Megan Ross

Cumulative Summary of Nanoscience Content

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|  | **Size and Scale** | **Surface Area to Volume Ratio** | **Forces & Interactions** | **Models** | **Size Dependent Properties** | **Self-Assembly** |
| **Explanation** | The size and shape of an object determine its properties and how it behaves with other objects. | As objects get smaller, the ratio between surface area and volume increases. This means that the volume becomes negligible and the main reason for interactions between objects is their surface area. | The two main forces discussed were the electromagnetic force and gravitational force. The gravitational force is an attractive force between two masses. The electromagnetic force is either attractive or repulsive between two charged particles. | Models help scientists visualize objects and phenomena that are too big or too small to study in a lab. Models are representations of objects. | Properties of matter change with scale and size. Intensive properties (contrary to common sense) change at the nanoscale, compared to objects made of the same material at the macroscale. | Some materials organize themselves together on their own under specific conditions. |
| **Connection to Activity** | In the How Big is It? activity, we had to determine which objects were bigger or smaller than the other. The objects ranged from the macroscale to the atomic scale. | One activity that addressed this concept was dissolving sugar in water. We had to see if a sugar cube or granulated sugar would dissolve faster. The granulated sugar has more overall surface area, so it dissolves faster than a sugar cube of the same mass. | The Does it Pour Out activity explored the cohesive and adhesive properties of water. A small test tube with a small opening does not allow water to pour out, while a large test tube does. In the smaller test tube, the electrostatic forces between water molecules overcomes gravity and keeps them together, which prevents the water from pouring. | The Gummy Capsule activity was a model of self-assembly. The actual capsule formation process was a chemical change; however, it was a macroscale model of two substances organizing together (self-assembly) without the need for stirring or heating. | The Gold Nanoparticles activity provided examples of size dependent properties. The different sized gold particles in solution had different colors and reacted with light differently. | The Self-Assembly Simulation and videos showed examples of self-assembly. In the simulation, we had to make objects stick together by manipulating the temperature and charges. The objects would not “stick” if conditions were not optimal. |
| **Connection to Presenter** | Alex Wei addressed size and scale properties in his discussion of gold nanoparticles used for cancer treatment. The particles attach to cancer cells and are heated in order to kill the cell. Since the particles are so small, they take very little energy to be heated. | Ali Shakouri discussed Atomic Layer Deposition, where atoms are arranged on a surface. In this process, the size of the particles does not matter as much as the surface area since they will only be interacting at the surface. | According to Peter Bermel’s presentation, the wavelength of photons will react differently with different substances. It is important to know which substances will absorb energy when designing photovoltaic cells. | Atomic Force Microscopes (AFM) are used to study the surface of nanoparticles. A tip scans across a surface to determine the topography. This allows scientists to make models of nanoscale objects without actually seeing the object (Ali Shakouri’s presentation) | In nanomedicine, it is vital to know the size, shape, composition, stability, and toxicity of a substance before it can be used as a medical treatment. These properties change at the nanoscale, so macroscale properties are no longer relevant (Alex Wei’s presentation). | An example of self-assembly from Ali Shakouri’s presentation is the formation of lipid bilayers in biological systems. The hydrophilic and hydrophobic ends of fatty acids organize themselves to make the bilayer. |
| **Connection to Nanoscience** | At the nanoscale (which is very small!) properties of substances change. The prominent force between objects changes and objects behave differently. | Very small particles have very small volumes. Scientists need to know what the surface of a nanoparticle is like because objects interact through surfaces. | At the nanoscale, mass is negligible. The only force that matters is the electrostatic force. For this reason, scientists need to know the strength and sign of charges on objects in order to know what will attract and repel. | Models are necessary in nanoscience because we cannot see nanoparticles. Scientists need to run tests that give them an idea of what the particles look like so that they can make a representation of the object. | Properties of materials at the nanoscale are often different than those at the macroscale. | Self-assembly is an easy way to manipulate matter at the nanoscale, as long as the conditions can be set. We cannot see nanoparticles, so we cannot easily move them to where we want them. It is easier to get them to self-assemble. |
| **1 Possible Student Misconception** | Students may believe that scale affects all properties equally |  |  | Models are exact replicas of nanoscale objects. | Intensive properties are always the same, no matter which scale the object is in. | If materials can self-assemble, they will assemble in any condition. |
| **How to Address the Misconception** | Size does not affect all properties the same; when doubling the length of all sides of a cube, the volume increases by a factor of 8, while the surface area increases by a factor of 4. Students can look at cubes and determine the surface area and volume. An analogy would be cutting up a hot potato into small pieces to allow it to cool. |  |  | Models of nanoparticles are similar to models of the universe. We cannot “zoom out” and look at the universe to know exactly what it looks like. We can only speculate based on evidence. Models are a best guess of what objects actually look like. | This misconception can be addressed through hands-on observations of gold nanoparticles. The color of solutions changes based on the size of the particles. | Materials need the correct conditions in order to self-assemble. An analogy would be that pasta does not cook in any water. There must be enough water for the amount of pasta and it must be boiling. |
| **1 Activity in PBL Unit to Cover this Concept** | How Big Is It? |  | Does it Pour Out? |  | Gold Nanoparticles | Self-Assembly Simulation |
| **Rationale for Including the Activity** | This is the first nano activity in the unit. It will help students wrap their heads around how small the nanoscale is. |  | Students will see how gravity is no longer a factor at smaller scales. Intermolecular forces between the water molecules dominate. |  | Students will be able to compare the solutions of gold nanoparticles to macroscale gold. They will see how properties change at different sizes. | Students are able to manipulate the conditions for self-assembly. They will see which conditions are favorable and which are preventative. |

**Connections Between Nano-Concepts:**

All of the concepts we have discussed are essentially size dependent properties. They change as the size changes, especially at the nanoscale. Three examples are forces and interactions, self-assembly, and models. At the macroscale, gravity is the main reason objects attract; however, at the nanoscale, electrostatic forces attract and repel objects because they have extremely small masses. Self-assembly occurs because of these electrostatic forces. At the macroscale, objects do not self-assemble due to the interference of gravity, but gravity does not affect nanoscale objects, allowing them to organize on their own. Models help us understand these concepts. We cannot see nanoscale objects with our naked eyes so we rely on models to show us what is happening as objects attract, self-assemble, and interact.

**The Driving Question:**

***Relation to nanoscience***- An example of the relation between our driving question and nanoscience is in solar energy; nanoparticles are used to make photovoltaic cells. Scientists need to find materials that absorb energy from the sun and can use it effectively and efficiently. Also, smaller devices use less energy. This provides motivation to find nanomaterials that can be used in batteries, sensors, etc.

***Connection to nano-concepts-*** Size dependent properties go hand in hand with the concept of size and scale. Smaller objects take up less space and use less energy. At the nanoscale, objects have different properties and different uses, which opens the door to alternative energy sources. The forces between objects at the nanoscale are utilized in self-assembly. This could lead to energy efficient methods of forming new materials.

**Lingering Questions on Nanoscience:**

1. I keep thinking about these concepts in the context of a chemistry class. How will my middle school students do with these ideas? What background information will they need before we can start this unit, that relates to the standards?
2. How can I stay informed on news and breakthroughs in this field?

**Resources**

Stevens, S. Y., Sutherland, L. M., & Krajcik, J. S. (2009). *The big ideas of nanoscience and engineering: A guidebook for secondary teachers*. Arlington, VA: National Science Teachers Association Press.

Professor Peter Bermels’ presentation

Professor Ali Shakouri’s presentation

Professor Alex Wei’s presentation