Introduction

Seawater is more dense 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 freshwater. 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?

Concepts

- Density
- Concentration
- Solution
- Calibration curve

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 by 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 laboratory glassware, such as a graduated cylinder, buret or pipet. In this experiment, liquid volumes will be measured using a pipet, which is designed to deliver an accurate and precise volume of liquid.

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 pattern 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 of the same substance are determined experimentally, a **calibration curve** (graph) can be constructed that shows a straight-line relationship between the density of the solution and the concentration of solute. The calibration curve can then be used to determine 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 and plotted on a graph to obtain a calibration curve of density versus percent sugar concentration. 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. 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 against the information provided on the nutrition labels for these beverages.

Materials

Beverages (juices, sodas, sports drinks)	Beaker, 100-mL
Sugar reference solutions (0, 5, 10, 15, and 20%), 25 mL each	Erlenmeyer flask, 125-mL
Water, distilled	Pipet, volumetric, 10-mL
Balance, electronic, 0.01-g precision	Pipet bulb or pipet filler

Safety Precautions

Although the materials in this experiment are considered nonhazardous, follow all normal laboratory safety guidelines. Wear chemical splash goggles whenever working with chemicals, heat or glassware in the lab. Food-grade items that have been brought into the lab are considered laboratory chemicals and are for laboratory use only. Do not taste or ingest any materials in the chemistry laboratory.

Laboratory Technique

Volumetric pipets are designed and used to accurately deliver a specific volume of liquid from one container to another. A 10-mL volumetric pipet has a tolerance of 10.00 ±0.02 mL.

Fill the pipet to the graduation mark as shown in Figure 1. After filling the pipet, wipe the sides of the pipet only with a clean paper towel. Do not blot the tip of the pipet. To transfer the liquid, place the pipet in a new container. Holding the pipet at a slight angle, allow the liquid to drain slowly into the container. **Never pipet by mouth.**

Procedure

Density of Reference Solutions

1. Place an empty 100-mL beaker on the balance and press 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.

Caution
Never Pipet by Mouth

1. Fill pipet past the graduation mark using a pipet bulb.

2. Place your forefinger over the top end of the pipet.

3. Release finger slowly until the bottom of the meniscus is on the graduation mark.

4. Allow the liquid to drain into the receiving vessel. Do not blow out the liquid remaining in the tip of the pipet.

Figure 1. How to Use a Pipet

3. Measure and record the mass of the solution.

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 four times to measure the masses of the four sugar reference solutions. Proceed in order from the **least** concentrated to the most concentrated reference solution.

   • 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 the Erlenmeyer flask.

   • Remember to rezero the balance prior to each new mass measurement.

7. Calculate the density of each solution and record the results. **Hint:** Recall that the volume of each solution should be 10.00 mL.

Beverage Densities

Determine the density of **two beverages** of your choice. Use clean glassware and record all mass and volume data. Rinse the pipet with the second beverage between successive beverage measurements.
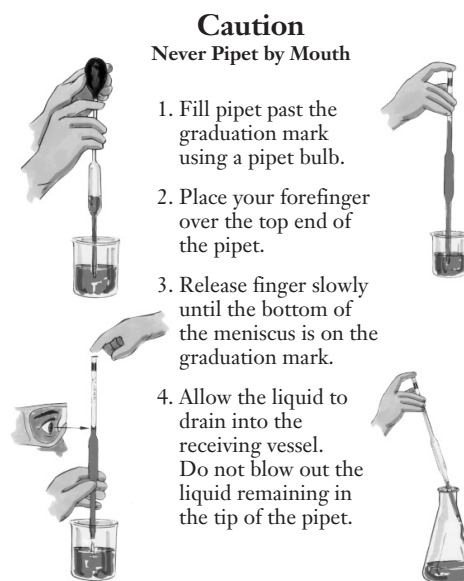
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Beverage Density Lab

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.

4. How well does the sweet taste of a beverage correlate with the amount of sugar it contains? Based on your **memory** of taste, **predict** the relative sugar content of the following beverages that will be tested in this lab: cola, grape juice, and sports drink.

5. The following graph is a calibration curve for the density of an aqueous salt solution versus percent salt concentration. If the density of seawater is 1.025 g/mL, what is the percent salt concentration?
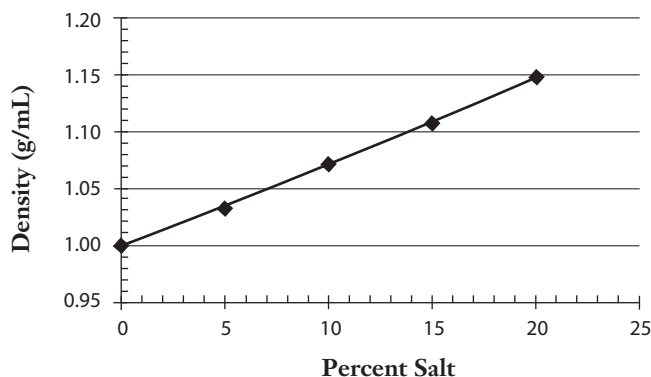
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Beverage Density Lab

**Density of Reference Solutions**

Solution	Mass, g	Sample Volume, mL	Density, g/mL
0% Sugar			
5% Sugar			
10% Sugar			
15% Sugar			
20% Sugar			

Beverage Densities

Beverage	Mass, g	Sample Volume, mL	Density, g/mL

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 spreadsheet program or ruler to draw a "best-fit" straight line through the data points.
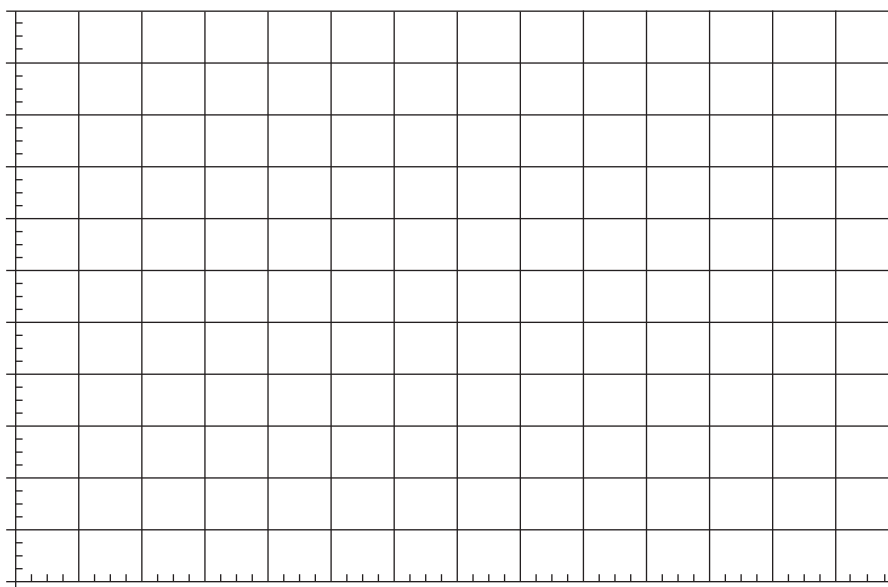
2. Use the graph to estimate the unknown sugar concentration in each beverage. To do this, locate the point on the *y*-axis that corresponds to the density of the beverage. Follow that point on the *y*-axis across horizontally to where it meets the best-fit straight line. Read down vertically from this point on the best-fit line to the *x*-axis to estimate the percent concentration of sugar in the beverage. Construct a *Results Table* on the next page and record the density of each beverage and its estimated percent sugar concentration.

3. 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*.

4. Calculate the percent error in your experimental determination of the sugar content in each beverage. Enter the percent error in the *Results Table*.

$$\text{Percent error} \; = \; \frac{|\,\text{Measured value} - \text{Accepted value}\,|}{\text{Accepted value}} \; \times \; 100\%$$

Results Table:

5. 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.

6. This lab looks at the relationship between the density of a beverage solution 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.

7. 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 sources of error in this experiment and their likely effect on the results.