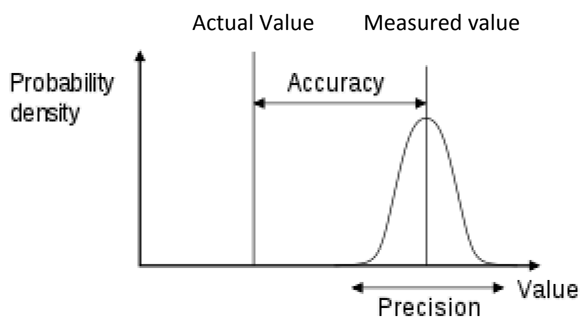
Experiment 1 - Accuracy and Precision

Experimental *error* is defined as the difference between an experimental value and the actual value of a quantity. This difference indicates the *accuracy* of the measurement. The accuracy is a measure of the degree of closeness of a measured or calculated value to its actual value. The percent error is the ratio of the error to the actual value multiplied by 100.

$$\% \, error = \frac{error}{actual \; value} \times 100$$

The *precision* of a measurement is a measure of the reproducibility of a set of measurements. The significant figures displayed on an instrument are an indication of the precision of the instrument. The diagram below illustrates the difference between accuracy and precision.



Measurement errors can be divided into two components: *random error* and *systematic error*. A <u>random error</u> is related to the precision of the instrument. These are inherent errors that are dependent on the instrument and can not be eliminated without changing the instrument. A <u>systematic error</u> is human error. These are errors related to imperfect experimental technique. Some examples include errors in experimental readings and imperfect instrument calibration. Systematic errors may be decreased as the laboratory techniques of the analyst improve. The accuracy of an experimental value is best determined by the *average value* of multiple measurements where x_i represents a measurement and n is the number of measurements.

$$average = \bar{x} = \frac{\sum_i x_i}{n}$$

The precision of a set of measurements can be determined by calculating the standard deviation for a set of data where n-1 is the degrees of freedom of the system.

$$standard \; deviation = s = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{n-1}}$$

The above calculations are the *absolute uncertainty* of a measurement. The *relative uncertainty* of a measured value can be determined by dividing the standard deviation by the average value. If you multiply the relative uncertainty by 100, then you obtain the percent standard deviation.

$$relative\ standard\ deviation = \frac{s}{\bar{x}}$$

$$percent\ relative\ standard\ deviation = \frac{s}{\bar{x}} \times 100$$

The relative uncertainty for any given experimental value is dependent upon the precision of the precision of the instruments being used. If more than one instrument is made for the determination of an experimental value, then the errors propagate to give a final relative uncertainty. For example, if a 25.00 mL buret was used to deliver 18.45 mL of a solution. If the precision of the buret was reported to be ± 0.03 mL, then the reported value is 18.45 ± 0.03 mL.

In part A of this experiment, a metal tag will be weighed on three different balances. The accuracy of each balance will be determined by calculated the percent error. In part B of this experiment, a digital balance (±0.2 mg) and a 25 mL volumetric pipet (±0.03 mL) and a 25 mL graduated cylinder (±0.3 mL) will be used. The accuracy and precision of the volume transferred will be determined by calculating the percent error and standard deviation.

Equipment and Reagents

Metal tag	triple beam balance	25 mL graduated cylinder
50 mL flask with stopper	centigram balance	25 mL volumetric pipet with bulb
Distilled water	analytical balance	Handbook of Chemistry and Physics

Procedure

Part A – Accuracy of Weighing.

1. Obtain a numbered metal tag and record the tag number in your notebook.
2. Weigh the metal tag on a triple beam balance and record the weight in your notebook. *The weight should include all of the measured significant digits.*
3. Weigh the metal tag on a centigram balance and record the weight in your notebook.
4. Weigh the metal tag on an analytical balance and record the weight in your notebook.
5. Show the data to the instructor and obtain the actual value of the tag from the instructor.
6. Calculate the percent error for the weight of the metal tag for each instrument used.

Part B – Accuracy and Precision of Volume Measurements.

1. Weigh a 50 ml flask with a stopper on the analytical balance. Add 25 mL of distilled water measured carefully with a graduated cylinder and re-weight the flask and stopper with the water.
2. Empty the water from the flask and repeat the above procedure two more times for a total of three measurements for the graduated cylinder. *No need to dry the flask in between trails because you are measuring the water transferred into the flask*.

3. Repeat the above procedure except you will replace the graduated cylinder with a 25 mL volumetric transfer pipet. Your lab instructor will demonstrate the use of the volumetric transfer pipet. You should have a total of three trials for the pipet.
4. Calculate the average percent error for each volumetric instrument used.
5. Calculate the standard deviation for each volumetric instrument used.
6. For each measuring device, report the average experimental value with the relative uncertainty. *A sample calculation is shown below*.

Results and Discussion

Tabulate the results for parts A and B.

For part A, clearly state which balance is the most accurate.

For part B, clearly state which instrument is more accurate and which has the greater precision. Also report the average experimental value with its relative uncertainty. See the following sample calculation.

An example of the relative errors for the pipet measurements:

$$relative\ error = \frac{0.0002}{25.0000} + \frac{0.03}{25.00} = 1.2x10^{-3}$$

Assuming the experimental value was determined to be 24.98 mL, the relative uncertainty is:

Relative uncertainty = 24.98 mL x 1.2x10^{-3} mL = 0.03 mL

Average experimental value plus the relative uncertainty:

24.98 ± 0.03 mL