Experiment 1: How Dense is an Egg?

Objective: In this experiment, you will determine the densities of eggs of varying degrees of freshness. You will also learn how to use a balance and four types of volumetric glassware.

Introduction

Maria's diner had gained quite a reputation for having the fluffiest omelets in town. Because the demand for them was so great, she purchased a large number of eggs from a local farmer who offered to sell them to her for a good price. Now she's afraid that some of these eggs have been in storage too long and are not fresh enough to satisfy her exacting standards. She remembers reading in a cookbook that an egg's ability to float in saltwater has something to do with its degree of freshness. She decides to make a saltwater solution in which one of her freshest eggs "just floats". She can then use this solution to test the freshness of the other eggs.

When Maria prepares a salt solution in which her egg just floats, she is making a solution that has the same density as the egg. **Density** is a characteristic property of matter that can be used to identify a substance. It is defined as the mass per unit volume of a substance and has the metric units g/mL (see Tro, pp 18-19). A solid substance will sink if it is placed in a liquid that is less dense than the solid, it will float in a liquid that is more dense and it will "just float" in a liquid of equal density.

The experiment

The question that is posed in this experiment is, "What is the density of an egg?" You will prepare a salt solution in which an egg just floats. You will obtain mass and volume measurements of this solution using a balance to measure the mass and a variety of devices to measure the volume. The values that you obtain for the mass and volume will be used to calculate the density of the salt solution and, by extension, the density of the egg itself. You will compare the density of a fresh egg with that of an egg that is past its prime.

In this experiment you will learn how to measure both mass and volume using laboratory equipment. In any quantitative operation, one must always be concerned with both the precision and accuracy of the measurements. The **precision** is determined by how closely two or more measurements of the same quantity agree with each other. *Random* errors, unpredictable variations in measurements that result from fluctuations such as mechanical vibrations or differences in reading scales, are reflected in the precision of the data. The best way to evaluate the overall precision of an experiment is to repeat the entire experiment several times, varying the amounts of the substances used, but otherwise performing each operation the same way, and then to check the reproducibility of the data. The **accuracy** of a measurement refers to its degree of correspondence with a true or known value. *Systematic* errors, which result from such things as defective instrumentation or faulty lab technique, lead to inaccurate measurements. High precision might seem to imply high accuracy in a result, but this is not necessarily the case. If an instrument is improperly calibrated, for example, it may consistently give an inaccurate result with a high precision. Precision is *not* the same as accuracy.

Every measuring device has a degree of precision, or uncertainty, associated with it. The general rule in using such a device is to estimate between the smallest calibrations

of the measuring scale in order to obtain a reading with one more digit. The pieces of equipment you will use in the experiment have the following uncertainties:

> top-loading balance: ±0.001 g
> 10 mL graduated cylinder: ±0.1 mL
> 10 mL volumetric flask: ±0.01 mL
> 10 mL volumetric pipet: ±0.01 mL
> 25 mL buret: ±0.01 mL

The sensitivity of the instrument and the size of the sample govern the number of significant figures that can be reported. The **significant figures** in a number consist of all the digits known with certainty to be correct, plus one estimated digit. In other words, the last figure on the right should be the *only* approximate figure in the number. Always be sure your measurements include the last estimated digit, *even if it is zero*.

It is important that a number which results from a calculation that incorporates more than one type of measurement does not claim a higher precision than was possible with the least precise measurement. In other words, the number of significant figures contained in the result *cannot exceed* the number of significant figures that are included in the least precise measurement. Keep this in mind when you read the ten-digit display on your calculator! Using the proper number of significant figures is a convenient way to estimate the uncertainty of a calculated result. The uncertainty will always be contained in the *last* digit of the result.

The following are guidelines for using significant figures. Also, see your textbook by Tro, pp 20-26:

1. All nonzero digits are significant, and zeroes between nonzero digits are significant. Zeroes to the left of the first nonzero digit are not significant.

2. Trailing zeroes after a decimal point are always significant.

3. Trailing zeroes before an implied decimal point are ambiguous and should be avoided by using scientific notation.

4. In addition and subtraction calculations, the result carries the same number of decimal places as the quantity with the fewest decimal places.

5. In multiplication and division calculations, the result carries the same number of significant figures as the factor with the fewest number of significant figures.

6. When rounding to the correct number of significant figures, round down if the last (or leftmost) digit dropped is four or less; round up if the last (or leftmost) digit is five or more.

7. To avoid rounding errors in multistep calculations, round only the final answer—do not round intermediate steps. If you write down intermediate steps, keep track of significant figures by underlining the least significant digit.

Note: When a problem involves both addition or subtraction and multiplication or division, the answer may have a different number of significant figures than the initial quantities.

Procedure

Before you begin the procedure, make a prediction about which egg is more dense, the fresh egg or the stale egg. Write your prediction in your notebook.

Preparing a salt solution in which a fresh egg floats

You will work with a partner on this part of the experiment. Make approximately 700 mL of a sodium chloride (salt) solution in which a fresh egg (marked "F") *just floats*. *Just floats* means that the top of the egg just touches the top of the solution, without a significant amount of the egg protruding above the solution. Use a plastic spoon to add the salt. When mixing solid sodium chloride with water, be sure to stir thoroughly with a scoopula or spatula until all of the salt dissolves. It is probably a good idea to remove the egg from the beaker when stirring the solution.

Finding the density of the salt solution

You will work alone on this part of the experiment. *Each* of you must determine the density of the salt solution using four different methods.

Clean and dry a 125 mL and two 250 mL Erlenmeyer flasks. A quick way to dry glassware that has just been rinsed with water is to rinse out the glassware with acetone. Acetone is a liquid that has a very low boiling point and consequently evaporates very quickly. However, it also is a compound that has some hazards associated with it. Acetone is **flammable** and should be kept away from heat sources and flames. It must be collected in a **Laboratory Byproducts** jar and **never** poured into the sink. Use about 1 mL of acetone to rinse out each flask, then collect the acetone in a beaker. When you have rinsed all the flasks, empty the acetone from the beaker into the **Laboratory Byproducts** jar labeled Acetone.

Weigh the three empty, dry Erlenmeyer flasks, and record the masses in your lab notebook.

1. Read the introduction to TECH II and sections A-C (pp. 25-27). Pour some of the salt solution into a 10 mL graduated cylinder until the bottom of the meniscus is at the 10 mL mark. Pour the solution from the graduated cylinder into one of the *dry* Erlenmeyer flasks. Obtain the mass of the Erlenmeyer flask plus solution. Repeat this procedure using the other two flasks.

2. Rinse the three Erlenmeyer flasks with water and dry with acetone. Read TECH II, section D (pp. 27-30). Using a 10 mL volumetric pipet, follow the instructions to draw up the salt solution with a pipet controller and adjust the meniscus so that the bottom of it is at the calibration mark. Transfer the pipet to one of the *dry* Erlenmeyer flasks. Remove the pipet controller and allow the liquid to drain into the flask. When the liquid has finished draining, touch the tip of the pipet to the side of the flask but do NOT blow the last bit of liquid out of the tip. Obtain the mass of the Erlenmeyer flask plus solution. Repeat this procedure using the other two flasks.

3. Rinse the three Erlenmeyer flasks with water and dry with acetone. Read TECH II, section E (pp. 30-31). Pour some of the salt solution into a 25 mL buret until the meniscus is slightly above the 0 mL mark. Turn the stopcock to allow a small amount of liquid to drain into a *beaker* (*not* a flask) so that the tip of the buret is filled. Record the volume reading at the bottom of the

meniscus to two decimal places. Place one of the *dry* flasks under the buret, open the stopcock and allow the liquid to drain into the flask. Close the stopcock when the meniscus is between the 10 and 11 mL mark. Record the volume reading to two decimal places. Obtain the mass of the Erlenmeyer flask plus solution. Repeat this procedure using the other two flasks.

4. Read TECH II, section G (p. 33). Obtain a 10 mL volumetric flask, clean it and dry it with acetone. Weigh the volumetric flask and record the mass in your notebook. Add the salt solution to the flask until the bottom of the meniscus is 1 or 2 cm below the calibration mark. The final amount of solution should be added dropwise from a medicine dropper until the meniscus is even with the calibration mark. Obtain the mass of the flask plus the solution. Repeat this procedure two more times.

Finding the density of a stale egg

Obtain an old egg (marked "O") and place it in your remaining salt solution. With your partner, adjust the concentration of the salt solution by adding either salt or water, as necessary, so that the stale egg "just floats". Each of you must then choose *one* of the four volumetric measuring devices and measure the volume and mass of the adjusted solution three times.

Calculations

1. Calculate the density of the solution in which the fresh egg just floated using the mass and volume data that you obtained. Make a table that displays the three density values obtained for each measuring device:

    a) the graduated cylinder

    b) the volumetric pipet

    c) the buret

    d) the volumetric flask

    Be sure to indicate the uncertainty associated with each density value by using the correct number of significant figures. Refer to the uncertainties of each measuring device given in the Introduction. Show your work for the density calculation once for each measuring device.

2. Using your data, calculate the three density values obtained for the solution in which the stale egg just floated. Indicate which volumetric measuring device you used.

Questions

1. Is the fresh egg more or less dense than the stale egg? Does the answer match the prediction that you made in your notebook? Give a reason that might explain why the fresh egg is more or less dense (depending on your findings).

2. Discuss the variation in density measurements that you observed for each volumetric measuring method. Which had the most variation and which had the least?

3. Discuss the advantages and disadvantages associated with each volumetric measuring device that you used in the experiment. How do some of these advantages and disadvantages relate to which methods had the most variation in results and which had the least?

4. A student who performed the "How Dense is an Egg" experiment did not make sure that the meniscus was at eye level every time he read the volume using the graduated cylinder. Explain how this error would affect both the accuracy and precision of the density results that he obtained when using this device.