Density of Materials

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Objective: The student will be able to determine the density of a regular solid, an irregular solid, a liquid, and test their understanding of density by determination of an unknown. As you proceed, you will discover density concepts of importance.

Background:

Have you ever wondered why an ocean liner floats on water? The answer is in the density of the ocean liner compared to the density of the water. Since the volume of the ocean liner is mostly air, its net density is less than that of the surrounding water. When two liquids of differing densities are placed in contact, the object that is less dense will float on the object that is denser. Density is, therefore, an important physical property of a substance.

Density is a derived unit (Chapter 1 Section 6 in Tro 2nd Edition). It is the ratio of the mass of a substance divided by the volume that the substance occupies. Several units can be used to express density. For a liquid, grams per milliliter is often used, whereas, for a regular solid, grams per centimeter cubed is the most common unit.

The density of a liquid is temperature dependent and therefore the specific gravity is often reported instead of density. Specific gravity equals the density of the object divided by the density of water at the specified temperature. Since the density of water is very close to 1 g mL^{-1} at temperatures near room temperature, the specific gravity of a substance usually has the same value as its density but is a unit-less quantity.

When working with liquids of varying density, the more dense liquid will settle below a less dense liquid, hence liquids of different densities will form layers unless they are miscible (soluble) in each other. Solutions of the same compound but different concentrations or at different temperatures will also form separate layers due to differences in density before they slowly mix as their compositions reach a single internal value. This phenomenon allows for the formation of a density gradient. A density gradient is a series of liquids of different densities that have been layered. If an irregular object is added to a density gradient the object will float in a liquid of the same density. If the object comes to rest between two layers, it means that the object's density is between those of the two liquids.

A common use of a density gradient is the separation of blood. A simple gradient for the separation of blood involves layering aqueous sucrose solutions of differing concentrations from 70% sucrose to 20% sucrose in increments of 10%. The blood is added to the density gradient and the container is centrifuged at forces in excess of 150,000 *g*. This type of density gradient can be used to purify viruses and ribosomes and to separate cell organelles into crude cellular extracts.

The mass of all materials can be determined using a balance. The method for determining the volume of a substance is dependent on the nature of the substance. Liquids are best measured with a graduated cylinder. The volume of a regular solid can be determined using a ruler and one or more geometric formulas (equations 1-5).

(1) Volume of a rectangular solid = length x width x height
(2) Volume of a cylinder = π x radius squared x height
(3) Radius = diameter / 2
(4) Circumference = $2\pi r$
(5) Volume of a sphere = $(4/3)\pi r^3$

Volumes of irregularly-shaped solids can be a challenge to determine. One method of determining the volume of an irregular solid uses the concept that no two objects can occupy the exact same space. If an irregular solid is added to a known volume of liquid, the liquid level will rise as the object displaces the liquid it is immersed in. The difference between the final volume of the liquid plus object and initial volume of liquid will be the volume of the solid. A second method used to determine the density of an irregular solid is by developing a density gradient.

Safety:

Do not drink the liquid laundry detergent or isopropyl alcohol.
Do not touch the hot plate when hot.
Wash hands before leaving the lab.
Specific safety considerations about the unknown will be given by the instructor.

Disposal:

Throw the paraffin in the trash.
Return all other solids to their appropriate containers.
Dispose of liquids down the drain.
Dispose of the unknown as directed by the instructor.

Procedure:

All measurements should be recorded using the correct number of significant figures appropriate to the equipment being used. All calculated values should be recorded to the correct number of significant digits. Carefully read Chapter 1 Section 7 in Tro 2nd Edition) to re-familiarize yourself with significant digits and being consistent with them in mathematical operations.

Temperature Dependence of a Liquid

1. Fill three 100-mL beakers with approximately 50-ml of tap water.
2. To the first beaker add 3 drops of blue food coloring, to the second beaker, add 3 drops of green food coloring, and to the third beaker, add 3 drops of red food coloring.
3. Add a handful of ice to the blue water and let it sit for about 10 minutes.
4. Place the beaker with the red water on a hot plate and heat. Do not heat to a boil, simply heat until steam is observed.
5. Do nothing to the beaker with the green water.
6. To a medium size test tube add approximately 2 mL of the blue water.
7. Using a plastic pipet, slowly add approximately 2 mL of the green water dropwise down the side of the test tube.
8. Using a second plastic pipet, slowly add approximately 2 mL of the red water dropwise down the side of the test tube. CAUTION: hot water has high vapor pressure and can shoot out of the end of the pipet. Handle this transfer carefully without pointing it at another student.
9. Indicate your observations on the result sheet.
10. Let the test tube sit until you have completed the remaining procedures.
11. Make a final observation of the test tube.

Irregular Solid

1. Weigh 30 5-mm glass beads and record the mass.
2. Add approximately 5 mL of water to a clean 10-mL graduated cylinder and record the volume.
3. Add the 30 glass beads to the graduated cylinder and record the new volume.
4. Drain the beads and dry using a paper towel and return to the instructor.

Liquid

1. Weigh a clean, dry 10-mL graduated cylinder and record the mass.
2. Fill the 10-mL cylinder with about 10 mL of clear Karo syrup. Record the volume.
3. Weigh the cylinder plus clear Karo syrup and record the mass.
4. Pour the Karo syrup into a large test tube.
5. Clean and dry the 10-mL graduated cylinder.
6. Fill the 10-mL cylinder with about 10 mL of liquid laundry detergent. Record the volume.
7. Weigh the cylinder plus liquid laundry detergent and record the mass.
8. Gently pour the liquid laundry detergent gently down the side of the large test tube. Be careful not to mix the liquids.
9. Clean and dry the 10-mL graduated cylinder.
10. Fill the 10-mL cylinder with about 10 mL of isopropyl alcohol. Record the volume.
11. Weigh the cylinder plus isopropyl alcohol and record the mass.
12. Gently pour the isopropyl alcohol gently down the side of the large test tube. Be careful not to mix the liquids.
13. Clean and dry the 10-mL graduated cylinder.

Approximate Densities

1. Add an aluminum paper clip, a plastic paper clip, a thumb tack, a piece of paraffin, and a cork stopper to the large test tube developed in the previous section, by allowing the object to slide gently down the side of the cylinder.
2. Allow the test tube to sit untouched for 5 minutes.
3. Record your observations.
4. Discard all solutions from the large test tube down the drain and wash the test tube.
5. Throw the paraffin away.
6. Rinse, dry, and return all other solids to the instructor.

Regular Solid

1. Record the color of the solid cylinder (silver, black, colorless)
2. Weigh the regular solid and record the mass.
3. Using the ruler provided by the instructor measure and record the diameter and height of the solid.

Unknown

1. Develop a procedure to determine the density of the unknown assigned by your instructor and clearly outline it on the data sheet below.
2. Determine the density of your unknown. Tabulate your experimental measurements using clear labels and units as appropriate.
3. Identify your unknown using the information below.

Density	Material Name		Density	Material Name
0.91	Polypropylene		1.41	Acetyl
1.04	Polystyrene		1.54	Chlorinated PVC (CPVC)
1.15	Polyamide (Nylon)		2.17	PTFE (Teflon®)
1.18	Acrylic		2.69	Aluminum
1.35	Phenolic		8.45	Brass
1.37	Polyvinylchloride (PVC)		8.88	Copper

A New Life for Soda Bottles

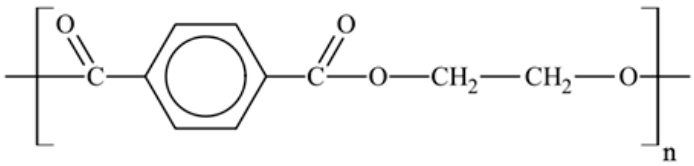
ACS Meeting News: Symposium explores the benefits and challenges of re

Bethany Halford

Newscom

READY FOR RECYCLING Bales of PET bottles await recycling at a facility in France.

C. & E. News 9/19/2011, v89. pp. 30 - 32



Polyethylene terephthalate

PETE

Density: Experimental Data and Results

Temperature Effects on Density

Does the temperature of a liquid directly impact its density? What observation led to this conclusion?

Depict what you observe in the diagram below. Label each part you draw.

Describe the appearance of the mixture at the end of the lab. Explain this observation.

Irregular Solid

Mass	_____ g
Initial Volume of water	_____ mL
Final Volume of water	_____ mL
Volume of Solid	_____ mL
Density of solid	_____ g/mL
Density of solid	_____ g/cm^3

What concept related to the determination of density did this experiment illustrate?

What volume, in mL, would one pound of glass beads occupy? (1 lb = 453.6 g)

Density of Liquids

Karo Syrup

Mass of empty 10-mL graduated cylinder (g) _____

Mass of 10-mL graduated cylinder + Karo (g) _____

Mass of Karo (g) _____

Volume of Karo (mL) _____

Density of Karo (g/mL) _____

Laundry Detergent

Mass of empty 10-mL graduated cylinder (g) _____

Mass of 10-mL graduated cylinder + detergent (g) _____

Mass of detergent (g) _____

Volume of detergent (mL) _____

Density of detergent (g/mL) _____

Isopropyl Alcohol

Mass of empty 10-mL graduated cylinder (g) _____

Mass of 10-mL graduated cylinder + alcohol (g) _____

Mass of alcohol (g) _____

Volume of alcohol (mL) _____

Density of alcohol (g/mL) _____

What did you build with the three liquids?

What density concept is illustrated by the density gradient?

Isopropyl alcohol is commonly purchased in one pint containers. What is the mass of isopropyl alcohol in that container? (1 pt = 473 mL)

Approximate Densities

Depict what you observe in the diagram below. Label each part you draw.

Estimated densities (g/mL):

Thumb tack _____

Aluminum paper clip _____

Plastic paper clip _____

Paraffin _____

Cork stopper _____

How does a density gradient work?

A student added a piece of metal to a density gradient. If the metal came to rest between a solution with a density of 1.00 g/mL and a solution with a density of 2.10 g/mL, what is the identity of the metal? Explain.

Metal	Density (g/cm^3)
Aluminum	2.70
Chromium	7.19
Gold	19.32
Lead	11.34
Magnesium	1.738
Nickel	8.9

Regular Solid - Color _____

Mass _____ g

Diameter _____ cm

Height _____ cm

Radius _____ cm

Volume _____ cm^3

Density _____ g/cm^3

List an additional way by which you could determine the density of the solid.

Unknown

Unknown description:

Procedure:

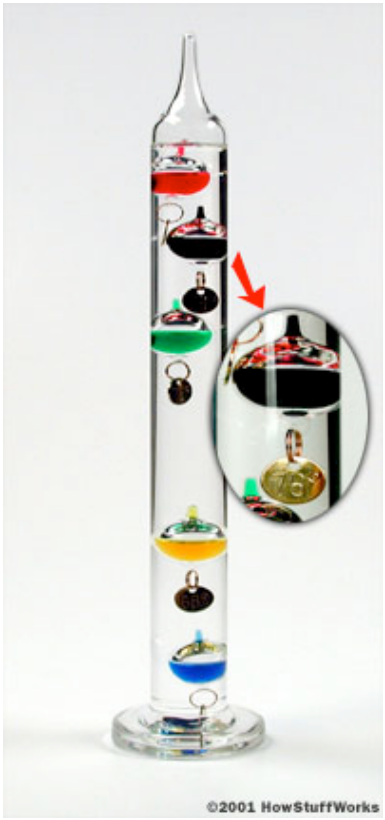
Data:

Density:

Unknown Identification:

Density: Pre-Laboratory Assignment

1. Below is an image of a Galileo Thermometer. The density of the colorless medium changes with the temperature of the room. If the bulbs contain liquids of differing densities, which of the colored liquids is the most dense? Clearly label your choice in the figure and explain your reasoning.



2. Soda and water bottles are made up of the polymer, polyethylene terephthalate (PET), and their lids are made from polyolefin. **Recycling** is a sensible approach for many petroleum-based materials. PET has been recycled to make items such as polyester carpeting, ski jacket filling, and cotton-polyester blend sheets. In order to recycle the PET to make these materials, the PET must be separated from the polyolefin. Consult the www and/or the *Chem. & Eng. News* article referenced on my website (CEN 9/19/2011, p 30-32).

    a. What is the density of PET?

    b. What is the density of polyolefin?

    c. How can water be used to separate PET from polyolefin?

3. How can bone density be used to identify a person with osteoporosis compared to individuals with healthy bones? (Read Chemistry and Medicine on pg 20 of Tro 2nd Edition.)

4. Explain the difference between *density* and *specific gravity*.

5. A student calculated the densities of three liquids. Liquid A had a density of 1.32 g/mL, liquid B had a density of 0.66 g/mL, and liquid C had a density of 1.00 g/mL. The student added these three liquids together in a test tube and observed that three layers formed.
    a. Explain this observation.

    b. Diagram and label this observation.

    c. A small solid object was added to the test tube and it came to rest between liquid A and liquid C, what can you conclude about the density of the solid object?

6. A block of wood was found to weigh 14.770 g and measured 3.00 cm x 2.95 cm x 2.98 cm:
    a. What is the density of the wood?

    b. What would be the mass of a block of the same wood if the block measured 25 in. x 31 in. x 23 in.? (2.54 cm = 1 in)