NanoLeap

Nanoscale Materials and Their Properties
Teacher Guide Unit 1: *Nanoscience: What Is It?*
Lesson 1.2 What Makes Nanoscience so Different?

Objectives for *Nanoscience: What Is It?*
Lesson objectives: What Makes Nanoscience so Different? **(bold)**
Students will be able to:

1. Define nanoscience as the study of the fundamental principles of structures having at least one dimension lying roughly between 1 and 100 nanometers.
    a. Compare and contrast the size of atoms, ions, and molecules to the size of nanoparticles.
    b. Identify structures that are appropriately measured in nanometers.
    c. Compare and contrast nanoparticle samples to atomic and macro-level samples in terms of the particle size, number of atoms, and operational model.
2. Explain the importance of nanoscience research and technology.
3. Evaluate the ethical considerations associated with nanoscience research and nanotechnology.
4. Recognize the interdisciplinary nature of nanoscience.
5. Identify the requirements of nanoscience and nanotechnology, including:
    a. new production methods,
    b. new measurement instruments, and
    c. a cleanroom environment for nanoscale research and technology.

Suggested Time Frame: 90–120 Minutes

Chemistry Concepts

- Unit analysis
- Interpretation of a chemical equation
- Quantum Chemistry Regime
- Classical Laws of Physics Regime
- Comparison of number of particles, size of sample, and regime of three types of samples (i.e., atomic/molecular, nanoparticle, macro-sized)

- ❖ **New Concept**
- • **Review**

At a Glance for the Teacher

- • Review "Problem Sheet 1–On the Nanoscale"
- • Complete "Problem Sheet 2–Nanoparticle Calculations"
- ❖ Complete "Problem Sheet–Sample Size Comparisons"
- ❖ Complete "Problem Sheet 4–Electrons vs. Satellites" (Prerequisite: basic understanding of force, mass, acceleration relationships)
- • Answer "Making Connections" questions
- • Review "Flow Chart"

Materials

- PowerPoint – *Nanoscience: What is it? What Makes Nanoscience so Different?*
- Computer with LCD Projector with Speakers
- Student Handbook
- Student Handbook –Teacher Version
- Calculator for students
- K-W-L Class Sheet

<u>Slide #</u> **Student Handbook Page #**	<u>*Teacher Background Information and Pedagogy*</u> **Teacher Script**
Slide 1 Title Slide	
Slide 2	**We have been studying atoms.** {Click} *1) Refer to the large periodic table in your classroom.* **What units would be appropriate to measure the radii of atoms?** *Depending upon your text, they are usually shown in either nanometers or picometers. Some texts may still use Ångstroms.* *Optional: One field test teacher told this joke: How many "boos" in a "pico boo?" Answer* 10^{-12} {Click} **Predict how many <u>atoms</u> you think a medium-sized nanoscale particle might contain.** *Encourage students to make educated estimates (guesses) based on the "Problem Sheet 1–On the Nanoscale." Accept all student answers. As students complete Problem Sheet 2, they will determine that five nanometers is equal to approximately 50 atomic diameters.*
Slide 3 "Problem Sheet 2–Nanoparticle Calculations" Student Handbook-TV: Page 21 Student Handbook Page: 11	**On the slide displayed, you see a <u>model</u> of a nanoparticle. It is not a completely accurate representation because nanoparticles are seldom rectangular, and, because their surfaces are made of atoms or molecules, they are not smooth.** *2) Refer to "Problem Sheet 2–Nanoparticle Calculations." After completing Problem Sheet 2:* *Ask the students:* **Do you think you could see a nanoparticle with your naked eyes?** *This question will help you to assess what students know about seeing an object verses an image of an object.*

<table>
<tr><td>Slide 4
“Problem Sheet 1–On the Nanoscale” Student Handbook-TV: Page 5

Student Handbook Page: 5</td><td>What IS nanoscience? How can we define it in terms of what we know about nanoparticles?
3) Refer to the K-W-L sheet that you have posted in the classroom. Let students respond with their own definitions or understandings about nanoscience.

4) Refer students to the sizeline on “Problem Sheet 1–On the Nanoscale.”
Nanoscience is usually defined as the study of the fundamental properties of nanoparticles or structures having <u>at least one dimension</u> lying roughly between 1 and 100 nanometers (the shaded region on the sizeline). Nanoparticles usually contain between 10 and 70,000 atoms, ions, or small molecules.

Your student handbook contains a glossary of terms that are commonly used in the field of nanoscience. You will be referring to it as we continue our study of nanoscience.

We have answered the first question: What is nanoscience? Let’s investigate what makes it so different from other scientific disciplines.</td></tr>
<tr><td>Slide 5</td><td>We can read the equation like this:
{Click } One <u>atom</u> of carbon reacts with
{Click}
{Click} one <u>molecule</u> of oxygen
{Click}
{Click} to yield
{Click} one <u>molecule</u> of carbon dioxide.</td></tr>
<tr><td>Slide 6</td><td>Let’s compare the relationships of types of samples (e.g., atoms/molecules, nanoparticles, and macrosamples) to the number of atoms/molecular units within each sample.
5) Point out the number of units in each example (columns 3–4).</td></tr>
</table>

Type of Sample			
Characteristics	**Atomic/ molecule Samples**	**Nano-particle Samples**	**Macro-sized samples**
Number of atoms/ molecular units in sample	1	10 - 70,000	$> 1 \times 10^5$ to multiples of moles 6.02×10^{23}

	{Click}	**If chemical equations represent what is happening at the atomic level, where in the second row of this table do you think that chemical equations would fit?** *Second column*
Slide 7	 {Click} {Click} {Click} {Click}	**We can also interpret these symbols as representing moles of the reactants and products. Then we would read the equation this way:** **One <u>mole</u> of carbon atoms reacts with** **one <u>mole</u> of oxygen molecules** **to yield** **<u>one</u> mole of carbon dioxide molecules.**
Slide 8		**If we interpret chemical equations in terms of <u>moles</u>, where in the second row of this table do chemical equations fit?** *Point out that the moles would fit in the fourth column.*
Slide 9 **“**Problem Sheet 3– Sample Size Comparisons” Student Handbook-TV: Page 23 Student Handbook Page:12	 *6) Refer to “Problem Sheet 3 –Sample Size Comparisons”*	**If atoms, ions, and some molecules form nanoparticles made of 10 to 70,000 atoms per particle, can chemistry be considered to be nanoscience?** *Accept student answers.* *Chemistry <u>could be</u> considered a nanoscience because some large molecules might qualify as nanostructures. However, in chemistry we usually work with and observe the properties of very large samples, or macrosamples, of matter. Nanoscientists work with and observe the properties of nano-sized samples of matter.* **Do you think that we have been working with any nano-sized particles in this year’s chemistry labs? Why or why not?** *In our chemistry class we usually work with and observe properties of very large samples of matter whereas nanoscientists work with and observe the properties of nano-sized samples of matter.*
Slide 10		(table below)

Characteristic	Atoms/ molecules	Nano-particles	Macro-samples
Number of atoms/ molecular units in sample	1	10 - 70,000	$> 1 \times 10^5$ 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	1 to ≈ 100 nanometers	>100 nm - ∞ nm

	0.2–2 nm / molecule		

Another unique characteristic of nanoparticles is the size of the particles.

How do the size of nanoparticles compare with each type of sample in our table?

Atomic radii are measured in nanometers (or picometers or Ångstroms), nanoparticles in nanometers, and macrosamples can be measured in units from nanometers to meters or even kilometers.

So, both the size of the nanoparticles and number of atoms or molecules in nanoparticles are in a range that is somewhere between that of individual atoms or molecules and samples that contain thousands, millions, or billions of atoms or molecules.

As we continue our study of nanoparticles, we will find that the *size of particles* and the *number of atoms in the particle* <u>do indeed</u> have great influences on both the physical and chemical properties of nanoparticles.

Now, let's look at why nanoparticles have been observed to have different properties than those same materials as macrosamples.

Slide 11

Characteristic	Atoms/ molecules	Nano-particles	Macro-samples
Number of atoms/ molecular units in sample	1	10 - 70,000	$> 1 \times 10^5$ 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	New or refined?	Classical Laws of Physics (Newtonian)

This last descriptive category in the table is labeled "Regime."

	What does the term "regime" mean to you? *Accept answers. Based on field test observations, many students said that a regime is a government or a set of laws that might impact a group of people. Help students connect this prior knowledge to this definition which may be new to them. A regime is* ***the characteristic conditions under which processes occur and models apply****. Ask students to talk about the type of conditions that may exist with a democratic government verses a communist government.* *Explain to students that in science there are* ***well-defined laws that operate in both quantum chemistry and the classical laws of physics.*** *What is happening at the nanoscale level is less understood and defined. Therefore, there is less predictability with properties of nanoscale materials.* **Look at the terms that are used to describe atoms and molecules and macrosamples. Atoms and molecules operate under the Quantum Chemistry regime, whereas macrosamples are subject to Classical Laws of Physics (Newtonian).** **Since the samples we have worked with in chemistry operate in these regimes, let's recall some of their differences in more detail.**
Slide 12 "Problem Sheet 4–Electrons vs. Satellites" Student Handbook-TV: Page 26 Student Handbook Page: 13	*7) Refer to "Problem Sheet 4–Electrons vs. Satellites." Before the students complete the questions in each column, ask students to identify and compare the size and scale and regimes that apply to electrons vs. satellites. Discuss with students what they recall what they know about atomic structure.* **To do this we will compare and contrast the probability description of an electron in an atom with the motion of a satellite in space around the Earth.**
Slide 13	**This slide then summarizes the contrast of the motion of a satellite with the motion of an electron around an atom. You may wish to take notes of these differences in the space provided on Problem Sheet 4.** *8) Continue with questions 7–10. Compare student answers with those provided on the PowerPoint slide. Emphasize that electrons are subatomic particles, obey quantum chemistry laws (described by probability regions), and are in very specific energy levels. Satellites are macro scale sized objects, obey the classic laws of physics (programmed and tracked with*

	technology), and require a force to place it into orbit.
Slide 14	**For large (or macro) samples of matter, like the samples we worked with in chemistry or large objects like a bicycle, a car, or a satellite, the <u>classical laws of physics</u> apply.** **But, if we focus on our observations of a single atom, we find that we need a regime of atomic structure called <u>quantum chemistry</u> to explain the motion of an electron as it moves around the nucleus.**
Slide 15	**The characteristics of nanoparticles, some of which have been observed, are somewhere between these two regimes.**
Slide 16	**In other words, nanoparticles sometimes act like they are not sure what they are or what regime they belong to!** **They have physical and chemical characteristics that are unlike either individual atoms/molecules or macrosamples!**
Slide 17	*9) 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: nanoparticles have between 1-70,000 units (except for discrete particles), with a size of between 1-100 nanometers, and operate in a different regime than either quantum mechanics or the classic laws of physics.*
Slide 18	*10) 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.*