Visualizing the Mole

Hands-on Activities and Demonstrations

Introduction

The concepts of Avogadro's number and a mole are difficult for many students to comprehend. Understanding these concepts and their usefulness to chemists is a fundamental building block to understanding many other chemical concepts.

Concepts

- Avogadro's number
- Mole
- Molar Mass

Introducing Avogadro's Number

1. Many numbers have names. Introduce the names that represent a certain value other than a mole. Showing samples of these values may be useful.
   - Pair, 2 (dice, people)
   - Dozen, 12 (eggs, donuts, etc.)
   - Score, 20 (Gettysburg Address)
   - Century, 100 (years)
   - Gross, 144 (pencils, straws, etc.)
   - Ream, 500 (paper)
   - Gig or Giga, 1 billion (GigaByte)
   - Ask your students for other examples.
2. Discuss how these words make it easier to measure or describe a specific quantity.
3. Discuss the size of an atom and the need to discuss a specific value or unit size of atoms. (Can we measure or handle a dozen, gross, or Giga of atoms?)
4. Introduce the value of Avogadro's number by writing the complete number out on the board (602 followed by 21 zeros!). Also show the scientific notation version of 6.02×10^{23}.
5. Introduce the term "mole" and its definition.
6. Introduce the term "molar mass" and its relationship to Avogadro's number and a mole.

Understanding the Magnitude of Avogadro's Number

1. Admit to students that the immensity of Avogadro's number is too large to comprehend. Many textbooks use analogies to illustrate the magnitude of the number. These analogies can either be given as exercises or presented as a demonstration.
2. How long would it take the entire population of the Earth (assume 6 billion) to collectively count an Avogadro's number of objects if they could count at the rate of one object per second?
   - $(6 \times 10^9$ people$) \times (1$ object/person•s$) \times (3 \times 10^7$s/yr$) = 18 \times 10^{16}$ objects/year
   - $(6.02 \times 10^{23}$ objects$)/(18 \times 10^{16}$ objects/year$) = 3.3 \times 10^6$ years or 3,300,000 years
3. Start with a mole of dollar bills. If you could have spent a million dollars every second since the earth was formed 4.5 billion years ago, would any of the money remain today? [Answer—About ¾ of the money would still be left and it would take another 15.5 billion years to spend it all.]
   - $(3 \times 10^7$s/yr$) \times (4.5 \times 10^9$ yr$) \times (\$1 \times 10^6/s) = \$13.5 \times 10^{22}$ or 1.35×10^{23}
   - $(6.02 \times 10^{23}$ dollars$) - (1.35 \times 10^{23}$ dollars spent$) = 4.67 \times 10^{23}$ dollars remain
4. If 18 g of specially-marked water (one mole) were spread evenly over the Earth's water supply, there would be more than 100 molecules of the specially-marked water in every 8-oz cup of water.
   - $(3.26 \times 10^{20}$ gallons of water on Earth$) \times (16$ cups/gallon$) = 5.2 \times 10^{21}$ cups of water
   - $(6.02 \times 10^{23}$ molecules of "special water"$)/(5.2 \times 10^{21}$ cups of water$) = 1.2 \times 10^2$ molecules of special water/cup

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Understanding the Relationship between Avogadro's Number, Moles, and Molar Mass

Teacher Demo

1. Mass a fresh piece of chalk.
2. Write your name or Avogadro's number on the chalkboard.
3. Mass the chalk again and determine the mass of chalk used to write on the board.
4. Explain to your students that chalk is pure calcium carbonate ($CaCO_3$).
5. Ask (or give) your student the molar mass of calcium carbonate (100 g/mol)
6. How many moles of calcium carbonate were used to write your name?
   - Mass of chalk used/100 g/mol = # moles
7. How many formula units (molecules) of calcium carbonate did it take to write your name?
   - # moles × 6.02 × 10^{23} formula units/mole = number of formula units.
8. How many moles of calcium carbonate are left in the piece of chalk?

Hands-on Activity

1. Divide the students into teams of 3–4 students. The students will need paper, pencil, and access to a centigram balance.
2. Ask them how long it would take them to scribble one mole of carbon (pencil lead) onto a sheet of paper.
3. To solve the problem, students must determine the number of grams (or milligrams) per minute they can scribble onto the paper. Convert the number of grams to moles using the M.W. of carbon (12 g/mol). Then determine how long it would take to scribble one mole (12 g). To start, they must weigh the paper (or pencil) before and after scribbling for a set period of time (usually 2–3 minutes).
4. The answer is roughly 20 hours.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure of atoms, structure and properties of matter

A variety of teaching aids to further demonstrate the mole concept are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6255	Flinn ChemTopic™ Labs, Volume 7, Molar Relationships and Stoichiometry
AP6213	Mole Banner
AP6159	Make-a-Mole, Hands-on Student Kit
AP4587	Mole Balloon Activity Kit
AP6174	Celebrate the Molennium CD

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.