NanoLeap

Nanoscale Materials and Their Properties
Teacher Guide Unit 2: *Metallic and Ionic Nanoparticles*: *Extendable Structures*
Lesson 2.3 Extendable Structures: Melting Point, Color, Conductivity

Objectives for *Metallic and Ionic Nanoparticles*: *Extendable Structures*
Lesson Objectives: Extendable Structures: Melting Point, Color, Conductivity **(bold)**
Students will be able to:

6. Define extendable solids.
    a. Identify elements and compounds that form extendable structures.
    b. Compare and contrast extendable solids.
7. **Recognize that an extendable nanostructure's physical and chemical properties are dominated by surface interactions.**
    a. **Relate the size and properties of a sample (both macro-samples and nano-samples) to the ratio of the surface particles to interior particles in the sample.**
    b. Define surface energy.
    c. **Compare and contrast the physical and chemical properties of metallic elements and ionic compounds at both the macro- and nano-scale (i.e., melting point, electrical conductivity, color,** reactivity, catalysis, and adsorption**).**
8. Evaluate the implications of nanoscale research and technology.

Suggested Time Frame: 90–120 Minutes

Chemistry Concepts

- Physical properties (color, conductivity, melting point)
- Atomic structure/electron orbitals

❖ **New Concept**
• **Review**

At a Glance for the Teacher

- Review "Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?" Parts 1–3
    - Optional: Philosophical Chairs Debate
- Review K-W-L
- ❖ Complete "Problem Sheet 6–Graphing the Melting Points of Gold Nanoparticles"
    - Optional Video: Melting Ice, http://www.mcrel.org/NanoLeap/multimedia/
- ❖ Discuss color and conductivity of nanoparticles
    - Optional Animation: Melting a nanoparticle, http://www.mcrel.org/NanoLeap/multimedia/
    - Optional Animation: Why do gold collards have color?, http://nanoed.org/concepts_apps/compu_anime/gold

- *Optional Experiment: Production of nanoscale gold from NanoSchoolBox information to order kit located at:* *http://www.nanoed.org/lessons/nanoschoolbox/*.

- Introduce Electron Orbital Variations
- Review K-W-L
- Answer “Making Connections” questions
- Review “Flow Chart”

Materials

- PowerPoint: *Metallic and Ionic Nanoparticles: Extendable Structures: Melting Point, Color, Conductivity*
- Computer with LCD Projector
- Student Handbook
- Student Handbook-Teacher Version
- Graph paper
- K-W-L

Slide # **Student Handbook Page #**	*Teacher Background Information and Pedagogy* **Teacher Script**
Slide 1 Title Slide	
Slide 2 "Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?" Student Handbook-TV: Page: 79 Student Handbook: Page: 44	**Let's review the answers to the questions from Problem Sheet 5.** *Click through each question.* • **How many grams of iron powder would it take to present a surface area equal to that of 1 gram of nanoparticles? ______** *37* 1) *Have students think about what this calculation means. Emphasize that 37 grams of macro iron powder has the same surface area as one gram of iron nanoparticles.* • **How would iron nanoparticles affect the rate of TCE cleanup?** *As surface area increases, the rate of TCE cleanup increases.* • **_____ liters of water can be cleaned by one gram of iron nanoparticles.** *10 Liters* • **Why is the cleansing ability estimate such a wide range?** *It depends on the concentration of the TCE.* *It depends on the conditions (porosity, permeability) of the sediment at the site.*
Slide 3 and 4 Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?" Student Handbook-TV: Page: 79 Student Handbook: Page: 44	2) *Use slides 3–4 to facilitate discussion of Problem Sheet 5, Part 2. For slide four have students look at the data in the table. Encourage pairs of students to look for patterns. If necessary, prompt students with the following questions:* • **For well one, what happens to the concentration of TCE as the distance from the well increases?** *(lower then slightly higher)* • **Does the same pattern hold true for well two?** *(No)* • **What happens to the concentration of TCE over time?** *(Lower then slightly higher)*

Slide 5 Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?" *Part 3* Student Handbook-TV: Page: 82 Student Handbook: Page: 49	3) *Refer students to Part 3, Ethical considerations involved in nanoparticle environmental cleanup. Ask students to read the text and answer the questions.* 4) *Optional: For question three, "Would you be in favor or opposed to the plan to use iron nanoparticles for decontamination? Explain the basis for your answer," use the philosophical chairs strategy for students to engage in a debate on the question.* 5) *Philosophical Chairs: Determine the mid-point of an issue that divides the students (i.e., the point where roughly half of the students fall into either the "for" or "against" categories). Let students decide where they stand on an issue. Those in favor of one position will form one group; those of an opposing position will form another; and those students who are undecided will form an undecided group. Use the image on slide 5 as a guide for setting up the room and positioning the students for the debate. Let the students explain their perspectives on an issue. Make sure that the arguments use evidence, have a logical line of reasoning, and do not attack another student personally. As the debate progresses, students are allowed to shift from group to group if they change their minds. Thus, undecided students may shift into either of the opposing groups, and students in those groups may shift to another group if they change their minds. Ensure that the debate remains orderly by having students raise their hands before speaking. Allow the debate to continue until all points have been exhausted. As a class, have students discuss what they learned, or have them engage in a persuasive-writing essay activity if desired.*
Slide 6	**We have explored the reactivity of nanoparticles. What physical properties are affected by the size of nanoparticles?** *Once students have answered click on the slide for the answers to appear.*
Slide 7 "Problem Sheet 6–Graphing the Melting Points of Gold Nanoparticles" Student Handbook-TV: Page: 83 Student Handbook Page: 51	6) *Refer to "Problem Sheet 6–Graphing the Melting Points of Gold Nanoparticles."* **One of the physical properties of a metallic solid is its melting point. Let's analyze some <u>experimental data</u> collected by observing different sizes of gold nanoparticles.** 7) *Allow students to work in groups for about 15–20 minutes to answer the questions.* *Optional: To save time, show the graph on slide 8 rather than having students graph the data.*

Slide 8 "Problem Sheet 6–Graphing the Melting Points of Gold Nanoparticles" Student Handbook-TV: Page: 83 Student Handbook Page: 51	*8) Review the answers to the questions in Problem Sheet 6. Use white boards for students to present responses and explanations to the rest of the class. See the Teacher Resource Guide on page 15 for an explanation on how to use white boards. This slide gives further explanation about the nonlinear relationships between the data sets (question six).* *9) For question four, you might want to show "Melting Ice" found at:* http://www.mcrel.org/nanoleap/multimedia/index.asp **Think (or look) back to your calculations in "*Activity 3–Metallic Closest Packing Up Close.*" The graph on the left shows data from your metallic cluster modeling activity.** **1. What variables are we comparing in the table on the left side of the screen?** *We are comparing the percentage surface atoms vs. number of atoms in the cluster.* **2. How does the percentage surface atoms change with increasing numbers of atoms in the cluster?** *It decreases.* **3. How does the trend in graph 1 (percentage of surface atoms vs. number of atoms in cluster) at left compare with the trend in graph 2 (melting point of gold vs. number of atoms in the cluster) shown on the right?** *The curved lines look very similar, but in graph 1, the percentage of surface decreases nonlinearly with increase in the number of atoms in the cluster, whereas graph 2 shows a nonlinear increase in melting point with an increase in the number of atoms.* **4. Since the independent variable in both graphs is the number of atoms in a nanoparticle, what general statement could we make that relates the trends shown in these two graphs?** *As the number of atoms (size) in a nanoparticle increases, the percentage of surface area decreases. As the percentage of surface area of a nanoparticle decreases, the melting point increases. And/or as the percentage of surface area increases, the average coordination number increases and the melting point decreases.*
Slide 9 "Problem Sheet 6–Graphing the Melting Points of Gold Nanoparticles" Student	*10) Refer to question six on Problem Sheet 6. For question four, you might want to show "Melting a Nanoparticle" found at:* http://www.mcrel.org/nanoleap/multimedia/index.asp **Nanosamples of gold have a much greater surface area to volume ratio compared with macrosamples. 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 macro samples vs. nanosamples of gold.** *It usually takes a particle that contains at least 1000 atoms to melt at a temperature close to the macro-sample melting point.*

Handbook-TV: Page: 83 Student Handbook Page: 51	
Slide 10	**This is an artist's rendition of several 5 nm gold nanoparticles (about 100 atoms) that were imaged with the use of an Atomic Force Microscope.** **What would the melting point of these particles be?** *Using the graph on the previous slide, students should state that the melting point is about 900 degrees Celsius.* *Note for teacher: The image represents nanoparticles in suspension. All of them are the same size. Those that appear smaller are farther away.*
Slide 11	**The data you have just studied involved nanoparticles of a metallic element, gold. Does the same trend occur with cadmium sulfide nanoparticles?** {Click} **This graph shows some experimental melting point data of Cadmium Sulfide nanocrystals.** **Is the same trend occurring? Explain your answer.** *The same <u>trend</u> appears to be shown; that is, melting point increases as particle size increases. It also does not appear to be a linear relationship. The variability may be related to a difference in the technique of determining melting point or it may be due to the fact that more data points were recorded at smaller differences in particle size.*
Slide 12	**We have traced the fundamental cause of** {Click} **decreased melting points,** {Click} **increased rates of some chemical reactions, and** {Click} **increased surface area to volume ratios of nanoparticles.** **But it has also been observed that the <u>color</u> of nanoparticles changes and <u>the electrical conductivity</u> decreases as the size of nanoparticles decreases. Are these changes also related to increased surface area? Let's examine this further.**

Slide 13	**Do you remember this image in the *NanoSize M*e video?** **In the macrosample at left, the gold beads have their usual lustrous gold color and are not soluble in toluene. On the right, gold nanoparticles that are 4-5 nm in diameter form a colloidal red-colored solution in toluene.** **1. As we studied atomic structure, which parts of the atom did we find determined the color of macroscopic samples?** *Electrons, specifically valence (surface) electron, determined the color of macroscopic samples.* **2. What property of these electrons enables them to determine the color of matter?** *Their ability to absorb, reflect, or transmit light (different wavelengths of electromagnetic radiation) at specific wavelengths (frequency/energy) enables them to determine the color of matter.*
Slide 14	**In macro metallic samples, surface electrons can absorb or reflect light of any energy.** {Click} **if surface electrons reflect most light, they** {Click} **produce a metallic luster in metals like silver.** {Click} **In metallic gold,** {Click} **some blue light is absorbed, so relatively more red and yellow light is reflected.**
Slide 15 Refer to the section "Surface Electrons and Color Changes" Teacher Resource Guide, page 27.	*11) Again, you might want to have students observe the 13-atom nanoclusters that they constructed or have a model of your own for demonstration.* **Now let's focus on what we have found happens to electron motion and energy at the nanoscale level.** **In the smallest nanoparticles like ones that you modeled, random, mobile surface electrons are confined in a very small space—between 1 and 5 nanometers across. And,** {Click} **as the size of nanoparticles decrease, and** {Click} **shapes change to include more edge and corner sites,** {Click} **the energy and motion of valence electrons change.** **And these changes in electron motion appear to affect the color of these metallic nanoscale particles.**
Slide 16	{Click, Click} **As light interacts with the sea of electrons at the surface of the nanoparticles, the electrons start moving in unison, forming waves.**

	{Click} **<u>These waves of electrons start behaving as if they were a single charged particle</u>, rather than individual mobile electrons with random motion. These highest-energy electrons closest to the surface absorb, reflect, or transmit <u>only specific frequencies</u> of electromagnetic radiation.** **Therefore, at nanoparticle size, gold no longer appears to be yellow and silver is no longer lustrous.**
Slide 17 Refer to the section "Surface Electrons and Color Changes" Teacher Resource Guide, page 27.	*12) Refer to the* Electrons and Nanoparticle Color Changes *section of the Appendix of the student handbook.* **The color of gold nanoparticles also changes with particle size, because <u>surface electrons have different energy levels</u> depending upon the size of the nanoparticle.** **The gold nanoparticles in ruby red stained glass are simple spheres about 25 nm in diameter. <u>Electrons at the surface of these nanoparticles slosh back and forth in unison, absorbing blue and yellow light, and reflecting red light off the particles.</u>** **Larger gold nanospheres are orange or greenish-brown.** **Smaller particles range in color from red to purple.** **Nanoparticles of silver in stained glass are bright yellow and smaller silver particles are blue.** *Use the animation "Why do gold colloids have colors "located at: http://www.nanoed.org/concepts_apps/compu_anime/gold to reinforce these concepts. This animation describes the unique optical properties of gold nanoparticles and how they are different from the common gold such as gold jewelry.* *Use Experiment 12: Production of nanoscale gold from NanoSchoolBox located at: http://www.nanoed.org/lessons/nanoschoolbox/. In this experiment students produce nanoscale gold clusters, which are identifiable through the manifestation of a typical ruby red color.*
Slide 18	**Not only does gold change colors at the nanoparticle level, it has been found that the <u>electrical conductivity</u> of gold and other kinds of nanoparticles <u>decreases</u> as the <u>particles decrease in size</u>.** **Which parts of the atom determine the conductivity of macroscopic samples?** *Electrons, specifically valence electrons, determine the conductivity of macroscopic samples.* {Click} **What property of these electrons makes electrical conductivity possible?** *Their mobility*

	{Click} **<u>In metals</u>, the "<u>sea of electrons</u>" are not tightly held by any one atom.** **We often indicate that electrons** {Click} **occupy s, p, d, or f orbitals surrounding a specific atom.** {Click} **We can visualize the electrons in atoms as having <u>random motion</u> within the orbital, being constrained only by the energy level of the electron itself.** {Click} **We also know that electrons can move to higher energy levels <u>within atoms or even be removed</u> from an atom by adding heat, light, or electricity.**
Slide 19 Refer to the section "What properties of electrons affect electrical conductivity at the macrolevel?" Teacher Resource Guide, page 31.	*13) Refer to the section "What properties of electrons affect electrical conductivity at the macrolevel?" in the Teacher Resource Guide.* **In macro samples of metals, the energy difference among molecular orbitals are so small we can think of them as bands of very closely spaced energy levels as shown on the image at left.** **The conductivity of nanoparticles is different from that of macro samples.** {Click} **It has been observed that as the size of metallic nanoparticles decreases, the size of the band gap increases. This means that some metallic nanoparticles change from conductors to semiconductors when nanoparticles are between 1-2 nm in diameter; that is, in nanoparticles containing between 200 and 400 atoms.**
Slide 20	**In this lesson we found <u>some</u> of the answers to the question, "How and why do the chemical and physical properties of nanosamples differ from those of macrosamples of the same substance?"** *14) Revisit K-W-L. Give students any further instructions necessary about the completion of the assessment assignment.*
Slide 21	*15) The "Making Connections" questions at the conclusion of each lesson can be used at the end of the class period or the beginning of the next day as a warm up. Generally the first few questions are a review of the present lesson, while the last question is a preview of future lessons.* *Answer for question one: melting point, color, and conductivity* *Answer for question two: as the size of the nanoparticle decrease:* o *the melting point decreased,* o *electromagnetic radiation interacts with free electrons to absorb, reflect, or transmit different colors of light, and* o *conductivity decreases.*

Slide 22	*16) The pilot-test teachers highly recommend using this flow chart at the end and/or beginning of each lesson. The end of each lesson contains this flow chart that provides an opportunity to show students the "big picture" and where they are in the lesson sequence.*