What happens to water in an isotonic solution

A special type of passive transport is the movement of water across a membrane, or osmosis. By definition, osmosis is the diffusion of water through a selectively permeable membrane from an area of high water potential (low solute concentration) to and area of low water potential (high solute concentration). Therefore, for osmosis to occur, the membrane must be permeable to water, but impermeable to the solute, and the concentration of the solute must be different on the two sides of the membrane. Water will move from the side with lower solute concentration to the side with higher solute concentration until the concentrations are equal, or until some external force prevents further movement of water. This is a passive process, in that no energy expenditure is required for the movement of water. In an artificial system such as the one depicted in the figure below, water will attempt to move from chamber B to chamber A. Since chamber A is a rigid chamber, pressure will develop. The pressure that is just sufficient to prevent water from moving across the membrane is referred to as osmotic pressure. Image by BYU-I student, Hannah Crowder, 2013. Movement of water from chamber B to chamber A will generate a pressure known as osmotic pressure. In the body, water will move into or out of cells, depending on the solute concentration (osmolarity) of the extracellular fluids vs. the intracellular fluids. If the solute concentration in the extracellular fluid is lower than the solute concentration in the cell, water moves into the cell and the cell will swell. Before we can explain why cells shrink or expand when placed in a certain kind of solution, we first need to discuss the difference between osmolarity and tonicity. Earlier this semester we discussed how the concentration of particles in a solution is expressed as osmolarity. Recall that osmlarity represents the number of moles of particles per liter of solution, while molarity represents the number of moles of molecules per liter of solution. Why do we have these different ways of expressing concentration? We have to change because different substances behave differently in solution. For example, when NaCl is dissolved in water, it breaks apart into Na+ and Cl- ions (this is a characteristic of substances held together by ionic bonds). Thus, there are now twice as many particles than there were when the substance was dry. Consequently a 1 molar solution of NaCl would be a 2 osmolar solution. Glucose is different. Glucose doesn't break apart in water because the atoms are covalently bonded. Therefore, a 1 molar solution of glucose will also be a 1 osmolar solution. The concentration of solutes in body fluids is 285-295 mOsmoles/liter (for simplicity we often round this number to 300). We place the small m, which stands for milli or one-housandth, in front of osmole because we are dealing with very small amounts, 1000 times less than an osmol. Osmolarity is a useful term because now we can use words to describe solutions like isosmotic, which means two solutions have the same number of particles, or hyperosmotic which means one solution is more concentrated than the other, or hyposmotic which means that one solution is less concentrated than the other. (Note: Osmolarity takes into account all of the particles in the solution. Therefore, if you have a liter of solution containing one mole of glucose and one mole of NaCl you would have a three osmolar solution.) Perhaps the most important concept when talking about solutions and how they affect the body is tonicity. Tonicity (G. tonus, tone = firmness or stretch of a tissue) is a term used to describe how a solution affects a cell when it is placed into the solution. One important characteristic is that now we begin to deal with membranes and particles. Why are cells affected by different solutions? The answer lies in the behavior of particles with regard to diffusion. Particles will tend to diffuse from areas of high concentration to areas of lower concentration to reach equilibrium. However, if the membrane is not permeable to the particles, then instead of particles moving or diffusing, water will move or diffuse through the cell membrane to reach equilibrium. Additionally, at equilibrium, the osmolarities of the two solutions will be the same. We call the movement or diffusion of water osmosis, as was mentioned above. When water moves out of a cell, the cell shrinks; likewise, when water moves into a cell, the cell swells. Thus, if we place a cell into an isotonic solution, the cell shape won't change because the solutions are already in equilibrium, so there will be no net movement of water or solutes across the membrane. In other words, isotonic solutions have the same concentration of osmotically active particles (osmotically particles are non-permeable particles) as are found in the cell. If the cell swells, we say that the solution was hypotonic, and if the cell shrinks (crenates) we say the solution was hypertonic. It seems simple enough. Water moves when the particles are impermeable to the membrane; however, when particles are permeable, the particles will diffuse through the cell membranes, instead of water. Remember the intracellular and extracellular fluids in the body always move to equilibrium, either by movement of solutes, if they can cross the membrane, or by the movement of water, if the solutes cannot cross. Let's look at another example. Five percent dextrose (dextrose is another name for glucose) is isosmotic with regard to body fluids because it has the same number of particles as blood; however, glucose is permeable to cell membranes. Thus, a 5% dextrose solution (D5W) may be isosmotic to the cells, but it behaves as a hypotonic solution—the solute moves into the cells accompanied by water, causing the cells to swell. Here is another way to think of osmolarity and tonicity; osmolarity can be used to compare the concentration of solutes in two solutions. It can also be used to compare the concentration of the solutes in a solution with those in the cell, before equilibrium is achieved. Tonicity is used to describe what effect the solution has on the cell. Osmolarity doesn't take into account the nature of the solutes while tonicity is dependent upon the concentration of the nonpermeable solutes. The figure below shows what happens to red blood cells when they are placed into hypertonic, isotonic or hypotonic solutions. Title: File:Osmotic pressure on blood cells diagram.svg; Author: LadyofHats; Site: Osmotic_pressure_on_blood_cells_diagram.svg; License: Public Domain When placed in a hypertonic solution, red blood cells will shrink or crenate. When placed in an isotonic solution, there will be no change in volume, and when placed in a hypotonic solution, they will swell. If the concentration of the solution is great enough, they will burst (lyse). The link below shows what happens to a wilted plant when it is placed into a hypotonic solution. To check our understanding, complete the table below by filling in the missing column items with regard to osmolarity and tonicity. Use the terms iso, hypo, and hyper to complete the table. SOLUTION OSMOLARITY TONICITY 0.9 % Saline 5% dextrose 5% dextrose + 0.9% Saline 0.45% Saline 5% dextrose + 0.45% Saline You have been given the answers for the table above. Be sure you understand why the answers are what they are. **Note: Other texts, even hospitals on occasion, tend to use less rigorous definitions of tonicity. In other words, definitions are loosely given to define all hyperosmolar solutions as hypertonic. This is based on the observation that water can cross the membrane faster than the permeable solute can cross. It may also be based on the incorrect assumption that tonicity and osmolarity are the same thing. Thus, the initial effect of an abrupt change in extracellular osmolality may be temporarily different from the predicted tonicity change. In other words, a 5% dextrose solution in saline would be considered hypertonic because there are more than 300 mosm of solutes in this solution. The problem with this definition is that it does not distinguish tonicity from osmolarity, as it makes no reference of whether the solutes are permeant or non-permeant, with respect to a particular membrane. We believe that loose definitions create confusion and therefore have defined tonicity by the more rigorous definition of "effective osmolarity." **You may use the buttons below to go to the next or previous reading in this Module** "Hypotonic" and "Hypertonic" redirect here. For the physical diseases, see Hypotonia and Hypertonia. This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "Tonicity" – news · newspapers · books · scholar · JSTOR (February 2018) (Learn how and when to remove this template message) Effect of different solutions on red blood cells Micrographs of osmotic pressure on red blood cells Tonicity is a measure of the effective osmotic pressure gradient; the water potential of two solutions separated by a semipermeable cell membrane. In other words, tonicity is the relative concentration of solutes dissolved in solution which determine the direction and extent of diffusion. It is commonly used when describing the response of cells immersed in an external solution. Unlike osmotic pressure, tonicity is influenced only by solutes that cannot cross the membrane, as only these exert an effective osmotic pressure. Solutes able to freely cross the membrane do not affect tonicity because they will always equilibrate with equal concentrations on both sides of the membrane without net solvent movement. It is also a factor affecting imbibition. There are three classifications of tonicity that one solution can have relative to another: hypertonic, hypotonic, and isotonic.[1] Etymology A solution having a higher solute concentration or lower water content than another solution is known as a hypertonic solution (Latin 'hyper' means 'over' or 'above'). A solution is considered hypotonic if it contains a lower solute concentration or higher water content than another solution. The Greek word 'hypo' stands for 'under' or 'low', whereas 'tonic' is derived from 'tonicity', which means 'relative concentration of a solution'. If two solutions contain the same solute and water content, they are considered isotonic to each other ('iso' in isotonic means 'same' or 'equal'). Hypertonic solution This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (January 2014) (Learn how and when to remove this template message) A red blood cell in a hypertonic solution, causing water to move out of the cell. A hypertonic solution has a greater concentration of solutes than another solution. In biology, the tonicity of a solution usually refers to its solute concentration relative to that of another solution on the opposite side of a cell membrane; a solution outside of a cell is called hypertonic if it has a greater concentration of solutes than the cytosol inside the cell. When a cell is immersed in a hypertonic solution, osmotic pressure tends to force water to flow out of the cell in order to balance the concentrations of the solutes on either side of the cell membrane. The cytosol is conversely categorized as hypotonic, opposite of the outer solution. When plant cells are in a hypertonic solution, the flexible cell membrane pulls away from the rigid cell wall, but remains joined to the cell wall at points called plasmodesmata. The cells often take on the appearance of a pincushion, and the plasmodesmata almost cease to function because they become constricted, a condition known as plasmolysis. In plant cells the terms isotonic, hypotonic and hypertonic cannot strictly be used accurately because the pressure exerted by the cell wall significantly affects the osmotic equilibrium point. Some organisms have evolved intricate methods of circumventing hypertonicity. For example, saltwater is hypertonic to the fish that live in it. Because the fish need a large surface area in their gills in contact with seawater for gas exchange, they lose water osmotically to the sea from gill cells. They respond to the loss by drinking large amounts of saltwater, and actively excreting the excess salt. This process is called osmoregulation. Hypotonic solution A red blood cell in a hypotonic solution, causing water to move into the cell. A hypotonic solution has a lower concentration of solutes than another solution. In biology, a solution outside of a cell is called hypotonic if it has a lower concentration of solutes relative to the cytosol. Due to osmotic pressure, water diffuses into the cell, and the cell often appears turgid, or bloated. For cells without a cell wall such as animal cells, if the gradient is large enough, the uptake of excess water can produce enough pressure to induce cytolysis, or rupturing of the cell. When plant cells are in a hypotonic solution, the central vacuole takes on extra water and pushes the cell membrane against the cell wall. Due to the rigidity of the cell wall, it pushes back, preventing the cell from bursting. This is called turgor pressure.[2] Isotonicity Depiction of a red blood cell in an isotonic solution. A solution is isotonic when its effective osmole concentration is the same as that of another solution. In biology, the solutions on either side of a cell membrane are isotonic if the concentration of solutes outside the cell is equal to the concentration of solutes inside the cell. In this case the cell neither swells nor shrinks because there is no concentration gradient to induce the diffusion of large amounts of water across the cell membrane. Water molecules freely diffuse through the plasma membrane in both directions, and as the rate of water diffusion is the same in each direction, the cell will neither gain nor lose water. An iso-osmolar solution can be hypotonic if the solute is able to penetrate the cell membrane. For example, an iso-osmolar urea solution is hypotonic to red blood cells, causing their lysis. This is due to urea entering the cell down its concentration gradient, followed by water. The osmolarity of normal saline, 9 grams NaCl dissolved in water to a total volume of one liter, is a close approximation to the osmolarity of NaCl in blood (about 290 mOsm/L). Thus, normal saline is almost isotonic to blood plasma. Neither sodium nor chloride ions can freely pass through the plasma membrane, unlike urea. See also Osmotic concentration Osmosis Salinity References ^ Sperelakis, Nicholas (2011). Cell Physiology Source Book: Essentials of Membrane Biophysics. Academic Press. p. 288. ISBN 978-0-12-387738-3. ^ "Definition — hypotonic". The Free Dictionary. Retrieved 23 August 2012. Retrieved from "