Evaluating Measurements

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CONCEPT 1 Evaluating Measurements

Lesson Objectives

The student will:

- define accuracy and precision.
- explain the difference between accuracy and precision.
- indicate whether a given data set is precise, accurate, both, or neither.
- calculate percent error in an experiment.

Vocabulary

accuracy reflects how close the measured value is to the actual value

percent error a measurement of how far an experimental value is from the accepted value

precision reflects how close the values in a set of measurements are to each other

Introduction

Accuracy and precision are two words that we hear a lot in science, math, and other everyday events. They are also, surprisingly, two words that are often misused. For example, you may hear car advertisements talking about the car's ability to handle precision driving. But what do these two words mean?

Accuracy and Precision

Every measurement compares the physical quantity being measured with a fixed standard of measurement, such as the centimeter or the gram. In describing the reliability of a measurement, scientists often use the terms accuracy and precision. **Accuracy** refers to how close a measurement is to the true value of the quantity being measured. **Precision** refers to how close the values in a set of measurements are to one another. If you are using a flawed measuring instrument, you could get very precise measurements (meaning they are very reproducible), but the measurements would be inaccurate. In many cases, the true value of the measurement is not known, and we must take our measurement as the true value. In such cases, instruments are checked carefully to verify that they are unflawed before a series of precise measurements are made. It is assumed that good instruments and precise measurements imply accuracy.

Suppose a student made the same volume measurement four times and obtained the following measurements: 34.25 mL, 34.45 mL, 34.33 mL, and 34.20 mL. The average of these four readings is 34.31 mL. If the actual volume was known to be 34.30 mL, what could we say about the accuracy and precision of these measurements, and how much

confidence would we have in the answer? Since the final average is very close to the actual value, we would say that the answer is accurate. However, the individual readings are not close to each other, so we would conclude that the measurements were not precise. If we did not know the correct answer, we would have very little confidence that these measurements produced an accurate value.

Consider the values obtained by another student making the same measurements: 35.27 mL, 35.26 mL, 35.27 mL, and 35.28 mL. In this case, the average measurement is 35.27 mL, and the set of measurements is quite precise since all readings are within 0.1 mL of the average measurement. We would normally have confidence in this measurement since the precision is so good, but if the actual volume is 34.30 mL, the measurements are not accurate. Generally, situations where the measurements are precise but not accurate are caused by a flawed measuring instrument. The ideal situation is to have quality measuring instruments so that precision will imply accuracy.

Percent Error

Percent error is a common way of evaluating the accuracy of a measured value. Anytime an experiment is conducted, a certain degree of uncertainty and error is expected. Scientists often express this uncertainty and error in measurement by reporting a percent error.

$$\text{percent error} = \frac{\text{(accepted value - experimental value)}}{\text{(accepted value)}} \times 100\%$$

The experimental value is what you recorded or calculated based on your own experiment in the lab. The value that can be found in reference tables is called the accepted value. Percent error is a measure of how far the experimental value is from the accepted value.

Example:

A student determined the density of a sample of silver to be 10.3 g/cm^3. The density of silver is actually 10.5 g/cm^3. What is the percent error in the experimentally determined density of silver?

$$\text{percent error} = \frac{10.5 \text{ g/cm}^3 - 10.3 \text{ g/cm}^3}{10.5 \text{ g/cm}^3} \times 100\% = 1.90\%$$

Lesson Summary

- Accuracy reflects how close the measured value is to the actual value.
- Precision reflects how close the values in a set of measurements are to each other.
- Accuracy is affected by the quality of the instrument or measurement.
- Percent error is a common way of evaluating the accuracy of a measured value.
- $\text{percent error} = \frac{\text{(accepted value - experimental value)}}{\text{(accepted value)}} \times 100\%$

Further Reading / Supplemental Links

This website has lessons, worksheets, and quizzes on various high school chemistry topics. Lesson 2-2 is on accuracy and precision.

- http://www.fordhamprep.org/gcurran/sho/sho/lessons/lesson22.htm

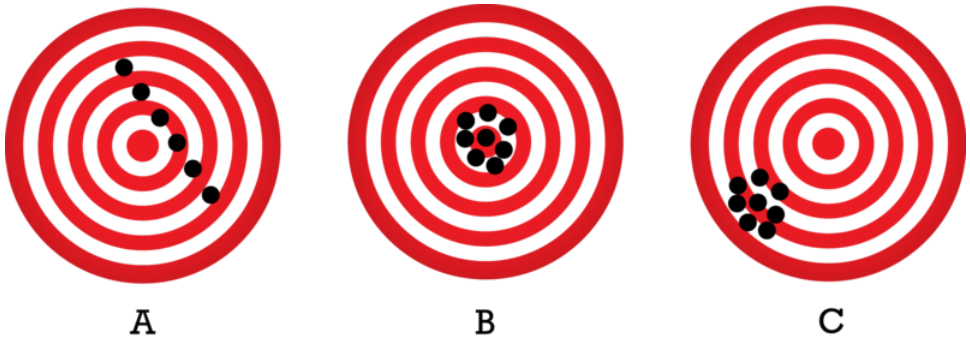
The *learner.org* website allows users to view streaming videos of the Annenberg series of chemistry videos. You are required to register before you can watch the videos, but there is no charge to register. The website has a video

that apply to this lesson called “Measurement: The Foundation of Chemistry” that details the value of accuracy and precision.

- http://learner.org/resources/series61.html

Review Questions

1. Suppose you want to hit the center of this circle with a paint ball gun. Which of the following are considered accurate? Precise? Both? Neither?



2. Four students take measurements to determine the volume of a cube. Their results are 15.32 cm^3, 15.33 cm^3, 15.33 cm^3, and 15.31 cm^3. The actual volume of the cube is 16.12 cm^3. What statement(s) can you make about the accuracy and precision in their measurements?
3. Distinguish between accuracy and precision.
4. Nisi was asked the following question on her lab exam: When doing an experiment, what term best describes the reproducibility in your results? What should she answer?
    a. accuracy
    b. care
    c. precision
    d. significance
    e. uncertainty
5. Karen was working in the lab doing reactions involving mass. She needed to weigh out 1.50 g of each reactant and put them together in her flask. She recorded her data in her data table (**Table** 1.1). What can you conclude by looking at Karen’s data?
    a. The data is accurate but not precise.
    b. The data is precise but not accurate.
    c. The data is neither precise nor accurate.
    d. The data is precise and accurate.
    e. You really need to see the balance Karen used.

TABLE 1.1: Data Table for Problem 5

	Mass of Reactant A	Mass of Reactant B
Trial 1	1.47 ± 0.02 g	1.48 ± 0.02 g
Trial 2	1.46 ± 0.02 g	1.46 ± 0.02 g
Trial 3	1.48 ± 0.02 g	1.50 ± 0.02 g

6. John uses his thermometer and finds the boiling point of ethanol to be 75°C. He looks in a reference book and

finds that the actual boiling point of ethanol is 78°C. What is his percent error?

7. The density of water at 4°C is known to be 1.00 g/mL. Kim experimentally found the density of water to be 1.085 g/mL. What is her percent error?
8. An object has a mass of 35.0 g. On a digital balance, Huey finds the mass of the object to be 34.92 g. What is the percent error of his balance?