanoparticle Calculations

Nanoparticle



1. How many atoms with a radius of 5×10^{-2} nanometers might fit on one 5 nm edge of this simulated nanoparticle? Show your work or explain how you arrived at your answer.

   Note: If necessary, prompt students about the relationship between radius and diameter.

   Solution:
   An atom with a radius of 5×10^{-2} nm would have a diameter of 10×10^{-2} nm or 1×10^{-1} nm.
   5 nm / 1×10^{-1} nm = 50 atomic diameters or 50 atoms on the 5 nm edge.

   Students are expected to work individually and then they may whiteboard in their groups.

2. How many atoms with a radius of 5×10^{-2} nanometers could this nanoparticle contain? Show your work or explain how you arrived at your answer.

   Note: You may wish to remind students that $(\text{atomic-diameters})^3$ are the same as a full three-dimensional atom, so dimensional analysis is consistent.

   Solution:
   If 5 nm = 50 atomic diameters, then 2 nm = 20 atomic diameters and 1 nm = 10 atom diameters. So, the nanoparticle could contain approximately 50 atoms x 10 atoms x 20 atoms = 10,000 atoms.

   Accept student answers based on their previous answers to the question.

Student Version: Problem Sheet 3–Sample Size Comparisons
(Student Handbook, Page 12)

Comparison of chemistry, nanoparticles, and macro-sized samples

Characteristic	Atoms/molecules	Nanoparticle Samples	Macro-sized samples
Number of atoms/molecular units in sample	1	10 - 70,000 except for discrete structures	> 1×10^4 atoms to multiples of moles 6.02×10^{23}
Size of particles in sample	3.5×10^{-2} to 2.6×10^{-1} nanometers/atomic radius to 0.2–2 nm / molecule	1 to ≈ 100 nanometers	>100 nm - ∞ nm
Regime	Quantum Chemistry	Refined	Classical Laws of Physics (Newtonian)

1. What is the smallest sample of any chemical that you worked with this year in the lab?

2. How many moles of the sample did you use?

3. How many atoms, ions, or molecules would this be?

4. So, did we ever work with fewer than 70,000 atoms in chemistry experiments?

5. Could you mass out a 70,000 atom/ion/molecule nanoparticle on your laboratory balances?

Teacher Guide and Answer Key:
Problem Sheet 3–Sample Size Comparisons

Have students carry out their calculations on paper and discuss in small groups. Have them put the answer to questions 2 and 3 on their whiteboards for whole group discussion.

Comparison of chemistry, nanoparticles, and macro-sized samples

Characteristic	Atoms/molecules	Nanoparticles	Macro-sized Samples
Number of atoms/molecular units in sample	1	10 - 70,000 Except for discrete structures	> 1×10^4 atoms to multiples of moles 6.02×10^{23}
Size of Particles in sample	3.5×10^{-2} to 2.6×10^{-1} nanometers/atomic radius to 0.2–2 nm / molecule	1 to ≈ 100 nanometers	>100 nm - ∞ nm
Regime	Quantum Chemistry	Refined	Classical Laws of Physics (Newtonian)

Answers to this question will vary with the content of your chemistry course. For some, it may be a serial dilution when determining the changes in rates of reaction as you decrease the concentration of solutions. However, this approach may be difficult since these are single atoms/molecules/ions in solution.

The answers to the following questions are based on a 2.50 g sample of NaCl

1. What is the smallest sample of any chemical that you worked with this year in the lab?
   Answers will vary depending on the example you choose for your sample

2. How many moles of the sample did you use?
   2.5 g NaCl ÷ 58.5 g/mol NaCl = 4.3×10^{-2} moles NaCl

3. How many atoms, ions, or molecules would this be?
   4.3×10^{-2} mol NaCl x $\frac{6.022 \times 10^{23} \text{ ions}}{1 \text{ mol NaCl}}$ = 2.6×10^{22} Na ions and 2.6×10^{22} Cl ions

4. So, did we ever work with fewer than 70,000 atoms in chemistry experiments?
   No. Research has shown that this is the upper limit at which nanoparticles still exhibit their unique properties as compared to macrosamples.

5. Could you mass out a 70,000 atom/ion/molecule nanoparticle on your laboratory balances?

The answer to this is also no.

A 70,000 ion nanoparticle of NaCl would contain 35,000 positive Na ions and 35,000 negative chloride ions...or 35,000 ionic units of NaCl. This means that you have 35,000 ionic units and 1 mole ionic unit is equal to 6.02×10^{23} ionic units, which each have a mass of 58.5 grams. Or, 3.5×10^4 ionic NaCl units x 1 mole ionic NaCl units/ 6.02×10^{23} ionic unit x 58.5 grams/1 mole = $3.5/6.02 \times 10^4/10^{23} \times 58.5 = 34 \times 10^{-19}$ gram or 3.4×10^{-18} grams.

Student Version: Problem Sheet 4–Electrons vs. Satellites
(Student Handbook, Page 13)

Motion and Position Descriptions

Electrons	Satellites
1. Why did we have to talk in terms of an electron's probability regions?	2. Can we determine exactly where the satellite is at any particular time? Why?
3. Can we determine where that electron is at any particular time?	4. Can we determine in which direction the satellite is moving?
5. Can we determine the direction of an electron in an atom?	6. How is tracking a satellite different from locating an electron?
7. Do electrons have properties commonly associated with matter, waves, or both?	8. Are satellites considered to be matter, waves, or both?
9. How might the energy of the electron be changed?	10. What provides the energy to keep the satellite in orbit?

Teacher Guide and Answer Key:
Problem Sheet 4–Electrons vs. Satellites

Have students complete the answers to these questions individually, then in small groups, and then as a class. Use whiteboards for students to "report out" if you wish.

Motion and Position Descriptions

Electrons	Satellites
1. Why did we have to talk in terms of an electron's probability regions? **Because electrons** o **obey quantum chemistry laws,** o **travel at almost the speed of light,** (average velocities of electrons within atoms are generally orders of magnitude less than the speed of light) **and** o **in very specific energy levels.**	2. Can we determine exactly where the satellite is at any particular time? Why? **Yes, with the proper technology we can.**
3. Can we determine where that electron is at any particular time? **We can only talk about the probability of its being found at a particular place at a particular time.** When a measurement is made, it changes the state of the electron and it will stay in that location afterwards. One cannot measure position and momentum simultaneously.	4. Can we determine in which direction the satellite is moving? **Yes, with proper mathematics, technology, and programming.**
5. Can we determine the direction of an electron in an atom? **One can measure the direction of motion of an electron. However, one cannot know the direction of motion of an electron within an atom without disturbing the atom and removing the electron.**	6. How is tracking a satellite different from locating an electron? **Satellites can be tracked but we can only describe the regions of highest probability in which the electron can be found.**
7. Do electrons have properties commonly associated with matter, waves, or both? **Both**	8. Are satellites considered to be matter, waves, or both? **Matter**
9. How might the energy of the electron be changed? **By absorption of a quantum/photon of light with the appropriate wavelength.**	10. What provides the energy to keep the satellite in orbit? **The satellite requires a force to place it in orbit and periodic boosts to counteract earth's gravity.**

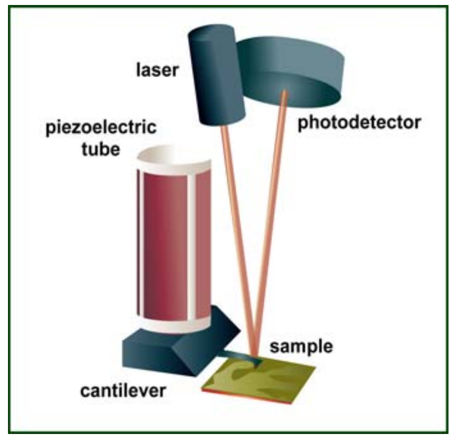
Lesson 1.3 What Makes Nanoscience so Important?
Student Version: Activity 2–Imaging What is Too Small to See
(Student Handbook, Pages 14–15)

Purpose

Nanoparticles are much too small to see, so how can they be analyzed and studied? In this activity you will use a magnetic probe to simulate the "seeing" of a nanoparticle, and develop an understanding of how sensing devices allow us to see at the nanoscale level.

The AFM has a cantilever with a probe tip that can be small enough that the end of the tip is a single atom. The distance between the tip and the surface is the thickness of a couple of atoms. The deflection of the cantilever (due to the force of the feature on the tip) is proportional to height of surface features (topography).

Background

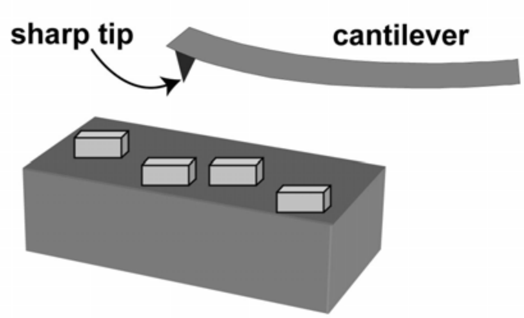


In the early 1980s scanning tunneling microscopy (STM), and atomic force microscopy (AFM) were developed. These instruments employed scanning probe techniques.

In scanning probe instruments, the probe tip is often so sharp that it ends in just a single atom. As this probe is dragged across a surface there will be a difference in force felt by the probe tip as it is closer or farther away from atoms in the surface. The magnitude of the deflection is captured by a laser that reflects at an oblique angle from the very end of the cantilever. A plot of the laser deflection versus tip position on the sample surface provides the resolution of the hills and valleys that constitute the topography of the surface. The AFM can work with the tip touching the sample (contact mode), or the tip can tap across the surface (tapping mode) much like the cane of a blind person.

Procedure:

A refrigerator magnet will simulate a nanoparticle that will be analyzed with a probe strip which simulates a scanning probe tip. The probe tip is positioned at the end of a cantilever beam shaped much like a diving board. As the tip is repelled by or attracted to the surface, the cantilever beam deflects.



1. Drag the probe strip across the surface of the magnet, and notice any deflections. You will need to hold the probe strip nearly horizontal to the surface. Probe the magnet on various sides and in various directions.

2. As you know, the north pole of a magnet will attract the south pole of another magnet, and two magnets with either their north poles or their south poles pointed at each other will repel.

3. With this in mind, draw a representation of the magnetic poles in the box below.
   - Be sure to include the number of up and down deflections that you observe as you probe your "nanoparticle."
   - What is the distance between the up and down deflections? ___________________
   - Are these distances uniform all the way across the surface, and in all directions? ____________

Top View Looking Down on the Magnet Surface

Images vs. Photographs
To learn how the colored images of nanoparticles are produced that are part of the *Nanoscale Materials and Their Properties* module, go to http://www.almaden.ibm.com/vis/stm/lobby.html.

Study the description of the eight-step process that converts the measurements made by a scanning tunneling microscope into a colored image and answer the following questions:

4. How are the images formed from scanning-probe instruments different from those made by a digital camera?

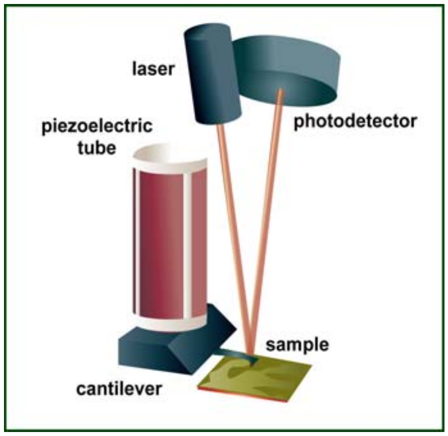
5. Are there any ways in which images formed from scanning-probe instruments are similar to those made by a digital camera?

Teacher Guide and Answer Key:
Activity 2–Imaging What is Too Small to See

Purpose
Nanoparticles are much too small to see, so how can they be analyzed and studied? In this activity you will use a magnetic probe to simulate the "seeing" of a nanoparticle, and develop an understanding of how sensing devices allow us to see at the nanoscale level.

The AFM has a cantilever with a probe tip that can be small enough so that the end of the tip is a single atom. The distance between the tip and the surface is the thickness of a couple of atoms. The deflection of the cantilever (due to the force of the feature on the tip) is proportional to height of surface feature (topography). These and other new tools and instruments used in nanoscience research and technology are described in more detail in the Teacher Resource Guide.

Background
In the early 1980s scanning tunneling microscopy (STM), and atomic force microscopy (AFM) were developed. These instruments employed scanning probe techniques.



In scanning probe instruments the probe tip is often so sharp that it ends in just a single atom. As this probe is dragged across a surface there will be a difference in force felt by the probe tip as it is closer or farther away from atoms in the surface. The magnitude of the deflection is captured by a laser that reflects at an oblique angle from the very end of the cantilever. A plot of the laser deflection versus tip position on the sample surface provides the resolution of the hills and valleys that constitute the topography of the surface. The AFM can work with the tip touching the sample (contact mode), or the tip can tap across the surface (tapping mode) much like the cane of a blind person.

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Advanced Preparation
Visit http://www.mcrel.org/nanoleap/multimedia/ and click on "Magnetic Probe Model" to see a video of this activity.

Teacher Procedure
1. Direct students to follow the procedure on the activity sheet without giving them much direction. Some students will start to complain that nothing happens. Encourage them to probe the magnet on various sides and in various directions. They will eventually turn the

magnet over so that the unprinted, dark side is up. They will get a response when they drag the probe strip with its unprinted side facing the unprinted side of the magnet in one of two perpendicular directions. The strip should be held nearly parallel to the magnet surface and very close to the surface without touching it.

2. As students work through step two, ask them to assume that the tip of the probe that they are using is south. They can then label the repulsion or attraction with an N and S. Students will get a pattern of the magnet field as illustrated in Figure 1 below.

Figure 1

In the pattern on the left, the magnetic field is in stripes, with the probe experiencing alternating north and south poles as it is scanned in one direction but not in the direction perpendicular to it. Other possible orientations are illustrated in Figure 1.

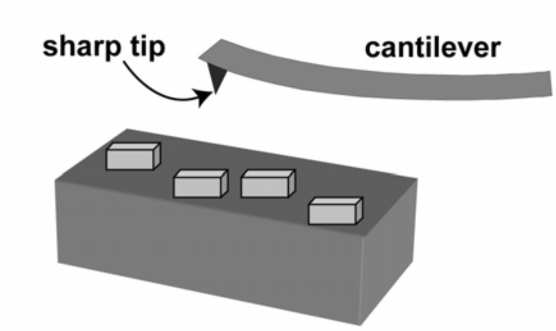
In the middle pattern there is only one orientation of the magnetic field, and the probe strip experiences the same force in all directions as it is dragged across the surface. In the pattern to the right, the magnetic poles are in a checkerboard arrangement, and the probe will experience alternating poles when scanned in either of the two perpendicular directions.

3. After students complete step 3, ask a student group to present a whiteboard which is a map of the magnetic poles of the refrigerator magnet. Their discussion should include the orientation of the north and south magnetic strips, how many strips there are across the magnet, the distance between them, and which poles were on the top and bottom of the magnet.

4. Ask another group to present their results to either substantiate or refute the results of the first group. If there is disagreement with the first group ask each group to provide justification for the results that they are reporting by asking the questions "how do you know?" They will come to realize that there are variables that need to be controlled so that each group is probing the magnet in the same way. While it may be fruitful to have students design a uniform procedure and repeat the activity, the point is for students to simulate the "seeing" of nanoparticles and gain some understanding of how a scanning probe microscope works.

Student Procedure

A refrigerator magnet will simulate a nanoparticle that will be analyzed with a probe strip which simulates a scanning probe tip. The probe tip is positioned at the end of a cantilever beam shaped much like a diving board. As the tip is repelled by or attracted to the surface, the cantilever beam deflects.



1. Drag the probe strip across the surface of the magnet, and notice any deflections. You will need to hold the probe strip nearly horizontal to the surface. Probe the magnet on various sides and in various directions.

2. As you know, the north pole of a magnet will attract the south pole of another magnet, and two magnets with either their north poles or their south poles pointed at each other will repel.

3. With this in mind, draw a representation of the magnetic poles in the box below.
   - Be sure to include the number of up and down deflections that you observe as you probe your “nanoparticle.”
   - What is the distance between the up and down deflections?
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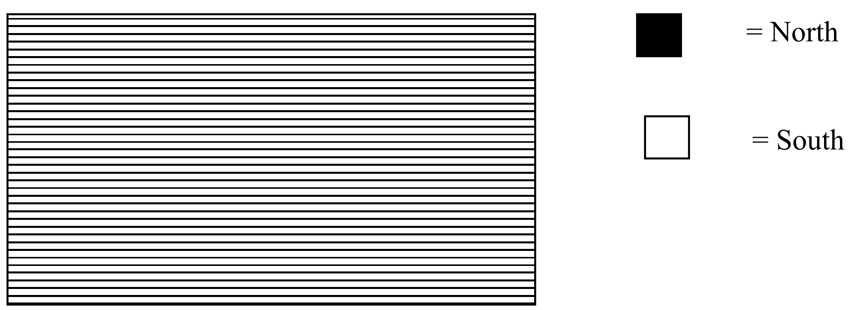

Top View Looking Down on the Magnet Surface

Images vs. Photographs
To learn how the colored images of nanoparticles in the *Nanoscale Materials and Their Properties* module are produced, go to http://www.almaden.ibm.com/vis/stm/lobby.html.

Study the description of the eight-step process that converts the measurements made by a scanning tunneling microscope into a colored image and answer the following questions:

4. How are the images formed from scanning-probe instruments different from those made by a digital camera?

Some possible answers include:

- **Digital cameras use optics to focus light on a silicon chip sensor containing light-sensitive spots. These photospots record the *amount of light* hitting it and convert the energy into photo-electrons.**
- **Scanning-probe instruments measure *attractive/repulsive forces* and translate them into electronic signals. Computers convert these electronic signals into a grid, which is used to construct images. The electronic images can be three-dimensional; whereas photographs are two dimensional.**

5. Are there any ways in which images formed from scanning-probe instruments are similar to those made by a digital camera?

   Some possible answers include:
   - **Digital cameras see in black and white, but each photosite has a filter that limits the spectrum of the light it sees. The camera then integrates the color information into full-color data.**
   - **The color of electronic images is painted on to emphasize a specific characteristic of the subject.**

Teacher Guide for Poster Fair Assessment

(Student Handbook, Page 16)

Overview

In this component of *Nanoscale Materials and Their Properties,* students will further investigate the essential question that they have considered throughout the module: **How and why do the chemical and physical properties of nanosamples differ from those of macrosamples?**

Assessment Objectives

1. Explain the importance of nanoscience research and technology.
2. Evaluate the ethical considerations associated with nanoscience research and nanotechnology.
3. Evaluate the usefulness and feasibility of nanotechnology research and products for the future.

Guiding Questions: Working with a partner, students will design and create an informational poster that they will exhibit during a Poster Fair. The text and images in the posters will answer the following guiding questions:

- What are the uses of this particular product?
- What are the physical and chemical characteristics of the product?
- How do the characteristics and uses of the nanoproduct differ from those of macro-scale samples? What are the underlying reasons for these differences?
- To help raise public awareness, what are the safety, social, and/or ethical issues resulting from the production or use of this product?

Project Alternatives

The procedure and rubric may be adopted for use in a number of project alternatives. Instead of a poster, students could demonstrate their research and learning by creating a Web site, PowerPoint presentation, or informational brochure. Also, projects may be completed individually rather than in pairs.

Family, the community, and/or the rest of the school could be invited to attend the exhibit of informational posters. One of the benefits of the Poster Fair is that it allows students to realize the wide range of nanoscale products and applications while only using one day of class time. Furthermore, combining the poster development process with the public display of the posters will strike a balance between content depth and breadth.

During the Poster Fair, students could be on hand to present informally and/or answer questions. Given this Poster Fair format, the information presented on the poster needs to be carefully planned, concise, and clearly written. Emphasize to students that multiple long paragraphs of text are not appropriate. Instead, they should convey information through brief paragraphs, bulleted lists, tables, charts, and images. Because of the public forum of the Poster Fair, adding a peer-review component is recommended in that the review process will help students not only develop a better understanding of the content, but also polish their writing and layout for the final poster. Use the *Peer Review Scoring Guides* to help guide the process. The peer review is optional. If the peer review is skipped, the rest of the assessment procedure remains the same.

The final project is meant to be integrated throughout the rest of the module. Students should select their topic and begin researching as soon as Unit 1 is completed. Most of the research and project preparation will take place outside of class time. To help students manage their time and fulfill the expectations of the project, the *Research Guide* and *Project Checklist* can provide some structure.

Suggested Timeline

The following table provides some guidelines regarding the time required to complete each task in this assessment.

Task	Class Time	Homework
Nanofabrication Video	~15 minutes	
Introduction to Project	30 minutes (after Unit 1)	
Topic Selection	45 minutes to 1 hour	
Research Progress (Stages 1 and 2)		Throughout the module, each partner should spend **30 minutes daily** conducting research on their selected nanoproduct.
Draft of Writing for Poster		Writing can be divided up between partners. Approximately 3 hours
Peer Review of Writing (*Optional)*	45 minutes to 1 hour	
Revise Writing		Will vary—at least 1 hour
Plan Layout for Poster		Approximately 1 hour
Peer Review of Layout (*Optional)*	30 minutes	
Assembling Final Poster		2–3 hours
Poster Fair Impressions *(Optional)*	45 minutes to 1 hour during Poster Fair	Finish for homework if necessary
Post-Fair Discussion	30 to 45 minutes	
APPROX. TOTAL TIME	**3 hrs 45 min to 4 hrs 45 min**	**11 to 12 hours**

Materials

- *Nanofabrication* from: http://www.mcrel.org/nanoleap/multimedia/index.asp. Choose from the Videos column.
- Poster boards (If you provide them for your students, the size you select will determine the amount of detail that can be included.)
- Copies of *Poster Assessment Description*, the *Getting Started* flowchart, the *Research Guide*, and *Project Checklist* (one per student)
- Access to Computers with Internet access for research and desktop publishing and/or word processing software to create text and graphics for posters
- Glue, glue sticks, double-sided tape to mount text and graphics onto poster board
- **Poster Assessment Rubric:** located on page 29 and in student handbook
- **For Peer Review** *(optional)*: folders/bins/or electronic files organized by nanoproduct category for paper submission; copies of *Peer Review Scoring Guides* (2 per student)
- **For Poster Fair** *(optional)*: Copies of *Poster Fair Impressions* sheet (1 per student)
- Guidance for students regarding proper citation format:
    - http://www.apapstyle.org/elecgeneral.html
    - http://www.lib.berkeley.edu/TeachingLib/Guides/APAstyle.pdf

Procedure

Introducing the Project

1. Begin this session by explaining that students will be researching a nanoscale product and its uses. In preparation for understanding how nanoproducts are produced, show the video: *Nanofabrication*, which demonstrates both top-down and bottom-up techniques as they are conducted in a cleanroom environment.
2. Refer to the *Poster Assessment Description*, the *Getting Started* flowchart, the *Final Poster Rubric,* the *Research Guide*, and the *Project Checklist*.
3. Discuss expectations for the poster and the format of the Poster Fair (e.g., who will be invited, to what extent students will be expected to present orally). Ensure students understand each of the research or guiding questions.
4. Explain the time-management and progress-check functions of the *Research Guide* and *Project Checklist* since most of the work for the project will occur outside of class time. Stress the importance of working on the project on a daily basis throughout the module. Also, emphasize the importance of achieving an effective partnership through planning, communication, and an equitable distribution of work; each student should contribute equally to the research and the poster development process.
5. As a class, go through the project stages as indicated on the checklist and assign appropriate timeframes and point values for each project stage. Determine how much progress students should make for each research checkpoint (Stages 1 and 2) and communicate your expectations. Also, communicate who will monitor students' progress and initial each checkpoint—you or peers.

> **Teacher Tip**
>
> If time permits, when introducing students to the rubric, use a sample paper to model how to use the rubric for evaluation. This will clarify the expectations of the project and encourage students to self-evaluate while developing their final project.

6. Make sure your students understand the final poster rubric that will be used to assess the poster. The more familiar students are with the expectations of the assessment, the more responsibility they can assume for their own work.

Selecting and Researching a Nanoproduct

7. Refer students to the list of keywords and product categories in their handbook.
8. Allow some class time for students to conduct Internet searches for nanoproducts within their selected categories. Provide support in topic selection as needed. Also remind students that they need to keep track of sources for both content and images used for their project. They are required to cite sources. Provide guidance to students on how they should cite the sources. Refer to APA citation in the Materials section above.
9. After the first progress check on the *Research Guide*, spend a few moments at the end of class reviewing the expectations for the poster format. Explain to students that while they will be available to answer questions about their nanoproduct during the Poster Fair, the poster should be able to speak for itself. To illustrate the importance of using text and images that are clear and concise, show an example that combines informative subtitles, brief paragraphs, bulleted lists, tables, charts, and images to convey information.
10. Complete the second and final progress check on the *Research Guide*.
11. Instruct students to refer to the rubric as they write the draft of their poster.

Troubleshooting Tips

Some nanoproducts may be so new that students will have trouble finding detailed information (e.g., production techniques and related safety issues). Instruct students to let you know if they run into this problem so that you can help them to troubleshoot. Meet with students to discuss the information they currently have, and ask questions to spur their thinking about what is possible. Some suggestions include:

- Help identify parallels with similar nanoproducts for which information may be more readily available.
- Highlight potential safety concerns that warrant further investigation.
- If time permits, interview an industry expert to get specific information.
- Suggest changing the topic to a related nanoproduct for which information is readily available.

Peer Review of Writing (Recommended Option)

Note: If you decide to skip the peer-review exercise, proceed to procedure #18 in the next section.

Rationale: The purpose of this instructional activity is to provide a writing-to-learn opportunity in preparation for the Poster Fair. The peer-review component will engage students in critical thinking and provide an opportunity for an in-depth exploration of a specific subject. Furthermore, feedback received through the peer-review process will help students refine their writing before the final poster is shared. They will also become very familiar with the rubric and take responsibility for evaluating their own work. Subsequently, the teacher’s paper load in this module can be minimized; you may only need to intervene and evaluate the writing when there is a large discrepancy among peer reviews.

12. In preparation for the peer review, label file folders, bins or, if doing an electronic peer review, create folders on the server organized around categories of nanoproducts (e.g., environmental cleanup, biomaterials, ceramics, electronic materials).
13. When students have completed a draft of the writing that will appear on their poster, devote 45 minutes to an hour of class time for a peer review. Ask students to submit their papers to the appropriate folder/bin according to their selected category of nanoproducts. Use the same folder/bin for all course sections if you would like students to review papers from other classes. Note, however, that you will need to have students submit their papers the day before the peer review, so that all papers are available for selection in each class. If there are only 1 or 2 papers in a category, combine related categories to ensure there are enough papers for each student to review two different ones.
14. Refer to the two *Peer Review Scoring Guides for Writing* (located at the end of the Student Handbook) to each student and ask them to identify themselves as reviewers by writing their name or their anonymous ID on the rubrics. Explain that each person is responsible for reviewing two different papers (preferably within the same nanoproduct category as their own).
15. Instruct students to pull a different paper from the same category as their own. When students complete their review, ask them to staple the rubric to the paper and return to the appropriate folder/bin. Then, they should repeat the process by reviewing a second paper. Once a paper has been reviewed twice, as indicated by the two attached and completed rubrics, it should be returned to the authors or you.
16. Allow some class time for students to review the feedback they received. If students feel there are significant discrepancies in the peer-review feedback, it will be necessary for you to intervene and provide some clarifications. Determine how you would like students to request your intervention (e.g., if class time permits, conduct one-on-one conferences with students as needed, or ask students to resubmit their papers and accompanying peer review rubrics for your review.)
17. Explain to students that the peer-review process was intended to be a trial run before the more public Poster Fair. Encourage students to revise and polish their writing according to the feedback they received.

Peer Review Options

- If you want the peer review to be anonymous, instruct students to code their papers, as well as the ones they review, with a specific ID. Keep a list of student names and corresponding IDs.
- To save class time, instruct students to swap papers and complete the peer review as homework.
- Ask the English teacher to allow time in English class for the peer review.

Teacher Tip

You may choose to emphasize more formal, oral presentations during the Poster Fair. To simulate an actual scientific conference poster session, have students arrange their posters on the walls of the classroom. Designate 5-10 minute increments in which all topics within a given category are presented. Students who are not presenting have the opportunity to visit any presentation during this allotted time. The audience members could then move from poster to poster during the presentations, forming a semicircle around the particular pair of students making the presentation.

Assembling the Poster

18. Instruct students to create a rough sketch of their poster's layout with appropriate headings that highlight where text and images will appear.
19. Refer to the "Organization" criterion on the rubric to ensure students plan a poster layout that will clearly communicate the information about the guiding questions to the Poster Fair audience.
20. ***Optional:*** Allow 30 minutes of class time for another peer review; this time students should provide feedback regarding the organization and layout of the poster (e.g., the flow of ideas visually, balance of text and images, the need for appropriate spacing, citations check, etc.). Students may use the *Peer Review Scoring Guides for Layout*.
21. After checking the poster layout, distribute the poster materials (if provided for the students) to complete their final poster.

Managing the Poster Fair

22. On the due date for the final poster, allow class time for students to display their posters in preparation for the Poster Fair.
23. Discuss expectations for the Poster Fair (e.g., how much time should be spent next to one's own exhibit to field any audience members' questions, when it's appropriate to tour the fair to become familiar with other nanoproducts).
24. **Optional: Notetaking during the Poster Fair**
    a) To ensure students make the most out of the Poster Fair experience, distribute the *Poster Fair Impressions* sheet beforehand and ask them to jot down notes about the social/ethical implications for three specific nanoproducts.
    b) After the Poster Fair, the *Poster Fair Impressions* sheet can form the basis of a concluding discussion in which students take a stand on whether or not further nanoscale research and technology is important for the public good. Students should use information about specific nanoproducts, gathered during the Poster Fair, as evidence to support their position.
    c) As students are viewing posters, have them use Post-It® notes to write comments related to what interested them or ask questions related to that poster.
25. Use the rubric to evaluate the final posters.

Post-Fair Discussion

26. After the Poster Fair, facilitate a class discussion by asking questions like the following:
    - *Based on what you've learned in this module and during the Poster Fair, do you think further nanoscale research and technology is important for the public good?*
    - *What are the benefits? Support your ideas with examples of nanoproducts you learned about.*
    - *What are the concerns? Are there any safety concerns, economic setbacks, ethical or social implications resulting from specific products, their uses, or production processes?*
    - *Do the benefits outweigh the concerns? What additional information/research is needed to determine if these concerns may outweigh the potential benefits to the public?*

27. During the discussion, keep track of student participation so that they may earn points on their *Project Checklist.*

Evaluating Student Work

The *Final Poster Rubric* and *Project Checklist* are designed to allow teacher flexibility in determining the point value to assign the various tasks in this performance assessment.

The ***Final Poster Rubric*** provides four ratings: Advanced, Proficient, Developing, and Novice. The grading scale below assigns points to each of the eight criteria, for a possible total of 32 points. Of course, you may choose to emphasize specific criteria by multiplying the point value.

A = 29–32 points
B = 28–26 points
C = 25–23 points
D = 22–20 points
F = 19 and below

In the ***Project Checklist***, the final column is left blank for you to determine the point value to assign to the various tasks. Be sure students are aware of the point value you are assigning to each task.

Getting Started

(Student Handbook, Pages 17–18)

Directions: This flowchart is designed to help you and your partner select a topic for your nanoproduct project and begin your preliminary research. Refer to the list of topics in the pages following this flowchart.

1. Select **three topics** that most interest you. Refer to the list of “Keywords and Categories.” Write them in the boxes below.

2. Conduct some preliminary Internet searches for each of the topics listed above. Use the topic as a keyword along with the prefix “nano” or the terms “nanoproducts” or “nanomaterials” with any of these categories. In the spaces below, list some of the **products** you found.

3. For each list above, **select one or two nanoproducts** that you would like to investigate further. In the spaces below, **note some basic information about the uses** of these products/applications.

4. Now, narrow down your list to **two choices of nanoproducts**. In the space below, consider the **pros and cons** of each topic. This could be the pros and cons of the product itself, or the benefits and drawbacks of selecting the topic for your research project (e.g., Pro: My uncle works in this industry and could provide some insight. Con: Based on a few Internet searches, there seems to be a limited number of resources.)

Nanoproduct Choice #1		**Nanoproduct Choice #2**	
PROS	**CONS**	**PROS**	**CONS**

5. Our choice is ____.

Let your teacher know the nanoproduct you selected.

Possible Research Topics and Key Words to Explore

(Student Handbook, Pages 19–22)

Biomaterials

- Tagging of DNA and DNAChips–coating gold nanoparticles with DNA strands

Catalytic materials

- Cerium oxide and iron oxide: chemical and environmental applications

Ceramics

- Nanocrystalline aluminum oxide and zirconia-toughened alumina for demanding environmental use
- Semiconductors

Coatings

- Transparent coatings and conducting films containing antimony and indium/tin oxides
- Self-cleaning polymer-based paints with titanium oxide have scratch and corrosion resistance
- Production of diamond films

Composites

- Clay nanoparticles add strength and resistance to PET bottle material
- Greener car parts: nanocomposites merge with bio-based plastics (made from plant oil) and reinforced with clay; fiber and tubular nanostructures may be recycled through composting
- Self-tinting automotive glass
- Development of composite polymers containing fullerenes/nanotubes that have new and useful properties
- Reinforcement of composites to improve strength
- Improvement of electrically conducting polymers by introducing fullerenes/nanotubes

Electronic materials

- Information storage
- Nanopens (atomic force microscope tips)
- Denser storage media: audio and video tapes and disks
- Faster computers: CdS nanowires, quantum computers
- Electrochemically etched silicon particles fluoresce in distinct colors useful for microelectronics, optoelectronics, and biomedial applications
- Nanowires and molecule electronic devices
- World’s smallest lasers, composed of CdS nanowire. Can be driven by simple electrical current.
- Development of superconductors: many fullerene and nanotube derivatives exhibit superconductor characteristics
- Possible replacement for silicon in chips as size parameters decrease
- Semiconductor manufacture utilizing fullerenes and or nanotubes
- Development of polymer electronics such as polymeric photocells

- New flat-screen light emitting display technology
- New electrodes for batteries
- Magnetic storage: buckyballs dispersed in ferromagnetic materials form films with promising magnetic properties

Energy

- Iron-polymer batteries for greater power generation
- Graphite nanofibers: hydrogen storage possibility
- Energy Capture and Storage: TiO_2 + special dye will absorb solar energy and convert it to electrical energy. Photovoltaic cells (with nanomaterials) more efficient, cost less
- Nanostructural tin in glass-forming matrix prevents volume expansion in lithium ions batteries
- High-surface-area electrodes
- Energy storage: Graphite nanofibers–hydrogen storage possibility
- Improved fuel cells using fullerenes/nanotubes
- Nanotubes are ideal thermal conductors, used for thermal energy transfer

Environmental Cleanup

- Iron nanoparticles used to clean organic toxins from ground water
- Palladium: convert toxic organic chemicals like TCE into harmless products
- Iron nanoparticles inside ferritin (animal blood protein) to remove chromium 6 “Brockovich” contaminant
- Silver nanoparticles: for cleaning contaminated water
- Titanium dioxide: photocatalyst for breakdown of pesticides and pharmaceutical residues**.** Now coating silver nanoparticles with titanium dioxide.
- Zinc oxide: reducing arsenic in drinking water
- Metallic oxides: CaO, MgO—relatively inert in the naturally occurring forms. In nanoparticle form, are capable of destroying many hazardous substances including chlorinated hydrocarbons, polychlorinate biphenyls (PCB), insecticides, acid gases, organophosphorus compounds, and military chemical agents.
- Alumina nanofibers used to remove trace metals from aqueous solutions
- Graphite nanofibers: removal of nuclear wastes
- Magnetic nanoparticle refrigerators with no need for refrigeration fluids

Environmental Hazard Protection

- Nanocrystal-based skin cream to protect against chemical/environmental hazards
- Chemical protective clothing and protective face masks that use metallic oxide nanoparticles coatings in mask: behave like fine powders without the killing action, the bacteria get into the filter and over time through multiplying the mask becomes dangerous.
- Nano filtration mask: blocks and destroys hazardous particulates/biological particles
- Ventilation systems and hospital breathing machines, high efficacy of clustered nanoparticles/enhanced to create ionization on the filter
- To protect against SARS, anthrax, and other biological threats, handheld devices are used for DNA-based testing to detect their presence.
- Sensors embedded in ultra-strong and lightweight nanomaterials for military uniforms

- MgO: material intended for first responders to neutralize toxic chemicals
- Spray forms of metallic oxide nanoparticles to contain and treat hazardous spills
- Use free radical scavenging properties of fullerenes to prevent food spoilage

Glasses/Optical materials–no specific suggestions

Magnetic materials–no specific suggestions

Medical Diagnostics
- Gold nanoparticles attached to DNA molecules, test for presence of lead in human body—turn from blue to red
- Gold nanoparticles used to build sensors to detect antibodies attaching to a protein associated with a disease, produces a fluorescent molecule in UV light, or attached to antibody and DNA "barcode" can test for onset of Alzheimer's
- Use derivatives of fullerenes as magnetic resonance imaging (MRI) contrast agents

Metals
- Metal-composite car bodies: resilient body panels that pop back into place
- Compressed metals exhibit surface hardness five time that of normal microcrystalline metals
- Thin metallic films made from metallic colloidal solutions
- Nanoscale metal crystallites formed by electrodeposition useful for transformers

Military Uses
- Military suits capable of different functions, Magneto Rheological Fluids: contain magnetic nanoparticles that harden fluid when bullet is "sensed"
  (see also **Environmental Hazard Protection**)

Pharmacy/Therapeutic Drugs
- Nanoshells made of hollow gold or silver sphere wrapped around a filling silica. Gold in different thicknesses absorb energy from light, changing frequency with thickness, promising for killing tumors
- Shrinking sizes of medicines—noninvasive
- Biological polymers similar to cell membranes
- RenaZorb: binds to phosphate in failing kidneys; surface area allows large absorption
- Improved topical healthcare products: zinc oxide for longer lasting, better coverage sunscreen lotions
- Exomuscles: embedded materials close to human capabilities; flexible, rigid on command, immobilize damaged arms/legs, tighten and constrict blood flow around wound
- Burn therapy
- Nanoscale Biostructures: designed to "mimic" some type of biological process, can interact with a biological mechanism, includes human repair and self-assembly
- Use fullerenes as drug delivery systems since they are sized to fit within cell structures
- Fullerenes are powerful anti-oxidants that react readily with free radicals, used to treat/prevent diseases that arise from free radical damage

- Use fullerenes as antiviral agents

Personal Products
- Stain-free clothing
- Scratch-resistant eyeglasses
- Use free radical scavenging properties of fullerenes in personal care products such as cosmetics

Polymers
- Better bone implants: nanoengineered more durable, better able to integrate with natural bone tissue than artificial joints and other micron-scale implants
- Ceramics, polymers, and metals: roughness of nanoparticles in metals creates a surface that bone cells are more likely to recognize
- Stronger, lighter, wear-resistant tires and flame-retardant plastics
- New lubricants involving fullerenes or nanotubes

Sensors
- New chemical or force sensors based on nanotube characteristics

Resources
(Student Handbook, Pages 23–28)

The following Web sites may contain information about additional nanoproducts.

General Resources

Nanotech briefs by *Engineering Breakthroughs in Nanotechnology & MEMS*. Retrieved April 5, 2007, from http://www.nanotechbriefs.com/NB_planner_07.pdf

Biomaterials/ Medical Diagnostics
Pharmacy/Therapeutic Drugs

Azonano. (2005, August 30). *Highly magnetized nanoparticles based on metallic iron could one day be used in a non-invasive therapy for cancer*. Retrieved April 5, 2007, from http://www.azonano.com/news.asp?newsID=1316

Azonano. (2005, May). *MEMS device combined with microfluidics to perform genetic analysis of small samples of DNA*. Retrieved April 5, 2007, from http://www.azonano.com/news.asp?newsID=949

Azonano. (2005, September 1). *Stealth nano particles may some day target tumor cells*. Retrieved April 5, 2007, from http://www.azonano.com/news.asp?newsID=1343

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EurekAlert. (2005, October 21). *Carbon nanoparticles stimulate blood clotting, researchers report*. Retrieved April 5, 2007, from http://www.eurekalert.org/pub_releases/2005-10/uoth-cns102105.php

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Ivanhoe.com. (2006, January 31). *Nanoshuttle destroys disease*. Retrieved April 5, 2007, from http://search.ivanhoe.com/channels/p_channelstory.cfm?storyid=13025&channelid=chan-100021

Johns Hopkins University. (2005, December 5). *New nanosensor uses quantum dots to detect DNA*. Retrieved April 5, 2007, from http://www.jhu.edu/news_info/news/home05/dec05/dnanano.html

Malsch, I. (2002). Biomedical applications of nanotechnology. *American Institute of Physics*. Retrieved April 5, 2007, from http://www.tipmagazine.com/INPHFA/vol-8/iss-3/p15.pdf

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Technology Research News. (2005, July 29). *DNA process stamps patterns*. Retrieved April 5, 2007, from http://www.trnmag.com/Stories/2005/081005/DNA_process_stamps_patterns_Brief_081005.html

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University of California San Francisco News Office. (2005, June 3).*Researchers demonstrate use of gold nanoparticles for cancer detection*. Retrieved April 5, 2007, from http://pub.ucsf.edu/newsservices/releases/200506033/

Ceramics

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Ceramics and nanotechnology by *The American Ceramic Society*. Retrieved April 5, 2007, from http://www.acers.org/news/factsheets/nanotechnology.asp

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Azonano. (2004, July 29). 3*D systems announces the availability of engineered nano-composite Bluestone™ SL material for SLA® systems*. Retrieved April 5, 2007, from http://www.azonano.com/details.asp?ArticleID=1024\

Energy

AZoM. *Energy dispersive x-ray fluorescence (EDXRF) analysis of copper, zinc, arsenic, and lead in a mine sample by PANalytical*. Retrieved April 5, 2007, from http://www.azom.com/Details.asp?ArticleID=3406

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Environmental Cleanup/Hazard Protection

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Glasses/Optical materials

Uni Osnabrück: Physics by *Universität Osnabrück*. Retrieved April 5, 2007, from http://reichling.physik.uos.de/pages/pD1.shtml

Magnetic materials

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Sporting Goods

Nanotech Briefs. Retrieved April 5, 2007, from http://www.nanotechproject.org/index.php?id=44&action=view

Sensors

Physorg.com. (2006, February 20). *Detection of DNA on nanotubes offers new sensing, sequencing technologies*. Retrieved April 5, 2007, from http://www.physorg.com/news11030.html

Carbon Nanotubes

Azom.com. *Dry adhesive–vertically aligned multiwalled carbon nanotube arrays from NextTechs Technologies*. Retrieved April 5, 2007, from http://www.azom.com/Details.asp?ArticleID=3397

Analytical Applications

AZoM. *Analytical ferrography laboratory for oil and lubricant testing automatic robotics system for oil analysis spectrometer*. Retrieved April 5, 2007, from http://www.azom.com/Details.asp?ArticleID=3404

Chang, K. (2005, February 22). Tiny is beautiful: Translating 'nano' into practical. *New York Times*. Retrieved April 5, 2007, from http://www.nytimes.com/2005/02/22/science/22nano.html?pagewanted=1&ei=5090&en=4ea37d77d2651a3f&ex=1266814800&partner=rssuserland

Final Poster Rubric

(Student Handbook, Page 29)

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Understanding of Content/Research *Use of Product*: **Explanations identify uses of product based on research.**			
Detailed and demonstrating a sophisticated understanding. **No inaccuracies. Extensive** research.	**Complete explanations**. **No clear** inaccuracies or misconceptions. **Solid research**.	Basic explanations are **inaccurate** or **incomplete**. **Average** research.	**Missing important** information and/or inaccuracies. **Little** research.
Physical and Chemical Characteristics: **Explanations identify the physical and chemical characteristics.**			
Clearly identifies both physical and chemical characteristics **in detail**.	**Clearly identifies** both physical and chemical characteristics.	Some **inaccurate or incomplete** physical and chemical characteristics.	**Not able to distinguish between** physical and chemical characteristics.
Nano vs. Macro Characteristics: **Explanations identify characteristics and differences between the nanoproduct and macro-scale. Explanations give underlying reasons for the differences.**			
Clearly identifies Nano and Macro characteristics and **reasons for the difference in detail.**	Clearly identifies Nano and Macro characteristics and **reasons for the difference.**	Some **inaccurate or incomplete** identification of Nano and Macro characteristics.	**Not able to distinguish between** Nano and Macro characteristics.
Thinking and Reasoning: Safety, social, and **ethical issues** resulting from production or product use.			
Valid and thoughtful with scientific and logical **supporting evidence**.	Valid **but little supporting** logic or scientific evidence.	**Does not fully support thinking** with specific evidence.	**No supporting** evidence provided.
Writing Style and Mechanics: Brief summary paragraphs, bulleted lists, text boxes, and tables that highlight *key* information.			
Concise, clear, and engaging explanations. Paraphrases. **Flawless** spelling and grammar.	**Concise and clearexplanations. Paraphrasing**. **Minor errors** in spelling and grammar.	**Appropriate writing**. **Paraphrases some. Many errors** in spelling and grammar.	**Little attention** to the writing format. **Poor** paraphrasing. **Many errors** in spelling and grammar.
Graphic Explanations / Images: Images communicate and reinforce concepts.			
Reinforcing **important concepts accurately** and creatively.	Captures **most important concepts.** Shows no misunderstanding.	Captures **few important concepts/ reflect inaccuracies.**	Graphics **do not** capture important concepts.
Organization and Poster components: Gives title, subheadings, writing, and graphic images. Has a flow of information, spacing, and balance between text and graphics/images.			
Sophisticated, organized, and neat, **balance of text and graphics**. Contains all poster components.	**Solid** organization with good design, layout, and neatness. **Appropriate balance of text and images** and **spacing.** Contains all poster components.	**Somewhat organized. Some imbalance between text and images**. Contains all poster components.	**Messy design**. **Significant imbalance between text and images.** Missing some poster components.
Citations: Citations on all sources including text and images.			
All text and images.	All but one or two text or images.	Missing more than two graphic text or images.	Provides few citations.

Research Guide
(Student Handbook, Page 30–32)

Directions: This sheet is designed to help you gather information to develop a poster that will answer the guiding questions. The Graphic Images column is intended to be a place for you to jot down notes about possible images you may incorporate into your poster. Be sure to note the specific resources used to gather each piece of information.

Topic: Selected Nanoproduct or Application ________________________________

Notes on Subtopics	Accompanying Graphic Images	Resources (Print and Web)
Introduction: *What is it?*		
Uses: *What are the uses of this particular product?*		

Notes on Subtopics	Accompanying Graphic Images	Resources (Print and Web)
Characteristics: *What are the* ***physical and chemical characteristics*** *of the product?*		
Nano vs. Macro: *How do the characteristics and uses of the* ***nanoproduct differ*** *from those of* ***macro-scale samples****? What are the* ***underlying reasons*** *for these differences?*		

Notes on Subtopics	Accompanying Graphic Images	Resources (Print and Web)
<u>Benefits and Concerns</u>: *To help raise public awareness, what are the* ***safety, social, and/or ethical issues*** *resulting from the production or use of this product?* OR *What additional information/ research is needed to* ***ensure the product and production techniques are safe****?*		
<u>Conclusion</u>*:* *Based on what you've researched, why do you think nanoscience research and technology is important? Do you think further nanoscale research and technology, related to your product, is* ***important for the public good****?*		

Name__________________________ Partner Name _________________________

Project Checklist

(Student Handbook, Page 33–34)

Directions: Most of the research and development for the final poster will occur outside of class time. You are expected to work daily to fulfill the tasks needed to create a quality poster. This sheet is designed to help you manage your time and monitor your progress in completing each task. Points will be assigned for the completion of each task. Your teacher may determine that some of the tasks outlined below are optional.

Task	Completion Date	Progress Check/ Task Completion (Initials/Signature)	Points Earned
Topic Selection (*Getting Started*)			
Research Progress Stage 1			
Research Progress Stage 2			
Draft of Writing for Poster			
Peer Review of Writing (2 reviews per paper) (see scoring guide at the end of the Student Handbook)			*Points earned for reviewing two peers' papers*
Revise Writing			

Task	Completion Date	Progress Check/ Task Completion (Initials/Signature)	Points Earned
Layout for Poster (with headings and graphic images)			
Peer Review of Layout (2 reviews per paper)			*Points earned for reviewing two peers' papers*
Final Poster			
Poster Fair Impressions Sheet			

TOTAL POINTS = ___________________

NanoLeap

Teacher Guide Unit 2: Metallic and Ionic Nanoparticles: Extendable Structures

Lesson 2.1 Extendable Solids

Fact Sheet 2 Types of Solids

(Student Handbook, Pages 35–36)

Types of Solids

The four basic types of solid structures, the intermolecular forces within them, some of their characteristics, and examples of each of them are shown in the table below.

Type of Solid	Structural Particles	Interparticle Attractive Forces	Typical Properties of Macrosamples	Structural Form/ Surface Features	Examples
Metallic	Metal atoms	Metallic bonds (attraction between the mobile delocalized electrons "sea of electrons" and surrounding metal atoms)	Lustrous, ductile, malleable, good conductors of heat and electricity, most melting points above room temperature, hardness varies	Extendable ----- High surface energy; unsatisfied coordination number at surface	Na, Mg, Al, Fe, Zn, Cu, Au, Ag
Ionic	Cations and anions	Ionic bonds	Hard, moderate to high melting points, nonconductors of electricity in solid state	Extendable ----- High surface energy; unsatisfied coordination number at surface	NaCl, $NaNO_3$, MgO, BaS, CaO, CaF_2
Network covalent	Atoms	Covalent bonds	Very hard, very high melting points, non- or semi-conductors of electricity	Extendable ----- High surface energy; unsatisfied coordination number and covalent bonds at surface	C (diamond, graphite*) SiC, SiO_2
Molecular	Molecules	Covalent bonds between atoms and intermolecular forces between molecules (van der Waals, dipole-dipole, hydrogen bonds)	Soft, low melting points, nonconductors of heat and electricity	Discrete ----- Satisfied coordination number at surface	CH_4 CO_2, P_4, S_8, I_2, H_2O C_{60} Buckyballs Nanotubes**

*Graphite is extendable in two dimensions and molecular-type in one.
**Nanotubes are extendable in one dimension and molecular-type in two.

The table, ***Types of Solids***, shows the different types of solids. An additional column indicates both the kind of structures and the surface features characteristic of each type of solid.

How do these types of solids relate to nanoparticles? Elements and compounds (with few exceptions) form the **same types of structures** at the nanoscale as they form at the macroscale level.

Solid nanoparticles can be either **extendable structures**, (like those formed by metallic, ionic, and some network solids) or **discrete structures** (like molecules), depending upon their surface features.

Extendable structures can be imagined to grow without limit (usually in three dimensions) if additional building blocks are available. Another way to visualize these types of nano materials is by representing **nanoscale-sized "chunks**" of everyday matter such as gold, magnesium oxide, or diamond, that are composed of an extendable three dimensional lattice of repeating components.

In **discrete structures** the main type of bonding between atoms is covalent and the structures are individual molecules. The structures *cannot* be extendable simply by adding more and more building blocks to a three-dimensional lattice.

These materials are like large, discrete molecules. At the nanolevel it is often a matter of choice, based on meaning or perspective, as to whether they are referred to as gigantic molecules or nanoparticles. Buckyballs, the first of these unusual materials to be discovered, were treated as particles because of their unique nanoscale-sized soccer ball shapes.

Extendable structures are investigated in more depth in Unit 2, while discrete structures are discussed in Unit 3.

Student Version: Activity 3–Metallic Closest Packing Up Close

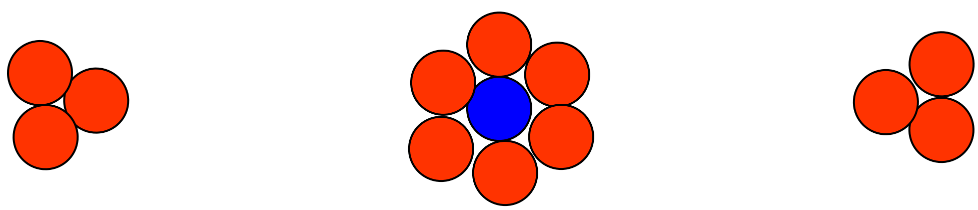
(Student Handbook, Pages 37–41)

Metals form "closest packed" solid crystalline structures because their valence electrons are mobile. The electrons are free to move and can be attracted to more than one positive ion in the crystal. Valence electrons hold the positive ions as close as the size of the ions and electrostatic forces on the ions will allow. At the macrolevel, most metals form crystalline structures in which the majority of the atoms in these structures are surrounded by 12 nearest neighbors. The nearest neighbors are also referred to as **coordination number (CN)**.

Part 1. Building a Metallic Model Using Clay Spheres

A. Using the three layers provided to represent a model of a metallic nanoparticle consisting of 13 atoms, make the following observations and respond to the questions in the space provided.

Layer 1 the bottom layer	Layer 2 the middle layer	Layer 3 the top layer



<u>Observe only Layer 1(the bottom layer):</u>

1. How many atoms are there in Layer 1? ________________
2. How many "nearest neighbors" does each atom of Layer 1 have? _____________

<u>Observe only Layer 2 (the middle layer):</u>

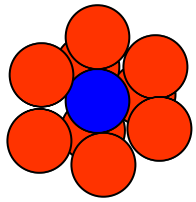
3. How many atoms are there in Layer 2? ________________
4. How many of them are surface atoms (that is, how many are on the outside) and how many are interior atoms (on the inside)? _______________
5. How many nearest neighbors does the interior atom have? ____________
6. How many nearest neighbors does each of the surface atoms have? _________________

<u>Observe only Layer 3 (the top layer):</u>

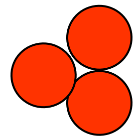
7. How many atoms are there in Layer 3? ________________
8. How many "nearest neighbors" does each atom of Layer 3 have? _____________

B. Place Layer 2 on top of Layer 1 so that if you looked at Layer 2 from the top, it would look like this.

Layer 2 on top of Layer 1



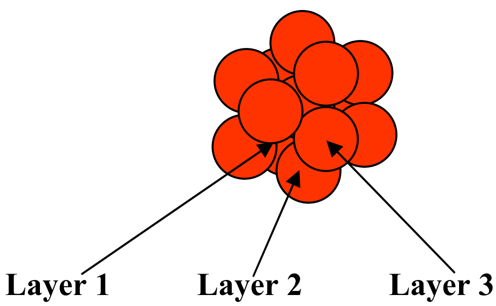
Layer 3 the top layer



<u>Observe Layers 1 and 2:</u>

9. How many nearest neighbors does the interior atom in Layer 2 have now? ____________
10. How many nearest neighbors does each of the surface atoms in Layer 2 have now? _____
11. How many nearest neighbors does each of the atoms in Layer 1 have now? ___________
12. Are the atoms in Layer 1 surface atoms or interior atoms? _____________

C. Move Layer 3 on top of Layer 2. The model viewed from the top should appear like the illustration below. This model represents the smallest metallic nanoparticle.



<u>Observe the complete nanoparticle:</u>

13. Are the atoms in Layer 3 surface atoms or interior atoms? _____________
14. a) How many nearest neighbors does the central atom in Layer 2 have now? __________
    b) What is the coordination number (CN) of the central atom? _____________
15. a) How many nearest neighbors does each surface atom in Layer 2 have now? ________
    b) What is the coordination number of each of the surface atoms in Layer 2? __________
16. Are these nearest neighbors surface or interior atoms? ________________

17. a) How many nearest neighbors does each of the atoms in Layers 1 and 3 have? _____
    b) What is the coordination number (CN) of the surface atoms? __________________
18. Are the nearest neighbors of Layers 1 and 3 atoms surface or interior atoms? ________
19. Do the surface atoms in this nanoparticle form edges or corners or both? ___________
20. How would you describe the shape of the nanoparticle that you have been observing? _________

D. Based on your observations of this model, complete Table 1 below.

Table 1

Number of Layers	Number of Atoms	Number of interior atoms	Number of surface atoms

E. Use data from Table 1 to complete Table 2.

Table 2

Number of Layers	Ratio of Surface Atoms/ Interior Atoms	Percentage of surface atoms	Average Coordination Number (CN) of all the atoms

*** Make sure you save your 13 atom clay models for the next lesson. ***

Part 2. Nanoparticle Builder
Access the Nanoparticle Builder computer simulation at
http://www.mcrel.org/nanoleap/multimedia/index.asp in the Interactives Column.

A. Build the 3-layer nanoparticle using the simulation and complete Table 3. Compare your results with the data from Tables 1 and 2 in Part 1.

B. Use the simulation to build a nanoparticle with five layers and record the data in the second row of Table 3. Repeat the procedure to build a seven-layer nanoparticle and complete the third row of Table 3.

C. Use the data given for 9- and 11-layer nanoparticles to complete the last two rows of Table 3. **Note:** Use an average **CN of 7 for all surface atoms** and average **CN of 12 for all interior atoms** to simplify the calculation of the average coordination number for nanoparticles having five or more layers.

Table 3

Number of Layers	Number of interior atoms	Number of surface atoms	Total Number of Atoms	Ratio: Surface to Interior Atoms	Percentage of Surface Atoms	Average Coordination Number
7	**55**	**92**				
9	**148**	**161**				
11	**309**	**252**				

Part 3. Analysis of Data

After analyzing the results of your observations and calculations, complete the following statements:

As the size of the nanoparticle **decreases**,

the ratio of surface atoms to interior atoms ___________________________

the percentage of surface atoms ____________________________________

the average coordination number ___________________________________

How would you describe the shape of these nanoparticles?

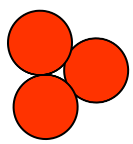
Did the basic shape of these nanoparticles change as the size changed?

Answer Key: Activity 3–Metallic Closest Packing Up Close

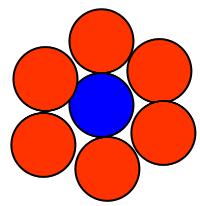
Metals form "closest packed" solid crystalline structures because their valence electrons are mobile. The electrons are free to move and can be attracted to more than one positive ion in the crystal. Valence electrons hold the positive ions as close as the size of the ions and electrostatic forces on the ions will allow. At the macrolevel, most metals form crystalline structures in which the majority of the atoms in these structures are surrounded by 12 nearest neighbors. The nearest neighbors are also referred to as **coordination number (CN)**.

Part 1. Building a Metallic Model Using Clay Spheres
A. Using the three layers provided to represent a model of a metallic nanoparticle consisting of 13 atoms, make the following observations and respond to the questions in the space provided.

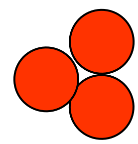
Layer 1
the bottom layer



Layer 2
the middle layer



Layer 3
the top layer



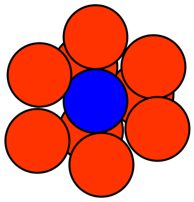
Observe only Layer 1(the bottom layer):
1. How many atoms are there in Layer 1? __**3**____
2. How many "nearest neighbors" does each atom of Layer 1 have? ______**2**______

Observe only Layer 2 (the middle layer):
3. How many atoms are there in Layer 2? __**7**____
4. How many of them are surface atoms (that is, how many are on the outside) and how many are interior atoms (on the inside)? **6 surface, 1 interior**
5. How many nearest neighbors does the interior atom have? _____**6**_____
6. How many nearest neighbors does each of the surface atoms have? _____**3**_____

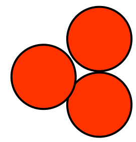
Observe only Layer 3 (the top layer):
7. How many atoms are there in Layer 3? __**3**____
8. How many "nearest neighbors" does each atom of Layer 3 have? ______**2**______

B. Place Layer 2 on top of Layer 1 so that if you looked at Layer 2 from the top, it would look like this.

Layer 2 on top of Layer 1



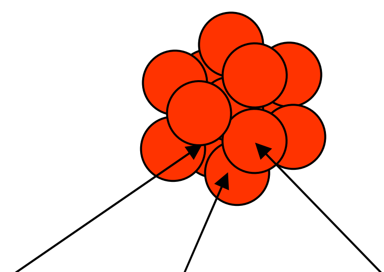
Layer 3 the top layer



Observe Layers 1 and 2:

9. How many nearest neighbors does the interior atom in Layer 2 have now? **9**
10. How many nearest neighbors does each of the surface atoms in Layer 2 have now? **4**
11. How many nearest neighbors does each of the atoms in Layer 1 have now? **5**
12. Are the atoms in Layer 1 surface atoms or interior atoms? **Surface**

C. Move Layer 3 on top of Layer 2. The model viewed from above should appear as illustrated below. This model represents the smallest metallic nanoparticle.



Observe the complete nanoparticle:

13. Are the atoms in Layer 3 surface atoms or interior atoms? **Surface**
14. a) How many nearest neighbors does the central atom in Layer 2 have now? **12**
    b) What is the coordination number (CN) of the central atom? **12**
15. a) How many nearest neighbors does each surface atom in Layer 2 have now? **5**
    b) What is the coordination number of each of the surface atoms in Layer 2? **5**
16. Are these nearest neighbors surface or interior atoms? **Both, four surface and one interior**

17. a) How many nearest neighbors does each of the atoms in Layers 1 and 3 have? __5__
    b) What is the coordination number (CN) of the surface atoms? __5__
18. Are the nearest neighbors of Layers 1 and 3 atoms surface or interior atoms? __Both__
19. Do the surface atoms in this nanoparticle form edges or corners or both? __Both__
20. How would you describe the shape of the nanoparticle that you have been observing?
    Hexagonal bipyramid

D. Based on your observations of this model, complete the Table 1 below.

Table 1

Number of Layers	Number of Atoms	Number of interior atoms	Number of surface atoms
3	**13**	**1**	**12**

E. Use data from Table 1 to complete Table 2.

Table 2

Number of Layers	Ratio of Surface Atoms/ Interior Atoms	Percentage of surface atoms	Average Coordination Number (CN) of all the atoms
3	**12:1**	**92%** $\left(\frac{\textbf{12 surface atoms}}{\textbf{13 total atoms}}\right)$ **X 100**	**1 atom x 12 CN = 12** **12 atoms x 5 CN = + 60** **72** $\frac{\textbf{72 CN}}{\textbf{13 atoms}}$ **= 5.5 average CN**

*** Make sure you save your 13 atom clay models for the next lesson. ***

Part 2. Nanoparticle Builder (Using Computer Interactive)
Access the Nanoparticle Builder computer simulation at
http://www.mcrel.org/nanoleap/multimedia/index.asp in the Interactives Column.

A. Build the 3-layer nanoparticle using the simulation and complete Table 3. Compare your results with the data from Tables 1 and 2 in Part 1.

B. Use the simulation to build a nanoparticle with five layers and record the data in the second row of Table 3. Repeat the procedure to build a seven-layer nanoparticle and complete the third row of Table 3.

C. Use the data given for 9- and 11-layer nanoparticles to complete the last two rows of Table 3. **Note:** Use an average **CN of 7 for all surface atoms** and average **CN of 12 for all interior atoms** to simplify the calculation of the average coordination number for nanoparticles having five or more layers.

Table 3

Number of Layers	Number of interior atoms	Number of surface atoms	Total Number of Atoms	Ratio: Surface to Interior Atoms	Percentage of Surface Atoms	Average Coordination Number
3	1	12	13	12:1	92%	5.5
5	13	42	55	3.2:1	76%	8.2
7	55	92	147	1.7:1	63%	8.8
9	148	161	309	1.1:1	52%	9.4
11	309	252	561	.82:1	45%	9.8

Part 3. Analysis of Data

After analyzing the results of your observations and calculations, complete the following statements:

As the size of the nanoparticle **decreases**,

the ratio of surface atoms to interior atoms _**increases**.

the percentage of surface atoms ______**increases**_____.

the average coordination number _______**decreases**___.

How would you describe the shape of these nanoparticles?

Ball shaped

Did the basic shape of these nanoparticles change as the size changed?

No

Optional Activity: Factors that affect the rate of Chemical Reactions: Observing reactions and making comparisons using antacid tablets

Recommend having 2–4 students work at a station

Materials for Every Station:
Stopwatches
1 pair of 250 mL beakers for each reaction
100 mL of water in each beaker
7 Antacid tablets- brand name- Alka Seltzer®

Materials for specific stations:
Mortar and pestle (Station 1, Station 2)
Heating Source – hot plates (Station 3)
Thermometer (Station 3)

Station 1: Whole vs. Crushed – Particle size

Preparation:
Use 2-250 mL beakers, label them 1 and 2
Use 2 antacid tablets, remove tablets from their wrapper
Leave one tablet whole, with the second tablet use a mortar and pestle to grind it finely

Running the experiment:
At the same time, add the whole tablet to beaker #1 and the crushed tablet to beaker #2– begin timing the reaction when you add the antacid to each beaker.

Make and record observations:
Compare and describe the dissolving rate of each beaker of antacid at:
10 seconds-

20 seconds-

30 seconds-

Questions:
At the end of 20 seconds which antacid tablet dissolved more? (**answer: beaker #2**)

What do you think affects the rate of the dissolving? (**answer: The ground antacid has more surface area to react in the water**)

Station 2: Concentration

Preparation:
Use 2-250 mL beakers, label them 1 and 2
Use 3 antacid tablets, remove tablets from their wrapper

Running the experiment:
At the same time add one tablet to beaker #1 and two tablets into beaker #2– begin timing the reaction when you add the antacid to each beaker.

Make and record observations:
Compare and describe the dissolving rate of each beaker of antacid at:
20 seconds-

30 seconds-

60 seconds-

Questions:
At the end of 30 seconds which antacid tablet dissolved more? (**answer: beaker #1**)

What do you think affects the rate of the dissolving? (**answer: There is more water to react with one tablet vs two tablets.)**

Station 3: Room temperature vs. adding heating

Preparation:
Use 2-250 mL beakers, label them 1 and 2

Use 2 antacid tablets, remove tablets from their wrapper
Turn on hot plates and heat the water in beaker #2 till it reaches 50° C or 120° F.

Running the experiment:
At the same time add one tablet to beaker #1 and one to beaker #2– begin timing the reaction when you add the antacid to each beaker.

Make and record observations:
Compare and describe the dissolving rate of each beaker of antacid at:
20 seconds-

30 seconds-

60 seconds-

Questions:
At the end of 30 seconds which antacid tablet dissolved more? (**answer: beaker #2**)

What do you think affects the rate of the dissolving? (**answer: The hot water accelerated the antacid in beaker # 2**)

Lesson 2.2 Extendable Solids: Reactivity, Catalysis, Adsorption
Student Version: Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?
(Student Handbook, Pages 44–48)

PART 1

Trichloroethylene (TCE) is a cancer-causing industrial chemical solvent used to degrease metals and electronic parts. When it is released into the ground, it stays in the soil until it is gradually leached into groundwater. Metallic iron has been shown to be effective for decomposing contaminants like TCE that have found their way into drinking water.

Iron nanoparticles used for TCE dechlorination have average diameters of 40 nm, so they can easily move within an aquifer.[2] They can also access the TCE molecules trapped in very small pores and microscopic flow channels in the saturated subsoil and rock under dump sites. From there they can move into underground reservoirs. They appear to be able to target, or seek out, the TCE by themselves once they have been introduced into the contaminated area.[3]

The chemistry of TCE dechlorination

The detailed pathways and mechanisms for TCE dechlorination reactions involving iron are still not known.[4] There are several possible mechanisms by which dechlorination may occur:

1. One method for removing chlorine from TCE may be initiated when iron reacts with oxygen to release electrons. These electrons then react with a molecule of TCE, breaking the bonds between the chlorine and carbon atoms. The products of this reaction are chloride ions and ethene. The overall net equation for this reaction can be written:
   $3Fe^{o} + \underbrace{C_2HCl_3}_{\text{TCE}} + 3H^{+} \rightarrow 3Fe^{+2} + 3Cl^{-} + \underbrace{C_2H_4}_{\text{Ethene}}$

2. Another possible pathway involves the corrosion of iron, which produces hydrogen. TCE then reacts with hydrogen and iron precipitates out as "green rust"[5], a mixture of iron II and iron III hydroxide salts.[6][7] The overall net equation for this reaction is:
   $3Fe + 6H_2O + C_2HCl_3 \rightarrow C_2H_4 + 3Cl^{-} + 3H^{+} + 3Fe(OH)_{2(s)}$

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2 Chan, D. B., et.al. Zero Valent Iron (ZVI) Powder injection for in-situ dechlorination of chlorinated organic compounds at Hunters Point Shipyard. San Francisco, CA http://www.arstechnologies.com/pp_drchan.ppt

3 Goho, A. Special Treatment: Tiny technology tackles mega messes. *Science News*. April 23, 2005, vol 167, p.266-268.

4 Modified iron filing remove contaminants from groundwater. Oak Ridge National Laboratory News Release. Jan. 4, 1996. http://www.ornl.gov/info/press_release/get_press_release.cmf?ReleaseNumber=mr19960104-00

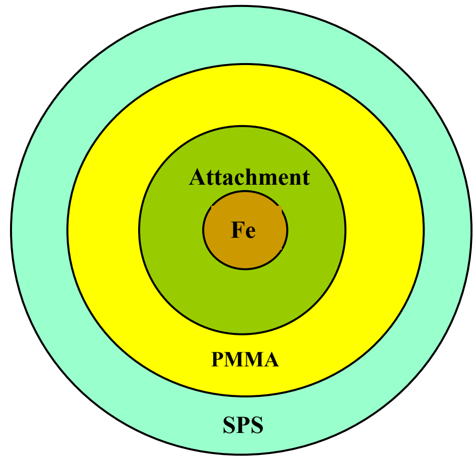
5 Modified iron filing remove contaminants from groundwater. Oak Ridge National Laboratory News Release. Jan. 4, 1996. http://www.ornl.gov/info/press_release/get_press_release.cmf?ReleaseNumber=mr19960104-00

6 Yabusaki, S., Cantrell, K., & Sass, B. Moffett Field Funnel and Gate TCE Treatment System: Interpretation of field performance using reactive transport modeling http://www.containment.fsu.edu/cd/content/pdf/059.pdf

7 Chan, D. B., et.al. Zero Valent Iron (ZVI) Powder injection for in-situ dechlorination of chlorinated organic compounds at Hunters Point Shipyard. San Francisco, CA http://www.arstechnologies.com/pp_drchan.ppt

3. Other research indicates that TCE may be adsorbed on iron particles, where the decomposition is catalyzed.[8]

Adding polymer coatings to iron nanoparticles makes it even easier for them to move through contaminated soil and to search for TCE molecules. The iron core of these nanoparticles is covered with three layers of polymers. The inner layer attaches the other two polymer layers to the iron. The middle layer of poly methyl methacrylate (PMMA) is hydrophobic (water-fearing) so it is attracted to TCE. The outer coating of sulphonated polystyrene (SPS) is hydrophilic (water-loving) and makes the particles soluble in water so that they can easily move throughout the groundwater.[9] See diagram.



Using nanoparticles could be an improvement over the current method of environment cleanup, which involves digging a trench and dumping a ton or more of iron powder into it. One reason for this is an increase in surface area of the reacting particles. The surface area of commercial iron powder is 0.900 m^2/g whereas 40 nm iron nanoparticles present a surface area of 33.5 m^2/g. Another reason is the significant financial savings when iron nanoparticles are used in place of iron powder to clean up groundwater. For example, a \$20 million macro cleanup project might cost \$5 million using nanoparticles. This represents a 75% savings. Iron nanoparticle prices in 2005 were \$9-\$11 per pound.[10] It is estimated that one pound (454 g) of nanoparticles can cleanse between 10,000 and 30,000 pounds of water. In small-scale tests, TCE levels were reduced by more than 90% using iron nanoparticles.[11]

Answer the following questions regarding the information above:

1. How many grams of iron powder would it take to present a surface area equal to that of 1 gram of nanoparticles?

$$\textbf{1 gram nanoparticles} \times \frac{\boxed{}}{\textbf{1 g np}} \times \frac{\textbf{1 gram iron powder}}{\boxed{}} = \boxed{}$$

2. Based on what you have learned about the affect of increased surface area, how would the use of nanoparticles affect the rate of TCE cleanup?

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[8] Chan, D. B., et.al. Zero Valent Iron (ZVI) Powder injection for in-situ dechlorination of chlorinated organic compounds at Hunters Point Shipyard. San Francisco, CA http://www.arstechnologies.com/pp_drchan.ppt

[9] Goho, A. Special Treatment: Tiny technology tackles mega messes. *Science News*. April 23, 2005, vol 167, p.266-268.

[10] Borschardt, J. K. Small science may clean a big problem. *Christian Science Monitor*. February 10, 2005 http://www.csmonitor.com/2005/01210/ p14s01-sten.html

[11] Borschardt, J. K. Small science may clean a big problem. *Christian Science Monitor*. February 10, 2005 http://www.csmonitor.com/2005/01210/ p14s01-sten.html

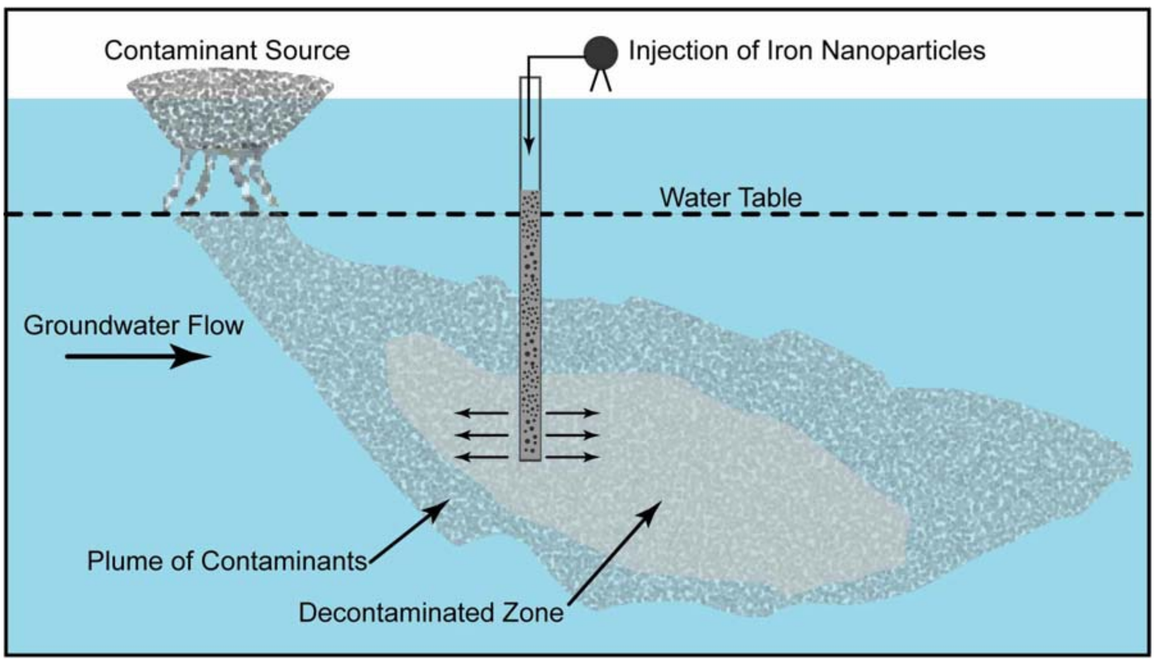
3. What is the minimum number of liters of water that can be cleansed of TCE by 1 g of iron nanoparticles?

$$\textbf{10,000 lb. } H_2O \times \frac{\boxed{}}{1 \text{ lb.}} \times \frac{1 \text{ L } H_2O}{\boxed{}} = \boxed{}\ H_2O \div \boxed{}\ \text{iron} = \boxed{}$$

4. Why is the estimate for the cleansing ability of one pound of iron nanoparticles given in such a wide range—10,000 to 30,000 pounds of water?

PART 2

On-Site Testing of the Dechlorination Process



Adapted from Goho, A., Special Treatment: Tiny technology tackles mega messes. *Science News*. April 23, 2005, vol. 167, p.266.

In a more extensive on-site test, iron nanoparticles coated with palladium and platinum were injected into TCE-contaminated groundwater and soil at Hunters Point Shipyard, close to San Francisco Bay, in a manner similar to that diagrammed above. The table below shows some partial results from this test.[12]

[12] Chan, D. B., et.al. Zero Valent Iron (ZVI) Powder injection for in-situ dechlorination of chlorinated organic compounds at Hunters Point Shipyard. San Francisco, CA http://www.arstechnologies.com/pp_drchan.ppt

Results of on-site injection of iron nanoparticles dechlorination project
Hunters Point Shipyard, San Francisco Bay[13]

Date of Test	**12/01/02**		**1/06/03**		**2/03/03**	
Distance from Injection Well 1	TCE Concentration ppb	pH	TCE Concentration ppb	pH	TCE Concentration ppb	pH
8 ft (2.4 m)	41,000	6.92	100	7.87	160	8.51
10 ft (3.6 m)	5,100	6.77	47	8.18	79	8.61
20 ft (7.1 m)	7,400	6.91	690	7.08	610	7.17
Distance from Injection Well 2						
0 ft (0 m)	88,000	7.32	11	8.24	78	8.27
6 ft (1.8 m)	76,000	6.9	420	8.52	730	7.91

Analyze the results shown in this data table.

5. a. Where did the greatest decrease in TCE concentration in both test sites occur?

   b. What might account for this?

   c. What percent decrease in TCE concentration is observed at 20 ft. from Well 1 between December 1, 2002 and January 6, 2003?

   d. How does this compare with the 90% decrease found in small scale test cases mentioned in part 1 above?

6. What might be a reason why TCE concentrations <u>increased</u> in most areas of cleanup from 1/6/03 to 2/03/03?

13 Chan, D. B., et.al. Zero Valent Iron (ZVI) Powder injection for in-situ dechlorination of chlorinated organic compounds at Hunters Point Shipyard. San Francisco, CA http://www.arstechnologies.com/pp_drchan.ppt

7. a. Why does the pH of the water increase during treatment?

   b. This pH change would tend to support which of the two possible pathways shown on the first page of this problem sheet?

8. Which form of iron nanoparticles do you think would present the least risk to the environment—those coated in polymers or those coated with platinum and palladium (see image)? State the reason(s) for you answer.

9.

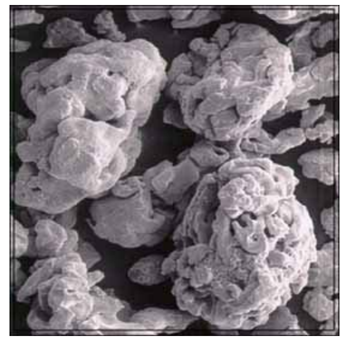


Image of platinum/palladium coated iron nanoparticles

10. What question(s) would you want to ask the investigators of this test project?

PART 3

Ethical considerations involved in nanoparticle environmental cleanup

When questioned about the possible by-products of using iron nanoparticles to clean-up TCE, scientists are fairly confident that there will be no negative impact. Most of the unused iron nanoparticles will attach to soil and slowly oxidize to form rust ($Fe_2O_3 \cdot H_2O$) and become part of the background soil.[14] However, scientists plan to perform more experiments to document this before iron nanoparticles go into wider use.

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly called the Superfund Act, which allows the federal government to identify and respond to land, air, and water sites that have become contaminated with toxic waste and pose an environmental and health threat to the area surrounding them. Superfund monies cover the clean-up of sites that the EPA has placed on its National Priority List, sites that are considered to be the most hazardous in the nation. TCE is one of the contaminants that qualifies a site for Superfund financing.

If you lived close to a Superfund site that contains TCE similar to the one at Hunters Point Shipyard, and environmental scientists were planning to decontaminate it using iron nanoparticles:

1. What specific concerns or questions would you have regarding the treatment of the Superfund site with iron nanoparticles?
2. What further scientific evidence would be needed in order for you to make a decision on using iron nanoparticles for decontamination?
3. Would you be in favor of or opposed to the plan to use iron nanoparticles for decontamination? Explain the basis for your answer.
4. Who do you think should be involved in making the final decision regarding the implementation of this plan?

   Write your answers on separate paper. You will be graded on a 4-point criteria scale for *each* question based upon your ability to write specific, well thought-out responses that are supported by evidence and logical reasoning. You may use evidence from other sources as necessary.

[14] Goho, A. Special Treatment: Tiny technology tackles mega messes. *Science News*. April 23, 2005, vol 167, p.266-268.

Teacher Guide: Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?

The problem presented here is briefly introduced at the beginning of PowerPoint Lesson 2.1. It will serve as the context for Unit 2 *Metallic and Ionic Nanoparticles: Extendable Structures.*

This problem sheet is divided into three parts. Decide whether to make each part an individual or a group assignment (or a combination of both). Small groups could discuss the answers to the questions and whiteboard their responses for reporting out at feedback sessions.

- **Part 1** is to be assigned at the conclusion of Lesson 2.2. Students should read all of the material in Part 1 and answer questions 1–4 following the reading. This may be assigned as homework. Lesson 2.3 begins by reviewing their answers to these questions.

- **Part 2** should be assigned at the conclusion of Lesson 2.3. The last few slides of this lesson show the diagram of the test site and data table as presented in Part 2 of their problem sheet. You may want to spend some time looking at these with students so that they can understand the diagram and the data table. Students should study the diagram and data table and answer questions 5–9 following the table on their problem sheet. This may be assigned as homework. You can review the answers to these questions in a discussion format on the due date.

- **Part 3** is to be completed prior to beginning Unit 3. Students must write responses to four ethics-related questions. This may also be assigned as homework after reviewing the first 9 questions from Parts 1 and 2. Students are encouraged to write out thoughtful and well-supported answers using the evidence from the problem sheet and other sources as needed. The grading rubric is on the answer key following this page. Additionally, you may choose to hold small-group or whole-class discussions on these ethics questions prior to continuing with the next unit. One option is to allow students to meet in small groups to discuss their individual responses, and then each small group drafts a final response to be handed in and graded using the rubric. A second option would be to use the philosophical chairs method described in the Teacher Guide as a forum for open debate using student responses to question 3.

Answer Key: Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?

PART 1

1. How many grams of iron powder would it take to present a surface area equal to that of 1 gram of nanoparticles?

   1 gram nanoparticles x $\frac{33.5\ m^2}{1\ g\ np}$ x $\frac{1\ gram\ iron\ powder}{0.900\ m^2}$ = 37 g

2. Based on what you have learned about the effect of increased surface area, how would the use of nanoparticles affect the rate of TCE cleanup?

   increased surface area increases the rate of reaction

3. What is the minimum number of liters of water that can be cleansed of TCE by 1 g of iron nanoparticles?

   This question may be solved two ways:

   10,000 lb. H_2O x $\frac{454\ g\ H_2O}{1\ lb.}$ x $\frac{1\ L\ H_2O}{1000g\ H_2O}$ = 4540 L H_2O / 454 g iron = 10 L

   Or

   1 g iron x $\frac{1\ lb\ iron}{454\ g\ iron}$ x $\frac{10{,}000\ lb.\ H_2O}{1\ lb.\ iron}$ x $\frac{454\ g\ H_2O}{1\ lb\ H_2O}$ x $\frac{1\ L\ H_2O}{1000\ g\ H_2O}$ = 10 L

   (For 30,000 pounds of water cleaned, it would be three times the answer above.)

4. Why is the estimate for the cleansing ability of one pound of iron nanoparticles given in such a wide range—10,000 to 30,000 pounds of water?

   It depends on the concentration of TCE in the water.

   It depends on the conditions (porosity, permeability) of the sediment at the site.

PART 2

Analyze the results shown in the data table in student handbook page 47.

5. a. Where did the greatest decrease in TCE concentration in both test sites occur?
Closest to injection point

b. What might account for this?
Highest concentration of iron nanoparticles are found nearest to the injection point

i. What percent decrease in TCE concentration is observed at 20 ft. from Well 1 between December 1, 2002 and January 6, 2003?

Even the smallest percent decrease (7400 ppb to 690 ppb) is a decrease of 91%.

d. How does this compare with the 90% decrease found in small scale test cases mentioned in part 1 above?
It is similar to the small scale test cases.

6. What might be a reason why TCE concentrations increased in most areas of cleanup from 1/6/03 to 2/03/03?
The flow patterns of the underground water may have spread out the remaining TCE to equalize the concentrations.

7 a. Why does the pH of the water increase during treatment?
One of the dechlorination reactions uses up H^+ ions, thus increasing the pH.

b. This pH change would tend to support which of the two possible pathways shown on the first page of this problem sheet?
The first one—where the iron is oxidized.

8. Which form of iron nanoparticles do you think would present the least risk to the environment—those coated in polymers or those coated with platinum and palladium (see image)? State the reason(s) for you answer.
Answers will vary.

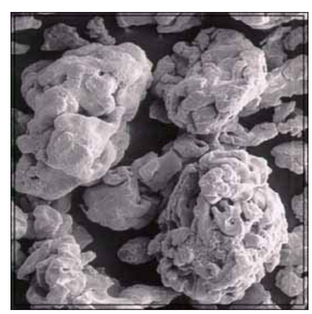


Image of platinum/palladium coated iron Nanoparticles

9. What question(s) would you want to ask the investigators of this test project?
Answers will vary.

Part 3 - Ethics *Criteria 1 Questioning*				
4 Advanced: The student provides specific questions that demonstrate a clear understanding of the nature of the contaminants, the scientific basis for the treatment, and the testing that has been or needs to be done before proceeding.	**3** Proficient: The student poses questions about the type and extent of testing that scientists plan to do with conditions similar to the contamination area. The student questions the long term and short term risks and benefits of the proposed methods compared with other options.	**2** Developing: The student questions the type of testing that has been done. The student questions the risks and benefits of the proposed method.	**1** Basic: The student provides a general question or questions what "fairly confident" means. It is not obvious why questions were chosen.	**0** An irrelevant response is given.
Criteria 2 Scientific Understanding				
4 Advanced: Clearly describes and explains the scientific evidence for *and* against using iron nanoparticles for decontamination. Shows understanding of past learning. Integrates other scientific ideas.	**3** Proficient: Describes the scientific evidence for *or* against using iron nanoparticles for decontamination. Shows understanding of past learning Integrates other scientific ideas.	**2** Developing: Describes the scientific evidence for *or* against using iron nanoparticles for decontamination. Explains information that is only available in the assigned reading/activities.	**1** Basic: Mentions some of the scientific reasons for making the decision.	**0** Fails to mention scientific data.
Criteria 3 Decision Making				
4 Advanced: Uses (or makes explicit) relevant criteria to favor or oppose the plan. The student explains why the plan selected is or is not appropriate based on scientific, economic, and social issues.	**3** Proficient: Uses relevant criteria to favor or oppose the plan, but does not completely explain why the plan is the most appropriate. Student includes scientific information but pays little attention to the economic and social issues.	**2** Developing: Uses criteria that are related to the plan but not the most relevant.	**1** Basic: Uses criteria that are unrelated to the plan.	**0** No judgment can be made.
Criteria 4 Decision Makers				
4 Advanced: States that the decision should be made by government authorities informed by scientists in conjunction with environmental agencies *and* local residents.	**3** Proficient: States that the decision should be made by government authorities informed by scientists in conjunction with environmental agencies *or* local residents.	**2** Developing: States that the decision should be made by the appropriate government authorities, but does not indicate they will be informed by scientists or local residents.	**1** Basic: States that the decision should be made only by the local residents.	**0** The student does not state who should make the decision.

Student Version: Problem Sheet 6–
Graphing the Melting Points of Gold Nanoparticles
(Student Handbook, Pages 51–52)

Instructions:
Use a computer with an electronic spread sheet application or graph paper to plot this experimental data.

Size of gold nanoclusters	Melting point (°C)
~ 20 atoms	~500
~ 50 atoms	~800
~100 atoms	~ 920
~200 atoms	~ 980

Note: the symbol "~" means "approximately."

Questions for analyzing the graph

1. Why do you think that all of these data are indicated to be approximations?

2. Describe the changes in kinetic energy of the atoms in a solid as the temperature of the solid increases. Explain your answer in terms of how atoms in a solid vibrate.

3. What is the definition of melting point? Describe what happens at the melting point in terms of the structure of the solid and the energy of the atoms involved.

4. When a solid melts, such as an ice cube, where do you observe the liquid forming first? Why do you think this is so? Explain your answer in terms of the number of nearest neighbors on the surface atoms compared with interior atoms.

5. Why do you think that all the melting points for nanosamples are lower than that of the macrosample melting point? Explain your answer by comparing the surface area to volume ratio of macro vs. nano samples and the energy needed to overcome attractive forces between atoms.

6. The melting point of a macrosample of gold is a physical constant, 1064 °C. Why don't nanosamples reach this melting point? Explain your answer in terms of surface area to volume ratios of macrosamples of gold vs. nanosamples of gold.

Lesson 2.3: Extendable Structures: Melting Point, Color, Conductivity
Teacher Guide: Problem Sheet 6–
Graphing the Melting Points of Gold Nanoparticles

Preparation of Materials
For each student (or each pair of students)

- computer with access to Microsoft Excel™ or similar electronic spread sheet/graphing program - OR - graph paper to plot this experimental data.

Procedure

1. Students should turn to *Problem Sheet 6– Graphing the Melting Points of Gold Nanoparticles* in their Student Handbook.
2. If necessary, give students further instructions for graphing the data using the appropriate program on their computer.
3. Circulate among the class to check student progress and encourage discussion as necessary.
4. When students are finished, review the answers for questions 1–5 in class and then proceed to slide 5 of Lesson 2.3 to review questions 6 and 7.

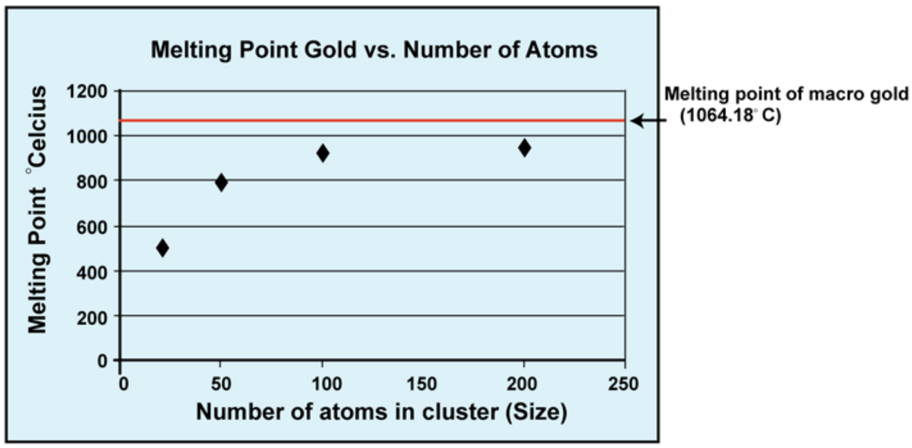
Optional:
This activity presents a good opportunity to discuss independent and dependent variables with students and how to graph correlated data.

In this case the independent variable is the size of the gold nanoparticle and it determines the dependent variable, the melting point. The dependent variable (melting point) always changes in response to the value of the dependent variable (the size of the nanoparticle). Thus, the dependent variable is “dependent upon” the independent variable.

Many students may not also know what type of graph to create (i.e., pie chart, bar graph, scatter plot, line graph). When graphing correlated data, the independent variable (size) should be on the X-axis, and the dependent variable should be on the Y-axis (melting point). When a relationship or correlation between data is desired, an X-Y scatter plot with data points connected (either “dot-to-dot” or with a best-fit line) is the most desirable.

Answer Key: Problem Sheet 6–
Graphing the Melting Points of Gold Nanoparticles

Instructions:
Use a computer with an electronic spread sheet application or graph paper to plot this experimental data.



Questions for analyzing the graph
1. Why do you think that all of these data are indicated to be approximations?
   These data are most likely *measured indirectly with instrumentation*. Since about 4 atoms of gold lined up side by side measure about 1 nm, even the largest of these nano-sized samples are not visible to the human eye. The temperatures may be approximations because with this small a sample, *melting may occur so rapidly* that it is difficult to read the temperature plateau, even with a very sensitive digital thermal probe.

2. Describe the changes in kinetic energy of the atoms in a solid as the temperature of the solid increases. Explain your answer in terms of how atoms in a solid vibrate.
   All atoms in the solid vibrate and as the temperature increases, the kinetic energy increases as the amplitude of these vibrations increases.

3. What is the definition of melting point? Describe what happens at the melting point in terms of the structure of the solid and the energy of the atoms involved.
   The melting point is the temperature at which the regular structure of a solid is disrupted and the solid is converted to the unordered arrangement of a liquid. The higher energy and vibrations of the atoms are strong enough to overcome the attractive forces between the atoms in the crystal.

4. When a solid melts, such as an ice cube*, where do you observe the liquid forming first? Explain your answer in terms of the number of nearest neighbors on the surface atoms compared with interior atoms.

   At the surface (outside). Surface atoms have fewer nearest neighbors attracting them (lower CN), so it would take less additional energy to make surface atoms vibrate strongly enough to overcome the attractive forces between it and its nearest neighbors. This phenomenon is called surface melting, and it is what enables ice skating.

*** Note to teacher: This would be a good time to show the video clip "Melting Ice" found at: http://www.mcrel.org/nanoleap/multimedia/index.asp.** Choose from the Videos column.

5. Why do you think that all the melting points for nanosamples are lower than that of the macrosample melting point? Explain your answer by comparing the surface area to volume ratio of macro vs. nano samples and the energy needed to overcome attractive forces between atoms.

   The melting points of metallic solids appeared to be directly related to the size of the nanoparticle. Since nanoparticles have very large fractions of surface atoms, there is sufficient energy to overcome the attractive forces between them and their nearest neighbors at a lower temperature.

6. The melting point of a macrosample of gold** is a physical constant, 1064 °C. Why don't nanosamples reach this melting point? Explain your answer in terms of surface area to volume ratios of macrosamples of gold vs. nanosamples of gold.

   Nanosamples of gold have a much greater surface area to volume ratio compared with macrosamples. At least 1000 atoms or more would be required to reach the melting point of macrosamples of gold.

** **Note to teacher: This would be a good time to show the animation "Melting a Nanoparticle" found at: http://www.mcrel.org/nanoleap/multimedia/index.asp.** Choose from the Videos column.

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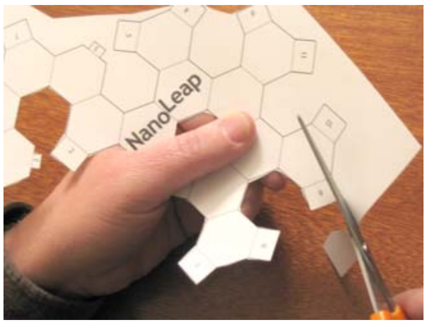
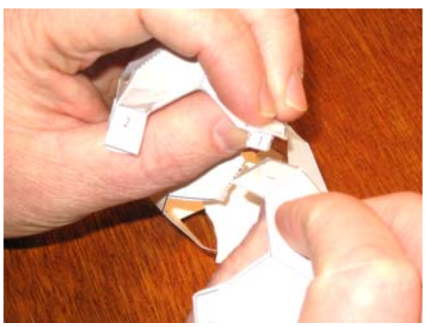
Teacher Guide Unit 3: Neat and Discrete Carbon Nanoparticles
Student Version: Problem Sheet 4–Buckyball Model
(Student Handbook, Page 53–55)

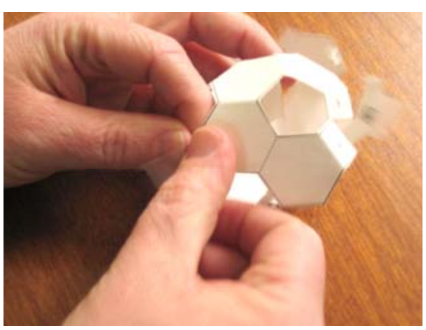
To make a model of a buckyball,
1) Cut out the figure along the solid lines. Do not cut the dotted lines.



2) Fold along the dotted lines. Make sure to fold along the hexagons as well as the tabs.
3) Begin to match up the tabs. Match large tab 1 with small tab 1. The dotted lines should be aligned with one another.



4) Attach a piece of tape to secure the tabs where the dotted lines of each tab meets.



5) Repeat the process matching tabs and taping them together (2 through 11).
6) When completed, you will have a model of a buckyball.

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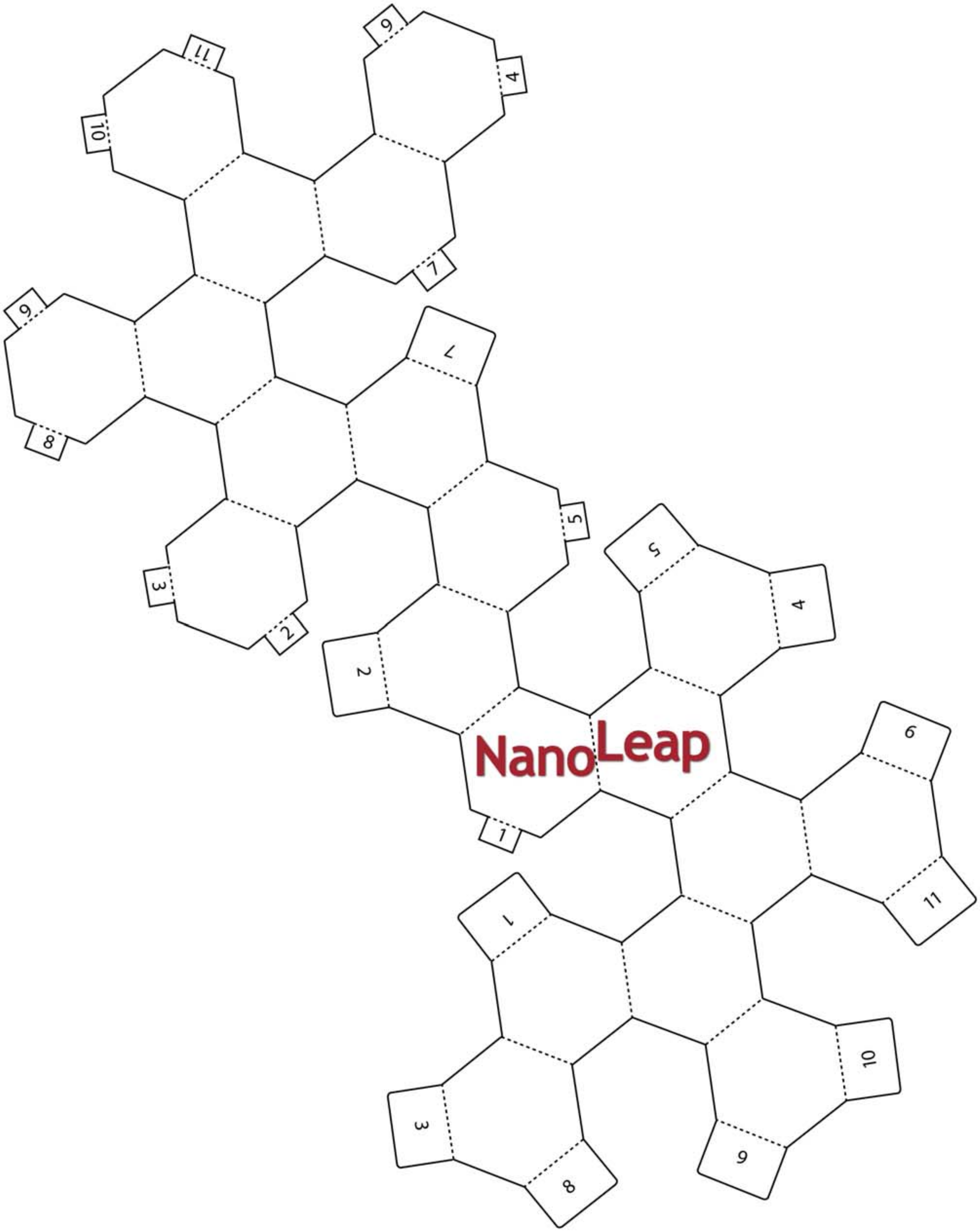
11
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Neat and Discrete Carbon Nanoparticles
Teacher Guide: Activity Sheet 4–Buckyball Model

Models are invaluable in helping students visualize the three-dimensional structures of organic substances, especially complex ones like buckyballs and other fullerene types of molecules. You are strongly urged to utilize model kits as you pursue this module. Buckyball kits are readily available as are the traditional ball and stick models that are so commonly used in chemistry courses.

Materials required:
- Problem Sheet 7
- Transparent tape (one long strip for each student – this can be taped to the edge of their desk before they begin the activity)
- Scissors – one pair for each student

Students will make a buckyball out of paper in this activity. Once they build a buckyball they can see the symmetry of the molecule and appreciate the equivalence of all of the carbon atoms. Make sure they observe the relative locations of the two kinds of rings. It looks like a soccer ball.

This is the structure that the scientists eventually decided is correct for C_{60}. It is a spherical structure that does NOT contain any dangling bonds. Therefore, all the carbon atom requirements are met in the structure. The lack of dangling bonds also accounts for its surprising lack of reactivity.

The buckyball, which is a solid, contains the repeating pattern of the geodesic domes made famous by the architect Buckminster Fuller. Consequently, it has been named *buckminsterfullerene* and often is referred to whimsically as a "buckyball." In 1991 it was named as the molecule of the year by the journal *Science.*

Also make note of the fact that buckyballs have now been identified in interstellar dust as well as in certain old geologic structures here on Earth. So in answer to the question "Are they old or new materials?" One can say they are new only to us!!

Resources:
- http://invention.smithsonian.org/centerpieces/ilives/kroto/buckyball.pdf
  This is a very good set of directions for guiding students in the construction of a paper model of a buckyball.

- www.chem.northwestern.edu/~todom/ret/RET%20handout-%20Garrett%20Forbes.pdf
  This is another set of buckyball model construction instructions with somewhat of a mathematical emphasis. Suitable for more advanced students.

- http://www.indigo.com/models/gphmodel/buckyball-fullerene-model-W.html
  This is a reasonably inexpensive model kit for constructing a buckyball. (ca. $20)

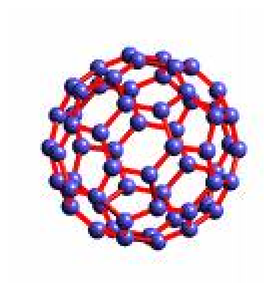
- http://bfi.easystorecreator.com/items/Toys%5EModels/list.htm
  This is another commercial source of very good buckyball models.

Neat and Discrete Carbon Nanoparticles

Problem Sheet 7–Volume of a Buckyball

(Student Handbook, Page 57)

1) What approximate shape is a buckyball?



2) What is the equation for the volume of that shape?

3) Using the diameter of 1nm, calculate the volume.
Show your work.

4) Would the following fit inside of a buckyball?
An ***atom*** of nitrogen –

A ***molecule*** of sulfuric acid –

A ***molecule*** of hydrogen –

Neat and Discrete Carbon Nanoparticles
Teacher Guide: Problem Sheet 7–Volume of a Buckyball

Materials Required:
- Problem Sheet 10
- Calculator for each student

What is the volume of a buckyball? This is a straightforward application of algebra. If the students do not remember the formula for calculating the volume of a sphere ($V = {}^4/_3\, \pi r^3$), give it to them and ask them to proceed with the calculation after reminding them that the approximate *diameter* of a buckyball is 1nm. Make sure they record their answers. The purpose of this calculation is largely to emphasize the idea that a buckyball is hollow and there is “empty” space inside of it.

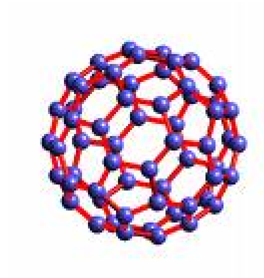
You may also introduce the angstrom as a dimension. This unit has been used for many years by chemists when discussing molecular sizes because it is so convenient--molecular sizes lie in the small-number range when angstrom units are used. If students read about fullerenes it is likely that they will encounter this unit; consequently, it is a good idea to introduce it here. One nanometer is 10 angstroms. The usually quoted diameter of a buckyball is 7.6 angstroms. As a rule the fullerenes have a diameter of 7 to 15 angstroms, which is 6 to 10 times the diameter of a typical atom.

If you are interested in making the students more conversant with units and conversions, ask them to compute the volume of a buckyball in cubic angstroms (**answer: 180 cubic angstroms**).

You may also ask them to compute the volume of a buckyball in cubic angstroms using a diameter of 7.6 Å (**answer: 230 $Å^3$**).

After students complete this problem sheet individually, continue with Lesson 3.2, Slide 6 to discuss the answers to question 4.

Neat and Discrete Carbon Nanoparticles
Answer Key: Problem Sheet 7–Volume of a Buckyball



1) What approximate shape is a buckyball?

sphere

2) What is the equation for the volume of that shape?

$V = {}^{4}/_{3}\ \pi\ r^{3}$

3) Using the diameter of 1nm, calculate the volume.
Show your work.

d = 1 nm, so radius (r) = 0.5 nm
$V = {}^{4}/_{3}\ \pi\ r^{3}$
$= {}^{4}/_{3}\ (3.14)\ (0.5)^{3}$
$= 0.52\ nm^{3}$

4) Would the following fit inside of a buckyball?
See slide 7 from Lesson 3.2
An ***atom*** of nitrogen–
Definitely

A ***molecule*** of sulfuric acid–
Not likely

A ***molecule*** of hydrogen–
Quite Possibly

Glossary
(Student Handbook, Pages 58–62)

Aggregate–A group of molecules that have clumped together.

Allotrope–One of two or more forms of an element in the same physical state. Different allotropes can have very different physical and chemical properties. The two allotropes of carbon commonly found in nature are diamond and graphite.

Angstrom (Å)–A unit of length that has been used extensively in chemistry for many years and is still found in the literature. It has been favored by chemists because molecular size in Angstroms often are small one or two digit numbers that are easy to remember. One nanometer equals ten Angstroms.

Atomic 2 p orbitals–Atoms possess three atomic orbitals (in the second shell) that are labeled with the letter "p" and are "dumbbell" shaped. The three orbitals are mutually orthogonal, meaning that one is directed along the x axis, one along the y axis, and one along the z axis in a Cartesian coordinate system. The orbitals are distinguished from each other by affixing a subscript to the letter "p" to indicate the direction of the orbital.

Bond–A linkage or connection between atoms that involves trading or sharing valence electrons.

Bond angle–The angle between two covalent bonds.

Bond strain–Refers to situations where a hybrid set of orbitals is forced into a non ideal geometry. For example, if a tetrahedral molecule is forced into a somewhat flattened geometry, strain is introduced into the sp^3 hybrid bonds. If the strain is sufficiently large, bonds break or the molecule adopts a different hybridization scheme.

Bottom-Up Production Techniques–Building larger objects from smaller building blocks. Nanotechnology seeks to use atoms and molecules as those building blocks.

Buckminsterfullerenes–A term used interchangeably with buckyballs. Named after the architect Buckminster Fuller, who is famous for the geodesic dome, which buckyballs resemble.

Buckyballs–C_{60} molecules; spherical molecules made up of 60 carbon atoms arranged in a series of interlocking hexagonal and pentagonal shapes, forming a structure similar to a soccer ball.

Bulk technology–Technology in which atoms and molecules are manipulated in bulk rather than individually. The production techniques described in your chemistry text are bulk techniques.

Ceramics–Materials that are hard, resistant to corrosion, and are electrical insulators. They are inorganic non-metallic materials whose formation is due to the action of heat.

Chemical Vapor Deposition (CVD)–A technique used to deposit coatings; in which reactant gases, heated above the substrate, react and form a film on the substrate.

Classical Physics–Physics based on principles developed before the rise of quantum theory, including Newton's Laws of Motion, mechanics, electrodynamics, and thermodynamics.

Clusters–A collection of up to 50 atoms or reactive molecules. Cluster compounds are usually surrounded by a ligand shell that allows isolation of the cluster.

Colloid–A stable liquid phase containing particles in the 1-1000 nm range. The gold particles embedded in liquid glass to form stained glass windows are colloids.

Composites–Engineered materials, such as concrete, made from two or more constituent materials that remain separate and distinct on the macroscopic level while forming a single component.

Covalent bond–A linkage produced through the sharing of one or more pairs of electrons in the region between two atoms.

Discrete nanoparticles–Have sizes in the range 1 to 100 nm and which resemble large molecules and cannot be extended in three dimensions to make a macro-sized material. They are "individual" particles that have unique characteristics determined by their composition and structure.

Dispersion force–A weak attractive force between molecules. The force is far weaker than a covalent bond.

Double bond–Two shared pairs of electrons between two bonded atoms.

Endohedral–On the inside of a closed polyhedral structure.

Exohedral–On the outside of a closed polyhedral structure.

Fullerenes–A molecular form of pure carbon discovered in 1985 that represents a new allotrope of carbon. These are cage-like structures of carbon atoms that contain 60 to 500 carbon atoms. The most readily available form is C_{60}–the well-known buckminsterfullerene.

Extendable Nanostructures–These are structures that can be imagined to grow without limit by adding more structures in (usually) three dimensions. As a rule, extendable structures are composed of metallic, ionic, or network solids.

Fullerenes–Are materials with:

- a three dimensional network of carbon atoms,
- each atom being connected to exactly three neighbors, and
- each atom being bonded by two single bonds and one double bond (e.g., C_{82}).

Graphene–Refers to a single layer of graphite.

Icosohedron–One of the five regular convex polyhedra. That is to say, polyhedra in which the faces are equivalent and are themselves regular polyhedra. The other members of the group are: tetrahedron, cube, octahedron, and dodecahedron.

Lewis structure–A representation of the electronic structure of a molecule or ion in which the electrons are shown by dots of lines (electron pairs). Also called Lewis electron dot structure.

Ligands–In macroscale chemistry, ligands are molecules or ions bonded to the central metal atom in coordination compounds. In nanotechnology, ligands are molecules or ions bonded to nanoparticle cores of ions or active atoms and molecules; they form shells that isolate, stabilize, and protect the nanoparticle cores.

Molecular geometry–The shape of a molecule in which the relative positions of the constituent atoms are defined. For example, if all of the constituent atoms of a molecule lie in a plane the molecule is referred to as a "planar" molecule.

Mass spectrometer–An instrument that accelerates ions and then sorts them according to mass by means of a magnetic field.

MWNT–Multiple walled nanotube.

Nanobalance–A device used to determine the mass of sub-micron particles such as viruses.

Nanobot–A nano-sized robot; envisioned as a futuristic robot that might, for example, be used to deliver drugs to specific cells in the body.

Nanocrystal–A particle that consists of a single crystal in the nanometer-size range. It can also describe an aggregate of anywhere from a few hundred to tens of thousands of atoms that combine into a crystalline form of matter known as a "cluster." Nanocrystals are about ten nanometers in diameter, which is larger than most molecules but smaller than bulk solid samples; therefore, they frequently exhibit physical and chemical properties somewhere in between. A nanocrystal is mostly surface and little interior, so its properties can vary considerably as the crystal grows in size.

Nanoelectromechanical systems (NEMS)–A generic term used to describe nanoscale electrical/mechanical devices.

Nanofabrication–The manufacturing or preparation of nanostructures.

Nanoparticle–A solid particle in the 1-100 nm size range that could be a single crystallite, noncrystalline, or an aggregate of crystallites.

Nanoscience–The study of fundamental principles of nanoparticles or structures with at least one dimension roughly between 1 and 100 nanometers.

Nanoshells–Nanoscale spheres which can absorb or scatter light at virtually any wavelength.

Nanostructured or nanophase material–Any solid material that has a nanometer dimension; particles have three such dimensions; thin films have two such dimensions; thin wires have one such dimension. These can be extendable or discrete (molecular-like) nanostructures.

Nanotechnology–The science of manufacturing materials and machines at the nanometer or the atomic/molecular scale; the ability to create and work with structures and materials at nano level.

Nanotubes–Composed largely of hexagonally arranged carbon atoms that have diameters in the nanometer range.

Nanowires–One-dimensional structures often with unique electrical and optical properties.

Network covalent–describes a structure in which all the atoms in a crystal are linked by a network of covalent bonds.

Octet rule–States that atoms like carbon always have a share in eight valence electrons.

Orbital–A region in space around an atom in which there is a high probability of finding an electron.

Physical Vapor Deposition–A technique to deposit coatings or thin films in which substances are first vaporized by heating or bombarding with ionized atoms and then deposited on a surface.

Positional Assembly–Constructing materials by arranging atoms or molecules one at a time using a manipulator.

Quantum dot–Nanometer-sized semiconductor crystals capable of confining a single or a few electrons in discrete energy states, just as they would be in an atom.

Quantum Mechanics–A mathematical explanation of the behavior of materials at the atomic and molecular level.

Reactivity–The tendency of molecules and atoms to undergo chemical change. Although reactivity often is difficult to predict, it is clear that two situations generally lead to high reactivity. First, if a molecule is electron deficient such that its constituent atoms do not possess an octet, it will tend to seek electrons from other molecules and thus be reactive. Second, if an atom in a molecule possesses pairs of electrons that are not bonded to another atom, the molecule will tend to be reactive if the atom in question does not have its preferred number of bonds to neighbors. Carbon always wants to have four bonds to nearest neighbors.

Resonance–A concept used to rationalize the properties of a molecule for which a single Lewis structure is inadequate or not unique. Resonance structures differ only in the distribution of the valence electrons. The molecular structures are the same from one resonance structure to the next.

Space Elevator–A cable with one end anchored to the surface of the Earth, the other to a satellite in stable orbit. It will be approximately 22,000 miles long and possibly constructed of mass-produced nanotubes.

SWNT–Single walled nanotube.

Tetrahedral–In a tetrahedral molecule the central atom is surrounded by four other atoms in the shape of a tetrahedron.

Top-Down Production–A method of building of nanostructures starting with large bulk material and creating smaller features by removing parts using precision and miniaturization techniques−photolithography and etching are examples of this production technique.

Trigonal planar–Refers to a structure in which the central atom is at the center of an equilateral triangle formed by three peripheral atoms. The entire structure is flat.

Unsatisfied valence–When an atom does not possess the number of bonds needed. If carbon is bonded to only three other atoms it would not be satisfied and would be said to have “unsatisfied valence.”

Valence–The number of bonds that a particular atom desires. The valence of carbon is four, meaning that carbon always wants to be in situations where it possesses four bonds. If it does not have four bonds it is not stable.

Valence electron–An electron located in the outermost energy level of an atom.

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Author Names ______________________________ ______________________________

Reviewer Name ______________________________

Peer Review Scoring Guide for Writing #1

Directions: Scientists rely on peers and colleagues to offer critical feedback so that they may strengthen their work. The scrutiny provided by the scientific community during the peer review process is essential to scientific investigations. This tool will assist you in helping your classmates strengthen the writing for their final posters before the Poster Fair. By providing detailed responses to the questions below and assigning a score, you can provide valuable feedback to your classmates.

1. Are there any guiding questions that were left unanswered or were only partially answered? Explain.

2. Based on what you studied, is there anything missing? Is there any information you would suggest including?

3. Is the conclusion well supported?

4. What scores do you think this writing should earn? Write in or circle the scores for each criterion. Also, circle comments on the rubric that you feel are particularly relevant.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Understanding of Content/Research *Use of Product*: **Explanations identify uses of product based on research.**			
Detailed and demonstrating a sophisticated understanding. **No inaccuracies. Extensive** research.	**Complete explanations**. **No clear** inaccuracies or misconceptions. **Solid research**.	Basic explanations are **inaccurate** or **incomplete**. **Average** research.	**Missing important** information and/or inaccuracies. **Little** research.
Physical and Chemical Characteristics: **Explanations identify the physical and chemical characteristics.**			
Clearly identifies both physical and chemical characteristics **in detail**.	**Clearly identifies** both physical and chemical characteristics.	Some **inaccurate or incomplete** physical and chemical characteristics.	**Not able to distinguish between** physical and chemical characteristics.
Nano vs. Macro Characteristics: **Explanations identify characteristics and differences between the nanoproduct and macro-scale. Explanations give underlying reasons for the differences.**			
Clearly identifies Nano and Macro characteristics and **reasons for the difference in detail.**	Clearly identifies Nano and Macro characteristics and **reasons for the difference.**	Some **inaccurate or incomplete** identification of Nano and Macro characteristics.	**Not able to distinguish between** Nano and Macro characteristics.
Thinking and Reasoning: Safety, social, and **ethical issues** resulting from production or product use.			
Valid and thoughtful with scientific and logical **supporting evidence**.	Valid **but little supporting** logic or scientific evidence.	**Does not fully support thinking** with specific evidence.	**No supporting** evidence provided.

5. Are there any parts that are confusing to read? Which parts could use some clarification?

6. Are there any parts that don't sound like the authors' own words? Explain what needs to be paraphrased better.

7. What score do you think this writing should earn? Circle the score for the criterion. Also, circle comments on the rubric that you feel are particularly relevant.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Writing Style and Mechanics: Brief summary paragraphs, bulleted lists, text boxes, and tables that highlight *key* information.			
Concise, clear, and engaging explanations. Paraphrases. **Flawless** spelling and grammar.	**Concise and clear explanations. Paraphrases**. **Minor errors** with spelling and grammar.	**Appropriate writing**. **Paraphrases some. Many errors** with spelling and grammar.	**Little attention** to the writing format. **Poor** paraphrase. **Many errors** with spelling and grammar.

NanoLeap

Author Names ______________________________ ______________________________

Reviewer Name ______________________________

Peer Review Scoring Guide for Writing #2

Directions: Scientists rely on peers and colleagues to offer critical feedback so that they may strengthen their work. The scrutiny provided by the scientific community during the peer review process is essential to scientific investigations. This tool will assist you in helping your classmates strengthen the writing for their final posters before the Poster Fair. By providing detailed responses to the questions below and assigning a score, you can provide valuable feedback to your classmates.

1. Are there any guiding questions that were left unanswered or were only partially answered? Explain.

2. Based on what you studied, is there anything missing? Is there any information you would suggest including?

3. Is the conclusion well supported?

4. What scores do you think this writing should earn? Write in or circle the scores for each criterion. Also, circle comments on the rubric that you feel are particularly relevant.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Understanding of Content/Research *Use of Product*: **Explanations identify uses of product based on research.**			
Detailed and demonstrating a sophisticated understanding. **No inaccuracies. Extensive** research.	**Complete explanations**. **No clear** inaccuracies or misconceptions. **Solid research**.	Basic explanations are **inaccurate** or **incomplete**. **Average** research.	**Missing important** information and/or inaccuracies. **Little** research.
Physical and Chemical Characteristics: **Explanations identify the physical and chemical characteristics.**			
Clearly identifies both physical and chemical characteristics **in detail**.	**Clearly identifies** both physical and chemical characteristics.	Some **inaccurate or incomplete** physical and chemical characteristics.	**Not able to distinguish between** physical and chemical characteristics.
Nano vs. Macro Characteristics: **Explanations identify characteristics and differences between the nanoproduct and macro-scale. Explanations give underlying reasons for the differences.**			
Clearly identifies Nano and Macro characteristics and **reasons for the difference in detail.**	Clearly identifies Nano and Macro characteristics and **reasons for the difference.**	Some **inaccurate or incomplete** identification of Nano and Macro characteristics.	**Not able to distinguish between** Nano and Macro characteristics.
Thinking and Reasoning: Safety, social, and **ethical issues** resulting from production or product use.			
Valid and thoughtful with scientific and logical **supporting evidence**.	Valid **but little supporting** logic or scientific evidence.	**Does not fully support thinking** with specific evidence.	**No supporting** evidence provided.

5. Are there any parts that are confusing to read? Which parts could use some clarification?

6. Are there any parts that don't sound like the authors' own words? Explain what needs to be paraphrased better.

7. What score do you think this writing should earn? Circle the score for the criterion. Also, circle comments on the rubric that you feel are particularly relevant.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Writing Style and Mechanics: Brief summary paragraphs, bulleted lists, text boxes, and tables that highlight *key* information.			
Concise, clear, and engaging explanations. Paraphrases. **Flawless** spelling and grammar.	**Concise and clear explanations. Paraphrases**. **Minor errors** with spelling and grammar.	**Appropriate writing**. **Paraphrases some. Many errors** with spelling and grammar.	**Little attention** to the writing format. **Poor** paraphrase. **Many errors** with spelling and grammar.

Author Names ______________________________ ______________________________

Reviewer Name _____________________________

Peer Review Scoring Guide for Visual Layout #1

Directions: In this final project, the visual arrangement is as important as the writing in getting your point across. This tool will assist you in helping your classmates strengthen the layout and organization for their final posters before the Poster Fair. By providing detailed responses to the questions below and assigning a score, you can provide valuable feedback to your classmates.

1. Are the images effective in communicating and illustrating key points? Offer an example to support your opinion.

2. What score would you assign this criterion? Circle the score and provide a rationale.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Graphic Explanations / Images: Images communicate and reinforce concepts.			
Reinforcing **important concepts accurately** and creatively.	Captures **most important concepts.** Shows no misunderstanding.	Captures **few important concepts/ reflect inaccuracies.**	Graphics **do not** capture important concepts.

3. Is there a logical flow of text, graphics, and images? Explain.

4. Is there an appropriate balance of text, graphics, and images? Too much text is not appropriate for a poster. However, too many pictures and not enough text may indicate a lack of information.

5. Is there an appropriate amount of margins and space between sections? Too little space may make the poster look messy. Too much space may indicate a lack of information.

6. What score would you assign this criterion? Circle the score and provide a rationale.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Organization and Poster components: Gives title, subheadings, writing, and graphic images. Has a flow of information, spacing, balance between text and graphics/images			
Sophisticated organized, neat, **balance of text and graphics**. Contains all poster components.	**Solid** organization with good design, layout, and neatness. **Appropriate balance of text and images** and **spacing.** Contains all poster components.	**Somewhat organized. Some imbalance between text and images**. Contains all poster components.	**Messy design**. **Significant imbalance between text and images.** Missing some poster components.

7. Do images include a source citation (e.g., Internet site, author, or title)?

8. Are the text citations in APA style? (e.g., author's last name or title)?

9. Is there a separate Works Cited section in APA style?

10. What score would you assign this criterion? Circle the score and provide a rationale.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Citations: Citations on all sources including text and images			
All text and images.	All but one or two text and images.	More than two graphic text or images.	Provides minimal citations.

Author Names ______________________________ ______________________________

Reviewer Name ______________________________

Peer Review Scoring Guide for Visual Layout #2

Directions: In this final project, the visual arrangement is as important as the writing in getting your point across. This tool will assist you in helping your classmates strengthen the layout and organization for their final posters before the Poster Fair. By providing detailed responses to the questions below and assigning a score, you can provide valuable feedback to your classmates.

1. Are the images effective in communicating and illustrating key points? Offer an example to support your opinion.

2. What score would you assign this criterion? Circle the score and provide a rationale.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Graphic Explanations / Images: Images communicate and reinforce concepts.			
Reinforcing **important concepts accurately** and creatively.	Captures **most important concepts.** Shows no misunderstanding.	Captures **few important concepts/ reflect inaccuracies.**	Graphics **do not** capture important concepts.

3. Is there a logical flow of text, graphics, and images? Explain.

4. Is there an appropriate balance of text, graphics, and images? Too much text is not appropriate for a poster. However, too many pictures and not enough text may indicate a lack of information.

5. Is there an appropriate amount of margins and space between sections? Too little space may make the poster look messy. Too much space may indicate a lack of information.

6. What score would you assign this criterion? Circle the score and provide a rationale.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Organization and Poster components: Gives title, subheadings, writing, and graphic images. Has a flow of information, spacing, balance between text and graphics/images			
Sophisticated organized, neat, **balance of text and graphics**. Contains all poster components.	**Solid** organization with good design, layout, and neatness. **Appropriate balance of text and images** and **spacing.** Contains all poster components.	**Somewhat organized. Some imbalance between text and images**. Contains all poster components.	**Messy design**. **Significant imbalance between text and images.** Missing some poster components.

7. Do images include a source citation (e.g., Internet site, author, or title)?

8. Are the text citations in APA style? (e.g., author's last name or title)?

9. Is there a separate Works Cited section in APA style?

10. What score would you assign this criterion? Circle the score and provide a rationale.

Advanced (4)	Proficient (3)	Developing (2)	Novice (1)
Citations: Citations on all sources including text and images			
All text and images.	All but one or two text and images.	More than two graphic text or images.	Provides minimal citations.

NanoLeap

Poster Fair Impressions

Directions: After the Poster Fair, you and your classmates will engage in a discussion about: 1) why nanoscience research and technology is important, and 2) whether or not further nanoscale research and technology is important for the public good. You will use information that you gather during the Poster Fair about three different nano products (other than your own) as evidence to support your position. To prepare for this class discussion, use the table below to jot down notes for three nanoproducts you learned about at the Poster Fair.

Nanoproduct • *What is it?* • *What does it do?* • *How is it used?* • *How is it produced?*	**For the Public Good** • *What benefits does it offer?* • *What problems does it help to solve?* • *Why is it in the public's best interest to support/use this nanoproduct?*	**Concerns about the Nanoproduct** • *Are there any safety concerns, economic setbacks, ethical, or social implications resulting from the product, its use, or production process? What are they?* • *What additional information/research is needed to determine if these concerns may outweigh the product's potential benefits to the public?*
1.		

Nanoproduct	For the Public Good	Concerns about the Nanoproduct
2.		
3.		