2D: Density

Key Question: Do equal sizes contain the same amount of matter?

Students will observe that different substances have different densities. The density of a material depends upon how much mass is in a given volume of material. In this investigation students will learn about the property described as density. Students measure the mass and volume of pennies and nickels and use these measurements to calculate the density for these substances. After using their measurements to calculate density students realize that density has more than one unit associated with it. In the end they observe that density does not vary with the amount of the substance.

Reading Summary

Students read section 1.1 "What is chemistry about" (pp. 8-11) before the Investigation.

Materials can have very different masses, even though they are the same size. The property that helps to explain this is called density. Density describes how much mass is in a given volume of material. Density is influenced by how tightly atoms and molecules are packed together. Substances that are less dense float on the surface of substances that are more dense. The density of a substance is unique and it can be used to help identify substances. The density of a substance does not vary with the amount of the substance. Density always remains constant for the same material.

Density can be calculated by measuring the mass and the volume of a substance. Density is equal to the mass of the substance divided by the volume. Density is a derived unit, meaning that is comprised of two or more units together, in this case grams per milliliter or g/cm^3.

Questions and Goals

Main Questions

- What is density?
- If different substances occupy the same volume do they contain the same amount of matter?
- How do you measure density?

Learning Goals

By the end of the Investigation, students will be able to:

- Explain why substances have different densities.
- Measure volume by water displacement.
- Calculate the densities of substances.
- Compare densities to assess the composition of coins.

Key Vocabulary

Mass, volume, density, significant figures.

Materials and Setup

Students work in groups of three to four at lab benches.

Each group should have:

- Balance, 50 pennies, 20 nickels, 100 mL graduated cylinder (see preparation instructions below)

Preparation

Be sure enough materials and equipment are available for each group. You will need to have enough coins for each group.

Hints:

- Have all the students use pennies of similar composition. Remove older pennies with a higher copper content (1982 or earlier).
- Emphasize the importance of reading the bottom of the meniscus on the graduated cylinder, so that the measurement of volume is relatively accurate.
- If you have time, have the students determine the density for fewer coins of the same type.

Suggestions:

- Remind students to add the coins slowly to the graduated cylinder.
- Review the concept of volume with the students.
- Ask them if they think density could be used to identify a substance. This will get them thinking about whether or not density is unique to a particular substance.

Details

Teaching Time One class period

Assignments Section 1.1 "What is chemistry about" in the **Student Text** before the Investigation.

Misconceptions Students think that density varies with the amount of a substance. Have them determine the density for 10 nickels and compare that value to 20 nickels.

Outline of the Investigation

1 Introducing the Investigation
2 The displacement method for measuring density
3 Calculating the density

Investigation sections	Part	Ideas and Dialog
Introducing the Investigation Review the concept of volume. Discuss the fact that substances with the same volume do not contain the same amount of matter. Show them an example using styrofoam and brick.		*Based on your reading, give an example of a substance that is more dense than water, and one that is less dense than water. What is the density of water?* From the table 1.2 students will select substances above and below 1 g / cm^3. *Can you give an example of density in your everyday life?* Students might mention the fact that ice floats and is less dense than water and this gives rise to all kinds interesting facts about nature. They may mention salad dressing and the fact that oil floats on the top. Simple examples like this are what to expect. *In this investigation, you will measure the densities of pennies and nickels. From your measurements you will be able to determine the density of each type of coin.*
Displacement method for measuring density Go over the instructions given for the Investigation. Discuss the importance of adding the coins slowly to the water and reading the meniscus carefully.	1	*Read and follow the directions on your investigation sheet. Each group will determine the density. What measurement do you feel is the least accurate?* Students only need to take two measurements, mass and volume. They should think about which one is going to give them a more "reliable" measurement. Using the balance gives a measurement of one place past the decimal and there is very little room for error, unless the scale is not set to zero. The volume measurement contains the most room for error. Show students how to slide their coins slowly down into the graduated cylinder, to avoid splashing. Explain to students that they need to estimate to one place past the decimal on their graduated cylinder, otherwise it will limit the number of significant figures in their answer. *Practice estimating between the lines of the graduated cylinder while taking your volume measurements, before and after adding your coins. Each partner should take a turn and you should compare your measurements. You should finish with the measurements you need to calculate the density of pennies and nickels.*
Calculating the density Allow students time to calculate their densities. Have them assess their results and consider what type(s) of metals are used to make pennies and nickels.	2	*Calculate the density of your pennies and nickels using the formula for density.* Have students calculate their densities for the pennies and nickels. They may think about dividing the density by the number of coins to obtain the density per coin. Will this work? Have them use measurements to determine the density of fewer coins and then compare their results. *Pennies used to be made out of copper. Does your density for pennies support the fact that they are still made out of copper? Explain your thinking.* Give the students time to think about their results and discuss them in their groups. The given the density in the table for copper is 8.96 g / cm^3. Their results will be lower than this, because there is more zinc inside the pennies. Their values may vary a little depending upon the years most of their pennies were minted, and how well students measured. *What is the most likely metal used to make pennies?* Final results will likely be close to the value for zinc, 7.13 g / cm^3, because today over 99% of each penny is made of zinc. *Which of the metals listed in the table was most likely used to make the nickels?* Students may say nickel, because the value for the densities of copper and nickel are so close that their data may not give them evidence to support the fact that nickels are mainly made of copper (75%) and 25% nickel.

Investigation 2D: Density

Part 2: Calculating the density

Density describes how much mass is in a given volume of a material. The units of density are mass divided by volume, often grams per cubic centimeter (g/cm^3). Lead has high density; it contains 11.34 grams of mass per cubic centimeter (11.34 g/cm^3). A one centimeter cube of cork plastic contains only 0.12 grams of matter (0.12 g/cm^3).

Density

$$\underset{(g/cm^3)}{\text{density}} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}}$$

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

- Density is a property of matter - independent of size or shape
- Density is mass per unit volume

Table 2:

Metal	Density
Aluminum	2.6
Zinc	7.13
Iron	7.85
Nickel	8.80
Copper	8.93
Silver	10.49
Lead	11.34
Gold	19.32

a. Calculate the density of the pennies and nickels.

b. Pennies used to be made of copper. Do your data support the conclusion that pennies are still made of copper? Why or why not?

c. What is the most likely metal used to make pennies (use the data from Table 2.)

d. Which of the metals in the table might have been used to make the nickels in your experiment?

Table 1: Density data for nickels and pennies

	Dry mass (g)	Initial volume of graduate cyl (mL)	Final volume of graduate cyl (mL)	Volume of metal (mL)
Pennies				
Nickels				

Example Answers

2a. Density of pennies = mass pennies / volume of pennies
Density of nickels = mass nickels / volume of nickels

2b. The data support a lower density value that is closer to zinc (Zn) has a value of 7.1 g / cm^3. No, because the density of the pennies is lower than the density of copper, pennies today are not made of pure copper.

2c. The most likely metal used to make pennies is Zn, zinc. This is assuming that the pennies are not old, which would contain a higher copper content.

2d. Nickel (or copper) will give the density value closest to their results.

Teaching tips

In this lab we have the students use ten coins so that their measurements are more accurate, particularly the volume displacement. Students can find the density with fewer coins but their measurements would not be as accurate. This is because with fewer coins the displacement of water would be less, making it harder to read the difference in volume.

This lab gives an opportunity to address significant figures too. Almost all students will record a mass with one place past the decimal, because that is what the scale reports. However, most students will record one significant figure for the volume, such as 7 mL instead of estimating to 7.2 mL with the graduated cylinder. When the density is calculated it is limited by the number with the least significant figures. A density value of 9 g / cm^3 gives less accuracy and precision than a value of 8.9 g / cm^3.

If there is time at the end of the investigation, it might be useful to have the students measure the mass and volume of fewer coins and see how the value of their density compares. This will reinforce the notion that density does not vary depending on the amount of the substance.