Experiment 2:
A Submarine Adventure: Density Saves the Day

Instructor Notes and Lab Preparation

Chemicals and Equipment

Various metal shapes of copper, nickel, lead, aluminum, brass, iron, and magnesium
10 mL graduated cylinder
100 mL graduated cylinder
Large tub of salt water (NaCl)
Round balloons
Disposable pipettes and bulbs
¼ ounce fishing weight egg pellets
Vernier calipers
Analytical balance

Preparation

There is very little preparation for this lab. The glassware and equipment above should be available to each student.

I have left the shape of the unknown metal objects up to the discretion of the instructor. I have most commonly used cylinders, but even balled up wire will work. The metal unknowns should be constructed such that each metal either has a different dimension or shape or is stamped with a code to differentiate them. Some of the metals should be either too large or too oddly shaped to measure by use of the calipers so that each student must calculate the volume by difference at least once.

The concentration of the salt in the ocean water is also up to the discretion of the instructor. I would suggest a density of about 1.2 g/mL. To save money, table salt or rock salt can be used instead of reagent-grade NaCl. For the reservoir, you can use a 5 L beaker or a plastic tub. Simply dissolve the desired amount of NaCl in distilled water to create the "ocean." I generally have the prep person take a sample of the prepared "ocean" and calculate the density so that I have a relative value to expect from the students.

Instruction Notes

This lab experiment normally takes about 2 hours for the students to complete both parts.

Part 1

For the best results in part 1, you should separate the metal unknowns into two groups: those whose volume can be determined by calculation and those whose volume must be determined by displacement. I generally have the students take one of each for investigation. The prelab determines the possible identities of the metal unknowns. If you would like to use other metals, the densities of those metals would simply need to be made available to the students.

A key teaching point in this part of the experiment is a discussion regarding which method of volume determination is more accurate. The metals over time tend to become scratched and dented so that the volume by displacement is more accurate. But students often think that the more numbers they collect, the more accurate their data become.

Another key point is the discussion of observation to assist in the identification of the metals. Obviously, copper and brass unknowns could probably be identified by their color alone. A discussion about how a scientist uses all of his or her senses to investigate a subject can be incorporated into the experiment.

Potential Problems

The greatest difficulty can arise when the students forget the difference between diameter and radius in their calculations. A reminder at the beginning of the lab session generally keeps the students straight on this point. Also, the prelaboratory exercise should be checked to make sure that the values the students transfer into their lab notebooks are accurate enough to use for their conclusions.

Part 2

The creation of the submarine, while silly, seems to really firm up the concept of density in the minds of the students in my labs. One of the main teaching points is the relationship between the mass and volume and how a change in either can cause a shift in the density. A good discussion point is which change has a greater impact. Even though the weight of 20 quarter-ounce lead pellets is well over 100 g, the total volume of the balloon and thus its diameter is still pretty small. Because they often must adjust their sub's volume to get a good submarine, students start to get a feel for how a very small adjustment in the volume can lead to big changes in density. A good submarine will very seldom end up floating exactly in the middle of the beaker/tub of water. A good submarine is a balloon that is completely below the water line with just the knot of the balloon touching the surface.

Potential Problems

Although we use round balloons, when they are blown up, they are still fairly small and thus not quite round in shape. The best way to get a good balloon volume is to set the calipers to the measured balloon diameter desired and lay it flat on the counter or table top. Then blow the balloon up as close as possible to that diameter while pressing the balloon into as round a shape as possible. Only once the correct diameter is achieved should the balloon be tied off.

The egg weights we use are quarter-ounce lead egg sinkers. The company we use is http://www.bulletweights.com/Products/Lead/eggsinkers.aspx. You can also use marbles to represent the passengers on the sub, but the number required to get a sufficient weight is often difficult to get into the balloon.

Experiment 2

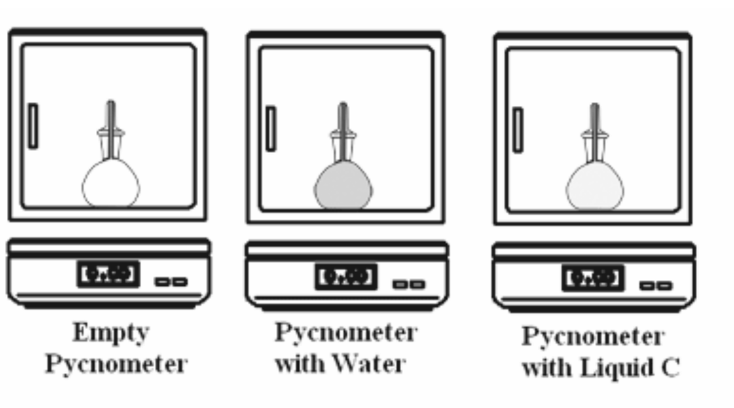
Prelaboratory Assignment KEY

Name: ____________________________ **Date:** __________________

Instructor: _____________________________ **Sec. #:** ___________

Show all work for full credit.

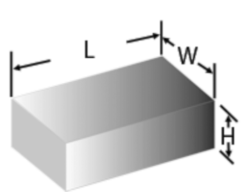
1) A pycnometer with a mass of 56.96 g when empty, has a mass of 108.22 g when filled with water (density = 1.000 g/mL), and a mass of 97.56 g when filled with liquid C.



(a) What is the volume of the pycnometer? **51.26 mL**

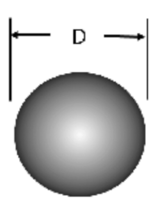
(b) What is the density of liquid C? **0.7920 g/mL**

2) Finding the density of solids requires a method of measuring the volume of the solid. If the solid has a regular geometric shape, the volume can be calculated from a measurement of the dimensions of the shape. Examples of three simple shapes are shown here, with the formulas for calculating their volumes.



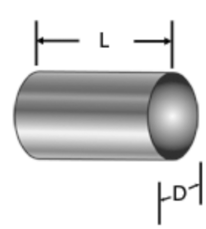
Rectangular Block

$$V = L \times W \times H$$



Sphere

$$V = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3$$



Cylinder

$$V = \pi\left(\frac{D}{2}\right)^2 \times L$$

You measure the following dimensions of a rectangular metal block of metal A:
length = 10.89 cm; width = 6.49 cm; height = 1.57 cm. It has a mass of 193.07 g.

What is the density of metal A? **1.74 g/cm^3**

A sphere of metal B has a mass of 298.15 g and a diameter of 3.09 cm.

What is the density of metal B? **19.3 g/cm^3**

You measure the following dimensions of a cylinder of metal C:
length = 9.49 cm; diameter = 2.35 cm. It has a mass of 469.24 g.

What is the density of metal C? **11.4 g/cm^3**

Metal	Density (g/cm^3)*
Nickel	8.90
Lead	11.4
Aluminum	2.70
Gold	19.3
Brass	8.51
Copper	8.92
Iron	7.86
Magnesium	1.74

Based on the densities in the table, identify the unknown metals A, B, and C:

Metal A = **magnesium**

Metal B = **gold**

Metal C = **lead**

3) You determine that the salt water in the tank has a density of 1.02 g/mL. The balloon weighs 2.0 g, and your weights have a mass of 30.0 g each. If you put six weights in your balloon, you must inflate the balloon to what diameter for it to have a density equal to the salt water, and therefore float in the middle of the tank?

6.98 cm

Lab Report Key

The title page should include:

Student's full name
Date of experiment
Complete title of lab report
Name of partner(s)
Instructor's name
Lab and section number

The purpose should include:
This experiment deals with several subjects, including density, balance use, caliper use, and measurements of volumes and masses using balances and graduated cylinders. The purpose should include references to most of these topics and should not be a copy of what is given in the manual. Full credit can be given if at least three of the aforementioned topics are discussed.

Procedure:

This should be an MLA form reference to the lab manual with any changes in the procedure noted.

Data:

The data section should include all observations made during the lab of the cylinders, balloons, and anything else involved in the experiment. A data table for determining the density of a metal cylinder should also be included with the following information **a)** measurements of the cylinders, **b)** volume of both cylinders, **c)** mass of the cylinders **d)** density of the cylinders, and **e)** identity of unknown metals.

A second data table with the submarine data should be included. Be sure that the table includes the following information: **a)** mass of graduated cylinder, **b)** volume of ocean water, **c)** mass of water, **d)** weight of balloon with weights, **e)** density of ocean water, **f)** volume of balloon needed to match salt water density, **g)** final volume of submarine design, and **h)** final density of submarine design.

Calculations:

The calculations section should have example calculations of the following: **a)** volume of the cylinders, **b)** mass of water, **c)** density of ocean water, **d)** volume of balloon needed to match salt water density, **e)** final volume of submarine, and **f)** final density of submarine. Units must be used correctly in all tables and calculations.

Conclusions:

The conclusion section should be in paragraph format. This section should summarize the information in the data section. For the density of the metal cylinder section, there should be a report of the density and identity of the unknown metals. There should be a discussion of any differences in the known and unknown density and the percent error. Also any experimental errors that might have led to these differences should be discussed.

For the submarine data, a report of the density of the ocean water, the ideal volume of the submarine, and the final volume and density of the submarine should be present. A description of the trial and error portion of making the submarine and the differences in the ideal volume of the submarine and the final volume of the submarine should be presented. Finally, a discussion of any errors in the submarine design and the experiment should be included.

Questions:

1) Give an example of the use of density (other than submarines) that you have observed in your own life.

   This could be salad dressing, hot air balloons, etc. Anything reasonable can apply.

2) What is third-person writing, and why is it used in the writing of scientific papers?

   When writing, "person" refers to the point of view of the author. First person is written from the "I" point of view, second person is written from the "we" point of view, and third person is written from the "it" point of view. Because much of science is collaborative in nature, most all papers are written without personalization of the text, i.e., from the third person neutral point of view. Writing from the first or second person implies that none of the information in the paper was contingent on any research/work done previously, which is seldom true.