Determination of the Molar Mass of Gases and Volatile Liquids

Inquiry Guidance and AP* Chemistry Curriculum Alignment

Introduction

Students will gain further understanding of the gas laws when applied to determine the molar mass of gases and volatile liquids. Amazing how two distinct concepts can be tied together in this advanced laboratory! The molar mass of a compound is an intrinsic property of a substance that is required for all chemical reactions and analyses. How is molar mass verified and how can the molar mass of an unknown be determined?

Opportunities for Inquiry

This laboratory encompasses important concepts and real-world applications of Avogadro's law, Dalton's law, and the ideal gas law. Applying these laws to the concept of molar mass will help students develop and answer many important critical thinking questions. The opportunities for inquiry are vast!

- Start the inquiry process with challenging pre-lab preparation. Students should consider: what gas-law equations apply in this experiment, what are we solving for, and what clues does the equation give about the data that must be collected during experiment?
- Let students determine the optimum conditions to successfully obtain data. Provide students with a brief overview of the purpose of the experiment, materials needed, and the apparatus set-up. Give them the essential procedure only, that they can collect gases in syringes and will need to evaporate at least 2–3 mL of any volatile liquid.
- For gases, provide the materials needed and refer students to academic resources to investigate how to generate and collect various gases in a syringe.
- For volatile liquids, students may research, investigate, and optimize the temperature and time required to evaporate or volatilize the liquid in a sealed bulb. Consider also providing nonpolar compounds such as hexanes or heptanes for an optional Part 2 of this experiment. Students will find that they need different experimental conditions for these liquids.
- Challenge students by providing volatile liquids and gases as unknowns. Provide the detailed procedure but assign different samples as unknowns for students to analyze and identify. Household or commercial products such as butane lighters may also be incorporated into the lab.

Alignment with AP Chemistry Curriculum Framework—Big Ideas 2 and 3

Enduring Understandings and Essential Knowledge

Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them. (Enduring Understanding 2A)

2A2: The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.

Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature. (Enduring Understanding 2B)

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2B1: London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.

Chemical and physical transformations may be observed in several ways and typically involve a change in energy. (Enduring Understanding 3C)

3C1: Production of heat or light, formation of a gas, and formation of a precipitate and/or a color change are possible evidences that a chemical change has occurred.

Learning Objectives

2.4 The student is able to use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors.

2.5 The student is able to refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample.

2.6 The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases.

2.11 The student is able to explain the trends in properties and/or predict properties of samples consisting of particles with no permanent dipole on the basis of London dispersion forces.

2.12 The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions.

3.10 The student is able to evaluate the classification of a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations and the distinction between rearrangement of covalent interactions and noncovalent interactions.

Science Practices

1.3 The student can refine representations and models of natural or man-made phenomena and systems in the domain.

1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

2.3 The student can estimate numerically quantities that describe natural phenomena.

5.1 The student can analyze data to identify patterns or relationships.

6.1 The student can justify claims with evidence.

6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices.

6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

6.5 The student can evaluate alternative scientific explanations.

7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

The *Determination of the Molar Mass of Gases and Volatile Liquids—AP Chemistry Classic Laboratory Kit* is available from Flinn Scientific, Inc.

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