Learning Objectives

Define a solution and the components of a solution.

Describe why osmosis occurs and what is required for osmosis to occur.

Describe osmotic pressure and how it can be used.

Explain how osmosis is important in biological systems.

Define isotonic, hypertonic and hypotonic solutions and the consequences in biological organisms.

Introduction

In order to understand osmosis, definitions for **solvent**, **solute** and **solution** need to be established. When considering a solution, first picture a glass of iced tea with sugar in it. The water that the iced tea was made with is the solvent; the tea flavoring and the sugar are solutes. Altogether they make up a solution. A *solution* is a homogeneous mixture of a solvent and one or more solutes. The *solvent* is the compound that dissolves or surrounds the solute. (The solute is said to be solvated). The *solute* is the component of the mixture that is usually in lesser quantity.

Osmosis is the movement of solvent molecules from a region of low solute concentration to an area of higher solute concentration through a semi-permeable membrane as shown in Figure OS.1.

At some point in time, the liquid levels observed in the diagrams above will no longer change due to osmotic pressure. **Osmotic pressure** is the pressure applied by a solution to prevent the inward flow of water across a semi-permeable membrane.

In order to visualize this effect, refer to Figure OS.1. As the water level in Side A increases, eventually the pressure exerted by the water in Side A becomes equal to the pressure exerted by the water in Side B which results in the rate at which water moves from Side A to Side B and from Side B to Side A to be equal. At this time, as the movement of water across the semi-permeable membrane is equal no further change in the heights of the water side and water plus solute side will occur.

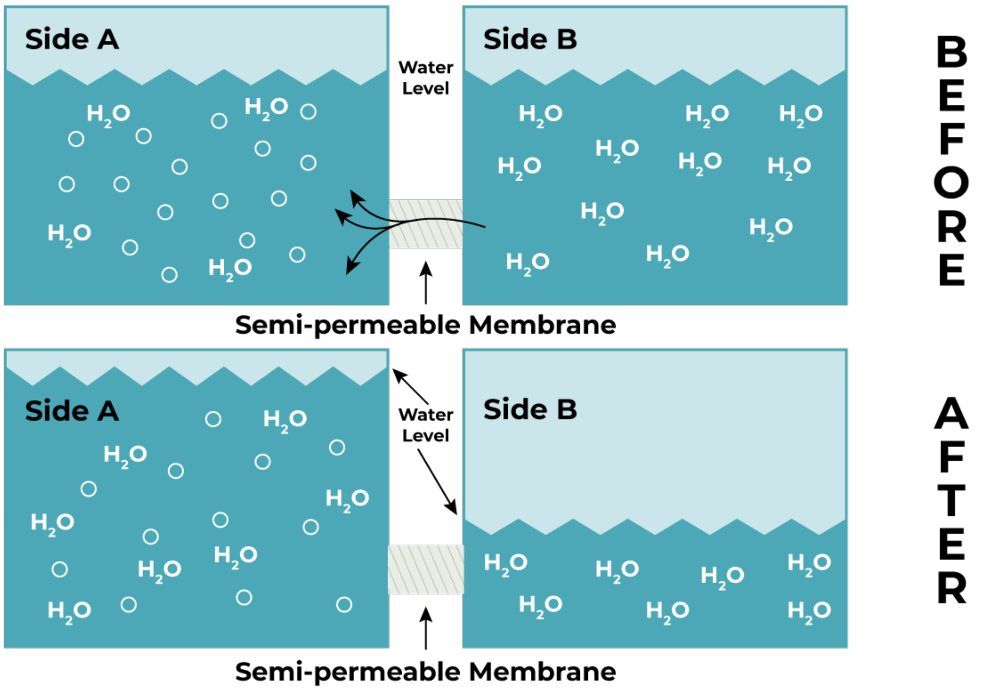

Figure OS.1: Notice the **before** picture: Side A contains many solute particles represented by circles and both water levels are the same height. Through the process of osmosis, the solvent (water) transfers through the semi-permeable membrane to the side with more concentrated solute. Thus, in the **after** picture, through the process of osmosis, side A has increased in volume and decreased in concentration of solute.

Osmotic pressure is the basis of filtering ("reverse osmosis"), a process commonly used to purify water. The water to be purified is placed in a chamber and put under an amount of pressure greater than the osmotic pressure exerted by the water and the solutes dissolved in it. Part of the chamber opens to a differentially permeable membrane that lets water molecules through, but not the solute particles. Reverse osmosis can produce fresh water from ocean salt water. Reverse osmosis is also used on a smaller scale in homes to further purify drinking water.

In this experiment, the cell walls of a potato will behave as semi-permeable membranes. The potato will be placed in pure water where the concentration of solute is lower than inside the potato cell walls. Since the solute concentration is lower in the water, the water is **hypotonic** relative to the solution inside the cell walls of the potato. The potato will also be placed in a very salty solution where the concentration of solute in the solution is greater than in the solution within the cell walls. The very salty solution is **hypertonic** relative to the solution inside the cell walls of the potato. Finally, the potato will be placed in a solution where the solute concentration is very similar to the solute concentration within the cell wall. This solution is **isotonic** and no osmotic flow should be observed.

As a further example of the effect of solutions on a biological cell, suppose an animal or a plant cell is placed in a solution of sugar or salt in water.

1. If the medium is **hypotonic** — a dilute solution, with a lower salt concentration than the cell — the cell will gain water through osmosis.
2. If the medium is **isotonic** — a solution with exactly the same salt concentration as the cell — there will be no net movement of water across the cell membrane, because the osmotic pressure is the same on both sides.
3. If the medium is **hypertonic** — a concentrated salt solution, with a higher salt concentration than the cell — the cell will lose water by osmosis.

Essentially, this means that if a cell is put into a solution, which has a solute concentration higher than its own (hypertonic), then it will shrivel up, and if it is put into a solution with a lower solute concentration than its own (hypotonic), the cell will expand and burst. If the cell is put into a solution with equal solute to its own (isotonic), the cell will experience no change in size.

An example of a hypotonic situation could be a shipwrecked group. At the time of the wreck sailors are hydrated and cells full of water. Eventually, fresh water supply is depleted and the only source of water would be the ocean water. If ocean water was consumed, since the cells are hypotonic (full of water) to the ocean water (salty) the cells would begin to shrink (crenate) water flowing out of the cells.

An example of a hypertonic situation can be a dried and withered plant. The addition of water to the plant soil results in the rejuvenation of the plant to a green and upright state. Water will flow into the hypertonic plant cells causing the cells to enlarge and support the plant. The cells do not burst as plant cells contain not only a cell membrane as with animal cells but a cell wall which restricts the swelling of the cells.

Aqueous solutions of 20% w/v (weight per volume) and of 0.9% w/v NaCl will be prepared for you. A 20% w/v solution means that the solution is 20% by weight sodium chloride, assuming that the density of water is 1.00 g/mL.

If you need to make up 50.0 mL of the 20% w/v solution of NaCl, how much NaCl will you need to use? In order to determine the amount of sodium chloride and water to use, it is convenient to remember that the density of water is 1.00 g/mL, which means 20.0 grams of water has a volume of 20.0 mL and 100.0 grams of water has a volume of 100.0 mL, etc. (We will make the assumption that the density of a solution of water with a salt is the same as that of pure water.) It is also convenient to realize that if you have 100.0 grams (or 100.0 mL) of a 20% w/v sodium chloride solution, then there are 20.0 grams of NaCl in 100 mL of solution. Start with the assumption in Equation OS.1:

$$\frac{20.0\text{ g NaCl}}{100.0\text{ mL of solution}} \times 50.0\text{ mL of solution} = 10.0\text{ g of solution} \qquad \text{(Equation OS.1)}$$

Therefore, to make 50.0 mL of a 20% w/v solution, add 10.0 grams of NaCl to a 50.0 mL volumetric flask and fill to the top with deionized water.

After the experiment, you will evaluate the percent change in the mass and in the volume of the potato slices. The change is referenced to the initial size Equation OS.2.

$$\text{Percent Change} = \frac{\text{final size - initial size}}{\text{initial size}} \times 100 \qquad \text{(Equation OS.2)}$$

Remember, the equation for the volume, V, of a cylinder is V= $\pi r^2 h$ where r is the radius and h is the height. The diameter is two times the radius. So, V= $\pi(\frac{d}{2})^2 h$.

If the potato decreases in size, the percent change will be negative. If the potato increases in size, the percent change will be positive. (Remember that the number of significant figures in your final answer will be determined by the number of significant figures in the difference between the final and initial sizes.)

Procedure

1. Cut three potato disks. They should be circular, 2-3 cm in diameter and 0.5 -1 cm in height using the appropriate tools. For best results, cut each disk so that it is the same height at all parts of the disk.

2. Measure the diameter and the height to the nearest 0.01 cm.(See the diagram below.) Do not confuse the three separate disks. Placing each one on a paper towel with the corresponding letter A, B, or C may help. It is highly recommended that you mark the place on the disk (perhaps with a permanent marker) where you have made these measurements.

3. Record the texture of each disk.

4. Measure the mass of each disk using an electronic balance.

5. Place disk A in a beaker or plastic cup provided and add 20% w/v NaCl solution until the disk is completely covered.

6. Place disk B in a separate beaker or plastic cup provided and cover with a solution of 0.9% w/v NaCl.

7. In a third beaker or plastic cup provided, cover disk C with deionized water.

8. Allow the potato slices to soak for 45 minutes. Make sure that the disks remain covered with the solutions during the entire time interval. If any of the disks float to the surface, put a glass stirring rod on the disks to hold them under the solution.

9. After 45 minutes,remove the potato disks from the solutions and pat them dry with a paper towel. Be consistence among drying each potato disk.

10. Record the texture of each disk after soaking.

11. Measure the diameter and the height of each disk (Figure OS.2) to the nearest 0.01 cm.

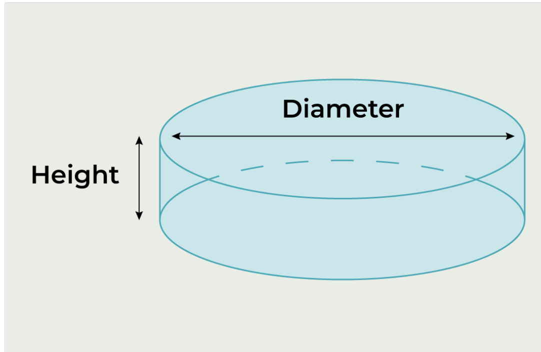

Figure OS.2: Diameter and height of a disk

12. Measure the mass of each disk.

Data

Record the data in Report Table OS.1 and Report Table OS.2.

1 pt for each blank.

Report Table OS.1: Potato Disks BEFORE Soaking

Disk Number	Mass	Diameter	Height
Potato Disk **A**(20% w/v NaCl solution)	________	________	________
Potato Disk **B** (0.9% w/v NaCl solution)	________	________	________
Potato Disk **C** (Distilled water)	________	________	________

Report Table OS.2: Potato Disks AFTER Soaking

Disk Number	Mass	Diameter	Height
Potato Disk **A**(20% w/v NaCl solution)	________	________	________
Potato Disk **B** (0.9% w/v NaCl solution)	________	________	________
Potato Disk **C** (Distilled water)	________	________	________

Calculations

Calculate the percent change of mass for the potato disks and record in Report Table OS.3

1 point for each blank except 2 points for percent change.

Report Table OS.3: Calculation of Mass Percent Change

Disk Number	Mass Before Soaking	Mass After Soaking	Mass Percent Change
Potato Disk **A**(20% w/v NaCl solution)	______	______	______
Potato Disk **B** (0.9% w/v NaCl solution)	______	______	______
Potato Disk **C** (Distilled water)	______	______	______

Calculate the percent change of volume for the potato disks and record in Report Table OS.4

1 point for each blank except 2 points for percent change.

Report Table OS.4: Calculation of Volume Percent Change

Disk Number	Volume Before Soaking	Volume After Soaking	Volume Percent Change
Potato Disk **A**(20% w/v NaCl solution)	______	______	______
Potato Disk **B** (0.9% w/v NaCl solution)	______	______	______
Potato Disk **C** (Distilled water)	______	______	______

Show the calculation for the **percent change in mass** for Disk A. (4 pts)

Show the calculation for the **volume** of Disk A before soaking. (2 pts)

Show the calculation for the **volume** for Disk A after soaking. (2 pts)

Show the calculation for the **percent volume change** that occurred in Disk A after soaking. (4 pts)

Questions

1. Define: (5 pts)

   A. Isotonic solution

   B. Hypotonic solution

   C. Hypertonic solution

2. Of the three solutions used in this lab, theoretically, which solution is: (1 pt each)

   A. isotonic relative to the potato?

   B. hypotonic relative to the potato?

   C. hypertonic relative to the potato?

3. Describe the effects of each solution on the textures, masses, and volumes of the potato disks. In each case, what happened to the cells in the potatoes and which direction did the water flow? (5 pts)

   A. 20% w/v NaCl solution

   B. 0.9% w/v NaCl solution

   C. Deionized water

4. Preparation of Solutions (5 pts)

   a) Calculate the mass of NaCl needed to prepare 35.0 mL of a 0.90 % w/v NaCl solution.

   b) Calculate the mass of NaCl needed to prepare 35.0 mL of a 20.0% w/v NaCl solution.

   c) Describe how you would make the solution for 4a. Be brief, but quantitative, in your answer.