**Activity 6**

**Size of Molecules**

**GOALS**

In this activity you will:

- Use the physical property of particle size to separate a mixture.
- Compare, on both a nanoscale and macroscale, important molecules found in the alimentary canal.
- Deduce which molecules can be easily absorbed through the intestinal wall.

**What Do You Think?**

Your eyes can see things that are smaller than 1/10th of a millimeter. A microscope can see things that are 1000 times smaller than this.

- Compare the size of a human hair and a water molecule. What would each look like through a microscope?

Record your ideas about this question in your *Active Chemistry* log. Be prepared to discuss your responses with your small group and the class.

**Investigate**

**Part A: Separating a Mixture**

1. Prepare a mixture of sand, BBs, gravel, and marbles. Observe the mixture. Without touching the materials with your hands or tweezers, invent a method to separate the three types of materials into different containers.

   a) What physical property could you take advantage of to separate this mixture?

   b) Describe your process to your teacher before moving forward.

   c) If you were given three different-sized molecules, could you use a similar method to separate them?
Part B: Relative Sizes in the Macro- and Nano- Worlds

1. Some of the important molecules that you have studied about in this chapter are water, starch, enzymes like pepsin and amylase, and glucose.

   a) What are the relative sizes of these molecules? Use the table to answer this question.

   b) How would they relate to you in size if you were shrunk down into their “nano-world?” The prefix “nano” means one-billionth. In other words, 1 nm = 1 × 10⁻⁹ m. For the purpose of your Chapter Challenge, when you enter the alimentary canal you become one-billionth of your normal size. Assuming that you are about 2 m tall now, you would be 2 nm in height for your ride through the alimentary canal. By folding yourself up into a ball, you could have an even smaller size of about 0.5 mm. Copy the table in your Active Chemistry log.

   c) Because it is difficult to think in such small terms, magnify everything in the table by a factor of one billion. A list of examples that are in the same relative size as the entries in the table is given. If you can arrange the “macro-world” examples according to their relative sizes in the proper boxes in column three of the table, you will get a sense of the relative sizes of the molecules and materials in the examples. Complete the table above with the following entries. (A couple of entries have been done for you.)

<table>
<thead>
<tr>
<th>“Nano-world” example</th>
<th>Diameter (nm)</th>
<th>“Macro-world” example</th>
<th>Diameter (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>water molecule</td>
<td>0.1</td>
<td>baseball</td>
<td>0.1</td>
</tr>
<tr>
<td>glucose</td>
<td>0.5</td>
<td>you</td>
<td>2 (or 0.5)</td>
</tr>
<tr>
<td>protein</td>
<td>5</td>
<td>you</td>
<td>2 (or 0.5)</td>
</tr>
<tr>
<td>enzyme</td>
<td>50</td>
<td>protein</td>
<td>5</td>
</tr>
<tr>
<td>starch</td>
<td>5000</td>
<td>blood cell</td>
<td>50,000</td>
</tr>
<tr>
<td>human hair</td>
<td>150,000</td>
<td>period in a textbook</td>
<td>500,000</td>
</tr>
</tbody>
</table>

- baseball
- distance from Chicago to Detroit
- distance from Chicago to the suburbs
- downtown Chicago
- hotel lobby
- hotel room
- width of Lake Michigan
2. Now, imagine the cell membrane of the small intestine. It is here that many molecules are absorbed through the lining of the intestine so that they can enter the bloodstream and be carried off to other parts of the body. Molecular size is very important in determining which substances can pass through the membrane. Assume that the thickness of the cell membrane is 10 nm. Also, assume that the opening through the membrane is 1 nm.

a) Which molecules that you have been studying could pass through and which could not?

3. To make it easier to understand, return to the “macro-world.” Here, everything is one billion times larger than the objects in the “nano-world.” The 1 nm opening through the cell membrane multiplied by one billion gives you 1 m. This is approximately the width of the door to your classroom. Depending on how large your classroom is, the thickness of the cell membrane, if blown up to the “macro-world,” would be about the distance from your door to the opposite wall.

a) With this perspective, how many of the molecules you have studied would be able to pass through your classroom door? Use the “macro-world” examples that you arranged in the table to help you make a decision.

**Chem Words**

- **nanometer:** one-billionth of a meter (1 nm = 1 × 10⁻⁹ m).

**Chem Talk**

**COMPARING THE MACRO- AND NANO-WORLDS**

This activity helped you to picture the relative sizes of the molecules and enzymes that have been presented so far. At your reduced nano-size, a bite of food would seem as big as the whole state of Illinois! Recall the prefix “nano” means one billionth. One **nanometer** is one-billionth of a meter (1 nm = 1 × 10⁻⁹ m). Just think, a food particle that would seem as large as the state of Illinois would ultimately have to be chopped up into pieces about the size of your classroom door in order to be absorbed into the body. Without ever thinking about it, food enters your mouth every day, and over a 24–36 hour period, passes down the alimentary canal, getting smaller and smaller until it is broken down into molecules that your body can finally use. The next time you eat a meal, think about all the high-powered chemistry that is required to keep you healthy and active.
What Do You Think Now?

At the beginning of this activity you were asked:

- Compare the size of a human hair and a water molecule. What would each look like through a microscope?

If you were located in the small intestine and encountered a molecule of amylase, how many times bigger would it be than you? How many times bigger than you might a starch molecule be? How small must the units of starch become before they can pass through the intestinal wall?

Chem Essential Questions

What does it mean?

Chemistry explains a macroscopic phenomenon (what you observe) with a description of what happens at the nanoscopic level (atoms and molecules) using symbolic structures as a way to communicate. Complete the chart below in your Active Chemistry log.

<table>
<thead>
<tr>
<th>MACRO</th>
<th>NANO</th>
<th>SYMBOLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare the “macro-world” examples to the “nano-world” of cells and hair.</td>
<td>How many times smaller must you be to fit inside the alimentary canal, and fit through the intestinal cell membrane?</td>
<td>For what purpose did you model the size of molecules in terms of objects in the city of Chicago?</td>
</tr>
</tbody>
</table>

How do you know?

In this activity you compared important molecules to objects found in Chicago, all the way from a baseball used by the Chicago Cubs to the size equal to the width of Lake Michigan. What can you now conclude about the importance of the hydrolysis of starch or proteins? (Reminder: Hydrolysis is the breakdown of the starches and proteins into smaller and smaller sizes by breaking the chemical bonds of these macromolecules.)

Why do you believe?

You used the idea of a scale model to help you better understand the sizes of molecules. How are a world map, a globe, and an architectural model of a new building helpful as models?

Why should you care?

This activity may be the most important in providing a perspective of the relative size of molecules you would encounter in an alimentary canal ride. How can you explain the ride of different molecules through the intestine with the information gathered in this activity?
**Reflecting on the Activity and the Challenge**

The first purpose of this activity was to try and give you a sense of the relative size of the molecules that you have been learning about. The second purpose was to provide you some appreciation of how really, really, really small the molecules have to be before they can be absorbed. With this new perspective, you should be able to better formulate events that will take place in your skit. Being only 2 nm tall, can you imagine what would happen to you if a huge enzyme or protein molecule collided with the piece of food on which you were riding? Splat! A drop of acid dripping off the roof of the stomach takes on a different meaning if you are in its path below. Truly, the digestive tract is a dangerous place when you are only 2 nm tall.

**Chem to Go**

1. The “macro-world” examples used in the table all dealt with Chicago. Develop a new set of examples that have the same scale as the “nano-world” and “macro-world” examples in the table in Step 1. (Don’t just use a city other than Chicago.)

2. If shrunk down to nano-size, how many of your objects would pass through the intestinal wall?

3. A drop of hydrochloric acid would have a volume of about 0.05 cm$^3$. If it dropped from the roof of the stomach towards you, how much larger would it be than you? The formula of a sphere is $V = \frac{4}{3} \pi r^3$.

4. **Preparing for the Chapter Challenge**

   Make a scale model of three things that you have seen in your ride down the alimentary canal. The three things are you (in your nano-size body), a molecule of starch, and a molecule of amylase. You must use multiples of the same object to represent the heights of the three substances. For example, if you used sugar cubes, you would represent the height of one of the objects with a certain number of sugar cubes. The other objects must be represented by enough sugar cubes to indicate their relative height to your first object. It is up to you as to what you choose the unit object to be.

**Inquiring Further**

**Bacteria and viruses**

Research the sizes of a bacterium, a virus, an atom, and a blood cell. How do they compare to the molecules in the table in this activity?