Determining Solute Concentration of a Potato using Hypertonic, Hypotonic and Isotonic Sucrose Solutions

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Abstract:

This investigation was done to determine the solute concentration of a white potato. Six slices of potato were placed in separate test tubes, each with different solute concentrations. Observations were made to the masses of each potato slice after 24 hours in order to determine which solution was hypertonic, hypotonic and isotonic. The solute concentration of the white potato was determined to be the solute concentration of the solution that was isotonic or the one that had the least percent change in mass. The concentration of the solutions used were 0 $mol.L^{-1}$, 0.2 $mol.L^{-1}$, 0.4 $mol.L^{-1}$, 0.6 $mol.L^{-1}$, 0.8 $mol.L^{-1}$ and 1.0 $mol.L^{-1}$.

Introduction:

Diffusion is the movement of molecules from a region of higher concentration to a region or lower concentration, until equilibrium is reached. Osmosis is a special case of diffusion involving water molecules. Osmosis occurs when water molecules move from areas of high water concentration to areas of low water concentration, down a concentration gradient, through a selectively permeable membrane (BBC Bitesize, 2014). The driving force of osmosis is osmotic pressure which is the tendency of solvent molecules to move in the direction of lower solvent activity (Chaplin, 2017). An osmotic pressure is a physical quantity dependent only on the concentration and temperature of the solution and does not determine the rate of passage of the water (Chaplin, 2017). The goal of osmosis is to reach equilibrium by producing more equal solute concentrations.

Solute concentration refers to the amount of solutes dissolved in a solution. Solutions are groups of molecules that are mixed and evenly distributed in a system (Chem4kids, 2017). A solution consists of a solute and a solvent. A solute is the substance to be dissolved and the solvent is the one doing the dissolving (Chem4kids, 2017). There are three types of solutions; hypertonic, hypotonic and isotonic. A hypotonic solution is the solution which contains the lesser total solute concentration. A hypertonic solution is the solution containing the greater total solute concentration. Water tends to diffuse from a hypotonic to a hypertonic solution. An isotonic solution is when two solutions have the same amount of solute concentration so there is none or very little net movement of water when both solutions are placed together and separated by a semipermeable membrane. Both diffusion and osmosis occur through a cell membrane or cell wall. They are the main transporters of molecules in and out of the cell.

A cell membrane is present in all cells and is semi-permeable whereas a cell wall is present only in plant cells and is completely permeable, so it allows water, molecules and proteins to freely exchange in and out of it. Potatoes have both a cell wall and cell membrane to allow the transport of molecules, water and proteins in and out of the cell. Potatoes are made up of 75% water and 21% carbohydrates of which the majority consists of starch (SFgate 2018). Being a carbohydrate, starch consists of alpha glucose molecules that are joined together by glycosidic bonds. The cell membrane of the potato transports water molecules in and out of the cell accordingly depending on what type of solution the potato is placed in. In a hypertonic solution, with higher glucose or starch concentration, water will move out of the potato and into the hypertonic solution as it will have greater solute concentration. In a hypotonic solution, water will move into the potato through the cell membrane as the potato will have the higher solute concentration. In an isotonic solution, there will be none or very little movement of water from across the cell membrane as the solute concentration in both the potato and the solution it is placed in, is equal or about the same.

The purpose of this lab is to determine the solute concentration of a potato. The solute concentration of the potato will be equal to the solute concentration of the solution in which no change in mass occurs as no change in mass will indicate isotonic solutions and equal solute concentrations.

Materials:

Refer to lab handout "A Study of Osmosis: Determining the Solute Concentration of Potatoes" given on March 1st, 2018.

Procedure:

Refer to lab handout "A Study of Osmosis: Determining the Solute Concentration of Potatoes" given on March 1st, 2018.

Results:

Table 1. Observation chart for change in potato mass

Test Tube #	**Solute concentration ($mol.L^{-1}$)**	**Initial Mass / (g)**	**Final Mass F (g)**	**Change in Mass (F - /) (g)**	**Percent Change in Mass $(\frac{(F-/)}{/}) \times 100$**
1	0	11.30	10.68	-0.62	-5.49%
2	0.2	11.61	11.81	0.2	1.72%
3	0.4	11.36	10.81	-0.55	-4.48%

4	0.6	11.44	10.29	-1.15	-10.05%
5	0.8	11.12	9.53	-1.59	-14.30%
6	1.0	11.34	9.46	-1.88	-16.58%

The potatoes placed in test tubes 1, 3, 4, 5 and 6 all decreased in mass after 24 hours. The decrease in mass resulted in a negative change in mass, this a negative percent change in mass. The percent change in mass of potatoes places in test tube 1, 3, 4, 5, and 6 are -5.49%, -4.48%, -10.05%, -14.30% and -16.58% respectively. The potato placed in test tube 2 was the only one that increased in mass. This is why it is the only potato that has a positive change in mass, resulting in a positive percent change in mass of 1.72%.

Data Analysis:

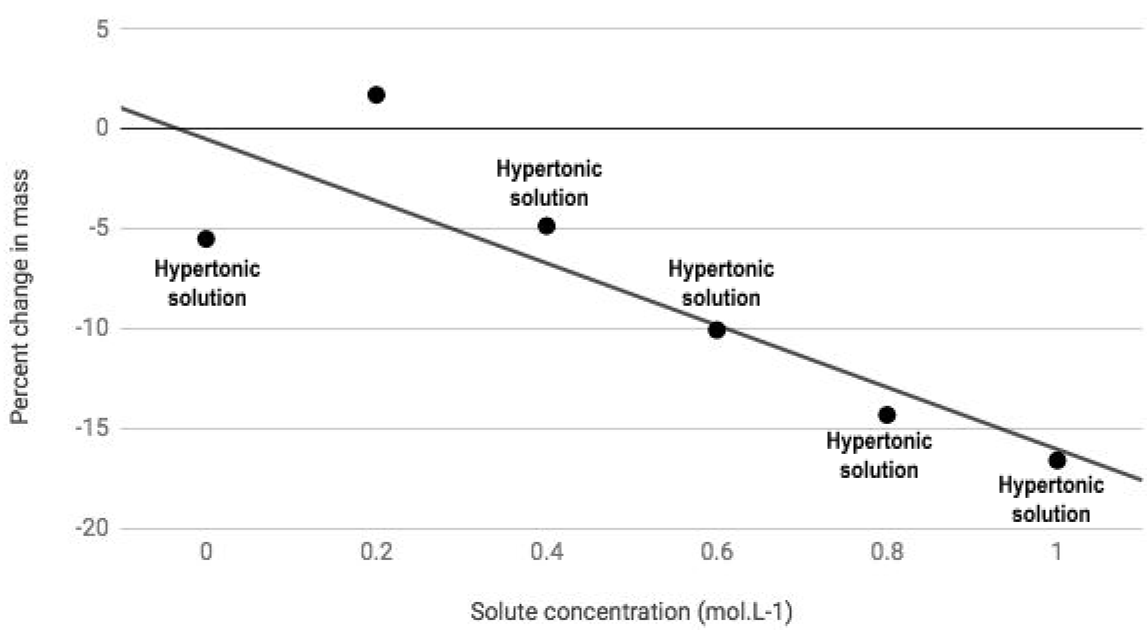

Figure 1. Percent Change in Mass vs. Solute Concentration

The trend of this graph is a negative linear relationship. Overall, the percent change in mass of the potato is decreasing as the solute concentration is increasing. The one point that is an outlier and does not follow the trend is the point at the solute concentration of 0.2 $mol.L^{-1}$. This point is where the potato was placed in a hypotonic solution and the only point with a positive percent change in mass.

Example calculation for 0.4 $mol.L^{-1}$ solute concentration:

1) Change in Mass:

= (Final Mass - Initial Mass)

= 10.81 g - 11.36 g

= -0.55 g

2) Percent Change in Mass:

$$= \frac{(Final\ Mass - Initial\ Mass)}{Initial\ Mass} \times 100\%$$

$$= \frac{10.81g - 11.36\,g}{11.36\,g} \times 100\%$$

= -4.84 %

Discussion:

The purpose of the lab was to determine the solute concentration of a potato. It was hypothesized that the solute concentration of the potato will be equal to the solute concentration of the solution in which the mass of potato did not change. This is because the solution in which the mass of the potato will not change is an isotonic solution, indicating that the solute concentration of both the solution and potato are equal. The independent variable in this lab was the solute concentration of the solution in which the potato is being placed in and the dependent variable was the change in mass of the potato. The controlled variables were time that the potatoes were left in the solution, temperature of solution and size of potato slices.

In test tube 1 the solute concentration was 0 $mol.L^{-1}$ and the initial mass of the potato was 11.30 grams. After being left in the solution for 24 hours, the potato's mass changed to 10.68 grams. The mass decreased and the potato had a percent change in mass of -5.49 %. The decrease in mass indicated that the solution was hypertonic and that the solute concentration in the potato was less than the solute concentration of the solution so water was transported from the potato to the solution in order to gain equilibrium. Water is transported in and out of a cell through the cell membrane. In this experiment the potato slices represent the cell. The potato slices show the effect on cells when they are placed in hypertonic, hypotonic and/or isotonic solutions. Since the cell membrane is made of water insoluble phospholipids, water cannot pass through. Therefore, there are globular protein pores known as aquaporins that allow lipid insoluble water molecules to pass through (Wisc-Online, 2018). Since membrane proteins are required to transport the water molecules across the cell membrane, this process is known as facilitated diffusion. The specific name for the movement of water molecules is osmosis. Osmosis occurs when water molecules move from areas of high water concentration to areas of low water concentration, down a concentration gradient, through a selectively permeable membrane (BBC Bitesize, 2014). The process of osmosis in plants is a useful idea to be known in grocery stores. The workers in grocery stores spray vegetables with water. The reason for this is because when produce is stripped from the vine or tree, it loses much of its natural hydration and the moisture loss can dry out fruits and vegetables to some extent in which they lose their size and weight (Anzalone, 2017). In order to keep these vegetables fresh for longer, workers spray them with water and since vegetables are plants too, the water is transported into the vegetable through the aquaporins in its cell membrane. The reason why water enters the vegetable is because the solute concentration in the vegetable is greater than the water itself, so the water molecules tend to move from a region of higher concentration to a region of lower concentration through osmosis. This is a good thing for store owners as it helps their products stay and look fresh for longer.

Test tube 2 had a solute concentration of 0.2 mol.L^{-1} and the initial mass of the potato in this test tube was 11.61 grams. The mass of the potato in this solution increased and became 11.81 grams and had a percent change in mass of 1.72 %. The increase in mass indicated that the solution in which the potato was placed in was a hypotonic solution which had lesser total solute concentration than the potato. Since the solution had lesser total solute concentration, water from the potato moved into the solution through the semipermeable cell membrane by the process of osmosis. The third test tube had a solution with a solute concentration of 0.4 mol.L^{-1} and a potato slice with an initial mass of 11.36 grams. The final mass of this potato was 10.81 grams and the percent change in mass was -4.84%. The mass of the potato in this test tube decreased, indicating that the solution was hypertonic and that water from the potato was transported into the solution to bring the total solute concentration to an equilibrium. Test tube 4 (0.6 mol.L^{-1}), 5 (0.8 mol.L^{-1}) and 6 (1.0mol.L^{-1}) also had hypertonic solutions as the mass of the potato decreased in all of them. The percent change in mass for the potatoes in test tubes 4, 5 and 6 was -10.05%, -14.30% and -16.58% respectively.

None of the prepared solutions were isotonic to the potato cell because there was no such test tube in which the percent change in mass was 0%. However, according to *Table.1* the closest of the percent change in mass was the potato in test tube 2 (0.2 $mol.L^{-1}$) which was 1.72%. The graph shows that at a 0% percent change in mass, the solute concentration is very close to 0.04 rather than 0.2. Since the trendline is a line of best fit it is just an estimation of the solute concentration so the actual solute concentration which would be isotonic to the potato cell would be close to 0.2 $mol.L^{-1}$ but not exactly since this solute concentration is hypotonic to the potato cell. Therefore, the solute concentration of the potato cell must be less than 0.2 $mol.L^{-1}$ but not too much as the percent change in mass is only 1.72%. In conclusion, the solute concentration of a potato cell is about 0.18 $mol.L^{-1}$. In a similar experiment done by Ehlenfeldt in 1992, it was found that the solution with the same water potential as white potatoes ranged from 0.24M to 0.31M (Ehlenfeldt, 1992)

The hypothesis was true that the solute concentration of the potato would be the solute concentration the solution which was isotonic to the potato cell. However, since there were no exact isotonic solutions, an estimate for the closest solute concentration was made in regards to the solute concentration of the solution in which the potato had the least percent change in mass. One source of error in the lab could have been that the difference in the surface area or water content in each potato strip was different in the beginning. Each potato strip was taken from a different part of the potato so the water level was slightly different in each when put into the test tubes. Also, some potato slices had some eroded holes in them which may have interfered with the osmosis process as their surfaces were not completely smooth. In order to avoid this error in the future, each potato slice should be taken from almost or exactly the same place of a potato and it is to be ensured that there are no holes on the surface of the potato slice.

References

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