Measurement and Calibration

Purpose

To gain an understanding of the relationships that exist between density, mass, and volume while calibrating laboratory glassware.

Introduction

Measurement is a regular part of life. For example, weight, height, and blood pressure are routinely measured in a doctor's office. In the kitchen, ingredients for a recipe must be measured. Devices, such as scales and measuring cups, were developed to make these measurements.

In chemistry, solutions are often used and transferred from one container to another. In some cases, it is important to know the amount of liquid transferred with certainty, especially when performing a quantitative analysis. Quantitative analysis is the determination of the concentration or amount of substance in a particular sample. The certainty of a measurement is determined by looking at both the accuracy and precision of a set of measurements. Accuracy is a measure of how well a set of measurements agree with an accepted (true) value, while precision measures how well a set of measurements agrees with each other. While ideal measurements should be both accurate and precise, measurements made in the lab are more often either accurate but not precise or precise but not accurate.

To help eliminate or reduce some sources of error, multiple measurements are made and the accuracy is determined by taking the average value and comparing it to the accepted value. Precision can be evaluated based on the relative error calculated using the measurement and accepted value.

In order to express accuracy and precision quantitatively, the proper number of significant figures must be used. When using balances, write down the mass with the same number of significant figures as the balance allows (in our case this is about 4 or 5). If a mass is displayed as 24.5674 grams, this means that all but the last digit are known with certainty; last digit has some degree of uncertainty. However, if the balance is fluctuating in the last two digits, then both of those numbers have error associated with them.

When reading a buret or other calibrated scale, the volume should be estimated to one digit beyond what the marking allows. Therefore, if a buret is calibrated to the nearest 0.1 mL, then the volume measurement should be made to the nearest 0.01 mL. This method is consistent with the recommended use of significant figures. For example in a volume reading of 11.74 mL, the 11.7 mL is known with certainty while the 0.04 mL was estimated by the person reading the buret.

An easy way to determine the accuracy of a set of measurements is to calculate the average value, then determine the relative error in the measurement compared to an accepted value using the equation shown at right. This value is often expressed as a positive number, regardless of whether the measured value is larger or smaller than the accepted value.

$$\%\ \text{error} = \frac{|\text{measured} - \text{accepted}|}{\text{accepted}} \times 100$$

Precision is often related to the person making the measurement; very seldom do two different people make the exact same measurement every time. However, as long as the measurement is made in a consistent manner, the precision should not be significantly affected.

In this experiment, water will be measured and delivered using a buret, a graduated cylinder, a beaker and a volumetric pipette; based on the results, the most accurate measuring device will be determined.

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Reference Data

Density of Water as a Function of Temperature	
T (^oC)	Density (g/mL)
20	0.9982071
21	0.9979955
22	0.9977735
23	0.9975415
24	0.9972995
25	0.9970479
26	0.9967867
27	0.9965162
28	0.9969748
29	0.9962365
30	0.9956502

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Procedure

Remember to record all measurements and unknown numbers (if given) on your data sheets. ***Remember to use the proper number of significant figures for all measurements.***

Part A: Determining the Accuracy of a Buret

A1. Obtain a buret, and fill with deionized water using a beaker and funnel. Let the water drain through the buret until the tip is full. Observe and sketch the form of the meniscus on the calculations page (page 7). Remember that measurements must always be made at the bottom of the meniscus for aqueous solutions in glass.

A2. Obtain a 50 mL beaker and measure its mass.

A3. Read the initial water level in the buret. Deliver approximately 15 mL of water to the pre-weighed beaker from the buret and read the water level in the buret again.

A4. Measure the mass of the beaker and water.

A5. Repeat steps A3 and A4 two more times.

A6. Measure the temperature of your water, and use this measurement and the attached density table to determine the density of the water.

A7. Use the mass of water delivered and the known density of water to determine the actual volume of water delivered.

Part B: Determining the Accuracy of a Graduated Cylinder

B1. Obtain a dry 100 mL graduated cylinder.

B2. Add deionized water to the 22 mL mark, using a dropper pipette to get as close to this mark as possible.

B3. Dry your 50 mL beaker from part A and weigh it. Transfer the water from the graduated cylinder to the beaker and weigh the beaker.

B4. Repeat steps B2 and B3 two more times.

B5. Using the density of water at the lab temperature, calculate the volume of water delivered from the graduated cylinder.

Part C: Determining the Accuracy of a 50 mL beaker

C1. Weigh a clean, dry 50 mL beaker that has graduation marks on it. Record its mass on your data sheets.

C2. Add deionized water to the 20 mL mark, using a dropper pipette to get as close to this mark as possible.

C3. Weigh the filled beaker. Record this value on your data sheets.

C4. Empty and dry the beaker, and then repeat this measurement two more times.

C5. Using the density of water at the lab temperature, calculate the volume of water delivered from the graduated cylinder.

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Part D: Determining the Accuracy of a 10 mL volumetric pipette

D1. Obtain a 50 mL beaker and measure its mass.

D2. Use a pipette bulb to fill the volumetric pipette to its calibration mark. Empty this volume of water into the weighed 50 mL beaker.

D3. Measure the mass of the beaker and water.

D4. Repeat steps D2 and D3 two more times.

D5. Measure the temperature of your water, and use this measurement and the attached density table to determine the density of the water.

D6. Use the mass of water delivered and the known density of water to determine the actual volume of water delivered.

Calculations

A1. Determine the volume of water delivered by the buret in each trial by subtracting the buret readings. This is your *measured value*.

A2. Determine the calculated volume of water using the mass of water delivered and the density value from the table on page 2. This is your *accepted value*.

A3. Compare these values to the calculated volumes obtained by using the density of water and the delivered mass of water. Then calculate the percent error for each trial.

B1. Assume the volume of water delivered from the graduated cylinder for each trial is 22.0 mL. Compare these values to the calculated volumes obtained by using the density of water and the delivered mass of water. Then calculate the percent error for each trial. Use the calculated value as the known (accepted) value.

C1. Assume the volume of water in the beaker for each trial is 20.0 mL. Compare this value to the calculated volumes obtained by using the density of water and the delivered mass of water. Then calculate the percent error for each trial. Use the calculated value as the known (accepted) value.

D1. Assume the volume of water delivered from the volumetric pipette for each trial is 10.00 mL. Compare this value to the calculated volumes obtained by using the density of water and the delivered mass of water. Then calculate the percent error for each trial. Use 10.00 mL as the known (accepted) value.

Enter data and calculated values into data tables. Make sure to label all values with units!

Attach sheet of calculations to data table sheet.

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Data Sheet

Name: ___________________________________ **Lab Partner:** _______________________________

Part A: Determining the Accuracy of a Buret

	Trial 1	**Trial 2**	**Trial 3**
Initial water level in buret			
Final water level in buret			
Volume of water delivered (measured)			
Initial mass of beaker			
Final mass of beaker			
Mass of water			
Temperature of water			
Density of water from table			
Calculated volume of water (accepted)			
% Error			

Part B: Determining the Accuracy of a Graduated Cylinder

	Trial 1	**Trial 2**	**Trial 3**
Initial mass of beaker			
Measured volume of water			
Final mass of beaker			
Mass of water			
Temperature of water			
Density of water from table			
Calculated volume of water (accepted)			
% Error			

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Part C: Determining the Accuracy of a 50 mL Beaker

	Trial 1	**Trial 2**	**Trial 3**
Initial mass of beaker			
Measured volume of water			
Final mass of beaker			
Mass of water			
Temperature of water			
Density of water from table			
Calculated volume of water (accepted)			
% Error			

Part D: Determining the Accuracy of a Volumetric Pipette

	Trial 1	**Trial 2**	**Trial 3**
Initial mass of beaker			
Measured volume of water			
Final mass of beaker			
Mass of water			
Temperature of water			
Density of water from table			
Calculated volume of water (accepted)			
% Error			

Calculations:

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Post-lab Assignment

Name: ___________________________________

1. Based on your results, which piece of glassware is more accurate in delivering liquids – the buret or the graduated cylinder? Explain your choice.

2. Based on the smallest scale division, which measuring device in question one should provide the more precise measurement of volume?

3. Is either piece of glassware completely accurate and precise in delivering a given volume of liquid? What additional factors must be acknowledged?

4. Consider the definition of precision. Do you feel any of the glassware used in lab today were precise? What criteria are you using to make your decision?

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Pre-lab Assignment

Name: ______________________________________

1. Define the following terms in your own words:
   a) Accuracy

   b) Precision

2. A student calibrated a 10-mL graduated cylinder using water. The empty graduated cylinder weighed 23.873 grams. When it was filled with 10.00 mL of deionized water, it weighed 33.1062 grams. The temperature of the water was 23.5^{o}C.
   a) Use the density of water obtained from the table on page 2 and the mass of water to determine the measured volume of the graduated cylinder.

   b) Calculate the % error of the graduated cylinder.