Density

Unit: Matter

NGSS Standards/MA Curriculum Frameworks (2016): HS-PS1-3, HS-PS2-8(MA)

Mastery Objective(s): (Students will be able to…)

- Understand and explain the concept of density.

- Perform calculations using the density equation $\rho = \dfrac{m}{V}$

Success Criteria:

- Descriptions include relationships between quantities.
- Calculations use correct algebra and have correct units.

Tier 2 Vocabulary: dense

Language Objectives:

- Explain what density is and how it relates to mass and volume.

Notes:

<u>mass</u> (*m*): the quantity of matter in something.

<u>volume</u> (*V*): the amount of space something takes up.

<u>density</u> (ρ^{*}): the relationship between an object's mass and the amount of space it takes up; how heavy the object is for its size.

Density is a *<u>characteristic property</u>* of matter, which means:

- Each different substance has its own density. For example, water has a different density from iron.

- Under the same conditions (same temperature, same pressure, *etc.*), every sample of the same substance has the same density.

This means that density can be used as a way to identify a substance.

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[*] The variable for density is the Greek letter *ρ* ("rho"). **It is not the same as the Roman letter p.** Some chemistry books use *D* instead of *ρ*, because their authors believe that students are not smart enough to be able to recognize and use Greek letters.

Use this space for summary and/or additional notes:

Big Ideas	Details	**Unit:** Matter

The most famous example of this is the story of the ancient Greek mathematician Archimedes. King Hieron II of Syracuse had commissioned the crafting of a gold crown as a tribute to the gods. He weighed the gold and gave it to a goldsmith to make the crown out of it. The king suspected that the goldsmith had stolen some of the gold and replaced it with silver. He hired Archimedes to find out.

Archimedes knew that gold is much denser than silver; a lump of gold weighs about twice as much as a lump of silver the same size. Weighing the crown was easy, but finding its volume was a challenge. When Archimedes got into a bathtub and it overflowed, he realized that his body must be displacing the water, and that he could use the same principle to find the volume of the crown. Once he knew the mass and the volume, he was able to calculate the density and compare it with the density of gold. The crown was less dense, which means the gold had been alloyed (mixed) with another (less dense) metal.

Archimedes was so excited when he realized how he could measure the volume that he jumped out of the bathtub and ran naked down the street shouting "Eureka!" (which is Greek for "I have found it!")

Density is calculated using the equation:

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

where:

ρ = density ($\frac{g}{cm^3}$ or $\frac{g}{mL}$)[*]

m = mass (g)

V = volume (cm^3 or mL)

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[*] In S.I. (standard metric) units, density should be measured in $\frac{kg}{m^3}$. However, kilograms and cubic meters are much too large to be useful in a chemistry laboratory.

Use this space for summary and/or additional notes:

The Problem-Solving Process: "*GUESS*"

Putting it all together, the following is an overview of the entire problem-solving process. The acronym "GUESS" may be helpful to remember it.

1. **Given**: Identify the given quantities in the problem, based on the units and any other information in the problem.

   - Assign the appropriate variables to those quantities.

2. **Unknown**: Identify the quantity that the question is asking for.

   - Assign the appropriate variable to the quantity.

3. **Equation**: Find an equation that contains the Unknown and one or more of the Given quantities.

   - The best choice is an equation in which *every quantity in the equation* is either the Unknown or one of the Givens.

   - If there is no equation in which every quantity is the unknown or one of the givens, choose the one that comes closest. However, ***the equation must contain the unknown*** or you won't be able to solve for it!

4. **Solve**: Use algebra to rearrange the equation to Solve it for the variable you're looking for. Do this by moving all of the other quantities to the other side by "undoing PE(MD)(AS)."[*].

5. **Substitute**: Replace the Given variables with their values and calculate the answer. (Remember to include the correct unit!)

Sample problem:

An object has a density of $4.5\,\frac{g}{cm^3}$. If its volume is $10\,cm^3$, what is its mass?

1. Identify the <u>given</u> quantities:

   An object has a density of $\underset{\text{—————}}{4.5\frac{g}{cm^3}}$ $\overset{\rho}{}$. If its volume is $\underline{10\,cm^3}$ $\overset{V}{}$, what is its <u>mass</u>?

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[*] If students do not have strong algebra skills it may be helpful to switch the order of steps 4 & 5, having students first substitute values into the equation, and then rearrange the equation when there is only one variable. However, it is strongly preferred that students rearrange the equation before substituting.

Use this space for summary and/or additional notes:

2. Identify the <u>unknown</u>:

An object has a density of $4.5\,\frac{\text{g}}{\text{cm}^3}$. If its volume is $10\,\text{cm}^3$, what is its <u>mass</u>?

3. Write down the equation:

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

4. Solve (rearrange) the equation for the desired variable:

$$\rho = \frac{m}{V} \;\rightarrow\; V \cdot \rho = \frac{m}{\cancel{V}} \cdot \cancel{V} \;\rightarrow\; V \cdot \rho = m$$

5. Substitute numbers into the rearranged equation:

$$m = V\rho$$
$$m = 10 \cdot 4.5$$
$$m = \boxed{45\,\text{g}}$$

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Homework Problems

1. What is the density of a metal if 15 g takes up a volume of 10 mL?

2. Pennies are made of nearly pure zinc. (The copper on the outside is a very thin coating.) The density of zinc is $7.13\frac{g}{cm^3}$, and the mass of a penny is 2.5 g. What is the volume of a penny?

3. A sheet of aluminum foil has a volume of 1.05 cm³. Aluminum has a density of $2.7\frac{g}{cm^3}$. What is the mass of the sheet of foil?

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