

In-Depth Extra Lecture

Nanotechnology: The Basics

Week 1

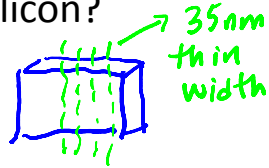
In-Depth Topics

- 1: Converting among size units
- 2: Estimating the number of things
- 3: Estimating the surface area of things
- 4: The size of things on the nanoscale
- 5: Atoms in a cluster

Please refer to the worksheet: `week1indepth` under course resources!!

Converting among different length units

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?



How many 35 nm pieces are in 1 cm?

$$1 \text{ cm} \times \frac{10^{-2} \text{ m}}{1 \text{ cm}} \times \frac{10^{+9} \text{ nm}}{1 \text{ m}} \times \left(\frac{1 \text{ probe}}{35 \text{ nm}} \right) = 2.9 \cdot 10^{+7} \cdot 10^{-2} \approx 3 \cdot 10^5, \text{ } \underline{\underline{300,000 \text{ Tips}}}$$

Probe
" "

$$1 \text{ probe is } 35 \text{ nm} \Rightarrow \frac{1 \text{ probe}}{35 \text{ nm}} \} \text{ equal to } 1$$

Hint:



→ CNTs will fit?

Example 2: If you could lay carbon nanotubes side by side, in a single layer, 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. Assume here that they are straight (which they would not be in reality)

Estimating Finding the number of objects

Example 3: You have made highly uniform, spherical, particles ^{= NP} 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

$$V = \frac{4}{3}\pi R^3 \quad V_{\text{one NP}} = \frac{4}{3} \cdot \pi \cdot (2.5 \text{ nm})^3 \cdot (10^{-7} \text{ cm} / 1 \text{ nm})^3 = \underline{6.5 \cdot 10^{-20} \text{ cm}^3}$$

$$\cancel{10 \mu\text{L}} \cdot \frac{\cancel{1 \text{ mL}}}{1000 \cancel{\mu\text{L}}} \cdot \frac{\cancel{1 \text{ cm}^3}}{\cancel{1 \text{ mL}}} \cdot \left(\frac{1 \text{ NP}}{6.5 \cdot 10^{-20} \cancel{\text{cm}^3}} \right) = 1.5 \cdot 10^{+17} \text{ NP or } \sim 10^5 \cdot 10^{12}$$

~ 100,000 TRILLION
~ 10 e17 $\leftrightarrow$ 10⁺¹⁷

Hint: Start with 1 gm, take that to volume, use conversion $1 \text{ NP} \approx 6 \cdot 10^{-20} \text{ cm}^3$

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.

Estimating

Finding the surface area of objects

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/cm^3 . How does this surface area change if the particle size drops to 1 nm in diameter? [try to do this for both spheres and cubes]

 $SA = 6 \cdot (2R)^2$

$\ominus SA = 4\pi R^2 \leftarrow$

 $V_c = (2R)^3$

$\ominus V_s = \frac{4}{3}\pi R^3 \leftarrow$

$$V_{np} = (2R)^3 = 8(5\text{ nm})^3 \cdot 10^{-21} \text{ cm}^3 / 1 \text{ nm}^3 = 6.4 \cdot 10^{-17} \text{ cm}^3$$

$$SA_{np} = 6(2R)^2 = 24 \cdot (5\text{ nm})^2 \cdot 10^{-14} \text{ cm}^2 / 1 \text{ nm}^2 = 6 \cdot 10^{-14} \text{ cm}^2$$

$$\left[\frac{1.0 \text{ gm} \cdot \frac{1 \text{ cm}^3}{1.2 \text{ gm}}}{\# \text{ of particles}} \cdot \frac{1 \text{ particle}}{6.4 \cdot 10^{-17} \text{ cm}^3} \right] \cdot \frac{6 \cdot 10^{-14} \text{ cm}^2}{1 \text{ particle}} \approx 100,000 \text{ cm}^2 !!$$

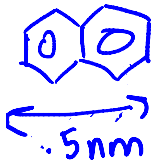
For spheres 60 m^2

Example 6: What is the total surface area in 500. mg gold catalyst (well approximated by a sphere) that is 15 nm in diameter? Note that the density of gold, which also holds for these catalysts, is 19.3 g/cm^3 . What happens to this number if you shrink the particle diameter to 1.5 nm?

start 500 mg $\rightarrow$ volume $\rightarrow$ # of NP $\rightarrow$ total SA.

The size of things on the nanoscale

Example 7: The molecule naphthalene is comprised of carbon-carbon bonds that are on the order of 1.4 angstroms. Based on its structure, it looks to be a flat oval molecule that looks to be about 5 angstroms on its long axis. If you were 1 nm tall, give some examples of objects that would be about the same size as this molecule.



$$1.65 \text{ m}_{\text{Big}} = 1 \text{ nm}_{\text{small}}$$

$$5 \text{ \AA} \times \frac{1 \text{ nm}_{\text{small}}}{1 \text{ \AA}} \times \frac{1.65 \text{ m}_{\text{Big}}}{1 \text{ nm}_{\text{small}}} \rightarrow \frac{1}{2} (1.65 \text{ m}) \text{ or } \frac{1}{2} \text{ my height}$$

Chair or Large Kite

Three times taller than "me" —

you are 1 nm

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.

The number of atoms in a particle (one element)

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?



$$V = \frac{4}{3}\pi (1.5 \text{ nm})^3 \cdot 10^{-21} \text{ cm}^3/\text{nm}^3 = 1.41 \cdot 10^{-20} \text{ cm}^3 \cdot 19.3 \text{ g/cm}^3 = \text{Weight}$$

÷ weight of 1 Nanoparticle by $200 \cdot 1.66 \cdot 10^{-24} \text{ g/atom}$

$$\left(\frac{4}{3}\pi \right) \cdot 10^{-21} \frac{\text{cm}^3}{\text{nm}^3} \cdot 19.3 \frac{\text{g}}{\text{cm}^3} \cdot \frac{1 \text{ gold atom}}{200 \cdot 1.66 \cdot 10^{-24} \text{ g}} \approx 820!!$$

Hint: 66 gold atoms → weight → volume → Radius → Diameter!

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?