1. Some Measurements of Mass and Volume

Introduction

Many experiments require some type of measurement, and often these are simple measurements of mass and volume. The validity of an experiment is likely to depend on the reliability of these measurements. A measurement's reliability is usually considered in terms of its *accuracy* and *precision* (Ebbing/Gammon, Section 1.5). The relationship among accuracy, precision, and error is discussed in Appendix: Mistakes, Errors, Accuracy, and Precision to this manual. The relationship between precision and significant (or meaningful) figures can also be found there.

After a quantity has been measured in an experiment, it may be necessary to use that measurement in a subsequent calculation. If a hand calculator is used for the arithmetic, eight or more digits may appear in the answer. Are all of these digits meaningful? Two simple rules for determining the number of significant figures that should appear in an answer are given in Appendix: Mistakes, Errors, Accuracy, and Precision.

Purpose

This experiment will allow you to measure the mass of an object with a balance and to calculate the volume of a liquid that is delivered from a transfer pipet. You will also determine the precision of your measurements. The experiment also includes an optional calculation of standard deviations using a computer and the Internet.

Balances

Figure 1.1 shows a single-pan balance, but other types of balances are in use. Some balances allow a precision of ± 0.001 g, whereas others offer considerably less. Your laboratory instructor will provide details about the operation of the balances in your laboratory and the precision that you can expect. You should be able to achieve the maximum precision offered by your balance almost immediately.

FIGURE 1.1
A single-pan balance.

Transfer pipets

A transfer pipet is calibrated to deliver a specified volume of a liquid. Correct use of this piece of glassware requires a good deal of manipulatory skill. As with any other skill, practice is mandatory. The precision that you can achieve with a pipet will depend on how much time you devote to practice.

The correct use of a pipet is discussed in the Introduction to this manual; it may also be demonstrated by your laboratory instructor. These instructions will make it clear that you will be filling the pipet with a liquid taken from one container and allowing the liquid to drain from the pipet into another container.

CAUTION: Never use your mouth to draw a liquid into the pipet, even if the liquid is water. Use a rubber suction bulb or some other suction device.

Concept of the experiment

You will be able to practice using a balance and a transfer pipet in order to gain confidence. Next you will measure the mass of a flask four times. You will examine the precision of your measurements when you determine the correct number of significant figures in the mean mass of the flask, using the method discussed in Appendix: Mistakes, Errors, Accuracy, and Precision.

You will add water to the flask from a filled 10-mL pipet and then measure the mass of the flask and water. You will repeat this process three more times. After calculating the mass of the water that was delivered each time from the pipet, you will calculate the volume of each addition from the mass and density of water. You will then determine the correct number of significant figures in the mean volume. This number will allow you to appreciate the precision that you have achieved with the pipet.

Procedure

Getting started

1. Obtain about 100 mL of distilled water in a beaker. Allow the beaker and water to sit on the laboratory bench while you are learning to use the balance and the pipet. The water should come to the temperature of the laboratory during that time.
2. Obtain also a 10-mL pipet, a thermometer, and a 50-mL Erlenmeyer flask with a rubber stopper.
3. Plan on using the same balance and pipet throughout the experiment.

Using your balance

1. Ask your laboratory instructor for the maximum precision offered by your balance. That precision is ± ..... g.
2. Obtain instructions for using your balance, and practice using it by measuring the mass of an object (such as a coin) several times.
3. Place the rubber stopper in the Erlenmeyer flask. Bring your balance to the zero or null position. Measure and record the combined masses of the flask and stopper.

4. Use tissue paper to remove the stoppered flask from the pan of the balance. (The tissue paper is used because some balances are sensitive enough to detect the oils from your fingerprints.)
5. Bring your balance to the zero or null position again. Measure and record the mass of the stoppered flask once more.
6. Repeat Steps 4 and 5 until you have measured the mass four times.
7. Calculate the mean mass.
8. The differences between the measured masses and the mean should be very small. Ask your laboratory instructor whether your results are satisfactory before you proceed.

Using the pipet

1. Practice with your pipet using distilled water (do not use the water you have set aside) until you are comfortable with the technique.
2. Using the thermometer, note the temperature of the laboratory and of the distilled water that you have set aside. When the temperatures are identical or very nearly identical, you are ready to begin. Record the temperature to the nearest degree.
3. Measure and record the mass of the stoppered flask again. Use tissue paper as you did before.
4. Remove the flask from the balance, using tissue paper. Pipet 10 mL of the room-temperature water into the flask without touching the flask with your fingers. Using tissue paper, replace the stopper to prevent evaporation.
5. Bring your balance to the zero or null position. Measure and record the combined mass of the water and the stoppered flask.
6. Remove the flask from the balance. Pipet another 10-mL sample into the flask. Do not pour out the first sample. The volume of water in the flask should now be 20 mL. Replace the stopper and repeat Step 5.
7. Repeat until four samples of water have been delivered to the flask and the final volume is 40 mL.
8. Calculate the mass of water that was delivered each time from your pipet. These masses should be approximately identical.

Table 1.1 Density (g/mL) of Water at Various Temperatures (°C)

Temp.	Density	Temp.	Density	Temp.	Density
17	0.9988	22	0.9978	27	0.9965
18	0.9986	23	0.9976	28	0.9962
19	0.9984	24	0.9973	29	0.9959
20	0.9982	25	0.9971	30	0.9956
21	0.9980	26	0.9968	31	0.9953

9. Calculate the volume of each sample from the mass and density of water. Use the density in Table 1.1 that corresponds to your recorded temperature. Due regard for significant figures (Appendix: Mistakes, Errors, Accuracy, and Precision) should be observed in your calculations. Do not attempt yet to limit the number of significant figures on the basis of the precision of your measurements.

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Date:	.....	Student name:	.....
Course:	.....	Team members:	.....
Section:	.....		.....
Instructor:	.....		.....

Prelaboratory assignment

1. Compare accuracy and precision.

2. a. Compare mistake and error.

   b. Compare systematic and random errors.

3. a. What is the rule concerning significant figures when measured quantities are added or subtracted (Appendix: Mistakes, Errors, Accuracy, and Precision)?

   b. What is the rule concerning significant figures when measured quantities are multiplied or divided (Appendix: Mistakes, Errors, Accuracy, and Precision)?

4. Suppose that a series of measurements have shown that the mean mass of an object is 201.3 g with a standard deviation of 1.3 g. How many significant figures are justified in the mean and how would you report the most probable mass of the object? Explain.

5. What safety rule concerning the pipet must be observed during this experiment?

Some Measurements of Mass and Volume

Date: ..... Student name: .....

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Section: .....

Instructor: .....

Results

1. *Using the analytical balance*

Mass of the stoppered flask (g)	.....	.....	.....	.....
Mean mass (g)	.....			

Calculation:

2. *Using the pipet*

Temperature (°C) .....

Addition No.	**1**	**2**	**3**	**4**
Mass *after* addition (g)	.....	.....	.....	.....
Mass *before* addition (g)	.....	.....	.....	.....
Mass of added water (g)	.....	.....	.....	.....
			Density of water (g/mL)	.....
Volume of water delivered each time (mL)	.....	.....	.....	.....
			Mean volume (mL)	.....

Calculations:

Questions

1. a. Calculate the standard deviation in the measured mass of the empty stoppered flask (see Appendix: Mistakes, Errors, Accuracy, and Precision).

   b. Determine the number of significant figures in the mean measured mass of the flask that is allowed by the precision of the mass measurement (see Appendix: Mistakes, Errors, Accuracy, and Precision). Give the mean mass with the correct number of significant figures.

   c. How does this result compare with the claimed precision of your balance?

   d. What, if anything, can you claim about the accuracy of the mean mass?

Student name: ..... Course/Section: ..... Date: .....

2. a. Using the mean volume of water and the standard deviation, determine the number of significant figures that is allowed by the precision inherent in your pipet technique. Give the mean volume with the correct number of significant figures.

b. Some claim that a precision of ± 0.01 mL can be achieved with a 10-mL pipet. However, students who are learning the technique of using a pipet may not achieve this precision. How do your results compare with the claim? If you have not been able to obtain this precision, try to pinpoint the deficiencies in your pipet technique.

3. With due regard for significant figures, determine what mass of water would be delivered from your pipet at 50°C. The density of water at that temperature is 0.9881 g/mL.

4. (Optional) Compare the standard deviations you obtained in Questions 1a and 2a to those you obtain using a computer and the Internet, as described in Appendix: Mistakes, Errors, Accuracy, and Precision. Discuss your results.