Electrolytes and ions

OBJECTIVES: The goals of this lab are to observe and explain the differences between strong, weak and non-electrolytes and to test experimentally for various ions present in common foods.

SAFETY AND DISPOSAL: Concentrated acids are corrosive. Immediately wash any spills with plenty of soap and water. Solutions containing molybdate and thiocyanate should be placed in the appropriate waste container. All other solutions can be flushed in the sink.

INTRODUCTION:

Anyone involved in strenuous exercise is aware of the importance of replenishing not just water but also the need to maintain a proper electrolyte balance. Electrolytes are compounds that dissolve in water to form ions. These ions play critical roles in cellular processes such as transmitting nerve impulses (Na^+, K^+), aiding in oxygen transport (Fe^{2+}) and bone growth (Ca^{2+}).

Some electrolyte solutions are good conductors of electricity since the electrolyte dissociates completely in water; these are termed strong electrolytes. Weak electrolytes, in contrast, are only slightly ionized in water. The presence of fewer dissolved ions makes the solution poor conductor of electrical current. A final class of soluble compounds are nonelectrolytes. Molecular compounds such as glucose are soluble in water but do not form ions and cannot conduct electrical current.

The presence of some electrolytes can be determined through simple laboratory tests. When done quantitatively, clinical tests can be used to monitor electrolyte levels. Imbalances which are diagnostic of potential disease can than be treated. Some common ions tested for include:

Calcium – for parathyroid function, calcium metabolism and malignancy activity.

Chloride – for inferential value and for diagnosis of acid-base disorders and correction of hypokalemic alkaosis.

Phosphate – for its relationship to calcium levels and parathyroid hormone levels.

Sodium – for renal and adrenal disturbances, acid-base balance and changes in water balance.

Potassium – for monitoring acidosis and diabetic ketoacidosis, acid-base imbalances, potentially lethal potassium imbalances.

Magnesium – for renal function, electrolyte status and magnesium metabolism.

Simple qualitative tests are also possible for many of these ions. This lab will test a common beverage, milk, for the presence of several electrolytes. The electrolyte content of several types of milk will be compared in order to assess how they compare to each other in nutritional value.

EXPERIMENTAL PROCEDURE:

I. Classification of Electrolytes

Set up an electrical conductivity apparatus. This apparatus tests the electrical conductivity of solutions and can be used classify substances as strong, weak or nonelectrolytes. A strong electrolyte will light a 60-watt bulb, a weak electrolyte will light a 15-watt bulb and a nonelectrolyte will not light any bulb. Test the following solutions, one at a time, rinsing the electrodes with deionized water between tests. Never touch the electrodes. Record all observations and classify each solution as a strong, weak or nonelectrolyte based on the intensity of light given off by the bulb.

Substances/Solutions
1. Deionized water
2. Tap water
3. Solid NaCl
4. 1M NaCl
5. 1M HCl
6. 1M CH_3CO_2H
7. Glacial CH_3CO_2H
8. Solid sucrose
9. 1M sucrose
10. 1M NaC_2O_4
11. 1M $CaSO_4$
12. Mixture of 10 and 11
13. 1M HCl
14. 1M $NaHCO_3$
15. Mixture of 13 and 14
16 1M KOH
17. 1M $MgCl_2$
18. Mixture of 16 and 17

II. Detection of ions in milk

Whole, skim and a non-dairy milk will be tested for the presence of calcium, phosphate and iron. (While iron is an electrolyte from the point of view of a chemist, it is not typically tested for during clinical electrolyte tests but is tested for separately. Other ions such as sodium and chloride may also be present in milk but will not be analyzed in this experiment. We will see a simple test for chloride in later experiments).

Separation of fats and proteins from the whey:

Pour 20 mL of whole milk into a 250 mL beaker and dilute by adding 20 mL of deionized water. Slowly add 10 mL of a 5% acetic acid solution while stirring the solution. The solids that precipitate are fats and protein. Allow the precipitate to settle and filter the solution using provided filter paper. Save the filtrate.

Repeat the above procedure with skim milk and non-dairy milk. Test each filtrate for the presence of ions using the procedures below.

Detection of ions:

Ca^{2+}: Pour 2 mL of filtrate into a test tube and add 2 mL of 4% ammonium oxalate, $(NH_4)_2C_2O_4$. A precipitate indicates the presence of calcium.

PO_4^{3-}: Warm 3 mL of filtrate in a test tube using a hot water bath. Add about 3 drops of concentrated nitric acid and 2 drops of ammonium molybdate reagent. Continue warming the tube. A yellow precipitate will develop if there is phosphate ion present.

Fe^{3+}: Pour 5 mL of filtrate into a test tube and add 1 mL of 0.1 M KSCN and stir. The appearance of a colored complex that ranges from orange to red indicates a positive reaction for Fe^{3+}.