BIG IDEA 2: Investigation 4, Diffusion and Osmosis

Overview of the Lab

In Part I you will create cell models with agar cubes and use them to calculate surface-area-to-volume ratios and make predictions about the rate of diffusion. In Part II, you will use dialysis tubing, which is selectively permeable, to create cell models to investigate questions about movement of molecules across the membrane. In Part III you will use a living tissue to observe and understand osmosis in cells.

> **YOU MUST KNOW**
>
> - Factors that affect diffusion across the membrane.
> - How water potential is measured and its relationship to solute concentration and pressure potential of a solution.
> - Water moves from a region where water potential is high to a region where water potential is low.
> - The relationship of molarity to osmotic concentration.
> - How to determine osmotic concentration of a solution from experimental data.

> **SCIENCE PRACTICES: CAN YOU . . .**
>
> - Design an experiment to measure the rate of osmosis in a model system?
> - Analyze data and make predictions about molecular movement through cellular membranes?
> - Connect the concepts of diffusion and osmosis to the structure of the membrane and molarity?
> - Use the principles of water potential to predict and justify the movement of water into plant tissue?

Hints and Review

- In the first part of this investigation, you will calculate both the surface area and volume of several sizes of agar cubes, which serve as models of cells. They are prepared in such a way that you can observe a color change in the cubes over a period. This will allow you to see that the distance material diffuses into the cubes is the same regardless of their size, and that the percentage of the total cube volume penetrated goes down drastically as the cubes get larger.
- Because cells exchange materials with their environment by diffusion, the conclusion you can draw from this is that smaller cells have more favorable surface-area-to-volume ratios.
- Refer to the AP Biology Equations and Formulas page to be sure you can calculate surface area and volumes. (See pages 346–347.) We will give you a practice problem on the sample test.
- Get a firm fix on the terminology! This is one topic where you will not get any credit if you understand the concept but garble the vocabulary. Let's add some more terms.

- **Osmosis** is the movement of water from a region of high concentration to a region of low concentration through a selectively permeable membrane.
- In **dynamic equilibrium** molecules are in motion, but there is no net change in concentration.
- Study Figure 4.1 to review some important terms.
- In Figure 4.1a the two solutions are equal in their solute concentrations. We say that they are **isotonic** to each other.

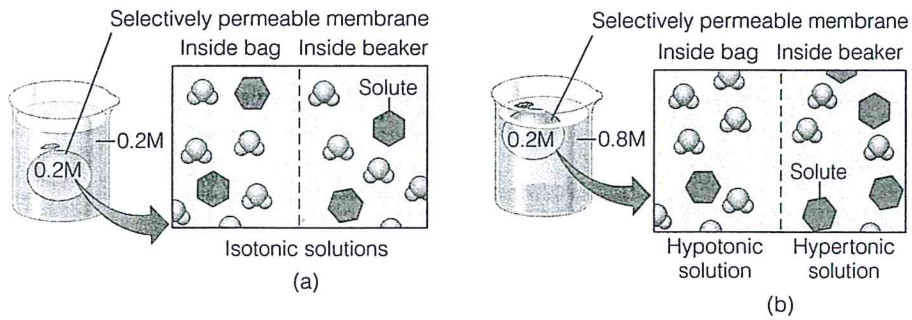

Figure 4.1 Diffusion across a selectively permeable membrane

- In Figure 4.1b, the solution in the bag contains less solute than the solution in the beaker. The solution in the bag is **hypotonic** (lower solute concentration) to the solution in the beaker. The solution in the beaker is **hypertonic** (higher solute concentration) to the one in the bag. Water will move from the hypotonic solution into the hypertonic solution.
- You must have a solid knowledge of the principles of diffusion to understand this lab, but what many students find most difficult in this laboratory is the concept of water potential. Here's a quick review.
- **Remember this:** *Water moves from a region where water potential is high to a region where water potential is low.* Think of water potential as potential energy, and you will understand why this is so.
- **Water potential** (Ψ) involves *two* components: solute potential (Ψ_S) and pressure potential (Ψ_P).
- In this laboratory we use bars as the unit of measure for water potential; 1 bar = approximately 1 atmosphere.
- **Solute potential (Ψ_S)** results from the presence of solutes. An increase in solute concentration will cause solute potential to decrease. (Ψ_S becomes more negative.) Adding solute therefore lowers the water potential.
- **Pressure potential (Ψ_P)** is zero in an open container. When a solution is enclosed by a rigid cell wall, the movement of water into the cell will exert pressure on the cell wall and the pressure potential (Ψ_P) will increase. This increase in pressure within the cell will raise the water potential.
- The water potential of pure water in an open container is zero because there is no solute and the pressure in the container is zero.
- A dehydrated potato slice does *not* have high water potential. Its water potential is low, and if placed in distilled water (which has high water potential), water will move into the potato cells.

Figure 4.2 will help you understand the relationships of water potential, solute potential, and pressure potential.

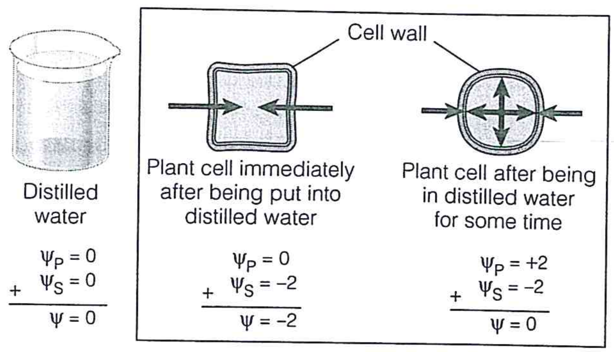

Figure 4.2 Water potential in a plant cell

Calculating Water Potential and Solute Potential

- Water potential is calculated using the following formula:

$$\Psi = \Psi_P + \Psi_S$$

Water potential (Ψ) = pressure potential (Ψ_P) + solute potential (Ψ_S)

- If you know the solute concentration, you can calculate solute potential (Ψ_S) using the following formula: $\Psi_S = -iCRT$
  where
  - i = The number of particles the molecule will make in water; for NaCl this would be 2; for sucrose or glucose, this number is 1
  - C = Molar concentration (from your experimental data)
  - R = Pressure constant = 0.0831 liter bar/mole K
  - T = Temperature in degrees Kelvin = 273 + °C of solution
- The formulas and values for T and R given above will be provided on the AP Biology Equations and Formulas page. (See pages 346–347.)
- What if you don't know the molarity? One way it can be determined is to take a sample of the cells and drop them into solutions of known molarity. In this lab, we use cores taken from potatoes. If the following results are obtained, what is the molarity of the potato cores? (See Figure 4.3)

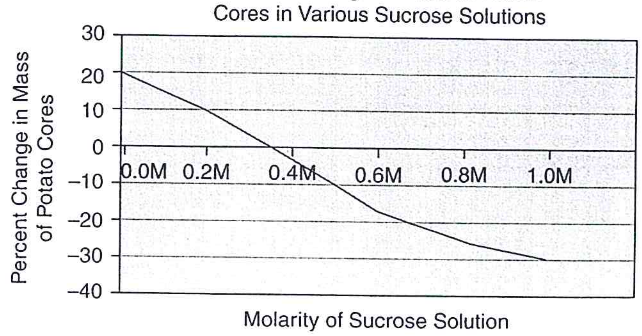

Figure 4.3 Percent change in mass of potato cores in various sucrose solutions

- The correct answer is approximately 0.35 M. This is determined by seeing at what molarity on the graph the cores neither gain nor lose mass. This is where the line crosses the X axis.
- Now that you have the molarity of the potato, if you know the temperature of the solution you can calculate the solute potential using the formula $\Psi_S = -iCRT$.

Questions

1. In beaker b, shown in Figure 4.4, what is the water potential of the distilled water in the beaker and of the beet core?

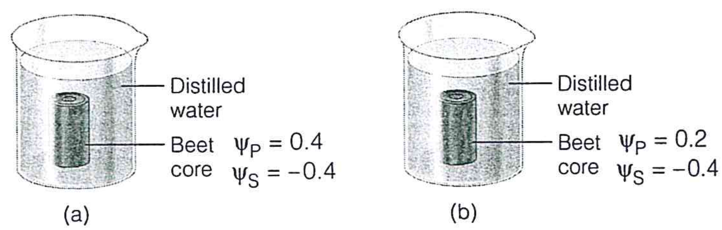

Figure 4.4 Water potential practice problem

   (A) water potential in the beaker = 0; water potential in the beet core = 0
   (B) water potential in the beaker = 0; water potential in the beet core = −0.2
   (C) water potential in the beaker = 0; water potential in the beet core = 0.2
   (D) water potential in the beaker cannot be calculated; water potential in the beet core = 0.2

2. Which of the following statements is true for the diagrams in Figure 4.4?
   (A) The beet core in beaker a is at equilibrium with the surrounding water.
   (B) The beet core in beaker b will lose water to the surrounding environment.
   (C) The beet core in beaker b would be more turgid than the beet core in beaker a.
   (D) The beet core in beaker a is likely to gain so much water that its cells will rupture.

3. Calculate the solute potential of the potato cores in Figure 4.3. The temperature is 21° C.

   Express your answer in bars, rounded to the nearest one-hundredth.