The following sample lab report has been kindly provided by ***Professor Deborah Exton*** for her Fall 2005 chemistry course (http://chemlabs.uoregon.edu/Classes/Exton/CH227/) at the ***University of Oregon***. It has been edited and adapted by Professor Todd Stone to fit the formal laboratory report requirements for *C117: Principles of Chemistry and Biochemistry* at Indiana University for Fall 2009.

The report below is a ***SUPERB*** example of a logical, cogent, and well written report which would easily have earned full credit (25 points) in this course. *Note well the clarity, depth of knowledge, neatness, and organization with which the report has been prepared*. All plots and tables are clearly labeled with titles, correct units, and other pertinent information and are neatly displayed within the relevant section of the report. Equations are constructed neatly with Microsoft Equation Editor, numbered and formatted properly, and sample calculations are evident and easy to follow.

References are clearly cited within the text of the report and collected at the end of the report in APA style.

Students in C117 should, at this point in their academic careers, be able to produce lab reports that are of the same basic quality as the sample. If you have difficulty with technical writing, please take advantage of University resources that will help you improve your written communication skills. The Associate Instructors are also frequently available for consultation regarding what is expected in terms of the structure and content of lab reports for C117.

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DETERMINATION OF THE ALCOHOL CONTENT OF WHISKEY

Introduction

The concentration of ethanol in alcoholic beverages is generally measured as percent alcohol by volume. However, many alcoholic beverages such as whiskey and vodka are not labeled with the percentage of alcohol. Rather, they are labeled with the proof value, which is twice the volume percentage of the alcohol in solution (Types of Alcoholic Beverages, 2007). Thus, 80 proof whiskey contains 40 percent ethanol. In this laboratory experiment, the attempt was made to experimentally verify that the alcohol content of 80 proof Monarch brand whiskey was 40 percent by volume.

The analysis of alcohol content in this experiment utilizes the density relationship, which relates the quantity of matter to the volume it occupies. The densities of many pure substances are known and tabulated. For example, at 20° C the density of water is 1.00 $\frac{g}{mL}$ and the density of ethanol is 0.789 $\frac{g}{mL}$ (Petrucci, 1989). The densities of mixtures such as whiskey reflect the components that make up the mixture. For example, the density of a mixture of water and ethanol would be expected to be less than the density of water and more than the density of ethanol. When the density is unknown, it can be determined by weighing a known volume of water on an analytical balance and calculating using the equation:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \qquad \textbf{(1)}$$

For this laboratory, a series of ethanol/water solutions was prepared by mixing known volumes of pure ethanol with known volumes of water. Aliquots of each mixture were then weighed and the density of each solution calculated. A plot of density versus concentration (percent by volume) was prepared and the concentration of the whiskey was determined using the results of a linear regression analysis.

Results

Table 1 below contains the mean mass and calculated density of each ethanol/water solution. The standard error in each measurement of the mass using analytical balance #12 was ± 0.0003 g in each case, while the error in each volume measurement due to the pipette was ± 0.05 mL (Exton, 1989).

Table 1: Mass and density of ethanol/water solutions

% Ethanol by Volume	*30%*	*45%*	*50%*	*60%*	*75%*	*85%*	*95%*
Mass (g)	4.7505	4.4700	4.5810	4.5050	4.2800	4.1910	4.000
Density $\left(\frac{g}{mL}\right)$	0.950	0.894	0.916	0.901	0.856	0.838	0.800

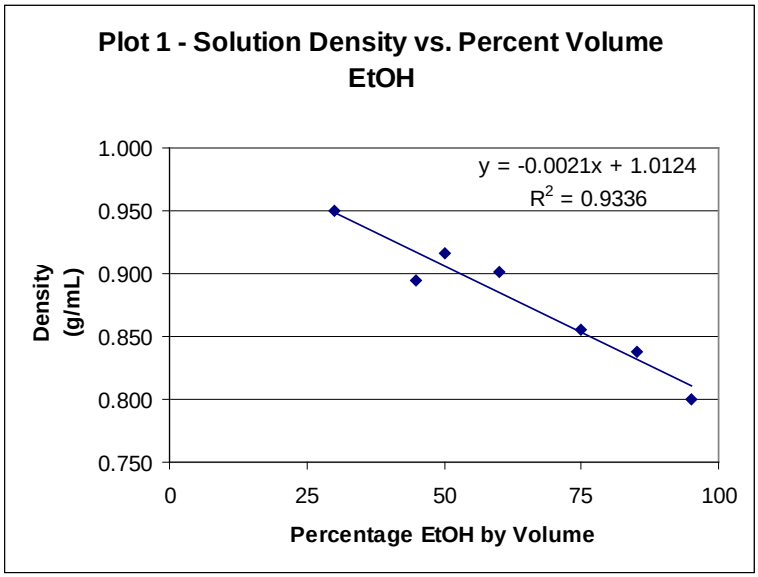
The densities were calculated according to equation (1). The following example is shown for the 30% ethanol/water sample:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{4.7505\ \text{g}}{5.00\ \text{mL}} = 0.950\ \frac{\text{g}}{\text{mL}} \qquad \textbf{(2)}$$

A 5.00 mL aliquot of Monarch whiskey was weighed on analytical balance #7 and the density determined:

$$\text{Mass}_{\text{whiskey}} = 4.575\ \text{g}$$
$$\text{Density}_{\text{whiskey}} = 0.915\ \frac{\text{g}}{\text{mL}}$$

Using the data in Table 1, a graph (Plot 1) was prepared by plotting solution density versus percentage ethanol by volume.



A linear regression of the data was performed using Microsoft Excel, and the equation of the best fit line was found to be

$$y = -0.0021\,x + 1.0124 \quad \textbf{(3)}$$

or in other words,

$$\text{Density of solution} = (-0.0021)(\text{Percent alcohol}) + 1.0124 \quad \textbf{(4)}$$

The percentage alcohol in whiskey was determined by rearranging equation (4) and using the calculated density of whiskey:

$$\text{Percent alcohol} = \frac{(\text{Density of solution}) - 1.0124}{-0.0021} \quad \textbf{(5)}$$

$$\text{Percent alcohol} = 46\%$$

Discussion / Conclusion

Determination of the concentration of the components of a mixture can often be accomplished by utilizing indirect methods (Exton, 1989). This experiment was performed for the purpose of determining the alcohol content (percentage by volume) of whiskey by measuring its density. Whiskey is a mixture of water, ethanol, and various other substances that influence the flavor and color. The densities of pure water and pure ethanol are known, but when the two are combined, the density of the resulting solution is a function of the ratio of the quantities of the two substances. Monarch brand whiskey was determined experimentally to have a density of 0.915 $^{g}/_{mL}$, which correlated to 46% ethanol by volume. This result contrasts somewhat with the 40% value stated on the bottle.

Before jumping to the conclusion that the bottle had been mislabeled, it is important to consider the many sources of error that were present in the experimental procedure. The first point of note is that density is a function of temperature and temperature recordings were not made during this procedure. It was assumed that the temperature remained constant but there may have been small fluctuations that would have contributed to this type of error. There was also an associated error present due to use of the volumetric pipettes. As this was the experimentalist's first experience with a pipette, the technique was somewhat imprecise. In particular, the use of the graduated volumetric pipette in the preparation of the known solutions was a challenging experimental technique. Too much added ethanol would cause a density calculation to be low, while too little ethanol would result in a high density value. These two sources of indeterminate error were the primary sources of scatter in the data, as seen clearly in Plot 1.

Table 1 and Plot 1 also reveal that there is a problem with the data recorded for the 45% by volume solution. It is unclear whether the solution was prepared improperly or the density was measured improperly, but the non-linearity of this data point suggests that the measurements should have been repeated if more time had been available. If this point is eliminated, the calculated value for whiskey drops to 44% by volume.

Sources of determinate error in this procedure could be found in the calibration of the pipettes and balances. Given the magnitude of the indeterminate error described above, one may not consider determinate errors in the volume measurements to be significant. However, different balances were used to weigh the known solutions and the whiskey sample. Inconsistencies in the balances would contribute to determinate error that could be eliminated by using the same balance for all samples.

There is also a flaw in the basic premise of this experiment. That is, whiskey with a large number of "impurities" was compared to mixtures of pure ethanol and water. Surely the other substances present in whiskey will affect its density to some extent, and therefore, also affect the percent by volume determination. However, this experiment was still a useful exercise in applying the concept of density to a real world question. The principle of assessing composition by measuring density has wide ranging applications, from establishing the purity of a silver candelabra to determination of the salinity of seawater.

REFERENCES

Exton, D. B. (1989). *General Chemistry in the Laboratory* (pp. 22 – 24). University of Oregon Course Packet.

Petrucci, R. (1989). *General Chemistry, 5/e* (p. 54). New York: Macmillan.

Types of Alcoholic Beverages, Retrieved August 27, 2007, from http://www.hsc.wvu.edu/som/cmed/alcohol/types-al-bev.htm.