Using a Hydrometer to Determine the Concentration of Sugar in a Commercial Soft Drink

Background

Figure 1. A hydrometer submerged in a glass cylinder.

At temperature and pressure conditions we would typically have in our science classroom, we could expect water to have a density *(ρ)* of about 1.00 g/ cm^3. If water-soluble substances such as sugar or salt are dissolved in water, the density of the resulting solution is greater than 1.00 g/ cm^3; in fact, the density varies directly with the concentration of the solutions. In the case of commercially-sweetened beverages, the higher the percentage of sugar, the greater the beverage's density.

Homebrewers of beer go to impressive lengths to be certain their brew has just the right amount of sugars, malt, and starch. Tthey can determine the combined concentration of these solutes by using a device called a *hydrometer*. A hydrometer is a long, tubular, weighted glass object that floats vertically in the solutions it tests (Figure 1).

When a typical hydrometer is placed in a sample of pure water, the device bobs up and down until it settles at about the 1.000 mark (Figure 2). This same hydrometer can be used to provide for us an indirect method for determining the concentration of sugar contained within a commercial beverage.

Note in Figure 2 the graduated lines along the stem of the hydrometer, which enable the experimenter to determine quantitatively just how high in the liquid sample the hydrometer is floating. The length of the stem that emerges from the liquid is a measure of the density of the liquid.

Figure 2. Note the position of the water level on the hydrometer, at the 1.000 mark.

For today's laboratory, you are going to establish the specific gravity of various commercial soft drinks, using a hydrometer. Specific gravity is simply a ratio of the density of a solution of interest to the density of water, and can be calculated as follows:

$$specific\ gravity\ = \frac{\rho}{\rho_s}$$

Where ρ is the density of the solution sample, and ρ_s is the density of a "standard," which in our case is water.

Once we know the specific gravity of the beverage, we can ascertain the sugar concentration from a concentration curve. While there are other solutes that contribute to the beverage's density, their concentrations are nominal compared to sucrose.

In Part A you will ascertain the specific gravity of five sugar solutions of known percent mass concentration and plot these on a graph (Part B) in order to establish a concentration curve for your sweetened beverage analysis. After the curve the completed, you can determine the % concentration of sugar by comparing its specific gravity to the concentration curve (Part C).

Part A – Establishing a Concentration Curve from Five Sugar Solutions of Known Concentration

Materials

Sucrose (table sugar) solutions, concentrations of 3%, 6%, 9%, 12% and 15% by mass

hydrometer

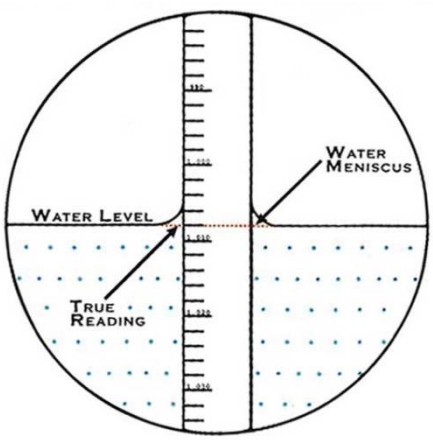
5 hydrometer jars (250-mL capacity graduated cylinders)

Procedure

1. Fill the graduated cylinder until the hydrometer could be completely immersed with the sucrose solution given to your group.

2. Lower the hydrometer into the solution in the cylinder until the bulb is submerged, then release the hydrometer, spinning it gently so as to remove any bubbles adhering to its sides.

3. Read the graduated line on the hydrometer, at the *water level*, not where the water climbs up the hydrometer. (Hint: You may want to try using a magnifying glass to see if it can help you in getting a more accurate reading.)



4. Record the reading on Table 1 and repeat two more times.

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

Repeat steps 2-5, for each of the other sucrose solutions of known concentration.

Part B -- Preparing a Line Graph of Stem Emergence Values vs. Concentration Values

Materials

graph paper

ruler

Procedure

1. Label the horizontal axis of a sheet of graph paper "*Percent Sugar*" and enter appropriate values (3%, 6%, 9%, 12%, 15%).

2. Label the vertical axis "*Specific Gravity*" and write out the appropriate values from Table 1.

3. 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.

4. 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 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 drink. Other types of drinks such as fruit juices could also be used.

All carbonated drinks must be degassed (all carbon dioxide gas removed) before using a hydrometer for analysis. 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.

Procedure

1. Fill the 250-mL capacity cylinder with a degassed* soft drink.

2. Place the hydrometer in the cylinder, spinning it gently as you release it.

3. Read the graduated line at the water level.

4. Record the stem emergence reading on Table 1.

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

6. Average the stem emergence readings and enter this value in Table 1.

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.

8. Compare your sugar concentration with that on the beverage label and perform an error analysis.

Table 1. Stem Emergence Reading (Specific Gravity)

Solution	1st Reading	2nd Reading	3rd Reading	Average
3% Sugar				
6% Sugar				
9% Sugar				
12% Sugar				
15% Sugar				

Concentration of sugar in soft drink derived from the graph: _____%
Concentration of sugar in soft drink (calculated from information on bottle): _____%

Error = experimental value - accepted value =

Percent Error = $\frac{|error|}{accepted\ value}$ x 100% =