Determining the Molar Volume of a Gas

Inquiry Guidance and AP* Chemistry Curriculum Alignment

FLINN SCIENTIFIC CHEM FAX!

Introduction

Avogadro, Boyle, Charles and Dalton—these scientists and their gas laws are well known. Together their work defined the relationships among four macroscopic gas properties: pressure, volume, temperature and the number of moles of gas. The gas laws have applications in physiology, meteorology, scuba-diving, and even hot-air ballooning or airbag construction. How much gas must be generated to fill a hot air balloon or an airbag? The amount of gas needed to fill any container can be calculated if we know the molar volume of the gas. Answering this general question requires knowledge of all of the gas laws (ABCs +D)!

Opportunities for Inquiry

Determining the molar volume of a gas is a classic experiment that ties together principles and concepts from several "big ideas" in chemistry. It also reinforces and integrates understanding of key learning objectives, from kinetic molecular theory to the ideal gas law and stoichiometry. Finally, the experiment draws upon and helps students develop science practice skills involving mathematical reasoning and data analysis. Opportunities for inquiry are abundant!

The classic experiment can be transitioned to guided inquiry using some or all of the following approaches, which will improve student preparation and increase the level of student engagement and their ownership of the results.

- Take away the data tables and post-lab questions! Replace worksheet calculations with a detailed overview of the experiment describing the general calculations: "The purpose of this experiment is to determine the volume of one mole of hydrogen gas at standard temperature and pressure (STP). Hydrogen will be generated by the reaction of a known mass of magnesium with excess hydrochloric acid in a gas measuring tube filled with water. The volume of hydrogen will be measured by water displacement after adjusting to atmospheric pressure, and must be corrected using (a) Avogadro's law for the number of moles of gas; (b) Dalton's law to account for the presence of water vapor in the collected gas; (c) the combined gas law to convert pressure and temperature to STP."
- This is a challenging lab, so make it a challenge! Rather than having students use a prescribed amount of magnesium to generate an unknown volume of gas, challenge them to produce a specific volume of hydrogen gas. Students must work backwards using the gas law calculations described above to calculate how much magnesium metal to use.
- Introduce the lab by demonstrating the general setup for generating and collecting a gas. Guide students to design the actual experimental procedure through a series of leading questions. What information (data) is needed to calculate the molar volume of a gas? What variables will influence the experimental data? Choose the independent and dependent variables for the experiment and describe the variables that should be kept constant during the experiment. Students could also discuss variables or other factors that will affect the accuracy of the results and how these may be controlled.
- Given the general macroscale procedure, students could design microscale experiments at different temperatures. Compare class results to identify trends in accuracy or deviations from ideal gas behavior as a function of temperature.
- Extend the lab to incorporate consumer products, such as analyzing butane gas collected from a lighter.

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

Enduring Understanding 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.

Publication No. 11195
061616

The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds. (Enduring Understanding 2C)

2C1: In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond.

Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form. (Enduring Understanding 3A)

3A2: Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to be simply an exercise done only by chemists.

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.

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

2.17 The student can predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements.

3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results.

3.4 The student is able to relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completions.

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.

6.4 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 *Determining the Molar Volume of a Gas—AP Chemistry Classic Laboratory Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP6450	Determining the Molar Volume of a Gas—AP Chemistry Classic Laboratory Kit

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