Lab: Chemistry Composition Challenge
FOR THE TEACHER

Summary
In this inquiry based lab, students will design a method to solve three chemistry problems involving moles, molecules, and density.

Grade Level
High School

NGSS Alignment
This lab will help prepare your students to meet the performance expectations in the following standards:

- **HS-ETS1-2**: Design a solution to a complex real-world problem by breaking it down into small, more manageable problems that can be solved through engineering.
- **Scientific and Engineering Practices**:
  - Using Mathematics and Computational Thinking
  - Planning and Carrying Out Investigations

Objectives
By the end of this lab, students should be able to

- Identify an unknown substance using density.
- Complete error analysis on an investigation.
- Understand the relationships between mass, moles, and molecules and related calculations.

Chemistry Topics
This lab supports students’ understanding of

- Dimensional Analysis
- Measurement
- Density
- The Mole
- Identifying an Unknown
- Error Analysis
- Molar Mass

Time
Teacher Preparation: 5 minutes
Lesson: 60-90 minutes

Materials (per student group)

- Ruler
- Digital scale or balance
- Aluminum Foil
- Sugar Cube
- 100 mL graduated cylinders
- Unknown Metal in powder, rock, or pellet form (Ex: Al, Zn, Fe)

Safety

- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
Teacher Notes

- Students will be tasked with designing a method to solve to following problems:
  - Problem 1: Experimentally determine the thickness of a piece of aluminum foil and compare that value to an actual value.
  - Problem 2: Determine the number of sugar molecules in a sugar cube. Also, determine the experimental mass and volume of one sugar molecule.
  - Problem 3: Determine the identity of an unknown metal. Determine the dimensions of a cube containing one mole of the identified metal in centimeters.
- This lab should be conducted after the students have been introduced to density and the mole concept. This lab can be conducted in college prep, honors, or AP Chemistry level. Varying levels of assistance will be required at each level.
- This lab can be completed individually but works best in groups of 2 to 4 students.
- When choosing the unknown metal, it should be in powder, rock, or pellet form. Although it can be done in sheet form, the method will change. Examples of metals to use could be: Al, Zn, Fe. Since the students are determining the identity of the metal using density, the amount of the metal is not significant.

- Clarifications, Solutions, Hints, and Post Lab:
  - Problem 1: Thickness of a piece of Aluminum Foil
    - Clarifications: Students need to find the thickness of a piece of Al foil WITHOUT folding it. Many students attempt to solve the problem by folding the foil several times, measuring the height of the folded foil, then dividing by the number of times they folded the foil.
    - Solution: Students should mass the foil and use the mass and the density of aluminum to solve for the volume of the piece of foil using the density equation (D=m/v). The students should then measure the length and width of the foil and use the calculated volume, to solve for thickness using the following equation, Volume = Length x Width x Thickness (Instead of the Height in this situation). The actual thickness of the foil can often be found on the packaging. If not, standard foil thickness is typically 0.004 mm, heavy duty is 0.008 mm.
    - Hints: The density of aluminum and the necessary equations can be given at the beginning of the activity or they can be given one by one as the class period progresses as hints to help guide the students to the solution.
    - Post Lab: The lab can be followed up with a discussion of error analysis and the % error equation. Error can be introduced into the lab by purposely crinkling the foil prior to distribution. This will cause the measured length and width to be lower than the true value and result in greater calculated thickness.
  - Problem 2: Sugar Cube Challenge
    - Clarifications: Students must find the numbers of sugar molecules in a sugar cube. Then must also determine the experimental mass and volume of ONE sugar molecule. Some students misinterpret these directions and find the mass and volume of the cube itself. Remind students that while that information is helpful, it does not answer the question.
    - Solution: To find the number of sugar molecules in the cube, students should mass the cube and convert the mass of sugar in the cube to moles of sugar by dividing by the molar mass of sugar (342 g/mole). The students should then multiply the number of moles of sugar by Avogadro’s number to determine the number of sugar molecules in the cube.
    - To determine the mass of one sugar molecules, students should divide the mass of the cube by the number of sugar molecules determined to be in the cube.
    - To determine the volume of one sugar molecule, students should divide the volume of the cube by the number of sugar molecules determined to be in the cube.
    - Hints: Analogies such as, “If I had 10 identical boxes that all together weigh 100 lbs., how
much does each box weight?” Can help guided students to the answer.

- **Post Lab:** Students can be guided to the answer if they were not able to solve the problem. Also error analysis on the investigation can be conducted. For example, the calculated volume of one sugar molecule is higher than the true value due to space between the molecules that is not accounted for in the calculation.

- **Problem 3: Metal Cube Identification**
  - **Clarification:** Students are to identify an unknown metal. Then determine the dimensions of a cube if they theoretically had one mole of the identified metal.
  - **Solution:** Students find the identity of the metal using density. Provide the students with a density chart containing the densities of several metals or have the students conduct their own web based research. Students can find the mass of the metal using a scale and find the volume by direct measurement or by water displacement. Once the student identifies the metal using density from the mass of the sample they used and the volume, they can use the density of the metal and molar mass of the compound to solve for the volume of one mole of the metal using the density equation. After solving for volume, the students realize that the sides of a cube are all equal in length. Therefore, the equation \( V = L \times W \times H \) can be re-written as \( V = L \times L \times L \) (or \( X \) as the variable). The student then takes the cubed root of the volume and solves for the length of one side of the cube.
  - **Hints:** Students may have varying backgrounds and strength in mathematics, some students may need assistance with the cubed root calculation.
  - **Post Lab:** Teacher may need to assist students with calculation.

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**FOR THE STUDENT**

**Lesson**

**Chemistry Composition Challenge**

**Objective**

Design a method to solve each of the following problems:

- **Problem 1:** Experimentally determine the thickness of a piece of aluminum foil and compare that value to an actual value.
- **Problem 2:** Determine the number of sugar molecules in a sugar cube. Also, determine the experimental mass and volume of one sugar molecule.
- **Problem 3:** Determine the identity of an unknown metal. Determine the dimensions of a cube containing one mole of the identified metal in centimeters.

**Materials**

- Ruler
- Digital scale or balance
- Aluminum Foil
- Sugar Cube
- 100 mL graduated cylinders
- Unknown Metal

**Safety**

- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow teacher instructions for clean-up of materials and disposal of any chemicals.

**Procedure**

In the space provided below, explain the method you used to solve each problem in detail.
Calculations and Data
In the space provided below, neatly organize all data and calculations used to solve each of the problems.

Analysis
- Complete error analysis on each of your investigations.
- For each problem: Identify an error, specifically explain how the error impacted the calculated result, and propose a possible solution to the error.