One Molecule at a Time

Self assembly, or a bottom up approach to nanofabrication, uses chemical or physical means to assemble nano-sized units to build larger structures. Scientists at Stanford University are using this idea to build very small transistors from graphene. The article describing their work is located at: http://engineering.stanford.edu/news/stanford-scientists-use-dna-assemble-transistor-graphene. The article is written so students can understand it. A nice, simple explanation of top-down and bottom-up nano approaches can be found at: http://www.conted.ox.ac.uk/courses/professional/nanobasics/nano/accessweb/construction.html.

The activity, One Molecule at a Time, illustrates one of the challenges of self assembly - time! If you have used Flinn Scientific's Ruby-Red Colloidal Gold kit (AP7117), you observed self assembly. When the solution is heated, the sodium citrate reduces the gold salt to metallic gold. The atoms stick together (self assemble) forming gold nanoparticles.

There is no preparation for One Molecule at a Time. If you don't want to distribute aspirin tablets to your students you can give them the data. This activity is best suited for older students that are in or have had a chemistry class. To modify the activity for younger students, eliminate some of the questions. Students interested in the medical field will enjoy the last several Summing Up questions. A simple Google search using the phrase drug delivery will find vast amounts of information.

Note: Activities very similar to this activity can be found at okcareertech.org and from the nanotechnology program at Dakota County Technical College.
One Molecule at a Time

Information: Self assembly demonstrates a bottom-up approach to nanotechnology. Watch as a seed germinates and grows into a mature plant, or a caterpillar becomes a butterfly, or tiny sugar crystals become tasty rock candy, and you are watching things self assemble. Stanford scientists are experimenting with using DNA to self assemble nanosized transistors. One of the challenges of self assembly is time. How long would it take to build something molecule by molecule?

Purpose: The purpose of this activity is to explore the amount of time it might take to self assemble a common drug - acetylsalicylic acid, otherwise known as aspirin.

Materials: aspirin tablet, ruler or calipers, calculator, Internet access

Procedure:
1. Obtain the following data for an aspirin tablet for future reference:
   a. diameter: 10.0mm
   b. height at the edge of the tablet: 2.0mm
   c. height at the center of the tablet: 4.0mm
   d. mass of the tablet: 0.363g
   e. recommended dose: 2 tablets
   f. amount of acetylsalicylic acid per tablet: 325mg

2. Brainstorm several different methods you could use to find the volume of an aspirin tablet. Briefly describe the methods below including any assumptions that will be made.
   Students should suggest several methods including assuming the tablet is a simple cylinder (using one of the heights or an average) and calculating the volume of the base cylinder and the top and bottom as pyramids. The use of water displacement (or other liquid) should also be mentioned. Make sure assumptions really are scientific assumptions.

3. Chose the method you believe will allow the most accurate calculation of the volume of the tablet. Make the calculations and show your work below.
   This data using the center height gives $3.14 \times 10^{20} \text{nm}^3$. 

Water displacement done quickly gives the same results.
4. Acetylsalicylic acid has the chemical formula of $C_9H_8O_4$ and measures approximately 1nm across. Assume the molecule is spherical and calculate how many molecules fit into one tablet. Show your work below. 

Answers will vary, this data shows a molecular volume of $0.524nm^3$ and $5.99 \times 10^{20}$ molecules in the tablet.

5. If aspirin could self assemble at a rate of 180,000 molecules per second, how long would it take to assemble one tablet? Show your work below. 

In this case, $3.33 \times 10^{15}$ seconds or 105,523,141 years.

Summing Up:

1. How long (in years) would it take to self assemble a dose of this brand of aspirin? 
   Two tablets will take twice as long as the answer to number 5 above.

2. Calculate the surface area of one tablet. 
   Using the short height for the cylinder and flat circles for the top and bottom, $2.2 \times 10^{14}cm^2$

3. If the same dose was delivered in four smaller tablets, would the surface area be greater, smaller or the same as the surface area you calculated in the above problem? Explain 
   The surface area would be greater. Students may show the math or mention other nano activities they have done.

4. How many moles of aspirin are in one tablet? 
   $9.95 \times 10^{-4}$ mole.

5. What percentage of the tablet is actually aspirin? 
   89.5%

6. How does this information affect your results? 
   Students should note their answers would be about 10% less than their original answers.
7. Pharmaceuticals are available in many forms, tablets, topical applications, coated, time released, nasal sprays, liquids and powders. Why? What are the advantages and disadvantages of a particular delivery system over another? Answers will vary but one thing students should talk about is dosage over time. Another factor that should be mentioned is age of the patient. Aspirin taken at the time of a suspected heat attack is chewed to facilitate delivery. Drugs given by IV must be in liquid form or dissolved in something. Pills may be coated to prevent absorption in the stomach. Drugs that degrade in the stomach are delivered by other routes.

8. Why are some drugs not delivered in the form of a loose powder? The very large surface area of a powder may result in too large of a dose delivered at one time or absorption in the mouth rather than in the stomach or intestine. That could be a bad thing for some medications.

9. Why do the directions on some medications say “Do not crush or chew tablet”? Pretty much for the same reasons as stated above. The medication may enter the body too fast or in the wrong place which could cause problems.

10. Aspirin has many medical uses. But there are consequences too. Research the side effects of aspirin use including information about Reye Syndrome. Answers will vary, but students should understand the risks of children and Reye Syndrome. Aspirin may increase bleeding problems and irritate the stomach lining.
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Purpose: The purpose of this activity is to explore the amount of time it might take to self assemble a common drug - acetylsalicylic acid, otherwise known as aspirin.

Materials: aspirin tablet, ruler or calipers, calculator, Internet access

Procedure:

11. Obtain the following data for an aspirin tablet for future reference:
   a. diameter:
   b. height at the edge of the tablet:
   c. height at the center of the tablet:
   d. mass of the tablet:
   e. recommended dose:
   f. amount of acetylsalicylic acid per tablet:

12. Brainstorm several different methods you could use to find the volume of an aspirin tablet. Briefly describe the methods below including any assumptions that will be made.

13. Chose the method you believe will allow the most accurate calculation of the volume of the tablet. Make the calculations and show your work below.
14. Acetylsalicylic acid has the chemical formula of $\text{C}_9\text{H}_8\text{O}_4$ and measures approximately 1 nm across. How many molecules fit into one tablet. Show your work below. Include any assumptions you made.

15. If aspirin could self assemble at a rate of 180,000 molecules per second, how long would it take to assemble one tablet? Show your work below.

Summing Up:

1. How long (in years) would it take to self assemble a dose of this brand of aspirin?

2. Calculate the surface area of one tablet.

3. If the same dose was delivered in four smaller tablets, would the surface area be greater, smaller or the same as the surface area you calculated in the above problem? Explain.

4. How many moles of aspirin are in one tablet?

5. What percentage of the tablet is actually aspirin?

6. How does this information affect your results?
7. Pharmaceuticals are available in many forms, tablets, topical applications, coated, time released, nasal sprays, liquids and powders. Why? What are the advantages and disadvantages of a particular delivery system over another?

8. Why are some drugs not delivered in the form of a loose powder?

9. Why do the directions on some medications say “Do not crush or chew tablet”?

10. Aspirin has many medical uses. But there are consequences too. Research the side effects of aspirin use including information about Reye Syndrome.