Freezing Point Depression: Can oceans freeze?
Student Advanced Version

Freezing point depression describes the process where the temperature at which a liquid freezes is lowered by adding another compound. It depends only on the number of dissolved particles in solution. This is known as a **colligative property**. For example, water freezes at 0°C, but when a **solute** such as salt or sugar is added to a **solvent** (water), the freezing point decreases. In order to see the freezing point depression of saltwater and how it changes with varying amounts of solute **concentration**, you will use 5 cups with water and varying amounts of salt and measure each individual temperature. Then, using the volume of the water and the volume of the solute, you will find the concentration of the solution expressed in **molality**. In the second part of the lab, you will use two freezer bags to observe how readily water freezes when surrounded by saltwater.

Key Concepts:

- A **solution** is a mixture composed of two or more substances. In a solution, the **solute** dissolves into another substance, referred to as the **solvent.**
- A solution's **colligative properties** refer to the number of dissolved particles contained in the solution and are not dependent on the identity of the solutes.
- A solution's **concentration** refers to the amount of solute mixed in with the solvent (e.g.10% saline solution).
- **Molality** is the number of moles of solute per kilogram of solvent and can be expressed in the following equation:

$$\frac{\text{Moles of solute (mol)}}{\text{Mass of solvent (kg)}} = \text{Molality of solution (mol/kg)}$$

Part 1 – Calculating Molality

1. **Separate the table on the last page of the lab for use during the lab.**

2. **Set up 5 cups in a line in front of you.**

3. **Label the cups** - "0mL of Salt", "10mL of Salt", "20mL of Salt", "30mL of Salt", and "Sugar".

4. **Fill the measuring cup to about 100mL of crushed ice. Slowly pour water into the cup until the ice/water mixture reaches 100mL.** (If your measuring cup does not measure in mL, 100mL is a little less than half a cup.) **Fill the first 4 salt cups with 100mL of ice/water.**

5. **Measure out each respective amount of salt, using tablespoons and teaspoons.**
   Note: 1 teaspoon=5mL and 1 tablespoon=15mL.

6. **Stir the amount of salt into each cup until the salt dissolves.** Note: If the saltwater is not continually stirred, the salt will pile up at the bottom. **Stir slowly to ensure salt dissolves. Also, for 30mL of solute, add the solute in portions.** (Example: 10mL first and then 20mL later).

Q1. Why does the 10mL of salt dissolve more readily than the 30mL of salt? How does the temperature of the solution affect the solubility of the solution?

Q2. What other factors can you think of that might affect the solubility of the solution?

7. **After you have stopped stirring, wait for the temperature to reach equilibrium.** This temperature is the "freezing point" of the solution. *Record the temperatures in Column B.*

Q3. How did the freezing point change by increasing the amount of salt in the water?

8. **Using a strainer, strain the ice out of each cup. Measure the volume of the remaining liquid (salt water) using the graduated cylinder.** *Record the results in Column C.*

9. Now, in the final foam cup, **add 30mL of sugar solute into 100mL of cold water.** *Record the freezing temperature below:*

*Freezing Temperature:*_____

Q4. How does the freezing temperature obtained by sugar water compare to the freezing temperature obtained when 30mL of salt were added to the same amount of water?

Concept Questions

Find the molal concentration of each solution using the equation below, but first find the moles of solute and mass of solvent. Follow the steps below to find these values.

$$\text{Molality (mol/kg)} = \frac{\text{Moles of solute (mol)}}{\text{Mass of solvent (kg)}}$$

First find the moles of solute (numerator):

First find the mass of the salt in grams. To find the mass of the salt, follow the example below:

Volume of Solute (mL) × Density of Salt (g/mL) = Mass of Salt (g)

The volume of salt solute can be found in Column A of the table, and the density of salt is 2.2 g/mL. Calculate the mass of salt for each cup.

Record your answer in Column D.

Next, using the grams of salt, find the moles of salt. First, find the Molar Mass of salt (NaCl) using a periodic table.

Q5. Find the Molar Mass of Na and Cl, then add those together to get the Molar Mass of NaCl (salt).

*Molar Mass of Na:*_____ *Molar Mass of Cl:* _____ *Molar Mass of NaCl (salt):* _____

Using the grams of solute and the molar mass, calculate the moles of salt:

$$\text{Mass of salt (g)} \times \frac{1 \text{ mole}}{\text{Molar mass of NaCl (g/m)}} = \text{Moles of salt (mol)}$$

The grams of salt were just entered in Column D of the table and the Molar Mass of salt is above so use the following equation to calculate the Molar Mass of salt for each cup.

Record your answers in Column E above.

Now find the mass of solvent (denominator):

First, convert the volume (mL) of the strained water to kilograms (kg). (mL ÷ 1000 = kg)

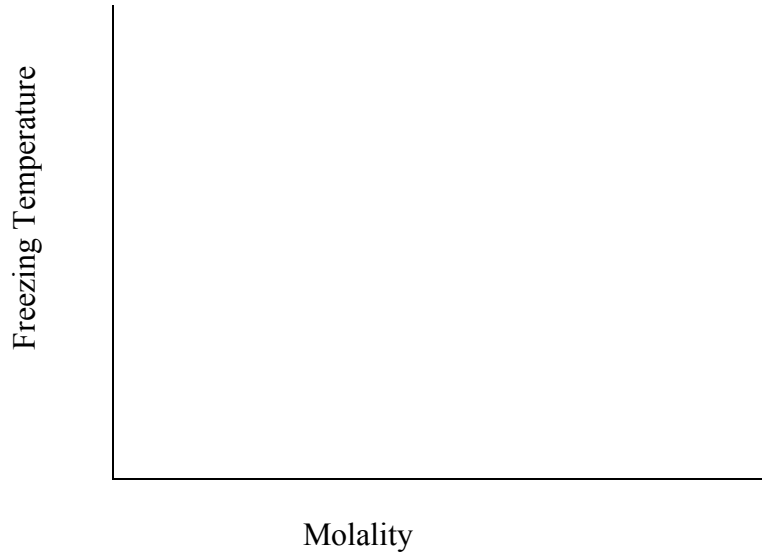
Record your answers in Column F.

Now, use the original equation to find the molality of the solution in molal units.

$$\text{Molality (mol/kg)} = \frac{\text{Moles of solute (mol)}}{\text{Mass of solvent (kg)}}$$

Record your answers in Column G.

Q6. Plot a molality vs. freezing temperature graph. Describe the relationship.



Q7. Why does salt depress the freezing point more than sugar? (Hint: covalent bonding vs. ionic bonding)

Q8. What freezing gtemperature would you predict if 40 mL of salt was placed in the water?

Part 2 – Freeze Water with Water

1. **Add crushed ice into the gallon freezer bag until the bag is ¼ full. Take the temperature.** *Record below:*

   *Temperature:*_____

2. **Add one cup of salt and ½ cup of water into the gallon freezer bag.**

3. **Squeeze out as much air as possible and close the gallon bag.**

4. **Mix until the ice has completely melted.** The bag will get very cold so put on gloves or hold the bag in a towel to protect your hands. **Rub your hands against the ice in order to melt the ice faster. Take the temperature.** *Record below.*

   *Temperature:*_____

Q9. How did the addition of salt change the freezing temperature? Is this similar to the first part of the lab?

Q10. If the temperature is below 0°C, the freezing point of water, why is the saltwater not frozen?

5. **Open the quart-size freezer bag and pour 1 ounce (2 tablespoons) of water into it.**

6. **Close the quart-size bag and put it inside the gallon freezer bag.**

7. **Let it sit for one minute.**

8. **Remove the quart size bag.**

Q11. Describe your observations below:

Concept Questions

Q12. Is it possible to make the salt water colder and colder forever just by adding more salt? Why or why not?

Q13. Why does the water inside the smaller freezer bag freeze so easily? Explain in terms of heat flow.

Q14. Why is the ocean able to maintain temperatures lower than 0°C without turning into ice?

References:

1. Freezing Point Depression Lab:
http://www.nphsscience.com/Dogancay/chem_h/labs/hlab09_fpdepression.pdf

2. Freezing Water in a Bag: http://www.hometrainingtools.com/article.asp?ai=1272&bhcd2=124871522

Results Table for Part 1

Column A	Column B	Column C	Column D	Column E	Column F	Column G
Solute	Temperature (C°)	Strained Water (mL)	Mass of Salt (g)	Moles of Salt	Kilograms of Water	Molality
0 mL salt						
10 mL salt						
20 mL salt						
30 mL salt						
30 mL sugar						