Beverage Density Lab
Sugar Content Analysis

Introduction

Have you ever been to the ocean? Does it seem that you can float or swim much easier in the ocean than in a swimming pool? Seawater is denser than freshwater due to the presence of dissolved salt in the ocean. As a result, our buoyancy – ability to float – is greater in salt water than in plain water. What factors determine the density of a solution? Can the density of a solution be used to determine how much of a particular substance is dissolved in it?

Background

The density of a pure substance is a characteristic physical property that can be used to identify the substance. Density is defined as the ratio of mass per unit volume. It is an "intensive" property, that is, it does not depend on the amount of the substance. The density of any material is determined by measuring its mass and volume and then dividing the mass of the volume. The mass of a substance can be measured directly using a balance. The volume of a liquid can also be measured directly using special laboratory glassware, such as a graduated cylinder, a buret, or a pipet. In this experiment, liquid volumes will be measured using a pipet. A pipet is designed to deliver an accurate and precise volume of liquid to another container.

The density of a *solution* depends on its *concentration*, that is, how much solute (solid) is dissolved in the solvent (liquid). The higher the concentration of solute, the greater the density of the solution. A convenient way to express concentration is in units of weight percent, which corresponds to the number of grams of solute that are present in 100 g of solution. A 20% salt solution is prepared by dissolving 20 g of sodium chloride in 80 g of water. (Notice that the final mass of the solution is 100 grams.) If the density of a solution is plotted on a graph against the concentration of solute, a regular patten is evident. Density is directly proportional to concentration. A 20% salt solution, for example, has a greater density than a 10% salt solution. If the densities of several solutions of known concentration are determined experimentally, a *calibration curve* (graph) can be constructed that shows a straight-line relationship between the density of a solution and the concentration of solute. The calibration curve can then be used to find the concentration of solute in an unknown solution.

Experiment Overview

The purpose of this experiment is to determine the percent sugar content in beverages. The density of five sugar "reference" solutions will be measured in Part A. The reference solutions contain known amounts of sugar (0-20%) and have been dyed with food coloring to make it easier to tell them apart. Their densities will be plotted on a graph to obtain a calibration curve of density versus percent sugar concentration. In Part B, the densities of two beverages will also be determined and the calibration curve used to find how much sugar they contain.

The results will be compared again the information provided on the nutrition labels for these beverages.

Pre-Lab Questions
1. If the following mass and volume data are used to calculate the density of solution, how many significant figures are allowed in the calculated density? Mass of solution = 12.53 g; volume of solution = 8.27 mL.
2. Calculate the density of the solution described in Question #1.
3. According to its nutrition label, orange soda contains 49 g of sugar per 355-mL serving. If the density of the beverage is 1.043 g/mL, what is the percent sugar concentration in orange soda? *Hint*: This is a 2 step problem. First, use the density to convert the 355-mL serving size to grams. Then calculate percent sugar in the beverage.

Materials
Distilled water
Beverages (juices, sodas, sports drinks)
Sugar reference solutions (0, 5, 10, 15, and 20%), 25 mL each
Balance
Beaker, 100 mL
Erlenmeyer flask, 125-mL (to collect rinse solutions)
Pipet, 10-mL
Pipet bulb or pipet filler

Procedure
Part A. Density of Reference Solutions
1. Place an empty 100-mL beaker on the balance and hit the "tare" or "rezero" button. The scale should read 0.00 g.
2. Draw up 10.00 mL of 0% sugar (distilled water) into a pipet and transfer the liquid to the empty beaker.
3. Record the mass of the solution in Data Table A.
4. Rezero the balance using the tare button.
5. Blot the tip of the pipet gently with a paper towel to clean out any residual solution.
6. Repeat steps 2-5 for the other four sugar reference solutions, proceeding in order from the least concentrated to the most concentrated.
   - Rinse the pipet once with each new solution before using the pipet to transfer the new solution to the beaker.
   - Drain the rinse solutions into an Erlenmeyer flask.
   - Don't forget to rezero the balance prior to each new mass measurement.
7. Calculate the density of each solution and record the value in Data Table 1. *Hint*: Since the volume is always 10.00 mL, the calculation should be easy – you don't even need a calculator !

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Part B. Beverage Densities
8. Use the procedure in Part A to determine the density of the beverages available. Use clean glassware and record all mass and volume data in Data Table B. Rinse the pipet with the second beverage between successive beverage measurements.

Post-Lab Calculations and Analysis
1. Plot density versus concentration for the five reference solutions on a graph. The concentration is the independent variable (x-axis) and the density is the dependent variable (y-axis). Use a ruler to draw the "best-fit" straight line through the data points.
2. Use the graph to estimate the unknown sugar concentration in the first beverage. To do this, locate the point on the y-axis that corresponds to the density value of the beverage. Follow that point on the y-axis across horizontally to where it meets the "best-fit" straight line through the data. Now read down vertically from this point on the "best-fit" line to the x-axis. The point where this vertical "line" meets the x-axis equals the percent concentration nof sugar in the beverage solution. Construct a *Results Table* and record the density of the beverage and the estimated percent sugar concentration.
3. Repeat step 2 to determine the percent sugar concentration of your beverages. Record all information in your results table.
4. Calculate the actual or accepted value of the sugar concentration in weight percent for each beverage, using the nutrition label information and the measured density value. *Hint*: See Pre-Lab Question #3 for how to do this calculation. Record both the nutrition label information and the actual percent sugar concentration in your results table.
5. Find the equation to calculate *percent error* in your book. Use it to calculate the percent error in your experimental determination of the sugar content in each beverage. Enter the percent error in the results table.
6. What was your measured density for pure water? (0% sugar solution)? The density of water is usually quoted as 1.00 g/mL, but this precise value is for 4°C. Comment on why your measured density might be higher or lower than 1.00 g/mL.
7. This lab looks at the relationship between the density of a beverage and its sugar content. What assumption is made concerning the other ingredients in the beverage and their effect on the density of the solution? Do you think this is a valid assumption? Explain.
8. When plotting data such as that obtained in this experiment, why is it not appropriate to "connect the dots?" If you were to repeat the lab, do you think you would get exactly the same results? Comment on the sources of error in this experiment and their likely effect on the results.