Investigating Osmosis Lab IV-2

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.

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.) Keeping the cup in the refrigerator may slow down the reaction somewhat, but it also keeps the eggs from spoiling. That won't matter unless you accidentally break the egg membrane, in which case it's better if the eggs aren't spoiled.

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.

WARNING

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.

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 10 minutes for at least one hour. If possible, extend the experiment for several hours, recording data every 10 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

Q1: Which of the eggs gained mass? Which lost mass? Propose an explanation for these mass changes.

Q2: What, if any, changes did you note in the appearance of the water and syrup?

Q3: Using the terms hypotonic and hypertonic, explain what occurred with each of the eggs.

Q4: Can isotonicity (isotonic equilibrium) be reached for the egg immersed in syrup? For the egg immersed in water?

Q5: Explain in terms of osmosis what occurs if you pour table salt on a slug.

Q6: Using Internet resources, find a practical application of osmosis in food preservation. In terms of osmosis, explain how this process works.

Q7: What percentage of mass gain or loss did you observe for each of the eggs?