EXPERIMENT 0

Density and Specific Gravity

A. Goal

The goal of this laboratory experiment is to experimentally measure density as well as specific gravity for a liquid.

B. Materials

- ☐ 50ml, 100mL cylinder
- ☐ a 100mL (or 25mL) beaker
- ☐ metallic object
- ☐ unknown solution
- ☐ a set of pennies

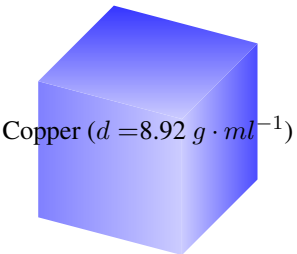
C. Background

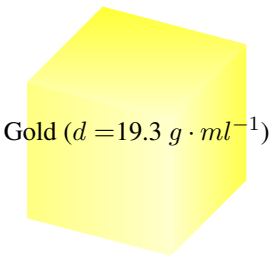
Density

Density refers to the mass of a substance with respect to its volume. This is an unique property for each substance. Table 2 reports the density of numerous substances. Indeed, density is often used as an identification tag. The formula for density is

$$\boxed{\text{Density} = \frac{\text{Mass of substance}}{\text{Volume of substance}}} \tag{1}$$

For example, the density for copper is 8.92 $g \cdot ml^{-1}$ and for gold is 19.3 $g \cdot ml^{-1}$. By measuring density only, you would be able to differentiate copper than gold. The larger density the more compact is an object and that means the more mass per volume it has. At the same time, for the same volume, the larger density the larger the mass of the metal.





Density and mixing

A small piece of ice will float on the water. The reason for that is density: the density of ice (0.9g/mL) is smaller than the density of water (1.0g/mL) and hence ice will stay on top of the water. Objects with a density larger than 1 g/mL will sink whereas objects with a density smaller than this value will float. Figure **??** showcases how objects with density larger than water will sink whereas objects with a smaller density will float. If you add a drop of vegetable oil to a glass of water, the drop will float. This is because the density of oil is smaller than 1g/mL.

Table 2 Density of some common substances at 273.15 K and 100 kPa		
Substance	Density (g/mL)	Physical State
Helium	0.2	gas
Hydrogen	0.1	gas
Water	1.0	Liquid
Cooking oil	0.9	Liquid
Mercury	13.5	Liquid
Tetrachloroethene	1.6	Liquid
Gold	19.3	solid
Plastics	1.2	solid
Ice	0.916*	solid

*Ice is given at T <273.15 K

Density and the volume of objects

Density depends on volume and in particular the larger volume the smaller density. Figure **??** displays the formulas to calculate the volume for some common objects, like a sphere or a cube. For example, the radius of a sphere with density d and mass m corresponds to $\sqrt[3]{3m/4d \cdot \pi}$, and the side of a cube with density d and mass m corresponds to $\sqrt[3]{m/d}$.

Immersion method

The density of liquids results from measuring the mass of a given volume of the liquid. Differently, density is harder to obtain for solids. For metals, we can calculate density by the immersion method: when a metal is immersed in water, the water rises. This increase in volume corresponds to the volume of the solid. This way, density results from the direct measurement of mass and the measurement of volume by displacement.

Specific gravity

The specific gravity (ρ) of a substance is the ratio between its density and the density of a reference, normally water. It is simply calculated by dividing the density of the substance and the density of water (1g/mL at room temperature).

$$\rho = \frac{\text{density of substance}}{\text{density of water}} \tag{2}$$

A substance with a specific gravity of 1 has a density of 1g/mL. This is a unitless property that can be measured with an instrument called a hydrometer. For example, the specific density of the urine in the body is used to identify diabetes or kidney malfunctioning. The following example demonstrates density calculation with the immersion method.

Sample Problem 1

After adding a 30g object into a cylinder filled of water, the level of water rises from 60mL to 90mL. Calculate the density of the object.

SOLUTION

Density is mass over volume. The mass of the object is 30g and its volume is (90-60)mL that is 30mL. Hence: $d = 30g/30mL = 1g/mL$.

STUDY CHECK

A lead weight used in the belt of a scuba diver has a mass of 226 g. When the weight is placed in a graduated cylinder containing 200.0 mL of water, the water level rises to 220.0 mL. What is the density of the lead weight (g/mL)?

▶Answer:11.3 g/mL.

D. Procedure

1. Density of water The goal of this mini-experiment is to calculate the density of water. In order to do this you will measure the mass of a specific volume of water and use the formula for density:

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

Step 1: – Place approximately 25mL of tab water into a 100mL cylinder. Indicate the exact volume you employed in the table below.

Step 2: – Place a 100mL (or 25mL) beaker in the scale and press zero. After that add the liquid from the cylinder and write down the mass in the table below.

Step 3: – Compute the value of density. Research the expected value from the internet and make sure your value is reasonable.

2. Density of a solution In this section you will calculate the density of an unknown solution by repeating the procedure from the previous mini-experiment. You will also compute the specific gravity by diving the density of the solution by the density of water.

$$\text{specific gravity} = \frac{d}{d_{water}}$$

Step 1: – Place approximately 25mL of the solution into a 100mL cylinder. Indicate the exact volume you employed in the table below.

Step 2: – Place a 100mL (or 25mL) beaker in the scale and press zero. After that add the liquid from the cylinder and write down the mass in the table below.

Step 3: – Measure the temperature of water and obtain the density of water at the measured temperature using the link below:

`http://antoine.frostburg.edu/chem/senese/javascript/water-density.html`

Step 4: – Compute the value of density.

3. Density of a solid In this mini-experiment you will calculate the density of a metal by a method called volume displacement. You will measure the volume of a liquid before and after adding the solid. The difference in volume is the volume of the solid. By means of this measurement and the mass of the solid you will be able to estimate density.

Step 1: – Obtain a metallic object and weight it. Record its mass in the table below.

Step 2: – Attach a string to the object and submerge it in a 50mL cylinder big enough to fit the object.

Step 3: – Add water until the object is covered. Record this volume in the table below. This is $V_{(After)}$.

Step 4: – Now using the string remove the object from the cylinder. Write down the liquid volume after the object is out. This is $V_{(Before)}$.

Step 5: – Calculate the volume of the object by subtracting the liquid volume before and after removing the object from the cylinder.

Step 6: – Use the formula of density to calculate the density of the solid.

5. Density by graphing The goal of this mini-experiment is to calculate the density of a metal by means of a graph. This method is useful for small pieces of metal which volume can not be computed by means of the volume displacement method. You will continuously add pieces of metal to a liquid so that the volume will progressively increase. By graphing mass vs. volume you will be able to compute density.

Step 1: – Place 25mL of water in a 100mL cylinder. Carefully record the liquid volume in the table below.

Step 2: – By means of a scale calculate the mass of the liquid and record the value reporting all decimals given by the scale.

Step 3: – Add metal pieces (or perhaps pennies) so that the liquid volume changes significantly. Write down the new volume and the new mass. Repeat this procedure until you fill up the Results table.

Step 4: – Keep on adding metal pieces until you fill in the table below.

Step 5: – Plot mass (vertical axis) vs. volume (horizontal axis) in the graph below.

Step 6: – You will calculate the density of the metal by selecting two arbitrary points from the plot (point 1 and point 2, where point 2 has a larger mass) and using the formula:

$$\text{density} = \frac{mass(2) - mass(1)}{volume(2) - volume(1)} = \frac{\qquad\qquad\qquad\qquad}{} = \qquad\qquad g/mL$$

6. Reading a hygrometer The goal of this mini-experiment is to calculate the specific gravity of two liquids by reading a hygrometer.

Step 1: – You will find two hygrometers displayed in the lab, one with water and another with an unknown liquid.

Step 2: – Read the measurements of both and write down the result in the table below.

STUDENT INFO

Name: _____ Date: _____

Pre-lab Questions

Density and Specific Gravity

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1. Do oil float on water? Explain why.

2. Research the meaning of specific gravity.

3. A 3g glucose solution occupies a volume of 0.1L. Calculate the density of the solution in g/mL.

4. Oil has a density of 0.9g/mL. Calculate the mass in grams of a 100mL oil sample.

5. An electrolyte solution has a density of 1.3g/mL. Calculate the volume in L of a 2mg sample.

STUDENT INFO

Name: _____ Date: _____

Results
EXPERIMENT

Density and Specific Gravity

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1. Density of water

Volume (mL)	mass (g)	Density (g/mL)

2. Density of a solution

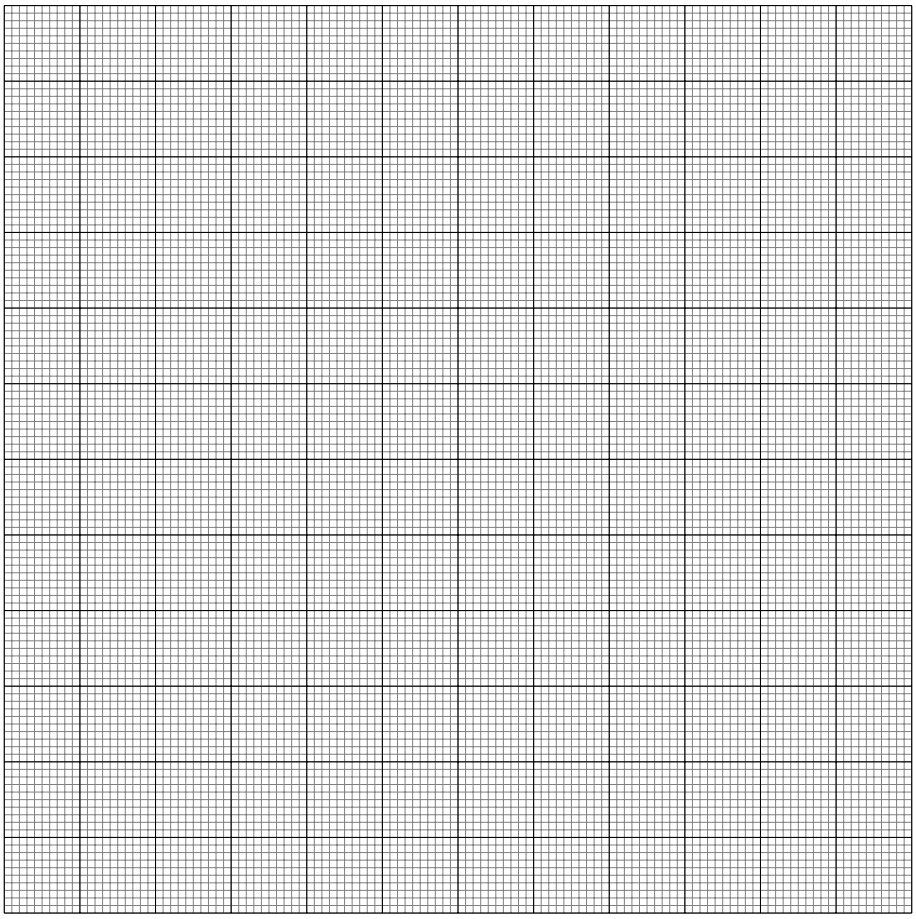
Volume (mL)	mass, (g)	Density of liquid (g/mL)	Density of water (g/mL)	Specific gravity

3. Density of a solid

Mass (g)	Volume before adding the object, $V_{(Before)}$ (mL)	Volume after adding he object, $V_{(After)}$ (mL)	$V_{(After)}$-$V_{(Before)}$ (mL)	Density (g/mL)

4. Density by graphing

Volume (mL)	mass (g)



Name of metal=_____

5. Reading a hygrometer

Specific gravity of water	Specific gravity of unknown

STUDENT INFO

Name: _____ Date: _____

Post-lab Questions

Density and Specific Gravity

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1. A nugget of metal with a mass of 400 g is added to 25.0 mL of water. The water level rises to a volume of 40 mL. What is the density of the metal?

2. Determine the density (g/mL) of a 0.3 L sample of a salt solution that has a mass of 40 g.

3. A graduated cylinder contains 25 mL of water. What is the new water level after 35 g of silver metal is submerged in the water if the density of silver is 11g/mL?