Molar Mass by Freezing Point Depression

Inquiry Guidance and AP* Chemistry Curriculum Alignment

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Introduction

The freezing point depression and other colligative properties of a solution were traditionally used to determine the molar mass of a solute. While this method has been superseded by modern instrumental methods for molar mass determination, it remains an interesting experiment for understanding the physical basis of the freezing point, and also for its applications to daily life.

Opportunities for Inquiry

This advanced laboratory contains excellent concepts and inquiry opportunities for students.

- Start the inquiry process with pre-lab preparation. Using the equation for the change in freezing point, ask students to identify what quantity they need to solve for and what measurements must be made during the experiment. Students should also review a theoretical cooling curve for both a pure liquid and a solution and identify the experimental factors that may cause the data to deviate from the theoretical curve. How is the freezing point of a solution extrapolated from the measurements of temperature versus time?
- Optimizing a procedure to obtain reliable data is an integral part of guided inquiry. Students may design and investigate procedures to determine the optimum amount of unknown substance needed to calculate the molar mass. Different groups of students may test different amounts of unknowns from 0.2 g – 1.0 g as part of a cooperative class study.
- Learning how to select and set up apparatus is also a crucial part of inquiry experiments. Give students the equipment list, including the beaker, test tube, hot plate, and support stand, and leave the actual design of the setup to the students. Always approve each student apparatus before they begin the experiment.
- While molar mass is not generally determined by freezing point depression today, these measurements may be used to investigate and understand deviations from ideal solution behavior. Rather than using the measurements to calculate molar mass, calculate the theoretical freezing point depression for different concentrations of the solute using its known molar mass. Determine the experimental error for different concentrations of different solutes and interpret the results in terms of ionic strength, vapor pressure lowering, and the properties of solutions.
- Convert the lab to a "target" or challenge lab. Give students a numerical target for selecting a solute and concentration that will result in a specific freezing point for a solution. This challenge has real-life applications beyond salting roads in the winter!

Alignment with AP Chemistry Curriculum Framework—Big Ideas 1, 2 and 5

Enduring Understandings and Essential Knowledge

All matter is made of atoms. There are a limited number of types of atoms; these are the elements. (Enduring Understanding 1A)

1A3: The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.

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)

2A3: Solutions are homogenous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of the solutes and solvent.

Two systems with different temperatures that are in thermal contact will exchange energy. The quantity of thermal energy transferred from one system to another is called heat. (Enduring Understanding 5A)

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5A1: Temperature is a measure of the average kinetic energy of atoms and molecules.

Energy is neither created nor destroyed, but only transformed from one form to another. (Enduring Understanding 5B)

5B3: Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.

Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy. (Enduring Understanding 5D)

5D2: At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.

Learning Objectives

1.4 The student is able to connect the number of particles, moles, mass, and volume of substance to one another, both qualitatively and quantitatively.

2.8 The student can draw and/or interpret representations of solutions that show the interactions between the solute and solvent.

2.9 The student is able to create or interpret representations that link the concept of molarity with particle views of solutions.

5.1 The student is able to create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular interactions), which influence the interaction strength.

5.2 The student is able to relate temperature to the motions of particles, either via particulate representations, such as drawings of particles with arrows indicating velocities, and/or via representation of average kinetic energy and distribution of kinetic energies of the particle, such as plots of the Maxwell-Boltzmann distribution.

5.6 The student is able to use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reactions, and relate energy changed to $P\Delta V$ work.

5.10 The student can support the claim about whether a process is a chemical or physical change (or may be classified as both) based on whether the process involves changes in intramolecular versus intermolecular interactions.

Science Practices:

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

1.2 The student can describe representation 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.

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

7.1 The student can connect phenomena and models across spatial and temporal scales.

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

The *Molar Mass by Freezing Point Depression—AP Chemistry Classic Laboratory Kit* is available from Flinn Scientific, Inc.

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