Experiment 2: Laboratory Measurements

This experiment was written with information from the following sources:
Santa Monica College, 1: Measurements in the Laboratory (Experiment)
CC-BY Torres & González-Urbina, Volumetric Experiments

Purpose: People working in a lab need to know how to use the instruments and glassware, how to organize their data, perform their calculations, and properly report their results. This week's experiment provides experience with all of these aspects of lab work.

Background: There are several different parts in this Laboratory Measurements experiment.

(A) General Information: This area discusses significant figures, accuracy and precision, standard deviation, volume by difference, and mass by difference.

(B) Determination of Density; Unknown Liquid: This involves the measurement of both the mass and volume of the unknown liquid sample. The volume is determined by use of a pipet, and the mass is determined by use of the lab balance. Density is calculated using the mass and volume data.

(C) Determination of Solubility; Unknown Solid: This experiment has a few crystals of solid immersed into a liquid solvent. An observation is made as to whether or not the solid dissolves. Three different solvents are used; water, ethanol, and cyclohexane.

(D) Determination of Solubility; Unknown Liquid: This experiment has the unknown liquid mixed into a liquid solvent. An observation is made as to whether or not the unknown liquid dissolves. Three different solvents are used; water, ethanol, and cyclohexane.

(E) Determination of Density; Pennies: This involves the measurement of both the mass and volume of a sample of 10 pennies (either pre-1982 or post-1982 pennies). The volume is determined by volume by difference, and the mass is determined by use of the lab balance. Density is calculated using the mass and volume data.

(A) General Information:

Significant Figures: The rules for identifying significant figures in written values and working with them in calculations are given in chapter 1 of your CHE115 textbook. The rules are summarized below:

1. All non-zero digits are significant.
2. Zeros at the beginning of a decimal number (these are called leading zeros) are not significant: 0.0123 has 3 SF.
3. Terminal zeros at the right of the decimal point (these are called trailing zeros) are significant: 0.120 has 3 SF
4. Terminal zeros in a whole number (a number without a decimal point shown) are not significant: 1,230 has 3 SF.
5. For a number in scientific notation, all numbers before the power of ten are significant: 1.50×10^{-5} has 3 SF.

The number of significant figures in a measured property is determined by the tool used for the measurement. When the data is used in subsequent calculations the uncertainty must be carried on with the results. The following two rules hold when determining the correct number of significant figures to report for the answer to a calculation:

1. When multiplying or dividing measured quantities, give as many significant figures in the answer as there are in the measurement with <u>the least number of significant figures</u>.
2. When adding or subtracting measured quantities, give the same number of decimal places in the answer as there are in the measurement with <u>the least number of decimal places</u>.

Accuracy & Precision: The definitions for accuracy and precision are given in chapter 1 of your CHE115 textbook. The definitions are summarized below.

Accuracy is how close the result is to the true value. Precision refers to the repeatability of the results when more than one trial is done.

Precision is sometimes used to describe equipment. Equipment that is made to give more significant figures is considered more precise than equipment that is made to give less significant figures. This definition of precision is used when referring to equipment, not for results.

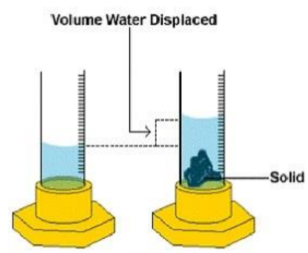
Standard Deviation: The standard deviation (sd) is a calculated number used to represent the sum of all experimental errors and uncertainty in an experiment. This gives a range in which you can expect to find the true value. The standard deviation is calculated with the following mathematical equation:

$$\text{standard deviation} = \sqrt{\frac{\text{(sum of squared deviations)}}{\text{(number of trials - 1)}}}$$

$$\text{squared deviation} = (\ /\text{trial result - average}/\ )^2$$

Example: For an average density of 6.24 g/mL $\pm$ 0.06 g/mL. The true value of the density should be between 6.18 g/mL and 6.30 g/mL.
The standard deviation value should end at the same decimal place as the reported value it belongs with.

Volume by Difference: The volume of (water + sample) minus the volume of only water gives the volume of the sample.



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Mass by Difference: The mass of (receiving vessel + sample) minus the mass of the empty receiving vessel gives the mass of the sample.
This is a good technique to use when you have to walk away from the lab balance during your experiment.

Chemicals:
Unknown Solid (most likely flammable)
Unknown Liquid (most likely flammable)
Pennies; pre-1982, Pennies;post-1982)
Deionized water
Ethanol
Cyclohexane

Equipment:
Laboratory balance
10 mL graduated cylinder for the unknown liquid
50 mL graduated cylinder for the pennies

Procedure:

(B) Determination of Density; Unknown Liquid

Perform this experiment three times; Trial 1, Trial 2, and Trial 3.
Do one trial at a time. Tabulate your data. Include the mass by difference for the unknown liquid in your data table.

1. Determine the mass and volume of your first trial.
   a) *Record the mass of your empty, dry, 10 mL graduated cylinder. Return to your lab bench so other people can use the balance.*
   b) *Add 10 mL of unknown liquid into the cylinder, so that the bottom of the meniscus is on the 10.0 mL line. Record the volume of liquid with the correct number of significant figures from the calibration marks on the cylinder.*
   c) Return to the same balance used in step 1a. Record the mass of the graduated cylinder and unknown liquid.
2. Repeat step 1 for your next two trials.

(C) Determination of Solubility: Unknown Solid

Three different solvents are used; water, ethanol, and cyclohexane. Tabulate your results.

1. Obtain 3 small test tubes.
2. Put approximately 2 mL of a solvent in a test tube (a little less than half-full). Each solvent should be in its own test tube.
3. Put a few crystals of unknown solid in each test tube. Put Parafilm over the opening of the tube. Hold the Parafilm in place and shake the tube side-to-side. Try to keep the Parafilm dry. *(Be careful not to dissolve the Parafilm.)*
4. Observe whether or not the unknown solid dissolves. If the solid dissolves, it is soluble in that solvent. If the solid does not change at all, it is insoluble in that solvent. If the solid changes slightly and the solvent becomes cloudy, it is slightly soluble in that solvent. Record your observations for each solvent.

(D) Determination of Solubility: Unknown Liquid

Three different solvents are used; water, ethanol, and cyclohexane. Tabulate your results.

1. Obtain 3 small test tubes.
2. Put approximately 2 mL of a solvent in a test tube (a little less than half-full). Each solvent should be in its own test tube.
3. Put about 5 drops of the unknown liquid in each test tube. Put Parafilm over the opening of the tube. Hold the Parafilm in place and shake the tube side-to-side. Try to keep the Parafilm dry. *(Be careful not to dissolve the Parafilm.)*
4. Observe whether or not the liquid dissolves (look for separate layers). If the unknown liquid dissolves (no layers, clear), it is soluble in that solvent. If the unknown liquid does not dissolve (two distinct layers), it is insoluble in that solvent. If there isn't two distinct layers but the solvent is now cloudy, the unknown liquid is slightly soluble in that solvent. Record your observations for each solvent.

(E) Determination of Density; Pennies
Perform this experiment three times; Trial 1, Trial 2, and Trial 3.
Do one trial at a time. Tabulate your data. Include the volume by difference for the pennies in your data table.

1. Determine the mass of your first trial.
   a) *Use an empty, clean, dry 50 mL beaker.*
   b) *Place the beaker on the lab balance and record the mass of the empty beaker.*
   c) *Remove the beaker from the balance and add the ten pennies to the beaker. Place the beaker back on the balance and record the mass of the beaker and pennies; record all of the digits for the mass that the balance shows.*
   d) *Return to your lab bench so other students can use the balance.*
2. Determine the volume of your first trial.
   a) *Obtain an empty 50 mL graduated cylinder.*
   b) *Add approximately 20 mL of DI water into the cylinder. Record the volume of water with the correct number of significant figures from the calibration marks on the cylinder.*
   c) *Add the pennies to the graduated cylinder. Use all of the sample that gave the recorded mass in step 1. Make sure all of the pennies are under the surface of the water.*
   d) *Use the calibration marks on the cylinder to record the volume of water and pennies now in the graduated cylinder.*
3. Pour the water and pennies from the graduated cylinder, then repeat steps 1 and 2 for your other two trials. Dry the pennies after each trial.

Calculations: Calculate the density, average density, and standard deviation for the pennies and unknown liquid. Tabulate your calculated results.

   a) *Calculate the density of your sample for each trial using the equation:*

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad d = \frac{m}{v}$$

   b) *Calculate the average density value.*
   c) *Calculate the standard deviation of the density using the equation:*

$$\text{standard deviation} = \sqrt{\frac{(\text{sum of squared deviations})}{(\text{number of trials - 1})}}$$

$$\text{squared deviation} = (\ /\text{trial result - average}/\ )^2$$

Identification of the Unknown Liquid:
Use the table below, along with your density and solubility results to determine the identity of the unknown liquid.
Table 1

Compound	Density, g/mL	Solubility in		
		Water	**Ethanol**	**Cyclohexane**
Acetone	0.79	*soluble*	*soluble*	*soluble*
Hexane	0.66	*insoluble*	*soluble*	*soluble*
Mineral Oil	0.84	*insoluble*	*insoluble*	*soluble*

Identification of the Unknown Solid:
Use the table below, along with your solubility results to determine the identity of the unknown solid.
Table 2

Compound	Solubility in		
	Water	**Ethanol**	**Cyclohexane**
Phenyl Benzoate	*insoluble*	*soluble*	*soluble*
Sucrose	*soluble*	*soluble*	*insoluble*
Napthalene	*insoluble*	*Slightly soluble*	*soluble*

Calculate the percent composition of the pennies as % Cu and % Zn.

a) Copper and zinc are the only elements in pennies. So, the % Cu and % Zn will add to 100%.
b) Use the density you calculated for your sample of pennies; assume all of the pennies in your sample had the same percent composition. Use literature values for the density of copper and zinc.
c) Follow the math equations below, so you are solving for only one unknown.

$$\text{density}_{\text{penny}} = \frac{p\, d_{Cu} + q\, d_{Zn}}{100}$$

p = the % Cu by mass and q = the % Zn by mass

You need to solve for p and q.

Rearrange to solve for one unknown at a time.

$$p + q = 100\ \%$$

$$q = (100 - p)$$

rewrite as

$$\text{density}_{\text{penny}} = \frac{p\, d_{Cu} + (100 - p)\, d_{Zn}}{100} \qquad \text{Solve for p}$$

$$q = (100 - p) \qquad \text{Solve for q}$$