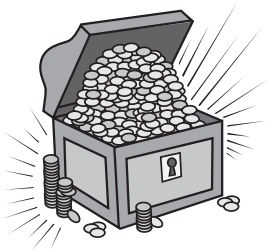
LESSON
5
OVERVIEW

All That Glitters

Density



Key Ideas

Lesson Type

Lab:
Pairs

In order to differentiate between different forms of matter, we can examine their *intensive* properties, such as density. Density is the measure of the mass of a substance per unit volume. Differences in density explain why two objects may have identical volumes but different masses, or identical masses but different volumes. While the mass and volume of a given substance can change, density does not (at least not at a specified temperature). (Density change as a function of temperature will be covered in Unit 3: Weather.)

As a result of this lesson, students will be able to

- define density as the amount of mass in a certain space, or mass per unit volume
- solve problems for density, mass, or volume using the equation $D = m/V$
- explain that density is an intensive property of matter that does not change at a given temperature, regardless of the amount of matter, and therefore can be used to identify a substance

Focus on Understanding

- Students often believe that the density of a substance changes if the size or shape of the substance changes.
- Students might assume that density depends on the size of the sample, growing greater with larger, heavier samples.

Key Terms

density
intensive property
extensive property

What Takes Place

This lesson builds on the previous lesson. Students work in pairs to compare the objects they measured in the previous lesson. They use mass and volume data to calculate the density of each item. Density is introduced as an intensive property of matter. Students use density to determine the identities of the various rods and to determine whether the gold-colored penny created in Lesson 2: A Penny for Your Thoughts is real gold.

Materials

- student worksheet (*Note:* If students measured something other than a crayon as the last object in Lesson 4: Mass Communication, alter the worksheet to match their data.)
- golden one-dollar coin (optional, for Check-in)

Per pair

- 1 balance
- 1 gold-colored penny from Lesson 2: A Penny for Your Thoughts (can be shared by two pairs)

LESSON 5

LESSON GUIDE

All That Glitters

Density

Engage (5 minutes)

Key Question: How can you use mass and volume to determine the identity of a substance?

ChemCatalyst

In the year 250 b.c.e., King Hiero commissioned a goldsmith to make him a crown out of pure gold. However, when he received the crown, he suspected that the goldsmith had taken some of the gold and replaced it with a cheaper metal, even though it still weighed the same. He asked Archimedes to determine whether the crown was solid gold.

How do you think Archimedes determined whether the crown was solid gold?

Sample Answers: He could have examined it to see if it was the right color. He could have measured the mass and the volume of the crown and compared them to the mass and volume of some gold. They both should have the same mass per volume if they are the same substance.

Discuss the ChemCatalyst

➠ Brainstorm ideas on how to tell similar-looking substances apart. Leave the discussion open-ended.

Sample Questions

- How can you tell whether something is gold? (Color, hardness, shininess, etc.; compare it to a pure gold sample.)
- Do you think a crown of gold and a crown of aluminum of identical size have the same volume? Would they have the same mass? (same volume, but not same mass)
- According to legend, Archimedes submerged the crown in water. What was Archimedes measuring? (volume)
- Could Archimedes determine the identity of the crown's metal only by putting it in water? Explain. (Maybe he would have to compare it to another gold sample with the same mass.)

Explore (20 minutes)

Introduce the Lab

➠ Students work in pairs.

LESSON 5

LAB

All That Glitters

Density

Name _____

Date _____ Period _____

Purpose

To use density to determine whether the gold-colored penny is solid gold.

Materials

- balance
- gold-colored penny

Part 1: Calculating Density

1. Density is mass divided by volume. Use the mass and volume measurements in this table to calculate the density of each object.

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

Density

Object	Mass	Volume (mL)	Density (g/mL)
5 cm gold-colored rod	55.4 g	6.6 mL	8.4 g/mL
5 cm silver-colored rod	17.8 g	6.6 mL	2.7 g/mL
10 cm silver-colored rod	35.6 g	13.2 mL	2.7 g/mL
10 cm crayon	3.2 g	13.3 mL	0.24 g/mL

2. Which object has the highest density? gold-colored rod

3. Which object has the lowest density? crayon

4. What does it mean to say that a substance has a high density?

There is a lot of matter in a small space.

5. Two of the objects have the same density. Explain how two objects with different masses and volumes can have the same density.

The two objects probably are made of the same material.

6. If you had a 1 cm^3 cube of the gold-colored metal, what would its mass be? How do you know?

8.4 g, because the density is 8.4 g/mL, and 1 mL = 1 cm^3.

7. The densities of several metals are given in the table on the next page. Based on your calculations, what are the identities of the gold-colored and silver-colored metals from your activity?

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Densities of Metals

Copper	Zinc	Gold	Aluminum	Brass
9.0 g/mL	7.1 g/mL	19.3 g/mL	2.7 g/mL	8.4 g/mL

The gold-colored metal is brass; the silver-colored metal is aluminum.

8. The density of an iron nail is the same as the density of an iron frying pan. Explain how this can be true.

The density of a substance doesn't change with the size or the shape of the substance.

Part 2: Comparing Densities

9. Find the mass of your gold-colored penny, then calculate the density. The volume of a penny is 0.36 mL.

mass = 2.6 g

$$D = \frac{m}{V} = \frac{2.6\ g}{0.36\ mL} = 7.2\ g/mL$$

10. Can you use the density value you just calculated to determine whether the gold-colored penny you made in class is gold? Explain.

The density of the golden penny is far less than that of pure gold. It is closest to the density of zinc.

11. You have a piece of metal with volume 30.0 mL and mass 81.0 g. What is its density? What kind of metal do you think it is?

$$D = \frac{m}{V} = \frac{81.0\ g}{30.0\ mL} = 2.7\ g/mL$$

The metal is probably aluminum.

12. Making Sense How can determining the density of an object help you figure out what it is made of?

Every material has a certain density that is different from the density of other materials. You can use the density value to make a tentative identification of the material.

13. If You Finish Early How much would 1 cubic meter of solid gold weigh in pounds? Here are some conversion factors:

1 lb = 454 g 1 mL = 1 cm^3 1 m^3 = 1,000,000 cm^3

1 m^3 = 1,000,000 cm^3 = 1,000,000 mL

$$m = DV = \frac{19.3\ g}{mL} \cdot 1{,}000{,}000\ mL = 19{,}300{,}000\ g$$

$$19{,}300{,}000\ g \cdot \frac{1\ lb}{454\ g} = 42{,}500\ lb$$

Explain and Elaborate (15 minutes)

Discuss Density as a Property of Matter

➠ Draw simple diagrams on the board to support the discussion.

Sample Questions

- How did the densities of the objects you measured compare to one another?
- How can density be used as evidence to differentiate between substances?
- If two objects have the same volume but different masses, which one is denser? (The object with the greater mass is denser.) What if they have the same mass but different volumes? (The object with the smaller volume is denser.)
- What is the density of a brass rod twice as long as the one you had in class? (The density remains the same regardless of size.)

Key Points

Density can be defined as the amount of substance or mass in a certain space, or the mass per unit volume.

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

For purposes of comparison, scientists use 1 cubic centimeter, cm^3, as the unit of volume being considered. However, instead of measuring a 1 cm^3 cube, you can simply divide the entire mass of an object by its volume in cubic centimeters. For example, if an object has mass 6.0 g and total volume 4.0 cm^3, its density can be calculated $D = m/V = 6.0\ g/4.0\ cm^3 = 1.5\ g/cm^3$.

Density is an intensive property that does not change with the size, shape, or amount of substance being considered. Intensive properties, such as color, hardness, and density, do not depend on the amount, size, or shape of matter and can be used to help identify a substance. Extensive properties, such as mass and volume, can change depending on the amount of matter being considered. Mass or volume alone can't help you identify a substance, but density can. Density changes with temperature. However, if they are at the *same* temperature, aluminum foil has the same density as an aluminum screw or an aluminum ladder. Some categories of substances have a range of densities. For example, the densities of plastics or cooking oil vary depending on the type of plastic or oil.

> **Intensive property:** A characteristic that does not depend on the size or the amount of matter.
>
> **Density:** The mass of a substance per unit volume. $D = m/V$, where D is density, m is mass, and V is volume. Density is usually reported in g/cm^3 or g/mL.
>
> **Extensive property:** A characteristic that is specific to the amount of matter.

Identify Substances Using Density Values

➠ Copy all or part of the density table from the next Key Point on the board.

Sample Questions

- Recall the ChemCatalyst question. Was it possible for Archimedes to determine the density of the crown? Why or why not? (Yes; he measured both mass and volume.)
- How could you use density to determine whether a crown is solid gold? (Compare its density to the density of pure gold—at least this way you would know if it's *not* gold.)
- What does the evidence tell us about the gold-colored penny? (It is not pure gold.)
- Do you have a hypothesis about what metal *was* created on the first day of class?

Key Points

Density can be used to identify what a substance is made of. The measurements and density calculations you made in class allowed you to identify the gold-colored and silver-colored rods as brass and aluminum. This table shows some common materials and their densities. Gold is the densest metal of those given in the table, even denser than lead.

Material	Density	Material	Density
zinc	7.1 g/cm^3	gold	19.3 g/cm^3
paper	0.9 g/cm^3	brass	8.4 g/cm^3
water	1.0 g/mL	copper	9.0 g/cm^3
aluminum	2.7 g/cm^3	lead	11.4 g/cm^3

In order to determine the density of an object, both the mass and the volume are needed. Archimedes could find the density of the crown if he measured both its volume and its mass. He could then compare the density of the crown to the density of gold.

The density of one of our golden pennies turns out to be around 7.2 g/mL, or 7.2 g/cm^3, too low a value to be gold, which has a density of 19.3 g/cm^3. However, it appears that the pennies are not made entirely of copper either, because the density value is also lower than that of copper. *Note:* Pennies currently are minted with a thin copper coating and a core of zinc. This is consistent with the density we measured, which is close to that of zinc, 7.1 g/cm^3. We still do not really know what the gold-colored coating is. At this point, we might speculate that the coating is brass, which is a combination of zinc and copper, because zinc was in the beaker.

Review a Density Calculation (optional)

➠ You might want to go over Question 15 from the lab worksheet. Students can approach the unit conversions in several ways to arrive at the correct answer. Have students share how they solved the problem on the board or an overhead.

Wrap-up

Key Question: How can you use mass and volume to determine the identity of a substance?

- One substance can be distinguished from another by examining its intensive physical properties, such as density.
- Density is a measure of the mass per unit volume of a substance.
- The density of any given substance is always the same (as long as the temperature remains constant).

Evaluate (5 minutes)

Check-in

In 1999, the United States Mint produced a coin called the Golden Dollar. It features an image of Sacagawea, the famous Native American guide for Lewis and Clark. It has a mass of 9.8 g and volume of 1.1 mL.

Is this coin truly gold? Explain. (The density of gold is 19.3 g/mL.)

Answer: The density of the Golden Dollar is 9.8 g/1.1 mL or 8.9 g/mL. This is much less than the density of gold, so the Golden Dollar is not solid gold.

Homework

Assign the reading and exercises for Alchemy Lesson 5 and the Section I Summary in the student text.