Beverage Density Lab

Density Lab Activities

Introduction

Nutritionists have recently raised concerns about the increasing popularity of sodas, fruit drinks, and other beverages due to their high sugar content. Do you know how much sugar is in your favorite beverage?

Concepts

- Density
- Concentration
- Solution
- Calibration curve

Background

The density of a *solution* depends on its *concentration*, that is, how much solute (solid) is dissolved in the solvent (liquid). If the density of a solution is plotted on a graph against the concentration of solute, a regular pattern is evident—density is proportional to concentration. The resulting graph, called a *calibration curve*, shows a straight-line relationship between the density of a solution and the concentration of solute. A calibration curve can be used to determine the concentration of solute in an unknown solution whose density has been measured.

The purpose of this cooperative class activity is to measure the densities of popular beverages and determine their sugar contents using a calibration curve obtained by plotting the densities for a series of reference solutions versus percent sugar. The experimentally determined percent sugar for the beverages will be compared against the information provided on their nutritional labels to evaluate the accuracy of this method.

Hypothesis

How well does the sweet taste of a beverage correlate with the amount of sugar it contains? Based on your *memory* of their taste, predict the relative sugar content in the following beverages: cola, grape juice, and sports drink. (Rank the beverages from 1, highest sugar content, to 3, lowest sugar content.)

Materials

Beverages (at room temperature)*

Balance, centigram (0.01-g precision)

Beaker, 100-mL

Cups, clear plastic, 8, labeled 0%, 5%, 10%, 15%, 20%, Cola, Grape Juice, Sport Drink

Paper towels

Volumetric pipet with bulb

**Any carbonated beverages must be "flattened" to remove dissolved carbon dioxide before testing. This can be accomplished by pouring the beverage back and forth from one container into another several times until it stops fizzing.*

Safety Precautions

Although the materials in this activity are considered nonhazardous, follow all normal laboratory safety guidelines. Any food-grade items that have been brought into the lab are considered laboratory chemicals and are for lab use only. Do not taste or ingest any materials in the laboratory, and do not remove any food items from the lab after use. Wear safety glasses or chemical splash goggles whenever working with chemicals, heat or glassware in the lab. Wash hands thoroughly with soap and water before leaving the lab.

Procedure

1. Place a small (100-mL) beaker on the balance and hit the "tare" or "rezero" button. The scale should read 0.00 g.
2. Draw up a precisely measured 10.00 mL of 0% sugar solution into a pipet. Then empty it into the beaker, toughing the tip of the pipet to the inside wall of the beaker to help get out most of the liquid in the tip. *Do not try to shake out*

any liquid that remains there. The pipets are designed TD ("to deliver") 10.00 mL and that remaining drop should not be squeezed out. Since the beaker has already been zeroed out, the mass is that of the liquid alone.

3. Record this mass in the data table below.
4. Push the "tare" button to rezero the scale for the next reading.
5. Touch the pipet to a paper towel to clean out any residual solution.
6. Repeat steps 2–5 with each of the remaining sugar solutions, and then with each of the three beverages. Do not put any of the solutions back into the cups from which they came, just leave then in the beaker. When the beaker get full, simple empty it into the sink, set it back on the scale, and push the "tare" button.
7. Calculate and record the density of each beverage sample. *Hint:* Since the sample volume is always 10.0 mL, the calculation should be easy—you don't even need a calculator!

Data Table

Percent Sugar/ Beverage	0%	5%	10%	15%	20%	Cola	Grape Juice	Sport Drink
Mass (g)								
Density (g/mL)								

Data Analysis

1. Plot the known density on the *y*-axis versus percent sugar on the *x*-axis for the following sugar reference solutions. Use a ruler to draw a "best fit" straight line through the data points.
2. Use the graph to estimate the sugar concentration in the beverage: Locate the point on the *y*-axis that corresponds to the beverage density. Follow that point on the *y*-axis across horizontally to where it meets the best-fit straight line through the data points for the reference solutions. Draw a vertical line from this point on the best-fit line down to the *x*-axis. The point where this vertical "line" meets the *x*-axis corresponds to the percent sugar in the beverage. Estimate and record the percent sugar for the beverage.
3. Consult the nutritional label for the beverage—it should list the sugar content in grams of sugar per serving size. This value can be converted to percent sugar in the beverage by dividing the grams of sugar per serving size by the volume of the serving size (in mL), dividing this result by the measured density of the beverage, and multiplying by 100. Record the nutrition label information and the calculated percent sugar for the beverage.

   Sample calculation: Measured density = 1.038 g/mL

   Nutritional label = 42 g of sugar per 355 mL

   (42 g/355 mL) × (1 mL/1.038 g) = 0.114 g sugar per g of beverage

   Percent sugar = 0.114 g sugar per g of beverage × 100% = 11.4%

4. Calculate the *percent error* in the experimental determination of the sugar content using the following equation.

   $$\text{Percent error} = \frac{|\text{Calculated value} - \text{Experimental value}|}{\text{Calculated value}} \times 100\%$$

5. This lab examines 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 its density? Is this a valid assumption? Why or why not?

Preparation

In empty 1-L or 2-L soda bottles, place the following:

* 0% = 1000 g of water

* 5% = 950 g of water, 50 g of sugar, two drops yellow food coloring

* 10% = 900 g of water, 100 g of sugar, one drop blue, one drop yellow

* 15% = 850 g of water, 150 g of sugar, two blue drops

* 20% = 800 g of water, 200 g of sugar, one drop blue, one drop red

**The sugar concentrations are mass percent.*

Then cap and shake well until sugar is all dissolved and solutions are homogeneous.

This makes up close to 1000 mL of each solution, more than enough for 5 sections of 24 students each, working in pairs.

The grape juice and powerade can be used as is from the bottles. The carbonated beverages should be "flattened" first. This should be done by pouring them back and forth several times between two large beakers. If this is not done, the carbonation can produce bubbles during pipetting and throw off the results. Certainly, any four (or more) beverages can be substituted in. It is wise to pick ones with somewhat different sugar contents (see labels), and with somewhat different colors.

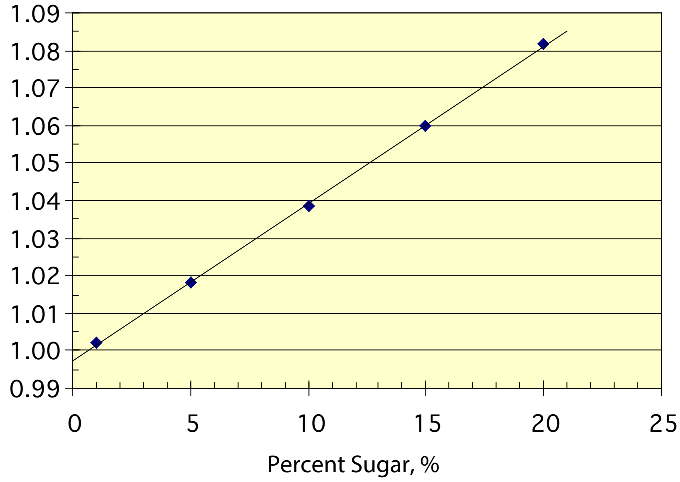
Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The beverage solutions may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- This experiment makes a great collaborative class activity. Make copies of pages 1 and 2 only for student use. Encourage students to bring in their favorite beverages for testing—this gives them "ownership" of their experiment and promotes friendly competition to determine the results of the testing. Try to obtain a variety of non-diet beverages.
- Fructose ("fruit sugar") is the main sugar present in fruit juices, fruit drinks such as Snapple,® and most carbonated sodas. For best results, the beverage samples should be at room temperature, as close to 20 °C as possible.
- Table sugar is sucrose, a disaccharide composed of one molecule of fructose joined with one molecule of glucose after loss of water. Both fructose and sucrose reference solutions were tested in this activity and both gave similar results and accuracy.
- Sports drinks such as Gatorade® are the "exception that proves the rule" in this study. The working assumption in this experiment is that sugar is the main ingredient whose concentration determines the beverage density. This assumption may be true for sodas and juices, but not for sports drinks, which contain large amounts of salts such as sodium and potassium chloride to maintain electrolyte balance.
- Help students see (literally!) the amount of sugar in the beverage by weighing out the amount of sugar shown on the nutritional label.

Sample Calibration Curve



Sample Results

Percent Sugar/ Beverage	0%	5%	10%	15%	20%	Cola	Grape Juice	Sport Drink
Mass (g)	9.98	10.18	10.38	10.59	10.81	10.4	10.6	10.3
Density (g/mL)	0.998	1.018	1.038	1.059	1.081	1.04	1.06	1.03
				Percent Sugar (Experimental)		10.2	15.0	7.8
				Nutrition Label		42 g/355 mL	40 g/240 mL	15 g/240 mL
				Percent Sugar (Calculated)		11.4	15.7	6.1
				Percent Error		10.7%	4.5%	28%

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter
Content Standard F: Science in Personal and Social Perspectives; personal and community health

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Beverage Density Lab* activity, presented by Bob Becker, is available in *Density Lab Activities* and in *Chemistry of Food*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Beverage Density Lab* are available from Flinn Scientific, Inc.

Catalog No.	Description
OB2141	Flinn Scientific Electronic Balance, 210 g × 0.01-g
GP1010	Beaker, Borosilicate Glass, 100-mL
AP7294	Cups, Clear Plastic, 10 oz., Pkg/50
GP7030	Volumetric Pipet, 10-mL
AP7082	Pipet Filler, Graduated, Pkg of 3
AP1887	Pipet Filler

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.