How Big Is a Mole?

"Imagining the Mole" Activities

Introduction

How big is a mole? Avogadro's number gives us the answer—6.02×10^{23} particles. The problem with this answer is that the number is so large, it's almost impossible to imagine. Use the following activities to help students visualize the size of a mole.

Concepts

- Avogadro's number
- Mole
- Molar Mass

Materials

Balance
Calculator
Chalk
Chalkboard

Introduce the Mole Concept

The word mole is used to describe a specific number of objects. Some other words that we use in our daily lives to describe a set number of objects include:

- Pair, 2 (dice, people, etc.)
- Dozen, 12 (eggs, donuts, etc.)
- Score, 20 (Gettysburg Address)
- Gross, 144 (pencils, straws, etc.)
- Ream, 500 (paper)

1. How do these words make it easier to measure or describe a specific quantity?
2. Review the size and mass of an atom. A typical hydrogen atom, for example, has a mass of 1.66×10^{-24} g. Imagine how big a number we would need to describe the number of atoms in a real-life sample of an element. Could we somehow measure or handle a dozen or a ream of atoms?
3. *(Optional)* The mass of a single aluminum atom is about 4.5×10^{-23} g. Tear off a small piece of aluminum foil and measure its mass. Calculate how many aluminum atoms are present in that small piece of aluminum foil.
4. Discuss Avogadro's original hypothesis and how this hypothesis eventually opened up a way to compare the number of atoms in different masses of a substance.
5. Introduce Avogadro's number. Write it out first in "long-hand" on the board (602 followed by 21 zeros), and then in scientific notation (6.02×10^{23}).
6. Define the mole, and introduce the concept of molar mass, which ties together Avogadro's number, moles, and mass.

The Size of Avogadro's Number

It is difficult to imagine, let alone comprehend, the enormous size of Avogadro's number. The following exercises can help us visualize the number of particles in a mole.

1. How long would it take the entire population of the Earth (6 billion people) to collectively count an Avogadro's number of objects? Assume that each person counts objects at the rate of one object per second.
   - $(6 \times 10^{9}$ people$) \times (1$ object/person·sec$) \times (3 \times 10^{7}$ sec/year$) = 18 \times 10^{16}$ objects/year
   - $(6.02 \times 10^{23}$ objects$) / (18 \times 10^{16}$ objects/year$) = 3.3 \times 10^{6}$ years (3.3 million years)
2. Imagine you have a mole of dollar bills and assume you can spend a million dollars a second. (That may not be too hard a reach for many teenagers!) How many years would you would be able to spend the money at this rate before the mole of dollar bills has been spent?
   - $(6.02 \times 10^{23}$ dollars$) / (1 \times 10^{6}$ dollars/sec$) = 6.02 \times 10^{17}$ sec

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- $(6.02 \times 10^{17}$ sec$) / (3 \times 10^{7}$ sec/year$) = 2.0 \times 10^{10}$ years (20 billion years)
  Note: The Earth itself is only about 4.5 billion years old.

3. If one mole of specially marked water molecules were spread out evenly throughout the Earth's water supply, how many molecules of the specially-marked water (water*) would there be in every 8-oz cup of water on Earth?

- 3.26×10^{20} gallons of water on Earth $\times$ 16 cups/gallon $= 5.2 \times 10^{21}$ cups water (approximate Earth's water supply)
- $(6.02 \times 10^{23}$ water* molecules$) / (5.2 \times 10^{21}$ cups$) = 1.2 \times 10^{2}$ water* molecules/cup

Counting-by-Weighing—Moles of Chalk

Since Avogadro's number is so large, a mole of molecules must be a lot—right? Not necessarily! A mole of water molecules, for instance, is only 18 g—hardly enough to quench your thirst on a hot day! Let's demonstrate the chemist's way of counting-.-.-.-by measuring out a known mass of a substance.

1. Measure the mass of a fresh piece of chalk.
2. Write your name on the chalkboard using this fresh piece of chalk.
3. Weigh the chalk again and determine the mass of chalk used to write on the board.
4. Chalk is pure calcium carbonate ($CaCO_3$). The molar mass of calcium carbonate is 100-grams per mole.
5. Calculate the number of moles of calcium carbonate that were used to write your name.
6. How many "formula units" of calcium carbonate did it take to write your name?
7. How many times would you have to write your name in order to use up a mole of calcium carbonate?

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure of atoms, structure and properties of matter

Reference

This activity was adapted from *Flinn ChemTopic™ Labs*, Volume 7, *Molar Relationships and Stoichiometry;* Cesa, I., Editor; Flinn Scientific: Batavia, IL (2002).

Materials for *How Big Is a Mole?—Imagining the Mole Activities* are available from Flinn Scientific, Inc.

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