DETERMINING THE CONCENTRATION OF SUGAR(S) IN A SOFT DRINK ON THE BASIS OF DENSITY USING A HYDROMETER

Overview

If a substance such as sugar is dissolved in water, the density of the resulting solution is greater than the density of water. The density of such solutions varies directly with the concentration of the solutions. Thus the higher the percentage of sugar in the solutions, the greater the density of the solutions.

Density of a solution can be measured with a device called a hydrometer, a long, tubular object that floats vertically in the solution to be tested. The more dense the solution, the higher in the liquid the hydrometer floats. Calibrations along the stem of the hydrometer enable the experimenter to determine quantitatively just how high in the liquid the hydrometer is floating. The length of the stem that emerges from the liquid is a measure of the density of the liquid.

A hydrometer is placed in water and then in a number of carefully prepared sugar solutions of different known concentrations. The stem emergence in each solution is measured. Then a line graph is prepared by plotting the stem emergence of each solution versus its corresponding concentration.

Next, the stem emergence of the same hydrometer in sugar solutions of unknown concentration (various soft drinks) is measured. Using the prepared graph, one can correlate each stem emergence value with a corresponding concentration value, thus determining the concentrations of the solutions.

Part A -- Determining The Stem Emergence Of The Hydrometer In Five Sugar Solutions Of Known Concentration

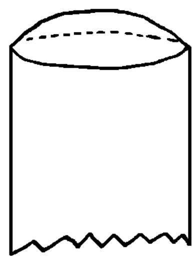
Materials

sugar solutions, concentrations of 3%, 6%, 9%, 12% and 15%
hydrometer
5 hydrometer jars

Procedure

1. Completely fill the hydrometer jar with the 3% sucrose solution.

2. Lower the hydrometer into the solution in the hydrometer jar until the bulb is submerged; then release the hydrometer. There will be some spillage as the liquid in the jar overflows. Because of surface tension the liquid will tend to protrude above the top of the hydrometer jar giving the effect of a “mound” of liquid. See drawing below.



1. Very carefully read the ruler at the point where the pipet stem emerges from the “mound” of liquid. Best readings are obtained by viewing the ruler somewhat from the side rather than head-on. Estimate the reading to the second decimal place (in cm).*

2. Record the reading on the Data Sheet on page 6.

3. Repeat this process two more times.

4. Empty, rinse, and dry the hydrometer jar.

5. Carefully wipe all traces of liquid from the hydrometer.

Repeat steps 1-7, for each of the other sucrose solutions of known concentration: 6%, 9%, 12% and 15%.

* Hints: You may want to try using a magnifying glass to see if it can help you in getting a more accurate reading.

Part B -- Preparing A Line Graph Of Stem Emergence Values Versus Concentration Values

Materials

graph paper
ruler

1. Label the horizontal axis (8½ wide) of a sheet of graph paper "*Percent Sugar*" and enter appropriate numerals. Label the vertical axis (11" long) "*Stem Emergence In Centimeters*" and enter appropriate numerals.

2. Enter the data points for each of the five sugar solutions. The location of each of these points is determined by the percent sugar value and the corresponding stem emergence value for each solution.

3. Connect the points with a smooth line. If it appears to be approximately a straight line, use a ruler to draw the best possible straight line through the points. See your instructor if you don't know how to do this.

Part C -- Using The Hydrometer And The Line Graph To Determine The Concentration Of Sugar In Various Soft Drinks

***NOTE*: It is imperative that the same hydrometer used in Part A be used for all measurements in Part B because stem emergences will vary from one hydrometer to another, even in the same solution.**

In this part of the experiment you will determine the sugar content of a degassed* soft drinks. Other types of drinks (fruit juices, etc.), could be used.

Procedure

1. Fill the hydrometer jar with a degassed* soft drink.

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* Degassing Carbonated Drinks

Ask your instructor if your soft drink has been degassed. If not, it can be done according to the procedure which follows.

All carbonated drinks must be degassed (all carbon dioxide gas removed) before using a hydrometer to determine the concentration of sugar in them. If this is not done, bubbles of gas will cling to the hydrometer making it more bu
\oyant and causing it to float higher in the liquid than it would otherwise.

To degas a soft drink, pour it into a wide-mouth container. Set the container in a larger container of warm water. Stir the drink vigorously for several minutes, allow it to stand 15 minutes, stir vigorously again, and then cool the drink back to room temperature.

2. Place the hydrometer in the hydrometer jar containing the unknown.

3. Read the ruler where it emerges from the liquid.

4. Record the stem emergence reading on the Data Sheet on page 6.

5. Repeat steps 2-4 of the procedure two more times.

6. Average the stem emergence readings and enter this value in the Data Sheet on page 6.

7. Locate the average stem emergence value of the soft drink on the graph prepared from solutions of known sugar concentrations. Read the concentration of sugar in the soft drink (as % sugar) on the x axis.

Data Sheet

	Stem Emergence (in cm)			
Solution, % Sugar	1st Detn.	2nd Detn.	3rd Detn.	Average
3%				
6%				
9%				
12%				
15%				
Soft Drink				

Concentration of sugar in soft drink (detn'd from graph) = _____%

Concentration of sugar in soft drink
(calculated from information on can) = _____%

Error = _____%

*Percent Error = _____%

$$^{*}\ \%\ \text{Error} = \frac{\text{error}}{\text{sugar concentration (from can)}} \times 100$$

TEACHER'S GUIDE TO

DETERMINING THE CONCENTRATION OF SUGAR(S) IN A SOFT DRINK ON THE BASIS OF DENSITY USING A HYDROMETER

I. PREPARING SUGAR SOLUTIONS OF KNOWN CONCENTRATIONS

Materials

balance
sucrose (table sugar)
weighing containers
6 clean, empty, 1-liter plastic drink bottles

General Discussion

Solutions of sucrose (table sugar) in water in concentrations of 3%, 6%, 9%, 12%, and 15% are made by weighing out five different quantities of sucrose; each is dissolved in water.[**]
Prior to preparing the solutions, you should know the answers to these questions:
(1) How many milliliters are needed to fill one hydrometer jar?

(2) How many hydrometer jars will be in use (i.e., how many student groups will be involved)?

Roughly 100 mL of each solution will be required by each group of students. Let's assume eight groups will be involved. You will need 800 mL (100 mL x 8) of each solution.

Plastic, Soft Drink Bottles May Be Substituted For Volumetric Flasks

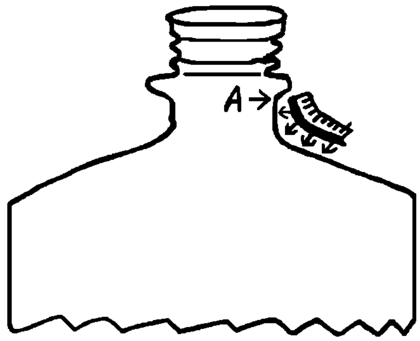
Chemists use volumetric flasks (calibrated long-necked flasks) in the preparation of solutions of specific concentrations. However, volumetric flasks are quite expensive.

We have found it to be convenient, cheap, and quite accurate to use 1-liter, plastic soft drink bottles instead of volumetric flasks for preparing these solutions.

[**] A professional chemist might ask why each of these solutions is being prepared by dissolving solid sugar. Why not prepare a large amount of the most concentrated solution and then dilute portions of this solution with water to prepare the various less concentrated solutions? It is our experience that most high school teachers do not have the necessary volumetric glassware nor containers for working with large amounts of solutions. Moreover, there are many opportunities for both mathematical and manipulative errors when calculating and performing the numerous dilutions that would be required to prepare the solutions.

Preparing The Plastic Bottles For Use As Volumetric Flasks In This Experiment

Tape a short piece of a flexible, plastic, metric rule to the neck of a 1-liter, plastic, soft drink bottle. The "zero end" of the rule should fit against the flange at point A as shown on the drawing below. Very carefully measure out 1 liter of water and pour it into the bottle. Note where the water level is on the metric rule and record this value to the nearest one-hundredth of a centimeter. (A typical value is 4.05 cm.)



Following the procedure described above, tape short pieces of a metric rule to five other 1-liter, clean, plastic, soft drink bottles. When these bottles are filled with liquid to the same value on the metric rule as that you recorded for water, you can assume you have 1 liter ±5 mL. A 5-mL error is only a 0.5% error which is so small that it is negligible in this experiment.

Preparing The Solutions

Although we only need 800 mL of each solution, we will actually prepare 1 liter of each because it is convenient and will give you some extra solution for emergencies. To make a 3% (wt/vol.) sucrose solution we would need 30 g (0.03 x 1000) of sucrose dissolved in enough water to make 1 liter of solution. A 6% solution would require 60 g (0.06 x 1000) of sucrose dissolved in enough water to make 1 liter of solution; and so on.

A very useful feature of using soft drink bottles in this particular experiment is the fact that the solutions can be prepared and kept in the bottles.

Fill the bottle about half full of water, add the sucrose, cap the bottle, shake vigorously for several minutes to dissolve all the sugar. Then add additional water to bring the liquid level up to the designated mark on the metric rule taped to the bottle. Be careful in adding the last few milliliters of water. You don't want the liquid level to go beyond the mark.

WARNINGS! (1) Remove all original labels from soft drink bottles and replace them with labels made for this experiment prior to preparing the sugar solutions. Never simply add a new label to the label al-

ready there. <u>Failure to label containers properly is one of the greatest sources of danger in the chemistry laboratory.</u>

(2) These sugar solutions, particularly the 3% and 6% solutions, should not be stored for more than a few days. They are good media for the growth of bacteria. Discard the solutions when your class finishes this experiment.

(3) Do not ever use plastic soft drink bottles for the mixing or storage of acidic or basic solutions, or liquid organic chemicals. All of these liquids have the potential to react with and/or dissolve the type of plastic used in soft drink bottles.

II. ACQUIRING PRESCRIPTION DRUG VIALS FOR USE AS HYDROMETER JARS

Ideally the hydrometer jars should have a flat bottom, be unbreakable, and as small as possible to minimize the amount of liquid required to float the Beral pipet hydrometer. Prescription drug vials are ideal for this purpose. They can probably be obtained free (or at a small cost) from the pharmacist at the drug store which you regularly patronize. We have found that the 16-dram vials best meet the needs of this experiment. These are 8 cm long with an outside diameter of about 3.3 cm. They have a capacity of approximately 56 mL. We prefer the milky-white translucent vials rather than the brown vials. However, either would be acceptable since one does not have to be concerned about seeing the liquid level in the vial.

III. DETERMINING THE CONCENTRATION OF SUGAR(S) IN A SOFT DRINK ON THE BASIS OF DENSITY USING A HYDROMETER

<u>Materials For Each Group</u>

100 mL each of 3%, 6%, 9%, 12% & 15% sucrose solutions
1 hydrometer
5 hydrometer jars
1 sheet graph paper
1 ruler
magnifying glass (optional)

IV. DEGASSING SOFT DRINKS

All carbonated drinks must be degassed (all carbon dioxide gas removed) before using a hydrometer to determine the concentration of sugar in them. If this is not done, bubbles of gas will cling to the hydrometer making it more buoyant and causing it to float higher in the liquid than it would otherwise.

To degas a soft drink, pour it into a wide-mouth container. Set the container in a larger container of warm water. Stir the drink vigorously for several minutes, allow it to stand 15 minutes, stir vigorously again, and then cool the drink back to room temperature.