Molecular Volume

Introduction

Estimate the number of molecules in a granule of sugar and the volume of one molecule of sugar.

Concepts

- Avogadro's Number
- Molar Mass or Molecular Weight
- Molecular Volume

Materials

Sucrose (table sugar), $C_{12}H_{22}O_{11}$, 342.3 g
Balance, milligram (0.001-g precision)
Beaker, 600-mL
Calipers, vernier (optional)
Ruler, 1 mm precision
Weighing dishes, 1 per student group

Safety Precautions

Food or household items become laboratory chemicals when they are brought into a laboratory setting. Never consume any material stored or used in a science laboratory. Wear chemical splash goggles. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Measure out 342.3 g of sucrose and, using an electronic or triple beam balance, place the mole of sucrose in a 600-mL beaker.
2. Explain to the class that the beaker contains 342.3 g (1 mole) of sucrose. This quantity of sucrose contains 6.02×10^{23} (Avogadro's number) of sucrose molecules.
3. Instruct the class to first determine the number of molecules of sucrose in an average sugar granule and then determine the approximate volume a sucrose molecule occupies in its crystal structure.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The sugar can be saved and reused or disposed of in the trash according to Flinn Disposal Method #26a.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter

Tips

- For best results, use large sucrose crystals such as those available from Flinn Scientific. Large crystals are easier to count and their dimensions are easier to measure.
- If a milligram balance is not available, a centigram balance may be used, but the results will be less precise.

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Discussion

Determine the number of molecules

1. Count out 100 granules of sugar into a tared weighing dish.
2. Determine the mass of 100 granules to the nearest milligram (0.001 g).
3. Divide the mass by 100 to determine the average mass of one (1) granule of sugar.
4. Divide the average mass of a single sugar granule by 342.3 g to determine the number of moles in one granule.
5. Multiply the number of moles by Avogadro's number, 6.02×10^{23}, to determine the number of molecules in the granule of sugar.

Sample calculation: $\frac{0.361\ \text{g}}{100\ \text{granules}} \bullet \frac{1\ \text{mole}}{342.3\ \text{g}} \bullet \frac{6.02 \times 10^{23}\ \text{molecules}}{1\ \text{mole}} = 6.35 \times 10^{18}\ \text{molecules/granule}$

Determine the volume of a sucrose granule

1. Select three representative granules of sucrose and measure the crystal size to the nearest 0.1 mm. (Estimate the tenth's place.)
2. Calculate the volume of a crystal in mm^3, then convert to $Å^3$ (1×10^{-10} m = 1×10^{-7} mm = 1 Å) by dividing by $1 \times 10^{-21}\ mm^3/Å^3$.

Sample calculation: $2.0\ \text{mm} \times 1.3\ \text{mm} \times 1.1\ \text{mm} = 2.9\ \text{mm}^3 \bullet \frac{1\ Å^3}{1 \times 10^{-21}\ \text{mm}^3} = 2.9 \times 10^{21}\ Å^3$

3. Calculate the approximate volume that a sucrose molecule occupies in its crystal structure by dividing crystal volume by number of molecules in the crystal.

Sample Calculation: $\frac{2.9 \times 10^{21}\ Å^3}{6.35 \times 10^{18}\ \text{molecules}} = 450\ Å^3/\text{molecule}$

4. Is this reasonable? Yes, a sucrose molecule is approximately 7 atoms long by 7 atoms tall by 7 atoms wide (see Figure 1).

If a carbon–hydrogen or oxygen–hydrogen bond is about an angstrom long and a carbon–carbon or carbon–oxygen bond is about 1.5 angstroms long, the size of the molecule could be a cube about 7–8 Å per side.

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Materials for *Molecular Volume* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0134	Sucrose, Reagent, 500 g
AP1278	Weighing Dishes, Disposable, 3 1/169 sq.
OB1061	Ohaus Precision Standard Series Electronic Balance, Capacity 120 g, Readability 0.001 g
OB2050	Ohaus Analytical Balance, Capacity 122 g, Readability 0.0001 g

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