NanoLeap

Nanoscale Materials and Their Properties
Teacher Guide Unit 2: *Metallic and Ionic Nanoparticles*: *Extendable Structures*
Lesson 2.2 Extendable Solids: Reactivity, Catalysis, Adsorption

Objectives for *Metallic and Ionic Nanoparticles: Extendable Structures*
Lesson Objectives: Extendable Solids: Reactivity, Catalysis, Adsorption **(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: 60–90 Minutes

Chemistry Concepts

- Coordination numbers
- Surface area to volume ratio
- Factors that affect chemical reaction rates
- Catalysis

❖ **New Concept** • **Review**

At a Glance for the Teacher

- Review "Activity 3–Metallic Closest Packing Up Close"
- ❖ Define surface energy
- ❖ Explore factors that affect reaction rate at the nanoscale
  - o Optional hands-on station's activities
  - o Optional NNIN Catalysis activity: *http://www.nnin.org/nnin_catalysis.html*
- ❖ Introduce "Problem Sheet 5–Nanoparticles in Your Backyard" (Can be assigned for homework.)
- Answer "Making Connections" questions

- Review “Flow Chart”

Materials

- PowerPoint – *Metallic and Ionic Nanoparticles, Extendable Solids: Reactivity, Catalysis, Absorption*
- Computer with LCD Projector
- 13 atom clay nanoparticle models from Lesson 2.1
- Student Handbook
- Student Handbook-Teacher Version

<u>Slide #</u> **Student Handbook Page #**	*<u>Teacher Background Information and Pedagogy</u>* **Teacher Script**
Slide 1 Title Slide	
Slide 2	**What happens to the ratio of surface area to volume and to the ratio of the number of surface atoms to interior atoms as particles decrease in size?** *They increase.* **The big questions that we will examine now are HOW and WHY these increased surface areas, these large numbers of surface atoms compared to interior atoms, make the properties of nanoparticles so different from macro samples of the same composition.**
Slide 3	**Let's go back to our definition of coordination number.** **How did we define coordination number?** *The number of nearest neighbors*
Slide 4	*1) Have students observe the second layer of their 13-atom nanoparticle model to confirm that the interior atom is indeed <u>attracted by atoms surrounding it</u>.* **And, in our exploration of metallic nanoparticles, what was the coordination number of the <u>interior</u> atoms?** *12* {Click} **These atoms in the interior of a solid** {Click} **are <u>attracted by atoms all around</u> them, so they** {Click} **have high coordination numbers.**
Slide 5	*2) Have students observe their 13-atom nanoparticle models to confirm that the surface atoms are attracted by atoms that would <u>pull inward only</u>.* **Where did we find the atoms with the lowest coordination numbers?** *On the surface of the particle* {Click} **At the surface** {Click} **atoms are attracted only to the <u>inward pull</u> of the atoms in the solid** {Click} **as indicated by the lower number of nearest neighbors or smaller Coordination Number.**

Slide 6 Refer to the section "Surface Energy" Teacher Resource Guide page 26	 {Click} {Click} {Click} {Click} {Click}	**Because the** **surface atoms feel the attraction of fewer other atoms,** **they have a higher energy than those in the interior.** **That difference between** **the energy of surface atoms and that of** **interior atoms, the excess energy,** **is called surface energy.**
Slide 7		**The surface is where the action is! This is true not only for metallic nanoparticles, which you have just modeled, but it is true for most nanoparticles.** **It is true for macrosamples as well. But as we have seen in our modeling activity, when comparing large and small samples, the larger samples have a lower number of surface atoms compared to their interior atoms. Larger samples have fewer atoms with high surface energy compared with smaller samples. There is more surface energy available from nanosamples compared with macrosamples. That's why surfaces are so important at the nanoscale level.**
Slide 8		**The surface is where the interactions that result in changes in physical and chemical properties occur.** **Let's explore chemical reactivity first. Chemical reactions take place at the surface of both metallic and ionic solids. Chemical processes such as adsorption, oxidation, reduction, decomposition, and synthesis all take place at the surface of reactants. Catalysis also occurs on the surface of the catalyst. What do you think happens when nanoparticles are involved?**
Slide 9 Optional: Factors that affect the rate of Chemical Reactions Student Handbook-TV: Page 71		*Students should remember at least some of these from general chemistry curriculum.* **Remember, when we were studying rates of chemical reactions, we found that there are four factors that affect reaction rates. These factors include:** **1. Size of reaction particles and increasing surface area** **2. Concentrations of reactants** **3. Temperature** **4. Presence of a catalyst**

Student Handbook Page: 42	*Optional: Use the "Factors that affect the rate of Chemical Reactions" for students to review of the first three factors described above. Have them complete the activities described on page 42 in the Student Handbook.* *One field test teacher used a demonstration in which students compared the flammability of flash paper vs. flash cotton.* *Explain that <u>temperature</u> can affect rates of reaction but it usually isn't as important at the nanoscale level as items number 1 and 4 listed above, or may not be practical. <u>Concentration</u> of reactants doesn't usually change since particles are usually very closely packed. The high reactivity of the surface usually overrides the effects of temperature and concentration.* *If students ask why this is true, explain that we will examine this further in the next couple of slides.*
Slide 10	*3) Ask students to recall examples used in class to illustrate the increase in reaction rate with decrease of size of particles and increase in surface area.* **What factors account for the increase in reaction rates of chemical processes at the nanoscale level?** *Allow sufficient wait time for students to consider their response. Remind students about the metallic nanoparticle activity ("Activity 3–Metallic Closest Packing Close Up") as they answer. Once students have answered, click for the answer to appear on the slide.* **In "Activity 3–Metallic Closest Packing Close Up," you observed that <u>as the size of the particle decreased</u>, the <u>ratio of surface atoms to interior atoms increased</u>.** {Click} **Another way of expressing this ratio is to say that as the <u>size</u> of nanoscale particles <u>decreases</u>, the <u>surface area to volume ratio increases</u>!** **If we restated this again in terms of surface energy, as the size of nanoscale particles decreases, the ratio of atoms with high surface energy (i.e., surface atoms) to those with zero surface energy (i.e., interior atoms) increases, and the total surface energy (of a certain mass or a given number of atoms) increases!**
Slide 11	**<u>Adsorption</u> is the ability of ions and molecules to attach to <u>a surface</u>. That surface, however, must present <u>acceptor sites</u> for those ions or molecules.**
Slide 12	**Let's see if we can put this into more understandable terms.** **Seven grams of nanoparticles (each nanoparticle measures four nanometer in diameter) will have a surface area equivalent to a football field. This represents a lot of reactivity potential.**

Slide 13	**We also know that catalysts can affect the rate of chemical reaction. And the key requirement for most catalytic reactions is that the reactants be adsorbed from a gaseous or solution phase onto the surface of the catalyst.** *Optional: Use the NNIN activity "Catalysis: Exploring Reactants, Catalysts, Adsoroption, Desorption, and Diffusion" that provides a teacher led demonstration and discussion on catalysis. The activity is located at: http://www.nnin.org/nnin_catalysis.html. You may also want to show the following video called* Genie in the Bottle *located at: http://www.youtube.com/watch?v=u7nrQ6dNsXM*
Slide 14	**This is especially true for nanoparticles. This is an image of electronic wires for electronic devices growing from vapor on a gold catalytic surface.** **Not all surface atoms are equally effective as catalysts, but with decreasing particle size, small metallic nanoparticles, such as palladium, copper, silver, gold, and platinum, become highly reactive heterogeneous catalysts because their surface atoms, especially edge and corner sites, are active centers for industrial catalytic processes.** *Note to Teacher: A heterogeneous catalyst refers to the use of a catalyst in a different phase than the reactants. In the case of nanowire growth, it refers to the fact that a "solid" catalyst is used (which turns into a liquid) and the reactants are a gas which is a different phase (gas vs. solid or liquid).*
Slide 15	**We have learned that:** {Click} **decreases in the size of particles** {Click} **increases the ratio of surface area to interior volume, and** {Click} **increases the rate of some chemical reactions in which nanoparticles are involved.** **The question now becomes, how can we utilize the reactivity of these ionic and metallic nanoparticles?**

Slide 16 "Problem Sheet 5: Iron Nanoparticles in YOUR Backyard?" Student Handbook-TV: Page 79 Student Handbook Page: 44	**Environmental hazards such as chlorinated hydrocarbons, phosphorus compounds, alcohols, aldehydes, ketones, and amines have been shown to be absorbed and decomposed by nanoparticles. Other nanoparticles can be used to scavenge metals and toxic gases like H_2S out of the environment.** **Recall that metallic iron has been shown to be effective for decomposing contaminants like trichloroethylene (TCE) that have found their way into drinking water. Let's take a closer look at the chemistry and social and ethical considerations involved in this method of environmental cleanup.** *4) Assign "Problem Sheet 5: Iron Nanoparticles in YOUR Backyard" parts 1–3 for homework to be reviewed at the beginning of the next class period. Parts one and two are designed to have students use a mathematical analysis to conclude that nanoparticles can be used to clean up the site. In part three, students consider the ethical considerations and decision making processes utilized by entities other than the scientific community. Part three can be assigned and then discussed during the next period or used as a writing assignment using the rubric provided.*
Slide 17	*5) 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: reaction rate due to particle size and effect of catalysts.* *Answer for question two: as the size of the nanoparticle decreases, there was an increase in surface energy and increase in reaction rate.*
Slide 18	*6) 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.*