NanoLeap

Nanoscale Materials and Their Properties
Teacher Guide Unit 2: *Metallic and Ionic Nanoparticle*s: *Extendable Structures*
Lesson 2.1 Extendable Solids

Objectives for *Metallic and Ionic Nanoparticles: Extendable Structures*
Lesson Objectives: Extendable Solids **(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. (This objective was addressed in the Poster Assessment that followed Lesson 1.3)**

Suggested Time Frame: 90–120 Minutes

Chemistry Concepts

- Types of solids
- Metallic, ionic, and covalent bonding
- Physical properties

❖ **New Concept**
• **Review**

At a Glance for the Teacher

- ❖ Introduce "Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?"
- • Review "Fact Sheet 2–Types of Solids"
- • Compare metallic and ionic solids
- ❖ Complete "Activity 3–Metallic Closest Packing Close Up" (Some of the questions can be assigned for homework.)
- • Answer "Making Connections" questions
- • Review "Flow Chart"

Materials

- PowerPoint – *Metallic and Ionic Nanoparticles: Extendable Structures*
- Computer with LCD Projector and Speakers
- Access to computers for students
- *NanoParticle Builder* interactive located at: http://www.mcrel.org/nanoleap/part_build.asp or http://www.mcrel.org/nanoleap/multimedia/index.asp (See advanced preparation for Flash requirements)
- For each student group modeling clay to make 13 spheres (two colors per team)
- Student Handbook
- Student Handbook-Teacher Version

Advanced Preparation

See Student Handbook-Teacher Version for specific material preparation. If you are using the *NanoParticle Builder* interactive in a computer lab or on multiple computers, make sure that you have Internet capability and Flash Player (5.0 or higher) loaded on each computer that will be used. The appropriate version can be found at: http://www.adobe.com/shockwave/download/index.cgi?P1_Prod_Version=ShockwaveFlash.

Have a clay model of the 13 sphere nanoparticle with three layers. Each sphere should be ¾ inch in diameter.

Teacher Tip

One field test teacher had student groups roll the clay into the thirteen spheres as they entered the room. The students then had them 'ready to go' when it came time to start the lab.

Slide # **Student Handbook Page #**	*Teacher Background Information and Pedagogy* **Teacher Script**
Slide 1 "Problem Sheet 5–Iron Nanoparticles in YOUR Backyard?" Student Handbook-TV: Page 79 Student Handbook Page: 44	1) *Refer to "Problem Sheet 5-Iron Nanoparticles in YOUR Backyard?" and background information for this unit. This problem is introduced here for context, but students will not refer to Problem Sheet 5 in their handbook until Lesson 2.2.* **We have just been alerted to a problem in our community:** **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 leaches into groundwater. Metallic iron has been shown to be effective for decomposing contaminants like TCE that have found their way into drinking water.** **A possible solution:** **Iron nanoparticles used for TCE dechlorination have average diameters of 40 nm, so they can easily move within an aquifer. 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.**
Slide 2	**Using iron nanoparticles could be an improvement over the current methods of environmental cleanup, which involve digging a trench and dumping a ton or more of iron powder into it. Would you be comfortable using nanoparticles to clean a contaminant in your backyard?** *Remind students of the ethical considerations and questions that were discussed in Lesson 1.3.* **What questions would you have about iron nanoparticles before the clean up would begin?** *Students in the pilot test wanted to know more about the costs involved, what effect these iron nanoparticles would have on the environment, and if there were any long-term health concerns.* **Let's take a closer look at the chemistry of metallic nanoparticles involved in this method of environmental cleanup.**

Slide 3 "Fact Sheet 2–Types of Solids" Student Handbook-TV: 59 Student Handbook page: 35		**As we were studying elements and compounds this year, we found that they formed four different kinds of solids– metallic, ionic, network, and molecular. The table in "Fact Sheet 2–Type of Solids" shows:** o **type of solid** o **structural particles** o **the attractive forces that hold those structural particles to each other to form the solid** o **the <u>properties of macroscale</u> samples of these solids** o **structural form and surface features** o **examples of each kind of solid** **The TYPE OF BONDING DOES NOT CHANGE in the formation of nanoparticles. Metals at the nanoscale still exhibit metallic bonding; ionic compounds are still held together by ionic bonds.**
Slide 4	 {Click}	**Metallic elements, ionic compounds, and network solids form nanoparticles that are extendable structures. Extendable structures are those that usually grow in three dimensions without limit so long as there are additional building blocks available.** *Students might be able to relate to crystalline solids (e.g., rock candy, rock salt, growing crystals).* **In discrete structures, the predominant mode of bonding between atoms in the molecule is covalent, and the structures formed are more or less self-contained. That is, the structures cannot be extended simply by adding more and more building blocks to a three-dimensional lattice. In a sense, these materials are like large, discrete molecules.** **Now we will compare metallic and ionic extendable solids. In Unit Three, we will explore network covalent extendable solids and discrete solids.**
Slides 5		**Where on the periodic table do you find elements that form metallic solids?** *Metals include Groups 1 through 12 (everything to the left of the metalloids).*
Slide 6		**How would the surface structure of an ionic nanoparticle be different from that of a metallic nanoparticle?** *In the metallic model, all the spheres are the same size. In an ionic model, metal ions (cations) would be smaller than nonmetal ions (anions). The ionic surface would not be as "regular" as the metallic, since it has large and small ions in it, but there would a pattern to the "bumps" and "holes."* **Imagine if you could rub your hand across the surface of each of these nanoparticles. How would each one feel? Which would feel smoother?** **So the surface of an ionic nanoparticle may <u>not</u> be as "regular" as that of a metallic nanoparticle and the structural particles are positive and negative ions.**

Slide 7		**How are the <u>attractive forces</u> between the structural particles of metallic and ionic solids <u>similar</u>?** *The attractive forces in both solids are electrostatic attractions.* **How are they <u>different?</u>** *In metallic solids, a mobile sea of delocalized electrons surrounds the metal nuclei. All of the delocalized electrons travel freely around the metal atoms. In ionic solids, the electrostatic attraction between the positive and negative ions is what makes the ionic bond.* **Are there any mobile electrons in ionic solids? Why or why not?** *No, all the electrons are part of the positive and negative ions. Electrons have either been lost or gained to form stable electron configurations.*
Slide 8 "Fact Sheet 2–Types of Solids*"* Student Handbook-TV: 59 Student Handbook page: 35	 {Click} {Click} {Click} {Click} {Click} {Click}	**What physical properties do macro samples of metallic solids exhibit? If you cannot remember, check the table in *"Fact Sheet 2–Types of Solids."*** **Metals have:** **high melting/boiling points** **good thermal/electrical conductivity** **metallic luster** **malleability** **ductility, and** **color.**
Slide 9	 {Click} {Click} {Click} {Click}	**What physical properties do ionic solids exhibit at the macro level?** *Elicit student responses before clicking on some answers.* **Ionic solids:** **have high melting points,** **are non-conductors in the solid state** **have a hard surface, and** **are brittle.** **Metallic and ionic extendable structures have some similarities yet are different. Scientists know that all extendable nanoparticles exhibit similar trends as the size of the nanoparticle decrease. We will now explore this further by investigating metallic solids.**

Slide 10	**Because metallic solids are <u>extendable solids</u>, the size of macro samples depend only upon the number of atoms available to build a crystalline structure.** **Remember that one mole of atoms is 6.02×10^{23} atoms, so solid samples at the <u>macro level</u> can literally consist of billions of atoms.** **Remember that nanoparticles usually have between 10 and 70,000 structural particles.** **The <u>size</u> of nanoparticles appears to be critical to the <u>physical</u> characteristics that nanoparticles exhibit.** *Additional Information for the Teacher:* *Extendable solids can be imagined to grow without limit by the addition of additional building blocks—usually in three dimensions. As a rule, metallic, ionic, and network solids form extendable structures.* *If sufficient building blocks are available—say on the order of hundreds of thousands—the nanoparticles become large enough that they can be manipulated by ordinary laboratory techniques and are no longer considered nanoparticles.* *If students inquire about how the size is limited or kept from growing, explain that a ligand (see below) reduces the formation of large macrosamples by reducing flocculation and limiting particle growth.* **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.
Slide 11 "Activity 3: Metallic Closest Packing Up Close" Student Handbook-TV: 61 Student Handbook page: 37	2) *Refer to "Activity 3–Metallic Closest Packing Up Close." We will be using "the number of nearest neighbors" as the definition of "coordination number" in this activity. If this term was defined differently earlier in your course, make sure that students make the connection between the different definitions.* **<u>Why</u> is the size of metallic nanoparticles important? To answer this question, we are going to examine the structures of some very small <u>metallic</u> nanoparticles.** **For any substance that we worked with this year, the sample's <u>physical</u> properties (such as melting point, color, and conductivity) would stay the same <u>regardless of the size of the macrosample</u> we used. At the nanoscale level, however, this is <u>not</u> the case.** **In this activity, we will explore some reasons why the <u>size</u> of nanoparticles of <u>metallic elements</u> impacts the**

	physical and chemical properties of these elements. *Click on the play button to link directly to the* NanoParticle Builder *interactive.* ******Make sure students save their 13 atom clay models for the next lesson. ******
Slide 12	**As the size of the nanoparticle <u>decreases</u>,** {Click} **The ratio of surface atoms to interior atoms does what?** *Increases* {Click after students answer} **The percentage of surface atoms does what?** *Increases* {Click after students answer} **The average coordination number of the atoms in the sample does what?** *Decreases* **Therefore, the ratio of surface area to volume increases when the particle size decreases.**
Slide 13	**Did the basic shape of these nanoparticles change as the size changed?** *No* {Click after students answer}
Slide 14	**How does the shape of these nanoparticles compare with the shape of metallic macro crystals?** *We tend to think of metallic macro crystals as having more regular rectangular shapes.*
Slide 15	**Metallic nanoparticles have lots of surface atoms. In fact, the large number of surface atoms compared to the number of interior atoms is a <u>major characteristic of metallic nanoparticles, and</u> according to Professor Christopher Chidsey, Chemistry Department, Stanford University, "Surfaces become more and more important as things get smaller and smaller. Surfaces are important even at large scale but they certainly become more important at smaller scale."**
Slide 16	*3) 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: as the size of the nanoparticle decreases, the ratio of surface atoms to interior atoms increases. *Answer for question two: as the size of the nanoparticle decreases, the coordination number decreases.*
Slide 17	*4) 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.*