Activity Title: Freezing Point Depression

Subject (Focus/Topic): Colligative Properties

Grade Level: Chemistry

Average Learning Time: One 90 or two 55-minute periods

Lesson Summary (Overview/Purpose): In this lesson, students will compare colligative properties of fresh water and seawater through a freezing point depression investigation.

Overall Concept (Big Idea/Essential Question): Seawater contains dissolved ions and is saline. The presence of these additional substances affects the freezing point (lowers freezing point) and impacts other properties of the substance (higher density, increased electrical conductivity, slightly basic)

Specific Concepts (Key Concepts):

- The freezing point of a solution is lower than the freezing point of a pure solvent.
- Most "water" we interact with is actually a solution. These dissolved ions change how water acts.
- The change in physical properties for seawater impacts both the biological communities that live in the ocean and how we interact with the ocean.

Focus Questions (Specific Questions):

- How is a solution different from a pure solvent?
- How is the freezing point of a solution affected by dissolved impurities?
- What other physical properties are affected by dissolved impurities?
- How do physical properties of solutions, such as seawater, affect the properties of the ocean?

Objectives/Learning Goals: Given the materials to measure the freezing point of a saline solution, students will be able to compare and contrast at least three physical properties between distilled water and saline water.

Background Information:

- Students should know
    - Types of matter (elements, compounds, homogeneous mixtures, heterogeneous mixtures)
    - Molar mass
    - Molarity calculations
    - Molality calculations
    - Difference between solute, solvent and solution
    - Percent

- Note: Ice-water bath will get quite cold. Use caution when handling and do not add hot water immediately or the glass may crack.

Review: Freezing Point Depression: $\Delta T_F = K_F \cdot m \cdot i$

- ΔT_F, the freezing point depression, is defined as $T_{F\ (pure\ solvent)} - T_{F\ (solution)}$.
- K_F, the cryoscopic constant, which is dependent on the properties of the solvent, not the solute. For water, K_F = 1.853 K*kg/mol.
- m is the molality (mol solute per kg of solvent)
- i is the van 't Hoff factor (number of solute particles per mol, e.g. i = 2 for NaCl).

Connections: Freezing Point depression also connects to the idea of "salting" roads during the winter. If timely, draw connections between the type of "salt" used to prevent freezing on roads and freezing point depression. Road salt is typically magnesium chloride. Ask students why $MgCl_2$ is preferable to NaCl based on the equation of freezing point depression (it relates to the van 't Hoff factor).

Common Misconceptions/Preconceptions:

- "Water" as a term can refer to both pure H_2O (referred to as distilled water) as well as mixtures of water and other ions (including tap water and sea water). A solution is another word for a homogeneous mixture.
- Molality is sometimes tricky for students because it requires them to think about moles and mass simultaneously rather than comparing mass to mass or moles to moles or moles to volume. It is also important to note that in molality you use the mass of the solvent rather than the mass (or volume) of the solution.

Materials:

Ice cubes	Salt (NaCl)
250-mL beaker	Ammonium Chloride (NH_4Cl)
20-mL test tube	Electronic Balance
Thermometer	Weigh Boat

Technical Requirements: Teachers must have access to an electronic balance to complete this lesson.

Teacher Preparation: Ice bath will get extremely cold. Teacher may elect to create ice baths for students ahead of time or to switch to the "low chemical alternative"

Keywords:

- Depression
- Colligative Properties

Pre-assessment Strategy/Anticipatory Set (Optional):

Thought Question: How are oceans different from <insert local body of freshwater>?

Students will brainstorm different properties about oceans and the local body of freshwater (size, density, components). We used the lake we had visited during an adventure trip so we had a common context. If students do not have a basic understanding of the nature of lakes, any freshwater body can be used.

Lesson Procedure:
Opening: Students will complete a short refresher activity on physical properties
Mini-Lesson: Teacher will provide overview of the lab and give refresher of lab materials
Laboratory Experiment: Students will create a 3.5% saline solution and then submerge it in an ammonium chloride ice bath to calculate the freezing point of saline solution.

> Low chemical alternative ~ Begin with ice cubes and calculate the temperature of an ice-water solution compared to the temperature of an ice-water-salt solution (again, aim for 3.5% saline solution). It is a less exciting lab but does omit the ammonium chloride, which has a poor shelf life.

Analysis: Students will use the measured temperature change to determine the difference in freezing point. As a class, teacher will guide students through the process of developing the freezing-point depression formula. Students will practice this skill on a homework assignment.
Context: Students will analyze the affect of dissolved particles on the ocean and brainstorm what other properties may be different between the ocean and freshwater we interact with inland.
Honors Extension: Students will research how the variation in the physical properties of specific ocean habitats affects the distribution and diversity of life in those habitats.

Assessment and Evaluation:

- Students will write a formal lab report on the experiment
- Students will complete reflection on the lesson answering the question "How are oceans different from bodies of freshwater?"
- Students will complete reading reflection on different habitats and their physical properties (HONORS ONLY)
- Students will practice calculating freezing point depression for theoretical solutes on a homework assignment and quiz.

Standards:
National Science Education Standard(s) Addressed: Teaching Standard A, B. Content Standard: Physical Science (Structure and Properties of Matter)
Ocean Literacy Principles Addressed: 1e, 5f, 6a, 6g
State Science Standard(s) Addressed: C.1.1, C.1.8, C.2.1, C.2.2, C.11.4, C.11.5, C.11.6
Other National or State Standards Addressed (Optional) N/A

Additional Resources: *Chemistry: Matter and Change* (Glencoe, 2008) serves as a general reference for all students. Honors students were encouraged to use the Internet for their research and to visit the National Museum of Natural History's Ocean portal (http://ocean.si.edu/) for more information.

Author: Rebecca Kimport
Capital City Public Charter School
3220 16th St NW
Washington DC, 20010
rkimport@ccpcs.org

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