

Lab #32: Determining Solution Concentration Relative to Human Extracellular Fluid (ECF)

Pre-Lab Activities

1. Read the entire **Introduction** “talking to the text” and completing tasks as you go.
2. **Interactive Lecture:** What are electrolytes?
3. Read **Materials and Methods**. Remember to complete the tasks and “talk to the text” as you read.
4. Set up your lab notebook for Lab #32. Be sure to transfer any important safety information and/or safety symbols into the “Safety Precautions” section.
5. Familiarize yourself with the new lab techniques during your Lab Techniques Discussion. Record any notes next to the appropriate **Procedure** steps.
6. Now you will be writing your own procedure to determine how concentration affects conductivity of a sodium chloride solution. Complete the following in your lab notebook.
 - a. First, decide on a range of concentrations to test. You will describe your solutions based on how many grams of sodium chloride they contain. We will calculate the molarity of your solutions after the lab is conducted.
 - b. What is an appropriate control group for your experiment?
 - c. What is the independent variable of your experiment?
 - d. What is the dependent variable?
 - e. What conditions will you keep constant?
 - f. Now, write a detailed procedure in your lab notebook.
7. Review the procedure and construct the necessary data tables in your lab notebook.
8. Read through the entire Introduction *a second time*. Put a star * next to concepts you have seen in previous labs and Strands. Indicate *when in the course* you have learned about these concepts or terms. You can write these observations right on this sheet in the margins.

Introduction

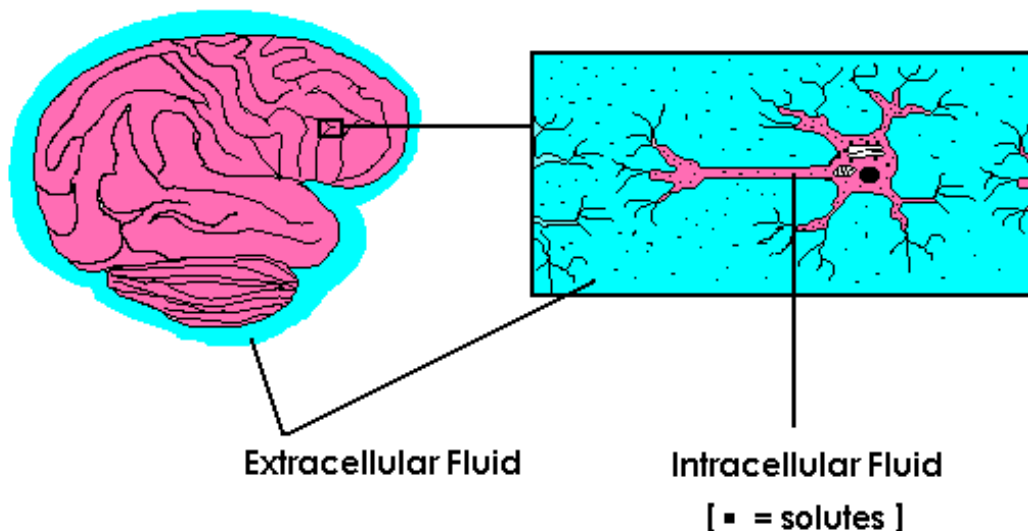
Human Body Composition: Water

Water constitutes 65% of the body’s mass. In general, 50-55% of a woman's body mass and 55-60% of man's mass is water. Men tend to have less body fat and more water, women the opposite. In the human body, the functions of water include: providing structure and form to the body, providing a solvent for diluting carrying waste, helping to maintain body temperature; allowing for the proper conduction of nerve impulses; and creating the necessary environment for *metabolism*, or the sum of all chemical reactions in the body.

Water in the body may be either *extracellular* or *intracellular*. *Extracellular fluid* (ECF) is water found outside of cells (the prefix *extra-* gives you that clue). Making up approximately 20% of total body weight, the ECF consists of blood plasma, interstitial fluid surrounding the cells, secretory fluid (water in transit) and dense tissue fluid, (water located within connective tissue such as cartilage and bone). *Intracellular fluid* (ICF) is the water inside the cells. It comprises approximately 35-40% of total body mass. Cytosol takes on a whole new meaning from that perspective! (See **Figure 1**)

Humans need to consume around 2.4 liters of water a day (see **Table 1**). Water is then removed from the body via one of several paths (see **Table 2**). Kidneys excrete approximately 1 to 2 liters of urine per day. Approximately 900 ml of this amount is water *excretion* that gets rid of cell wastes and byproducts of cellular reactions, and is fairly constant from day to day. Heavy perspiration may cause greater water losses through the skin via *secretion*.

Figure 1: Extracellular Fluid (ECF) and Intracellular Fluid (ICF)



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Solutes in the Body Solution

There is more to body water than H₂O. For example, it also contains small amounts of dissolved minerals from our diet, such as sodium, potassium, calcium, copper, and magnesium.

These solutes in the body solution are vital for life. Calcium is essential to bone formation and blood clotting (we will explore this further in Lab #33), while sodium and potassium are needed to produce energy, conduct nerve

Table 1: Sources & Relative Amounts of Daily Water Intake for the Human Body

Source of Water	Percentage of Daily Water Intake (approximately)
fluid consumption	55
food consumption	35
product of metabolic reactions	10

Table 2: Pathways & Relative Amounts of Daily Water Removal for the Human Body

Water Removal Pathways	Average Volume Removed, in mL
kidneys, via urine	1000 - 2000
diffusion through the skin	350
perspiration	100
respiration	350
feces	150 - 200

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impulses, and keep the heart beating.

There are three main types of solutes present in humans: electrolytes, plasma proteins, and small organic compounds. In this lab we will investigate electrolytes. *Electrolytes* are molecules that can dissociate into ions and can conduct electrical currents. An electrical current is essentially the movement of electrons from one atom to the next. In the case of metals such as copper, the arrangement of electrons in the outer orbitals allows these electrons to move in both solid and liquid states. The electrons move freely between the nuclei of metallic elements (See **Figure 2**). This sharing of electrons between atoms of the same elemental metal is referred to as *metallic bonding*; this kind of bonding also allows the metal to conduct electrical current.

Electrolytes, once dissociated into ions, can facilitate this same type of movement. However, in electrolytes the *ions* (charged particles) move, not the electrons. While solid metals can still conduct current, when electrolytes are in their solid, neutral form they cannot conduct electrical current. This is because all of their electrons are accounted for in the lattice structure of the solid (See **Figure 3**).

Figure 2: A Schematic of the Electron Arrangement in Solid Copper

In metals such as copper, the electrons move freely from copper nucleus to copper nucleus. The free movement of electrons is referred to as a "sea of electrons" (a). This property of metals allows for the stretching of copper into wire (b), as well as the solid wire's ability to conduct electricity (c). The electronic current excites electrons of copper nuclei, which in turn conduct this energy to the next copper atom's electrons, and so forth, along the wire.

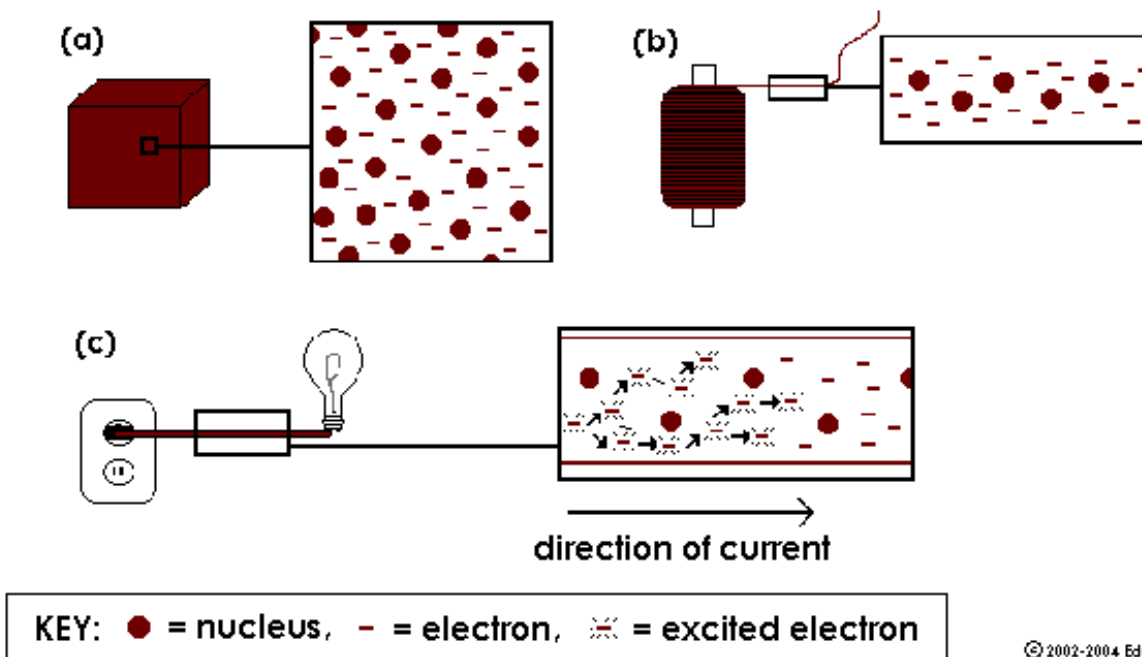
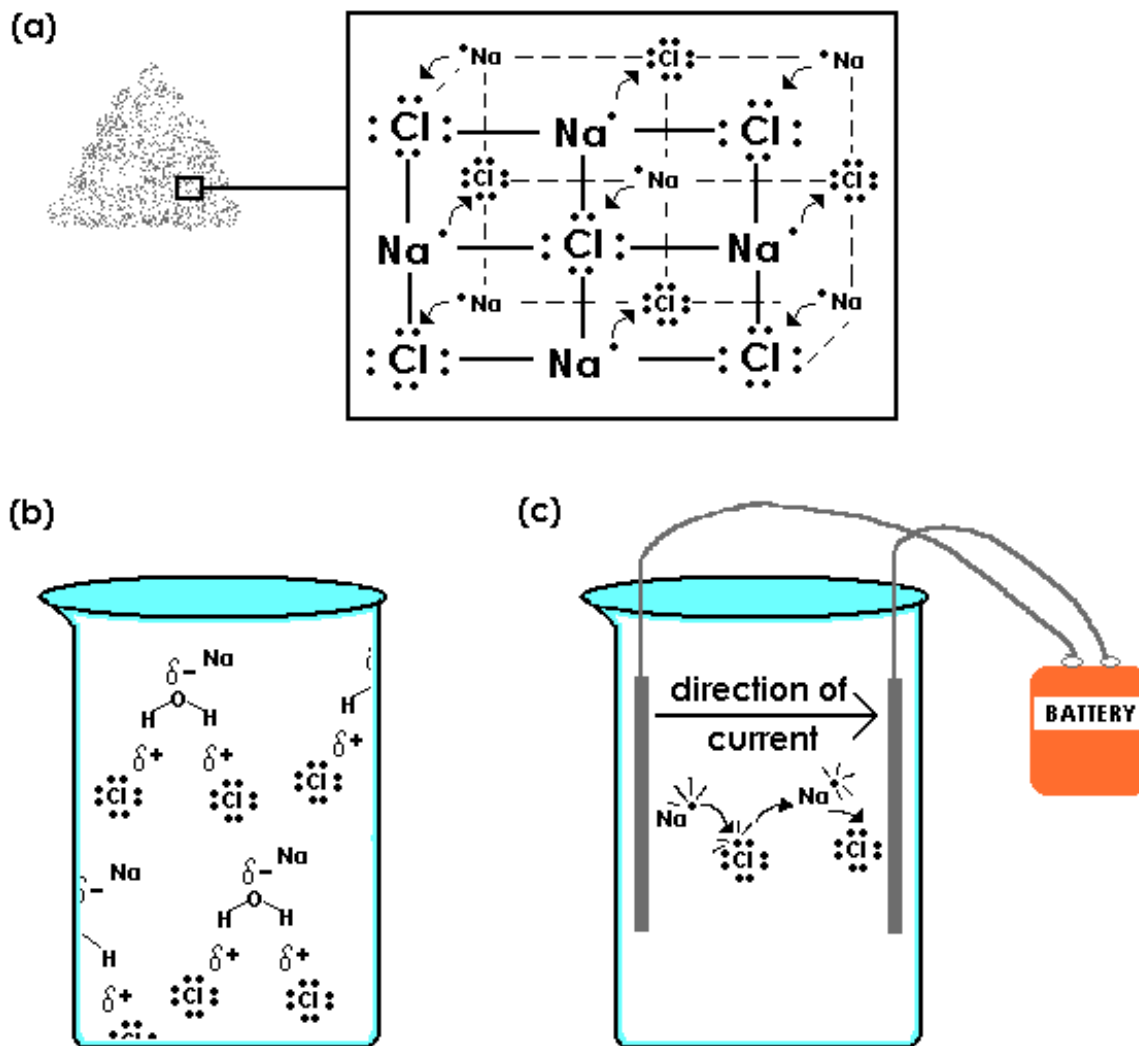


Figure 3: A Schematic of the Electron Arrangement in Solid Sodium Chloride and in Aqueous Solution

In sodium chloride, the electrons are specifically arranged, creating a lattice structure (a). This specific electron arrangement prohibits the conductance of electricity. In water, sodium and chlorine atoms dissociate, freeing the electrons (b). When a current is applied to the solution, the freer electrons are able to conduct the electrical energy from atom to atom (c).



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In humans, sodium chloride comprises about 45% of the total electrolyte concentration—this equals about 1.02×10^{-1} kg. Sodium chloride, a salt, is a strong electrolyte, completely dissociating in solution. Other electrolytes in the body are weaker, and thus would not conduct the current as efficaciously.

Electrolytes in the Nervous System

The presence of electrolytes in the body can allow the entire human body to conduct electricity. Thus, if the current is great enough humans can be *electrocuted*. This ability to conduct electricity is very important to the overall functioning of the nervous system. Like other systems in the body, the nervous system is composed of organs—

principally the brain, spinal cord, nerves, and ganglia. These, in turn, consist of various tissues: nerve, blood, and connective. Together these organs and tissues carry out the complex activities of the nervous system.

Although the nervous system is very complex, there are only two main types of cells in nerve tissue. The type of nerve cell responsible for transmitting the impulse is the *neuron*. The other type of cell is neuroglia, or glial, cell. The word *neuroglia* means “nerve glue.” These cells are nonconductive and provide a support system for the neurons. They are a special type of connective tissue for the nervous system.

Neurons are highly specialized and *amitotic*; this means that if a neuron is destroyed, it cannot be replaced because neurons do not go through mitosis. **Figure 4** illustrates the structure of a typical neuron. Each neuron has three basic parts: cell body (soma), one or more dendrites, and a single axon.

Millions of sensory receptors around the body detect changes in the environment (both internal and external to the body), called *stimuli*. The receptors monitor such things as temperature, light, and sound from the external environment. Internal receptors detect variations in pressure, pH, carbon dioxide concentration, and the levels of various electrolytes from within. All of this information is converted into electrical signals called *nerve impulses* that are transmitted to the brain, from which a response is then sent as nerve impulses back to the affected area.

The conduction of nerve impulses depends on rapid changes in the electrical potential difference across nerve cell membranes. The propagation of such electrical impulses throughout the nervous system requires rapid shifts of various electrolytes, primarily sodium and potassium ions, across cellular membranes. In many ways, the conduction of a nerve impulse resembles dominoes falling in a line. The stimulus signals the brain to initiate a series of chemical signals resulting in the movement of

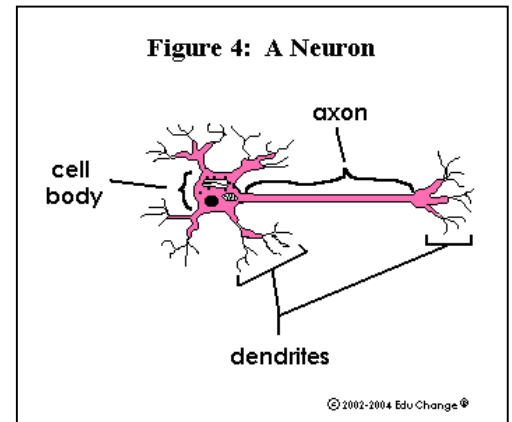
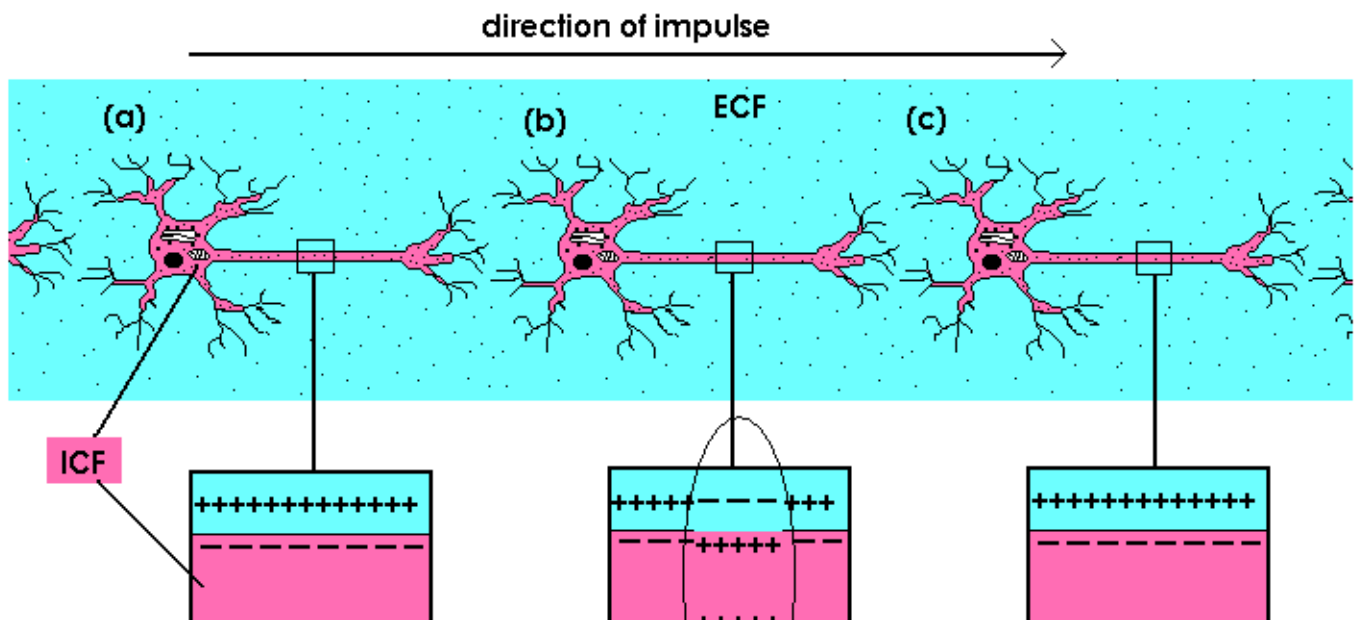


Figure 5: A Schematic of the Transmission of a Nerve Impulse

In a resting neuron, (a) & (c), the cell is at homeostasis when there is a higher concentration of positively charged ions, such as sodium and potassium, in the ECF, and a higher concentration of negatively charged organic molecules in the ICF. When the neuron is stimulated by an impulse, the cell membrane permeability to the ions increases along the axon, and there is an immediate switching of charge across the cell membrane, which sets off the next segment of the cell membrane to undergo the same change. Once this impulse has passed, the cell membrane recovers, and the cell returns to homeostasis (b). The impulse in neuron (b) will travel from its dendrites to the dendrites of neuron (c).



ions across the nerve cell membrane. This initial movement of electrolytes is like pushing the first domino over. From that point forth, the impulse is sent via chain reaction. The first domino topples the second; the second domino topples the third; and so on. The shift in ions results in an imbalance in a given neuron. This imbalance results in further shifts of ions in neighboring cells, propagating the nerve impulse until it reaches the *terminus* and the chain reaction ceases (**Figure 5**). The correct level of electrolytes in the body is essential to the basic functioning of the nervous system.

Maintaining the Dynamic Equilibrium of Water

The body uses ions to maintain the proper amount of water in the ECF and ICF. Electrolytic sodium cations are often the primary osmotic factors ensuring appropriate cellular water levels in the ECF. Chloride, the main anion in ECF, balances the sodium. The ICF contains other electrolytes: potassium and phosphate. The maintenance of correct proportions of ECF and ICF is vital to proper functioning of the body.

Water balance presents a fabulous example of the body's balance. The body maintains fluid balance by altering water intake and excretion, and via internal processes controlling water distribution. The maintenance of this dynamic equilibrium in the human body solution is as complex as it is remarkable. For example, the thirst mechanism in animals is a complex feedback loop involving control centers in the brain and hypothalamus. It makes sense that thirst is linked to water loss, but there is an actual threshold—when total body fluid volume decreases by 0.5-1.0%—that must be reached before the thirst mechanism is activated. A decrease of as little as 10% of adult body water due to excessive vomiting or diarrhea is considered serious, and in a young child could be fatal. A 2% drop in water volume can cause short-term memory loss. And did you know that water depletion is the number one cause of daytime fatigue among most people?

In addition to the feedback loops around systemic water level maintenance, at the levels of cells and tissues water also moves via passive transport. Water molecules will move from a more dilute solution with relatively high water concentrations and low solute concentrations to a less dilute environment with relatively low water concentration and high solute concentration. If this occurs across a membrane, this phenomenon, as you will recall from **Lab #14**, is called *osmosis*. The bodies of animals maintain proper fluid balance automatically, in most cases. When the body alters the solute concentration in a localized area, water moves accordingly to equalize the concentration.

Dehydration as Disequilibrium

Usually caused by excessive loss of water or low water intake, *hypertonic dehydration* refers to the bodily condition when there is less water in the ECF relative to the ICF in a tissue, causing water to shift from the cell into the ECF. In this scenario, water loss exceeds solute losses. Symptoms of hypertonic dehydration include thirst, a hot and dry body, vomiting, disorientation, and low output of concentrated urine. There are a variety of possible reasons for inadequate water intake, including a defective thirst center, impaired consciousness, a lack of water, or an inability to drink water.

Conversely, humans can become dehydrated when water shifts from the ECF into the cells. This is called *hypotonic dehydration*, and can be caused by excessive intake of water without an adequate amount of electrolytes. Ironically, the ICF is full of water, but the problem is that there is no balance of water between the ICF and ECF. Symptoms include weakness without thirst, or decreased urine output. An interesting note about dehydration is that it concerns local water balance in the tissues, not necessarily overall water volume in the body.

Electrolytes in Your Diet

Unfortunately, some common dietary practices in the United States can inhibit the body's efforts to maintain water balance. We all know that drinking plenty of fluids can stave off dehydration. What many of us do not realize is that in order for the body to properly utilize the ingested water, we also must ingest electrolytes. Electrolytes help the body retain a certain amount of water, and excrete the rest. Too few electrolytes in the body are a source of positive feedback to make the excretory system release more water. This causes the additional loss of electrolytes.

This cycle can continue with dire consequences. Eventually the body has too few electrolytes to function properly. Nerve and muscle function can be impaired if left unchecked. Not only do we need to be drinking water, but we must also ingest the necessary amounts of electrolytes via fluids or foods.

Some fluids contain ingredients known as diuretics. *Diuretics*, such as caffeine, are a class of drugs that cause the body to excrete water at a higher than normal rate. This frequent urination also expels salts that are necessary for proper nerve and muscle function.

The consumption of large quantities of alcohol, another diuretic, can also result in extreme dehydration and resulting headaches and dry mouth. Studies have shown that drinking about 250 milliliters of an alcoholic beverage causes the body to excrete 800 to 1,000 milliliters of water—four times as much liquid lost as gained. This net loss occurs because as alcohol enters the bloodstream it causes the pituitary gland in the brain to block the creation of vasopressin. Without this chemical, the kidneys send water directly to the bladder instead of reabsorbing it into the body. The diuretic effect decreases as the alcohol in the bloodstream decreases, but the resultant dehydration causes feelings of illness. The morning after a large quantity of alcohol has been consumed, the body sends a desperate message to replenish its lost water supply. This message often manifests as an extremely dry mouth that encourages the consumption of fluids. The headaches associated with severe dehydration or the over-indulgence of alcohol result from attempts by the body's organs to correct their own water loss by stealing water from the brain. This results in a temporary decrease in the size of the brain. As the brain shrinks, it pulls in the membranes that connect the brain to the skull, resulting in pain. In many ways, it is similar to the behavior of a plant cell that is placed in a hypertonic solution (**Lab #14**), with the plasma membrane pulling away from the outer cell wall.

Ultimately, it is important that humans, as well as most other organisms, maintain the proper balance of fluids and electrolytes. Think about all the fluids you consume during the course of an average day. Make a T chart indicating types and daily quantities in the space provided:

Now think about which of those fluids contain diuretics. What percentage of your fluid intake is made up of diuretic containing fluids? These fluids are not really contributing to your overall balance of electrolytes and water as they often cause your body to expel more electrolytes than they provide. If you find that the majority of your beverage choices contain diuretics, think about some alternatives and write them in the space provided.

Materials and Methods

Use of a Conductivity Apparatus

In this lab, you will determine the effect that the concentration of solute has on the conductivity of an electrolytic solution. For this experiment, the solute is sodium chloride and the solvent is distilled water. You will use a piece of equipment known as a *conductivity tester* (or *conductivity apparatus*) to determine the relative conductivity of solutions of sodium chloride. The conductivity apparatus is basically a light bulb with two protruding electrodes beneath the bulb. These electrodes are not connected to one another, therefore even when plugged in there is not a complete circuit and the light bulb will not emit light. If we dip the two electrodes into an electrolytic solution, however, the movement of charged particles through the solution will complete the circuit and the light bulb will emit light.

Materials Per Team of 2:

sodium chloride
distilled water
electronic balance
100 ml graduated cylinder
weigh paper or weigh boat
50 ml beaker
150 ml beaker
Conductivity tester

Step 1: Refer to the procedure you wrote in Pre- Lab #6.

Step 2: Prepare solutions. If you will not be performing the experiment right away, cover your solutions with parafilm and place in designated area.

Step 3: Perform experiment. Record data.

Post – Lab Activities:

1. Calculate the molarity (M) of each of your solutions.
2. Graph your results, in terms of molarity vs. conductivity. Pick a type of graph that will best represent your data.
3. Based on your results, how does the concentration of the solute affect the conductivity of a solution?
4. How will the information you have garnered from this lab impact your decisions about when to consume fluids, or what types of fluids to consume? Give two specific examples.
5. Now test the conductivity of your unknown solution. Using your standard curve from Post- Lab #2, predict the concentration of the unknown solution.