Density: A Characteristic Property

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Chemistry I- 3A

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October 18, 2016

Introduction

Purpose: The purpose of this lab was to experimentally determine the density of various substances and to understand how density is used to characterize those substances.

Background: Density is a physical property and is one of the different ways to identify substance because each substance has unique density. Density is an intensive property which means it is a property that is independent of the amount of matter. It is the ratio between mass and volume. It tells whether a substance is compact or loosely packed. Mathematically, density is mass divided by its volume:

$$D = \frac{m}{V}$$

Where:

D is the density;
M is the mass; and
V is its volume.

Density is commonly compared to water and used to know whether a substance will float or sink when placed in it. Water has a density of 0.9999 g/mL at 1 atm and 4^{o}C. Anything that is less dense than water will float and those that are more dense will sink.

Densities of substances used in this experiment are listed in the table below.

Table 1-1. Densities of Some Liquid Substances at 25^{o}C.

Liquid Substance	Density (g/mL)
Acetone, CH_3COCH_3	0.791
Ethyl Acetate, $CH_3COOCH_2CH_3$	0.902
Ethyl Alcohol, CH_2CH_3OH	0.785
Hexane, C_6H_{14}	0.659
Silicon, Si	2.33
Tin, Sn	7.31
Germanium, Ge	5.323

Since density is a way of identifying substances, it will tell the identity of the unknown substance. If the density obtained will be close to any of those listed in Table 1-1, then the identity of the substance will be known.

Materials

- Electronic Analytical Balance
- 1-mL Volumetric pipettes
- 1-mL pipettors
- Vial with stopper
- Liquid and solid samples of various substances (list all)
- 25-mL Beaker
- 10-mL Graduated Cylinder

Procedure

A previously cleaned and dried empty vial with stopper was weighed in the balance. Using a 1.00-mL volumetric pipet, a liquid samples was pipetted and placed in the weighed vial. This was repeated for all liquid samples and for each liquid sample, three trials were prepared and measured. The same procedure was done for the unknown liquid sample. All data are recorded in Table 1-2.

For the density of solids, an empty 25-mL beaker was weighed. Enough amounts of solids were placed in the beaker and weighed. A 10-mL graduated cylinder was half-filled with water and the solid was placed in it. The amount of solid placed was enough to make the water rise to about 3-mL. The same procedure was done for both solids used and three trials for each solid were done. Data for this part of the experiment are recorded in Table 1-3.

The density of germanium was obtained from the densities of tin and silicon.

Observations and Results

Part A of the experiment is the determination of densities of different liquid substances. The mass and volume obtained from this experiment and the calculated densities of the liquid substances are shown in the table below.

Table 1-2. Mass, Volume & Densities of Liquid Substances.

Liquid Substance	**Acetone**			**Ethyl Acetate**			**Hexane**		
Trial Number	1	2	3	1	2	3	1	2	3
Mass of Empty Vial + Stopper (grams)	64.9774	64.9774	64.9774	69.9967	69.9967	69.9967	68.2992	68.2992	68.2992
Mass of Vial with Liquid and Stopper (grams)	65.7822	65.8510	65.7882	70.9762	70.9318	70.9816	69.0499	69.0812	69.0772
Mass of Liquid (grams)	0.8048	0.8736	0.8108	0.9795	0.9351	0.9849	0.7507	0.7820	0.7780
Volume of Liquid (mL)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Density of Liquid (g/mL)	0.805	0.874	0.811	0.980	0.935	0.985	0.751	0.782	0.778
Mean (g/mL)	0.830			0.967			0.770		
Accepted Density (g/mL)	0.791			0.902			0.659		

From the table above, average densities for acetone, ethyl acetate and hexane are 0.830 g/mL, 0.967 g/mL and 0.770 g/mL, respectively.

Table 1-3. Deviation and Percent Error on Densities of Liquid Substances.

Liquid Substance	Acetone			Ethyl Acetate			Hexane		
Trial Number	1	2	3	1	2	3	1	2	3
Density of Liquid (g/mL)	0.805	0.874	0.811	0.980	0.935	0.985	0.751	0.782	0.778
Accepted Density of Liquid (g/mL)	0.791			0.902			0.659		
Absolute Deviation	0.014	0.083	0.020	0.078	0.033	0.083	0.092	0.123	0.119
Average Deviation	0.039			0.065			0.11		
Density (g/mL)	0.830 ± 0.039			0.967 ± 0.065			0.770 ± 0.11		
Error (%)	4.9			7.2			16		

The table above shows that the experimental values of the densities for the liquid samples obtained is 0.830 ± 0.039 g/mL for acetone, 0.967 ± 0.065 g/mL for ethyl acetate and 0.770 ± 0.11 g/mL for hexane. Furthermore, the errors from the experiment were 4.9% for acetone, 7.2% for ethyl acetate and 16% for hexane.

Table 1-4. Determination of Density of Unknown Liquid.

	Trial 1	Trial 2	Trial 3
Mass of Empty Test Tube + Stopper (grams)	45.1035	45.1035	45.1035
Mass of Test Tube with Unknown Liquid and Stopper (grams)	46.0395	45.9533	46.0307
Mass of Unknown Liquid (grams)	0.9360	0.8498	0.9272
Volume of Unknown Liquid (mL)	1.00	1.00	1.00
Density of Unknown Liquid (g/mL)	0.936	0.850	0.928
Mean Density of Unknown (g/mL)	0.905		
Average Deviation	0.003		
Error (%)	0.3		

The unknown substance was found to have a density of 0.905 ± 0.003 g/mL which indicates that it is ethyl acetate. The result showed an error of 0.3%.

In Part B, the density of solids were obtained and were used to calculate the density of germanium.

Table 1.5. Determination of Density of Silicon and Tin.

Substance	Silicon			Tin		
	Trial 1	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
Mass of Container (grams)	7.9042	7.9068	7.9051	8.0186	8.0170	8.0175
Mass of Container and Solid (grams)	8.2628	9.2903	9.7229	11.2019	12.1108	12.7777
Volume of Water (mL)	5.0	5.0	6.8	5.2	5.2	7.6
Volume of Water and Solid (mL)	5.3	5.6	7.2	5.6	6.4	7.9
Volume of Solid (mL)	0.3	0.6	0.4	0.4	1.2	0.3
Mass of Remaining Solid (grams)	0	0	0	0	0	0
Mass of Solid (grams)	0.3586	1.3835	1.1445	3.1833	4.0938	2.7389
Density of Solid (g/mL)	1.1953	2.3058	2.8613	7.9583	3.4115	9.1297
Mean Density (g/mL)	2.1208			6.833		
Accepted Value (g/mL)	2.33			7.31		
Absolute Deviation	1.1347	0.0242	0.5313	0.6483	3.8985	1.8197
Average Deviation	0.563			2.1222		
Error (%)	24			29		

The density obtained for silicon is 2.33 ± 0.563 g/mL with an error of 24% and that of tin was 6.833 ± 2.1222 g/mL with an error of 29%.

The calculated density of germanium based from the data above, is 4.82 g/mL ± 0.503 g/mL. Since the accepted value is 5.323 g/mL, the calculated value has a deviation of 0.503 and an error of 9.4%. Therefore, the calculated density of germanium is 4.82 ± 0.503 g/mL.

Calculations

1. Density was calculated using the formula D=m/V. A sample calculation of the density of acetone using trial 1 is shown below.

$$D = \frac{m}{V} = \frac{\text{mass of acetone}}{\text{Volume of acetone}} = \frac{0.8048\ \text{g}}{1.00\ \text{mL}} = 0.805\ \text{g/mL}$$

2. A sample calculation of how the mean density for acetone was obtained is also shown below.

$$\text{Mean Density of Acetone} = \frac{\text{Trial 1 Density} + \text{Trial 1 Density} + \text{Trial 1 Density}}{3}$$

$$= \frac{0.8048 + 0.8736 + 0.8108}{3} = 0.830\ \text{g/mL}$$

3. Calculation for the percent error for acetone is shown below. It uses the formula:

$$\text{Percent Error} = \frac{|\ \text{Accepted Value} - \text{Experimental Value}\ |}{\text{Accepted Value}} \times 100$$

$$= \frac{|\ 0.791 - 0.830\ |}{0.791} \times 100 = 4.9\ \%$$

4. The calculated density was obtained as follows:

$$\frac{\text{Atomic Number of Ge - Atomic Number of Si}}{\text{Atomic Number of Sn - Atomic Number of Si}} = \frac{\text{Density of Ge - Density of Si}}{\text{Density of Sn - Density of Si}}$$

$$\frac{32 - 14}{50 - 14} = \frac{\text{Density of Ge} - 2.33}{7.31 - 2.33}$$

$$\frac{18}{36} = \frac{\text{Density of Ge} - 2.33}{4.98}$$

$$(18)(4.98) = (36)(\text{Density of Ge} - 2.33)$$

$$89.64 = 36(\text{Density of Ge}) - 83.88$$

$$\text{Density of Ge} = \frac{(89.64 + 83.88)}{36} = 4.82 \text{ g/mL}$$

Conclusion

The densities of acetone, ethyl acetate and hexane were 0.830 ± 0.039 g/mL, 0.967 ± 0.065 g/mL and 0.770 ± 0.11 g/mL, respectively. The errors from the determination of the densities were 4.9% for acetone, 7.2% for ethyl acetate and 16% for hexane. The unknown liquid was determined to be ethyl acetate with a density of 0.905 ± 0.003 g/mL. There was an error of 0.3%.

There was large deviation in the densities obtained for ethyl acetate and hexane. Less error was found in the density of acetone and very minimal error in the determination of the density of the unknown. The large errors could be attributed to the lack of vials. All three trials were done using only one vial which resulted to having some liquid left-over from the previous trial.

The density obtained for silicon was 2.33 ± 0.563 g/mL with an error of 24% and that of tin was 6.833 ± 2.1222 g/mL with an error of 29%. The density of germanium was calculated to be 4.82 ± 0.503 g/mL and an error of 9.4%. The errors were mostly due to lack of experience in the use of the equipment.