Winter Woes: Instructor Guide

Title:

Winter Woes

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Discipline:

Chemistry and Biochemistry

Target Audience

Introductory, majors or nonmajors

Keywords

Colligative properties, freezing and boiling points, intermolecular forces, osmosis, solutions, vapor pressure

Length of Time/Staging

The problem comprises several parts that may be used separately or together, depending on time restraints.

Abstract

A series of events on a cold winter's day are used to introduce various concepts associated with solutions, including driving forces behind solution formation and colligative properties.

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Format of Delivery

The problem has multiple independent parts that may be used alone or separately. Students in groups of four work to answer the questions posed, followed by reporting out and a whole class discussion.

Student Learning Objectives

Part 1

1. to review the relationships among molecular structure, intermolecular forces, and physical properties.
2. to analyze the types and relative strengths of intermolecular forces in a solution,with the goal of predicting whether two substances will form a solution or not.
3. to recognize the roles of enthalpic and entropic considerations underlying the "like dissolves like" rule.

Part 2

1. to understand the molecular basis for freezing point depression.
2. to be able to calculate and compare the quantitative effects of different solutes on freezing points, including recognition of the special behaviors of electrolytes.
3. to gain experience in making reasonable assumptions and estimates in addressing a complex problem.

Part 3

1. to understand the effects of temperature and pressure on the solubility of a solute.
2. to learn common conventions for expressing the concentration of a solution.
3. to investigate the role of certain common agents in water purification processes.

Part 4

1. to understand the molecular basis for distillation, and the effect of solutes on the boiling point of a liquid.
2. to recognize how the presence of a volatile solute in a liquid influences the vapor pressure and boiling point of the system
3. to understand the molecular basis for osmosis, and its relationship to other colligative properties.
4. to recognize the practical applications and manifestations of osmosis, particularly in biological systems.

Student Resources

Standard general chemistry textbook

Author's Teaching Notes

In recent years, parts 1 and 4 of this problem have been used in class, with parts 2 and 3 being incorporated into other assignments (problem sets and lab). Part 1 of the problem is used on the first day of class in the second half of the general chemistry sequence, and helps students to recall ideas learned in the first half that are important for understanding solutions—namely, the connections between molecular structures and intermolecular forces. After part 1 has been completed, there is a whole class discussion of molecular mechanisms by which a solute might affect the freezing point of a solution, as a means of developing a rate-based analysis for all the colligative properties. That rate argument is then used in analyzing subsequent phenomena.

The effects of a volatile solute on the vapor pressure of a solution, and the idea of different compositions for the vapor and liquid phases seem to be difficult for students to grasp fully. Part 4 provides an opportunity to extend the usual limited consideration of nonvolatile solutes into the important area of separations through fractional distillation. It also introduces the students to osmosis—a topic that they have generally seen in a biology context, but without really understanding the molecular mechanism by which this process occurs.

Assessment Strategies

Students prepare either written reports or overhead transparencies of their results; often, each group is assigned primary responsibility for one of the focus questions, and presents that to the class. Examination questions probe the student's ability to interpret data related to a solution or colligative-property phenomenon and offer a narrative explaining such a situation, in addition to more traditional quantitative applications of these ideas.