Experiment Three – Density Determinations

Objective

Density is an important property of matter that may be useful as a method of identification. In this experiment, you will determine the densities of regularly and irregularly shaped solids, as well as the densities of pure liquids.

Introduction:

Density is a measure of the matter present within a unit of volume space, mass per volume (mass/Volume). For most samples mass is measured in grams (g) or kilograms (kg), while volume is typically measured in centimeters (cm^3) for solids, milliliters (mL) for liquids, and Liters (L) for gasses. Since we seldom deal with exactly 1.0 mL of a substance in the chemistry laboratory, we usually represent density as mass of the sample divided by its volume. The units will depend on what phase the sample is in, but it's always some version of mass over Volume: solid = g/cm^3, liquid = g/mL, gas = g/L.

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

The density effectively represents the ratio of mass/volume of *any* size sample, this allows us to use density as an **intensive property** (property that doesn't depend on the amount of a substance, *example* – the density of water will be 1.0 g/mL regardless of if you have 10mL or 5000mL). An **extensive property** on the other hand will depend on the amount of material present; mass and volume are examples of extensive properties.

Density is usually reported at around 20°C (room temperature) because volume of a substance, and hence density, will often vary with temperature. This variation is most obvious in gases, with smaller (but often noticeable) changes for liquids and solids.

Density of Solids:

Depending on whether or not the solid is regularly shaped, there are different methods for the determination of the volume.

Regular Shape Solids: If a solid has a regular shape (e.g., cube, rectangle, cylinder), the volume of the solid may be determined by geometry:

For a cube or rectangle solid, volume = length • width • height

For a cylindrical solid, volume = $\pi \cdot (\text{radius})^2 \cdot$ height

Irregular Shape Solids: If a solid does *not* have a regular shape, it may be possible to determine the volume of the solid making use of **Archimedes' principle**, which state that an insoluble, non-reactive solid will *displace* a volume of liquid equal to its own volume. Typically, an irregularly shaped solid is added to a liquid in a graduated cylinder and the change in liquid level is determined. Figure 3.2 below demonstrates the change in water level, and the displacement of water.

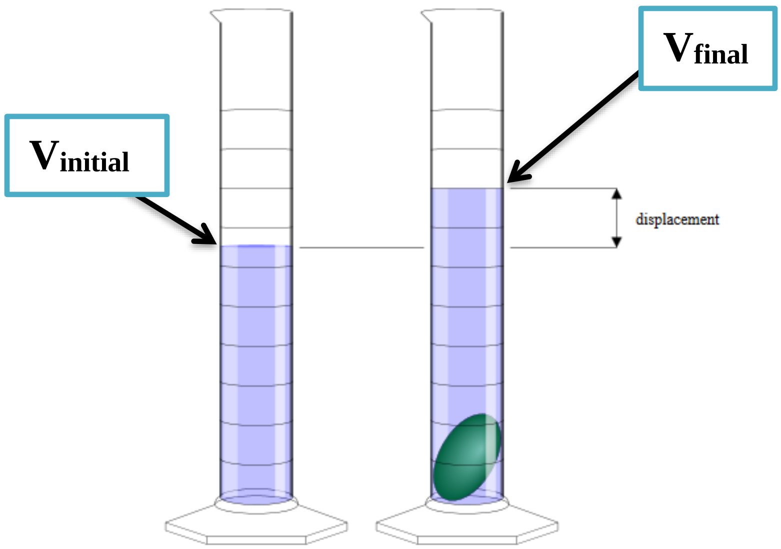

Figure 3.1 – displacement method of determining volume of a solid.

Density of Liquids:

For liquids, very precise values of density may be determined by pipetting an exact volume of liquid into a beaker or other glass container and then determining the mass of the liquid that was pipetted. A more convenient method for routine density determinations for liquids is to weigh a particular volume of liquid as contained in a graduated cylinder.

Calculations

% error

Percentage error is a way to check your experimental technique as well as the equipment used, against what is accepted by the science community. The percent error is based on the experimentally determined values obtained by a student in the lab, against the literature values accepted by science. If percent error is high it's an indication that there is an experimental issue: human error as a result of poor technique or flawed equipment providing inaccurate measurements; most often it's a combination of the two.

$$\boxed{\%\ error = \frac{experimental\ denisty - actual\ density}{actual\ denisty} x100}$$

Procedure:

Part I – Regular Shaped Solid

1. Obtain a regularly shaped solid, and *record its ID number*.
2. With a ruler, determine the physical dimensions (length, width, and height) of the solid to the nearest 0.01 mm.
3. Convert the values you just obtained to cm, a sample calculation is below. Record the length, width, and height in your data sheet in cm.
4. Calculate the volume of your sample, where Volume = L x W x H, in cm^3. Record the result as *"Volume of wood sample"* on your data sheet.
5. Weigh the sample on a balance and *record its mass as "mass of wood sample"* on the data sheet.
6. Calculate the density of your regularly shaped solid in g/cm^3. Record the result as *"density of wood sample"* on your data sheet.
7. Obtain the "actual" density of the wood from your instructor and use this value to determine the % error in your density determination.

ID # of regular wood sample ________________

Dimensions of the wood (in cm)

Length ________________ cm

Width ________________ cm

Height ________________ cm

Volume of wood sample ________________

Mass of wood sample ________________

Density of wood sample ________________

Actual density (obtain from instructor) ________________

% Error (show calculation for full credit!!)

Part II – Metal Shot (irregularly shaped solid)

1. Obtain a test tube of metal shot from your instructor and *record the metal type on your data sheet*.
2. Weigh the sample of metal shot, test tube, and cork top. *Record the value as "mass of shot + glassware" in your data sheet.*
3. Back at the bench, fill a graduated cylinder with enough water to ensure the metal shot will be complete submerged by this water once the metal is added to the graduated cylinder. <u>BEFORE YOU ADD THE METAL SHOT TO THE WATER IN THE GRADUATED CYLINDER</u>, record the volume of the water as *"Volume (initial)"* to one decimal place (ex. 13.2 ml)
4. Carefully add your metal shot to the water in the graduated cylinder without losing any of the metal. After all of the metal shot is in the graduated cylinder gently shake and/or stir the sample to remove any air bubbles, as air bubbles will displace water and give you an incorrect volume. Determine the new volume of water in the graduated cylinder and record it as *"Volume (final)"*.
5. Now that your test tube is empty, it's a convenient time to obtain the mas of the empty test tube, cork and any other glassware included in the initial mass determination of the metal shot. Weigh the glassware and cork without the metal and record the value as *"mass of glassware"*.
6. Calculate the mass of your metal shot (*"mass of metal shot + glassware" – "mass of glassware"*), record the result as *"mass of metal shot"*.
7. Calculate the change in volume (ΔV) of the water; which represents the volume of water that was displaced by the metal shot and thus the volume of the metal shot. Record the value as *"Volume of metal shot"* in your data sheet.

$$\boldsymbol{\Delta V = V_{final} - V_{initial}}$$

8. Calculate the density of your metal shot using the *"mass of metal shot"* and *"Volume of metal shot"*.
9. After determining the density, decant most of the water from the metal sample and dry the metal shot on a paper towel. Once it's dry place the sample back in the test tube.
10. Based on your answer determine what type of metal you have from the data table below and *record your best guess in the data sheet*
11. Obtain the "actual" density of the wood from your instructor and use this value to determine the % error in your density determination..

Part II – Metal Shot (irregularly shaped solid) - *continued*

Type of metal shot	________________
mass of shot + glassware	________________
mass of glassware	________________
mass of metal shot	________________
Volume (final)	________________
Volume (initial)	________________
Volume of metal shot	________________
Experimental density of metal shot	________________
Actual density of metal shot (obtain from instructor)	________________

% Error (show calculation for full credit!!)

Part III – Density of liquids

Here, we will determine the density of three pure liquids, allowing us to deliver these liquids to a 50ml graduated cylinder from most dense (poured first) to least dense (poured last), such that the liquids will produce 3 visibly separate layers within the graduated cylinder.

1. Label three empty 50ml beakers and record the mass of each beaker as *"mass of graduated cylinder"* on your data sheet.

2. Use a 10ml volumetric pipet to transfer exactly 10mL of each of your pure liquids to a separate 50ml beaker. <u>Rinse the pipet with water after each transfer to reduce contaminating your samples</u>.

3. Weigh the 50ml beaker with the pure liquid in it and record the value as "mass of graduated cylinder *+ pure liquid"*.

4. Calculate the mass of the pure liquid by subtracting the *"mass of graduated cylinder"* from the *"mass of graduated cylinder + unknown liquid"*. Record the result as *"mass of unknown liquid"* on your data sheet.

5. Calculate the density of the pure liquid by dividing the "mass of unknown liquid" by "Volume of *unknown liquid"*. Record the result on your data sheet as *"density of the pure liquid"*.

Color of pure liquid	________________
mass of graduated cylinder + pure liquid	________________
mass of graduated cylinder	________________
mass of pure liquid	________________
Volume of pure liquid (from 10ml pipet)	_____10ml_____
density of pure liquid	________________
Color of pure liquid	________________
mass of graduated cylinder + pure liquid	________________
mass of graduated cylinder	________________
mass of pure liquid	________________
Volume of pure liquid (from 10ml pipet)	_____10.00 ml_____
density of pure liquid	________________
Color of pure liquid	________________
mass of graduated cylinder + pure liquid	________________
mass of graduated cylinder	________________
mass of pure liquid	________________
Volume of pure liquid (from 10ml pipet)	_____10.00 ml_____
density of pure liquid	________________

6. Slowly pure each of these liquids down the side of a clean, dry 50ml graduated cylinder from most dense (poured first) to least dense (poured last). If you do this correctly you should get 3 separate layers. If the layers begin to mix, then you likely had an error in your density determinations. Have your instructor sign off on this layered display.

Instructor's signature: ___________________ Comment: _____________________________________

Post-Lab Questions

1. a.) Had you not stirred/shaken the metal shot to remove adhering air bubbles while determining the density of the irregularly shaped metal shot, would there be a “mass error” or “volume error”.

   ☐ mass error

   ☐ volume error

   b.) Given this “air bubble error” mentioned above, would the calculated density be too high or too low?

   ☐ density would be too high

   ☐ density would be too low

   Explain your answer:

2. a.) What error would be introduced into the determination of the density of the regularly shaped solid if the solid were hollow?

   ☐ mass error

   ☐ volume error

   b.) Would the apparent volume of the solid be larger or smaller than the actual volume?

   ☐ larger volume

   ☐ smaller volume

   c.) Would the calculated density of this hollow solid be too high or low?

   ☐ density would be too high

   ☐ density would be too low

   Explain your answer:

3. Pure aluminum metal has a density of 2.70 g/cm^3. If we add a solid aluminum cylinder to a graduated cylinder containing 19.2 mL of water, and the water level in the cylinder rises to 24.7 mL, what is the mass of the aluminum cylinder? **(show your work for full credit)**

4. Acetone, a common solvent, has a density of 0.79 g/mL at 20^{o}C.

   a) What is the volume of 85.1 g of acetone at 20^{o}C? **(show your work for full credit)**

   b) What is the mass of 125 mL of acetone at 20^{o}C? **(show your work for full credit)**