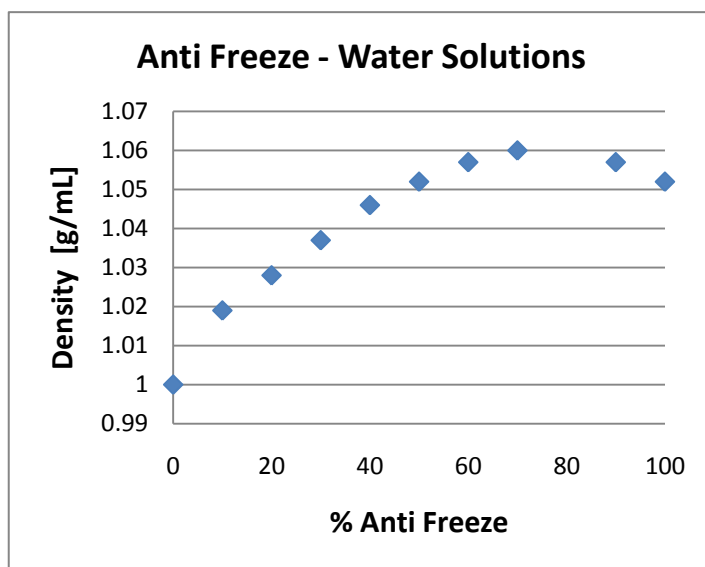


Laboratory Exercise: Density Determinations

In this exercise we will determine the densities of several solids, a liquid and a gas. In the case of the solids we will measure the density of Table Salt (NaCl) and compare our result with an accepted, tabulated result. Then we will determine the density of an unknown metal and compare the result with a list of densities for metals in order to determine its identity. Methanol will be the liquid whose density we will determine; and again, we will compare our result with an accepted value. Finally, we will determine the density of gaseous Cyclohexane. We will do this using an old technique first employed by Jean-Baptiste Dumas in 1826.

Recall, intensive physical properties are useful in classifying and identifying a substance. And, the density is a particularly useful property because it can be measured very, very accurately and it is very sensitive to the composition and condition of a substance. For instance, the density of solutions of Antifreeze mixed with Water varies significantly as the composition of the mixture changes.

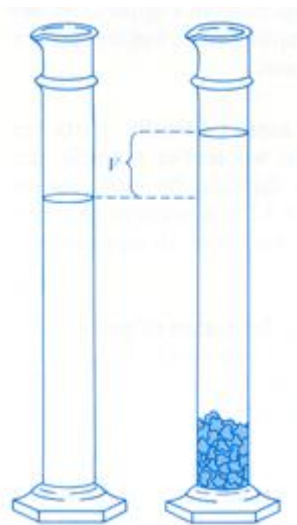


Thus, the amount of Antifreeze in your car's cooling system can be determined by measuring the coolant's density with a hydrometer. The hydrometer is calibrated to convert the density measurement into a percentage Antifreeze in the coolant using the above data.

The density of a substance, or object, is defined as the ratio of its mass to volume:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

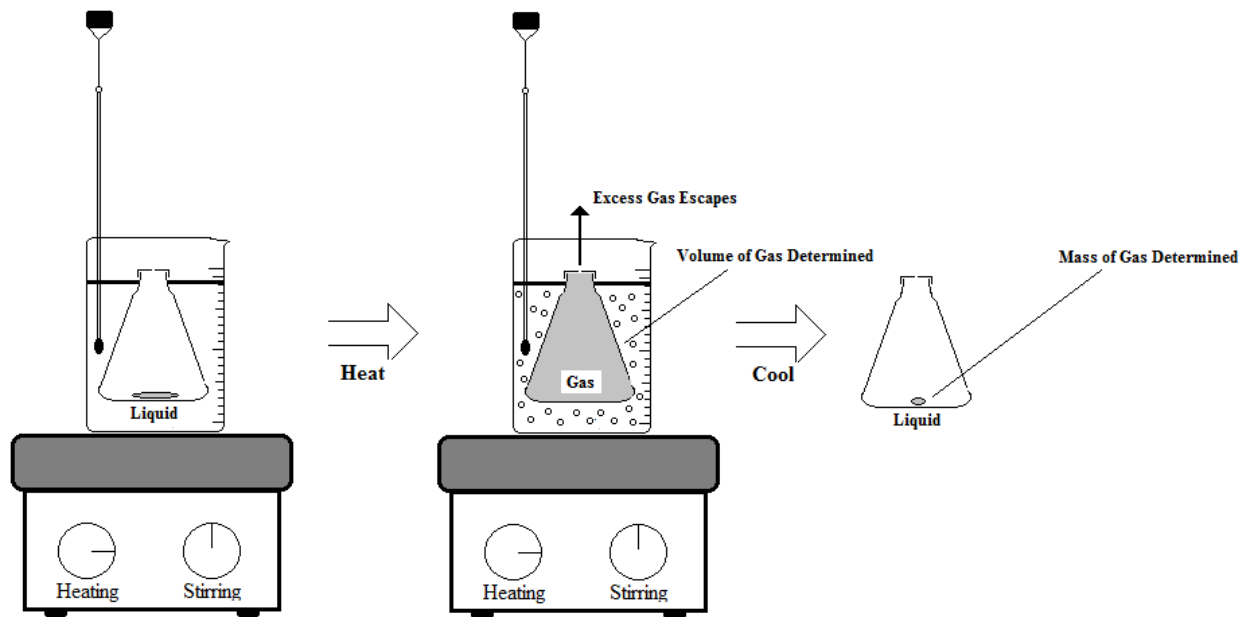
In effect, the density is a measure of the substance's compactness. Two independent measurements are required to determine the density; mass and volume. Mass measurements are easy; high precision pan balances were developed by the early metallurgists. It is the volume measurement that can be tricky. In the case of liquids, the volume can be measured directly with a graduated cylinder. For irregular solids the volume needs to be determined indirectly. One trick is to measure the volume by displacement. A liquid in which the solid will not dissolve is added to a graduated cylinder. A weighed portion of the solid is then added. The volume increase in the level of the liquid will be due to the added solid.



For gases, we will use a trick first used by Dumas. The trick is to start with a liquid and heat it until it vaporizes into a gas; the gas whose density is to be determined. The vessel in which the liquid is heated has a pin-hole such that excess gas can escape. Once heated, the gas fills the vessel's entire volume. Measuring the volume of the container gives us the volume of the gas. And, cooling the gas back into a liquid allows us to determine its mass. *Viola*, we now have the gas's density.



Jean-Baptiste Dumas



Procedure

All your measurements must be made to the correct number of significant figures and must have the unit of measurement indicated.

Density of a Solid

1. Obtain a dry 10 mL graduated cylinder with a cork. **In a fume hood**, with an eyedropper, add exactly 5 mL of liquid Hexane. Read the volume precisely.
2. Obtain an amount of Sodium Chloride that can be added to the cylinder without exceeding the volume of the cylinder. Determine the mass of this sample.
3. Add the solid to the cylinder. Read the new volume precisely.
4. Calculate the density of solid Sodium Chloride. Compare this to the accepted value. Calculate the percentage error for your measurement.
5. Repeat this procedure for one of the unknown metals. Make sure the cylinder is completely dry before adding the new liquid. For the metals, use Water as the displaced liquid. Determine the density of the metal. Compare this density with that of the following possibilities for the metal. Identify your metal.

<u>Metal</u>	<u>Density (g/mL)</u>
Aluminum	2.70
Zinc	7.14
Lead	11.34

Density of a Liquid

1. Obtain a dry 10 mL graduated cylinder with a cork. Weigh this accurately on an analytical balance.
2. **In a fume hood**, with an eyedropper, add exactly 5 mL of liquid Methanol to the cylinder. Read the volume precisely. Re-cork the cylinder and re-weigh it.
3. Calculate the density of liquid Methanol. Compare this to the accepted value. Calculate the percentage error for your measurement.

Density of a Gas

1. Pour approximately 700mL of water into a 1000mL beaker. Add a few boiling chips to the water.
2. Obtain a 250 mL Erlenmeyer flask and assemble an Aluminum cap.
3. Weigh the empty 250mL Erlenmeyer flask with cap assembly. The flask and cap must be dry.
4. Remove the cap and add approximately 5mL of liquid Cyclohexane to the flask. Replace the cap. Use a pin to place a pin-hole in the cap.

5. Submerge the flask in the beaker of water. Use a clamp to hold the flask in place. Adjust the water level so that water will come to the neck of the flask, but will not splash out of the beaker when boiling. The bottom of the flask should be 1 cm above the bottom of the beaker.
6. As directed, suspend a thermometer in the water with a suitable clamp. Do not let the thermometer touch the beaker or the flask.
7. Heat the water to boiling.
8. Note when the liquid begins to boil. Continue heating for 5 minutes after the liquid has completely vaporized and record the temperature of the boiling water as the density of the gas will depend very heavily on its temperature.
9. Remove the flask from the boiling water and immerse the flask under cold running water. Keep the water away from the cap.
10. After the flask has cooled to room temperature, carefully dry the outside of the flask and cap. Weight the flask, cap and condensed sample.
11. Remove the cap and and rinse the flask with water. Drain dry and fill the flask with deionized water.
12. Use a large graduated cylinder to measure the volume of the Water that fills the flask.
13. The density of a gas depends very heavily on its pressure. Make a barometric reading of the atmospheric pressure, which will equal the pressure of the gas.

Density Determinations

Density of a Solid

Sodium Chloride

Obs:

Vol. Liq. in Cylinder _____

Vol. Liq. in Cyl. after Solid _____

Mass Solid _____

Unknown Solid

Obs:

Vol. Liq. in Cylinder _____

Vol. Liq. in Cyl. after Solid _____

Mass Solid _____

Density of a Liquid

Obs:

Vol. Added to Cylin. _____

Mass Cylinder _____

Mass Cylinder & Methanol _____

Density of a Gas

Obs:

Vol. of Flask _____

Mass Flask Empty _____

Mass Flask & Liquid _____

Temperature _____

Pressure _____

Name: _____

Date: _____

Signature: _____

Data Analysis

Calculate the density of each sample below. You should show each calculation fully as:

$$\text{density} = \frac{\text{Mass}}{\text{Volume}} = \frac{3.5784 \text{ g}}{4.8 \text{ mL}} = 0.74 \text{ g/mL}$$

You must track the units of measurement and significant figures correctly.

Density of a Solid

Sodium Chloride

Calculate the Density of Sodium Chloride. Compare your Result with the Accepted Result.
Calculate your Percentage Error.

Unknown Metal

Calculate the Density of your Unknown Metal. Determine the Identity of the Metal.

Density of a Liquid

Calculate the Density of Methanol. Compare your Result with the Accepted Result.
Calculate your Percentage Error.

Density of a Gas

Calculate the Density of Gaseous Cyclohexane. Report the Temperature and Pressure at which this Determination is Performed.

Post Lab Questions:

1. The density of Water is roughly 1 g/mL. Use this fact to determine the mass of Water in a 10 gallon aquarium. What is the weight of this Water in pounds?
2. Elemental Osmium was first discovered in 1803 as the solid residue left when crude Platinum was dissolved in Aqua Regia. It is a lustrous blue-white metal that is currently credited with being the heaviest element; although the measured density is in doubt and is very close to that of elemental Iridium. X-ray crystallographic measurements suggest the density of metallic Osmium is 22.661 g/cm^3 . What is the mass a cube of this metal, reported in grams, whose sides each measure 1 ft? What is the weight of this cube in pounds?
3. As we have indicated, the *SI* Standard of mass is the 1 kilogram *International Prototype Kilogram* stored in a vault in the basement of the International Bureau of Weights and Measures in Sevres, France. It is composed of an alloy that is 90% Platinum and 10% Iridium; having a density of 21.186 g/cm^3 . What is the volume of the Standard Kilogram?
4. The Standard Kilogram is constructed as a Right-Circular Cylinder with Height equal Diameter. Based on your Volume determination above, what is the Height of the Standard Kilogram?