

Nanotechnology: The Basics, Week 1 “In-Depth” Handout
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Lecture this week gave you an introduction to nanotechnology that included its definition, a bit about its history, the motivation for ‘going small’ with materials, and some examples of broad classes of nanomaterials and their most common applications. Please take our 10 question “basics” quiz which will engage you with the lecture slides and help reinforce the material of the week. This material is meant to help you with the “in-depth” quiz and in particular the quantitative problem-solving.

Item 1: Converting between various size units

An important skill we expect students to have in this class is to convert between length units. We will limit simply to the metric system for this short course. Below are two example problems of how to convert which use the method of ‘dimensional’ analysis.

Example 1: You have measured the dimensions of an atomic force microscope silicon probe to be a rectangle 35 nanometers by 1 cm – a long strip of silicon the width of a silicon wafer. The fabrication of the probe requires that you use lithography of a silicon wafer to cut these probes from the larger material. How many AFM probes can you make from a 1 cm square piece of silicon?

Example 2: If you could lay carbon nanotubes side by side on top of a 4 cm post-it note, how many would fit? CNT are tubes 1 nm in width with lengths up to a millimeter or more.

Item 2: Estimating the number of particles in a certain weight or volume (refer also to nanofruit.xls)

The key for this calculation is to understand that every nanoscale object has a volume. Then, if you know the macroscopic volume you wish to fill you can estimate the number of objects you need through simple division. Its like saying you have sugar cubes 1 cm³ volume, and a 100 cm³ box, how many cubes can fit in it? Well, 100! If you are given weight instead of volume, you will need the density (g/cm³) of the substance which converts between weight and volume. You can either assume your objects are cubes, with (2R)³ volume or spheres with $\frac{4}{3}\pi(R)^3$ volume – since we are estimating this doesn’t matter much. Also, we are of course neglecting that a bunch of spheres will not totally fill all space, which means our answer is really an order of magnitude estimate.

Example 3: You have made highly uniform, spherical, particles that are 5 nanometers in diameter. How many of these particles do you estimate will fit in a drug delivery device with a 10 microliter injection capability? You do not need to know the density, but you do need to know that 1 milliliter = 1 cm³

Example 4: For the objects discussed in example 3, how many of these particles would weigh 1 gram? In this case you do need to know the density is 2 g/cm³.

Item 3: Estimating the surface area of particles in a certain weight or volume (refer also to the nanofruit.xls sheet)

The key for this calculation is to calculate the surface area of your single nanoscale object, then multiply by the total number of objects found as in examples 3 and 4. Again you can assume either cubes with an area of 6*(2R)² or you can assume spheres with $4\pi(R)^2$ as this is an estimated calculation.

Example 5: What is the total surface area in 1.0 gram of quartz nanoparticles that are 10. nm in diameter? Assume a density of 1.2 g/cm³. How does this surface area change if the particle size drops to 1 nm in diameter?

Example 6: What is the total surface area in 500. mg gold catalyst that is 15 nm in diameter? Note that the density of gold, which also holds for these catalysts, is 19.3 g/cm³.

Item 4: If you were 10 nm tall, how big would X be to you? (see the demo, nanoworlds)

In the demo nanoworlds, we discussed how big various objects would be if you were only 10 nm tall. Our objective was to give students a sense of what '10 nm' really meant in terms of other length scales relevant to biology, chemistry and physics. In this example, you will be going through the calculations that Dr. Colvin did to figure out how big things should be on the nanoscale.

Example 7: The molecule naphthalene is comprised of carbon-carbon bonds that are on the order of .15 nm. Based on its structure, it looks to be a flat oval molecule that looks to be about 4 C-C bonds across. If you were 1 nm tall, give some examples of objects that would be about the same size as this molecule.

Example 8: The protein lysozyme is relatively small, egg-shaped with dimensions of 3 by 2 nm; it is part of the cellular machinery that destroys malfunctioning biomolecules. If you were 1 nm tall, give some examples of objects that would be about the same size as this protein.

Item 5: The number of atoms in nanosized particles (EXTRA)

For those of you who want to push yourselves, let me take an extra step and explain how to get to the number of atoms in a nanoscale object made of one element only. There are a few ways of doing this kind of problem and I use density and the weight of a single atom. This is only going to work when the nanometer scale structure of a solid is identical to that of the bulk phase. What you have to recall to do this is that the atomic mass unit for an element is its atomic number (think periodic table, big number above element symbol) multiplied by the atomic mass unit or 1.66×10^{-24} g.

Example 9: If you had a gold cluster that was essentially spherical, and 3 nm in diameter, how many atoms of gold would it contain?

Example 10: A researcher has made a gold nanocrystal called Au₆₆ where "66" refers to the number of atoms in the gold cluster. Can you estimate the diameter of the nanocrystal?