Lab IV-2

Investigating Osmosis

Equipment and Materials

You'll need the following items to complete this lab session. (The standard kit for this book, available from *www.thehomescientist.com*, includes the items listed in the first group.)

Materials from Kit

- □ None

Materials You Provide

- □ Gloves
- □ Balance
- □ Eggs, uncooked (2)
- □ Foam cups
- □ Graph paper, calculator, or software
- □ Marking pen
- □ Paper towels
- □ Syrup (corn, maple, pancake, waffle, etc.)
- □ Tablespoons, plastic or metal (2)
- □ Vinegar, distilled white
- □ Watch or clock with second hand

Background

In this lab session we'll investigate *osmosis*, the diffusion of water across a *semipermeable membrane* to equalize solute concentrations on both sides of the membrane. A semipermeable membrane allows the free passage of small molecules (such as water) through the membrane, while blocking the passage of larger molecules (such as salts, sugars, and other organic compounds).

If two aqueous solutions of different concentrations are divided by a semipermeable membrane, a phenomenon called *osmotic pressure* causes water molecules to migrate across the membrane from the more dilute side to the more concentrated side until the concentration is the same (in equilibrium) on both sides of the membrane.

For example, assume that you make up two sugar solutions, one with one teaspoon of sugar dissolved in 100 mL of water, and the other with three teaspoons of sugar dissolved in 100 mL of water. You then place these two solutions in a two-part container with a semipermeable membrane dividing them. Because the first solution is more dilute, water molecules will pass from it through the membrane and into the more concentrated solution, thereby increasing the concentration of the first solution and decreasing the concentration of the second.

The two solutions reach equilibrium when the sugar concentration is the same in both. Because sugar molecules cannot pass through the membrane, that means the volumes of the two solutions must change to effect that change in concentration. Because the second solution contained three times as much sugar as the first, its final volume must also be three times as much as the first solution. This is achieved when 50 mL of water has migrated from the first to the second solution, leaving the first solution containing one teaspoon of sugar in 50 mL of water and the second solution containing three teaspoons of sugar in 150 mL of water, which of course means the concentrations of the two solutions are identical.

> With respect to two solutions divided by a semipermeable membrane, scientists refer to the more concentrated solution as *hypertonic* and the less concentrated as *hypotonic*. If the two solutions have reached equilibrium (have the same concentration), they are referred to as *isotonic*. Note that these three terms are meaningless except when comparing two solutions against each other.

Osmosis is an important phenomenon in biological systems. Semipermeable cell membranes are typically permeable to molecules that are small and/or nonpolar—including oxygen, carbon dioxide, water, as well as lipids—while being impermeable to larger and/or more polar molecules, including polysaccharides, proteins, and other large organic molecules, as well as ions. Osmosis and related diffusive processes plays a role in many biological functions, from water transport into and out of cells to elimination of wastes to cellular respiration.

In this lab session, we'll prepare two decalcified eggs by dissolving their shells in vinegar. We'll then determine the mass of each egg before immersing it for measured times in either water—which, because it contains essential no solutes, is hypotonic with respect to the egg—or syrup, which because it contains a high concentration of dissolved sugars, is hypertonic with respect to the egg. We'll determine the mass change over time for each egg and use that data to determine the effects of osmosis in our controlled environment.

> You may have heard the term *reverse osmosis*, which is a technique used in some industrial processes, particularly water desalinization. Reverse osmosis forces water from the more concentrated solution to the less concentrated by applying physical pressure or other means. As applied to desalinization, for example, sea water (which contains a high concentration of salts) is placed under pressure, which forces pure water through a semipermeable membrane, leaving more concentrated sea water on the pressurized side of the membrane and producing pure drinking water on the other side.

Procedure IV-2-1: Observing osmosis in chicken eggs

Eggshells are primarily calcium carbonate, a chemical compound that is also familiar in the form of chalk, limestone, and marble. Calcium carbonate reacts readily with acids to form calcium salts and carbon dioxide gas. In this procedure, we'll immerse two raw eggs in an acidic solution and allow the reaction to consume the eggshells, leaving only the raw eggs within the membrane that surrounds the white and yolk.

> Raw eggs may be contaminated with salmonella or other pathogens. Wear gloves when handling the eggs and wash your hands thoroughly with soap and water after you finish the experiment. Discard both the eggs and the syrup when the experiment concludes.

1. Place two raw eggs in a large foam cup or other suitable container.
2. Fill the cup with distilled white vinegar, ensuring that both eggs are fully submerged, and cover the cup loosely to allow carbon dioxide gas to escape. (It's okay for the eggs to be in contact.)
3. Observe the eggs periodically. Over a period of three to four days, the eggshells gradually react with the vinegar until the eggshells disappear entirely.
4. When the eggshells are completely decalcified, carefully pour off the waste solution and use a spoon (gently!) to remove each egg and place it on a paper towel. Carefully blot each egg to remove as much of the excess liquid as possible.

   Be extremely gentle handling the decalcified eggs. With the shells gone, it's very easy to break the membrane and ruin the experiment.

5. Weigh two foam cups and record the mass on each cup.
6. Carefully transfer one egg to each of the cups. Reweigh the cups and subtract the mass of the cup from the mass of the cup+egg to determine the mass of the egg alone.
7. Note the time and fill one of the cups with syrup just sufficient to cover the egg with a centimeter or so to spare. Record the time in your lab notebook.
8. After a couple of minutes, repeat step 7 for the second egg, immersing it in water.
9. After about 10 minutes have elapsed, note the time and use one of the spoons to remove the egg from the syrup. Rinse the egg gently for a moment in a trickle of tap water to remove as much syrup as possible, and then very gently blot the egg dry with a paper towel. Reweigh the egg and record its current mass and the elapsed time in your lab notebook.
10. Return the egg to the syrup, again recording the start time in your lab notebook.
11. By the time you complete steps 9 and 10, the egg in water should be nearing the 10 minute mark. Note the time and use the other spoon to remove the egg from the water. Very gently blot the egg dry with a paper towel. Reweigh the egg and record its current mass and the elapsed time in your lab notebook.
12. Return the egg to the water, again recording the start time in your lab notebook.
13. Repeat steps 9 through 12 every ten minutes for at least one hour. If possible, extend the experiment for several hours, recording data every ten minutes until you run out of time or until the mass of one or both eggs remains constant between cycles.
14. After you complete the final mass determination for both eggs, fill two additional cups with water and syrup to the same level as the original cups. Compare the appearances of both unused liquids to the appearances of the liquids used during the experiment, and record your observations in your lab notebook.
15. Using your data, calculate the percentage mass change at each weighing for each egg and graph the results.

Review Questions

??? Production: Please strip the answers (formatted as comments) from the final layout. RBT

1. Which of the eggs gained mass? Which lost mass? Propose an explanation for these mass changes.

   The egg immersed in water gained mass; the egg immersed in syrup lost mass. The egg immersed in water gained mass as water flowed into the egg from the surrounding water because the solute concentration in the egg was higher than that of the surrounding water.

The egg immersed in syrup lost mass as water flow from the egg into the surrounding syrup because the solute concentration in the syrup was higher than that of the egg.

2. What, if any, changes did you note in the appearance of the water and syrup?

   There was no change in the water (except a small decline in its volume) because water flowed from the surrounding water into the egg. Students may or may not report a change in appearance of the syrup, depending on the type of syrup, how much was used, and the time the egg was exposed to the syrup. If a relatively small amount of relatively light colored syrup was used and the experiment was run for at least an hour of immersion time in the syrup, students may notice that the syrup became lighter colored and a bit less viscous.

3. Using the terms hypotonic and hypertonic, explain what occurred with each of the eggs.

   The egg immersed in water was in a hypotonic environment because the concentration of solutes in the egg was higher than the concentration of solutes in the surrounding water. Accordingly, water migrated by osmosis from the surrounding water into the egg. The egg immersed in syrup was in a hypertonic environment because the concentration of solutes in the syrup was higher than the concentration of solutes in the egg. Accordingly, water migrated by osmosis from the egg into the syrup.

4. Can isotonicity (isotonic equilibrium) be reached for the egg immersed in syrup? For the egg immersed in water?

   In theory, isotonicity can be reached for the egg immersed in syrup, because water can migrate from the egg to the syrup or vice versa until the solute concentrations are equal. Isotonicity can never be reached for the egg immersed in water, because the solute concentration of the water is zero and that of the egg is greater than zero. As the egg continues to absorb water, the solute concentration decreases, but can never reach the zero concentration of the surrounding water. If the osmotic pressure is sufficient, the egg membrane will eventually burst, mixing the contents of the egg with the surrounding water. Otherwise, the egg will absorb water only until the osmotic pressure equals the resistance of the membrane to further expansion, leaving you with a swollen egg that is in metastable non-isotonic equilibrium.

5. Explain in terms of osmosis what occurs if you pour table salt on a slug.

   The slug is surrounded by a semipermeable membrane. When salt comes into contact with that membrane, some of the salt dissolves in surface water present on the membrane, producing an extremely concentrated salt solution. That solution is extremely hypertonic with respect to the slug, so water flows from the slug through the semipermeable membrane and into the surrounding salt solution. Because undissolved salt remains, water continues to be drawn across the membrane until the slug is dehydrated and shrivels up.

6. Using Internet resources, find a practical application of osmosis in food preservation. In terms of osmosis, explain how this process works.

   Although it is now much less commonly used, before the advent of canning and refrigeration “salting down” was the primary method used to preserve meat for extended periods. By infusing the meat with a highly concentrated salt solution and/or packing the meat in containers filled with solid salt, one creates an extremely hypertonic environment for any microorganisms present in the meat, either killing them outright by dehydration or at least suppressing their ability to reproduce.

7. What percentage of mass gain or loss did you observe for each of the eggs?

   Answers will vary according to individual data, influenced by experimental conditions such as type of syrup, freshness of the eggs, duration of testing, and so on, but the final mass determination should show that the egg immersed in water increased in mass by 2% to 3% while the egg immersed in syrup showed about the same percentage of mass loss.