DETERMINING THE CONCENTRATION OF SUGAR(S) IN A SOFT DRINK ON THE BASIS OF DENSITY USING A TIME-OF-FALL APPARATUS

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 liquid can be measured by determining how long it takes an object of appropriate density to fall from the top of the bottom of a vertically mounted tube filled with the liquid.

The tube is filled sequentially with a number of carefully prepared sugar solutions of different known concentrations. A plastic ball is allowed to fall through each solution and its time-of-fall measured. Then a line graph is prepared by plotting the time of fall in each solution versus the concentration of that solution.

Next, the time-of-fall of the same plastic ball through sugar solutions of unknown concentrations (various soft drinks) is measured. Using the prepared graph, one can correlate each time-of-fall value with a concentration value, thus determining the concentrations of the solutions.

Part A -- Determining The Time-Of-Fall Of The Ball In Water And In Five Sugar Solutions Of Known Concentrations

Materials

3-foot transparent plastic tube
plastic ball of density 1.0650 g/cc
forceps or tweezers
2 rubber stoppers to fit plastic tube
stopwatch (or watch or clock with a “stopwatch” capability)
small funnel
coat hanger (straightened)
paper towels
cotton balls
a container for transporting liquid
tygon tubing cut in 14” length
graph paper
sugar solutions (3%, 6%, 9%, 12% 15%)

Procedure

1. Insert a rubber stopper in one end of the plastic tube to give a tight fit. Holding the tube vertically, insert a small funnel in the open end. Then pour a 3% solution of sucrose in water into the tube until it is about half full. Gently tap the tube with your hand to dislodge any air bubbles that may be around the stopper. Drop a water-moistened plastic ball into the tube. Completely fill the tube with the sugar solution. Again tap gently to remove any air bubbles, and then, using a twisting motion, very carefully insert the other rubber stopper into the open end of the tube to completely seal it.*

   Again check for air bubbles. If bubbles are seen, remove one of the stoppers and tap the tube to dislodge the bubbles. Add a small amount of the solution to again completely fill the tube, then again very carefully insert the rubber stopper. Repeat this process, if necessary, until no bubbles are seen.

2. The operator of the stopwatch says, "Ready . . ., Set . . ., Go," and starts the stopwatch. At the word "Go" the tube handler quickly inverts the tube and rests it on a flat surface and holds it against a vertical surface to make sure the tube remains vertical. As soon as the tube is inverted, the ball begins its descent.

3. The stopwatch operator watches the fall of the ball carefully. The instant the ball touches the bottom, the stopwatch is stopped. The elapsed time is recorded on the Data Sheet on page 5 under 1st Determination (Detn.).

4. Repeat steps 4 and 5 three times -- giving a total of four readings. Record these readings in the appropriate boxes on the Data Sheet. Average the four readings and record the average value on the data sheet.

5. Drain the sugar solution from the plastic tube into a receptacle from which you can retrieve the plastic ball with forceps or tongs. Place the ball into a container of water.

   ***WARNING**: Never work with the plastic ball over a sink or over the floor. It is small and, therefore, easily dropped and lost. If the ball is lost, the experiment must be begun again, from the start, using a new ball*.

6. Rinse the tube by pushing a wet cotton ball through it with a straightened, all-wire coat hanger with a "handle" at one end for easy grasping and rotation of the wire. Then dry the tube by pushing a loosely wadded piece of paper towel through it with the coat hanger.

7. Using the other sugar solutions sequentially, repeat steps 3-8 for each solution.

---

* This can be a bit messy since some of the solution will be forced out of the tube when the stopper is inserted. Have paper towels available to wipe spilled liquid from the outside of the tube and from the desk top.

Part B -- Preparing A Line Graph Of Time-Of-Fall Values Versus Concentration Values

1. Label the horizontal axis (8 ½ wide) of a sheet of graph paper "*Percent Sugar*" and enter appropriate numerals. Label the vertical axis (11" long) "*Time-of-Fall In Seconds*" 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 time-of-fall value for each solution.

3. Connect the points with a smooth line. Since the line may not be straight, use a sheet of flexible plastic or plastic tubing as your guide in order to make the line a smooth curve.

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

In this part of the experiment the students determine the sugar content in various degassed* soft drinks. Sugar solutions of other (unknown) concentrations, as well as other types of drinks (fruit juices, etc.), could be used.

Procedure

1. Fill the long plastic tube with a degassed* soft drink following exactly the procedure in step 3 of Part A.

2. Determine the time-of-fall of the ball through the soft drink following exactly steps 4-6 of Part A.

3. Average the time-of-fall values.

4. Locate the time-of-fall 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.

---

* 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 time-of-fall apparatus to determine the concentration of sugar in them. If this is not done, bubbles of gas will cling to the plastic ball making it more buoyant and either preventing it from falling or causing it to fall at a slower rate 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.

Data Sheet

	Time of Fall (in sec)				
Solution, % Sugar	1st Detn.	2nd Detn.	3rd Detn.	4th Detn.	Average Value
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 TIME-OF-FALL APPARATUS

Materials For Each Group

1 3-foot acrylic plastic transparent tube (1/2" O.D., 3/8" I.D.)
2 #000 rubber stoppers
5 sugar solutions (3%, 6%, 9%, 12%, 15%)
soft drink
1.065 g/cc ball (from an antifreeze tester)
cotton balls
paper towels
coat hanger (straightened)
stop watch
tygon tubing
tweezers
graph paper
water
waste container

I. ACQUIRING THE BALL TO BE USED IN THE TIME-OF-FALL EXPERIMENT

The density of the ball used is critical to the success of this experiment. The density required is approximately 1.0650 g/cc. Our only source to date of a ball of this density is one of the plastic balls found in the Victor model V-330 Antifreeze and Coolant Tester. The specific ball required is the one second from the bottom. It has a red or pink color. The tester, which can be purchased for about $1.00 at certain automotive supply stores, can be dissembled easily and the red ball removed for use in this experiment. WARNING! -- The ball is very small and readily lost if you (or your students) are not careful. Don't pour a liquid with the ball in it into a sink because the ball can easily be lost down the drain. Instead pour the liquid into a shallow pan, recover the ball with forceps or tweezers, and then pour the liquid from the pan into the sink.

II. ACQUIRING THE TUBES USED IN THE TIME OF FALL EXPERIMENT

The tubes used in this experiment are 3 ft lengths of rigid, transparent acrylic tubing (3/8" I.D.; 1/2" O.D.). They can be purchased through Mississippi Rubber and Specialty Company, 715E McDowell Road, P.O. Box 6489, Jackson, MS 39282-6489, phone: (601) 948-2575. The tubes can be ordered only in 6-foot increments and cost $0.32/foot. To cut a 6-foot tube into two 3-foot lengths, use a saw with a fine-tooth blade.

CAUTION: These plastic tubes should be used only for water solutions of non-corrosive solids. The tubes are soluble in organic solvents, such as acetone. Therefore, don't ever pour organic liquids into the tubes or even allow the liquids to come in contact with the tubes. If you do you will mar or ruin the tubes.

III. PREPARING SUGAR SOLUTIONS OF KNOWN CONCENTRATIONS

See page 9 of Teacher's Guide for preparation of sugar solutions for Activity 2. If both Activities 2 and 3 are conducted, the same solutions can be used for both experiments.

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.

QUESTIONS TO BE USED WITH THE VIDEO
SCIENTIFIC GRAPHS: HOW TO MAKE THEM AND MAKE SENSE OF THEM

1. What is a graph?
   ans.: A visual presentation of numbers.

2. Did stacking pennies aid in understanding what a bar graph represents?
   ans.: Yes, it gives a concrete example of what the graph represents more abstractly

3. What is the difference between a bar graph and a line graph?
   ans.: A line graph ties figures together..

4. In what way is a line graph more useful than a bar graph?
   ans.: It allows information to be obtained for values which are not directly measured.

5. What type of graph is most commonly used in science?
   ans.: line graph

6. Does a line graph have to start at zero?
   ans.: No, it can start at any value.

7. What are the steps in making a line graph?
   ans.: a. collect data
   b. plot points
   c. connect points smoothly
   d. interpret results

8. Is a line graph always a straight line?
   ans.: No; only when the quantities being measured are related by the general formula $y = mx + b$.

9. How do you estimate volume for a known pressure that was not experimentally determined in the Boyle's Law determination?
   ans.: On the curve locate the value of the pressure for which you are seeking the volume. Determine the value for volume at that point from the y axis.

Post Viewing question to be discussed:

1. What quantity (dependent variable or independent variable) is used to determine a value not experimentally measured?
   ans.: You must know one of the two quantities. It doesn't matter whether the value you are seeking is a dependent or an independent variable.

QUESTIONS TO BE USED WITH THE VIDEO
SCIENTIFIC GRAPHS: HOW TO MAKE THEM AND MAKE SENSE OF THEM

1. What is a graph?

2. Did stacking pennies aid in understanding what a bar graph represents?

3. What is the difference between a bar graph and a line graph?

4. In what way is a line graph more useful than a bar graph?

5. What type of graph is most commonly used in science?

6. Does a line graph have to start at zero?

7. What are the steps in making a line graph?

8. Is a line graph always a straight line?

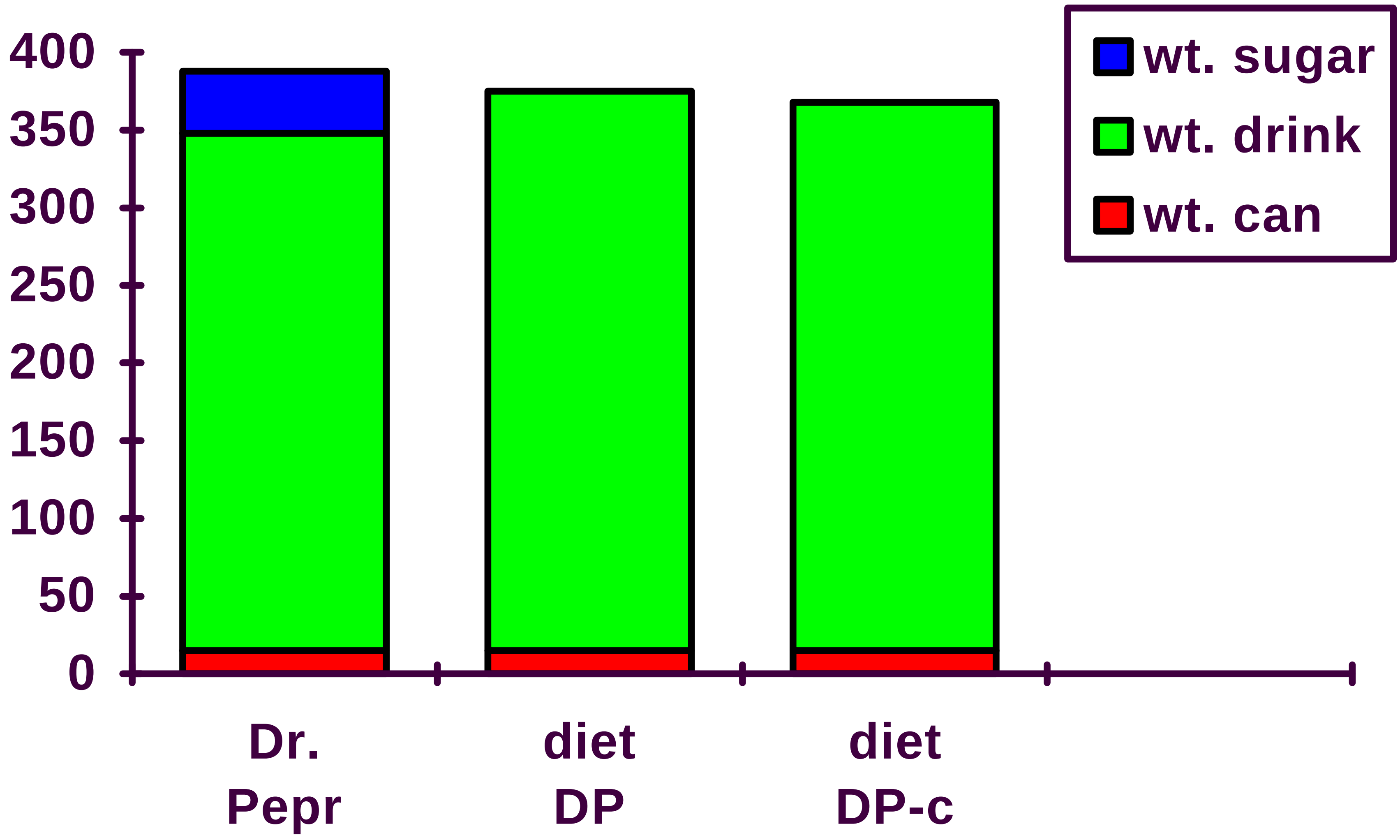
9. How do you estimate volume for a known pressure that was not experimentally determined in the Boyle's Law determination?

Post Viewing question to be discussed:

1. What quantity (dependent variable or independent variable) is used to determine a value not experimentally measured?

PERCENT SUGAR IN VARIOUS SOFT DRINKS

DRINK	AMT. SUGAR	% SUGAR
Coke Classic	39 g	11.0%
Coke Classic caffeine free	39 g	11.0%
Diet Coke	0 g	0%
Cherry Coke	42 g	11.8%
Sprite	38 g	10.7%
Diet Sprite	0 g	0%
Dr. Pepper	40 g	11.3%
Diet Dr. Pepper	0 g	0%
Diet Dr. Pepper caffeine free	0 g	0%
Fresca	0 g	0%
Mountain Dew	46 g	13.0%
Diet Mountain Dew	0 g	0%
Pepsi	41 g	11.5%
Diet Pepsi	0 g	0%
Minute Maid Orange	47 g	13.2%
Welch’s Strawberry	51 g	14.4%
Hawaiian Punch	44 g	12.4%


400
350
300
250
200
150
100
50
0
wt. sugar
wt. drink
wt. can
Dr. Pepr
diet DP
diet DP-c