<u>Colligative Properties of Solutions: A Study of Boiling Point Elevation</u>

Amina El-Ashmawy, Collin County Community College
(With contributions by Timm Pschigoda,
St. Joseph High School, St. Joseph, MI)

OBJECTIVES:

- To calculate the value of the boiling point constant for water.
- To use colligative properties to determine the molecular weight of a substance.

MATERIALS & CHEMICALS:

- 400mL Beaker
- Non-iodized Sodium Chloride
- Deionized Water
- Hot Plate
- Unknown Substance

DISCUSSION:

A true solution is a *homogeneous* mixture of one or more *solutes* mixed with a compatible *solvent*. A solute is usually solid or liquid present in lesser amount in the mixture. If it is a solid, the solute is said to be **dissolved** by the solvent. The solvent is usually present in great abundance and is said to cause dissolution, or **solvate** the solute. Solvent particles and solute particles evenly mix to form a solution in which all parts of the mixture are physically and chemically uniform and identical. Once a solvent has solvated a solute, its properties are going to change.

The solvation process involves intermolecular forces of attraction between the solute and solvent particles. The stronger these interactions are the more pronounced the changes to the properties of the solvent. These physical properties of the solution are called *colligative properties*.

The **colligative properties** include:

- lowering of vapor pressure
- freezing point depression
- boiling point elevation
- osmotic pressure

Vapor pressure is the escaping tendency of the solvent particles. When the vapor pressure is the same as the atmospheric pressure the liquid is said to be boiling. Since, in solutions, the solvent particles have other particles that are interacting with them and not allowing them to escape the liquid state as readily, the vapor pressure becomes lowered. Therefore, a higher temperature is needed to reach a vapor pressure equal to the atmospheric pressure, and the boiling point is higher. The intermolecular forces also cause the solvent in the liquid state to require a lower temperature in order to go to the solid state.

The relationship between the freezing point and boiling point of a solution compared to the pure solvent can be expressed by

$$\Delta T = K\, m \text{ (for non-ionizing solutes)}$$
$$\Delta T = i\, K\, m \text{ (for ionizing solutes)}$$

ΔT = boiling point elevation or freezing point depression
i = the van't Hoff factor ~ the number of ions per formula
K = a constant that is specific to each solvent
m = molality of the solute (moles of solute particles / 1000g solvent)

Some constants for different solvents are given in Table 1.

In this experiment, you will determine the boiling point elevation constant for water and the molecular weight of an unknown. You will do this by observing the boiling points of solutions of known solute and of solutions with an unknown solute.

TABLE 1

Solvent	FP (°C)	K_f (°C/*m*)	BP (°C)	K_b (°C/*m*)
Acetic Acid ($HC_2H_3O_2$)	16.6	3.90	118.1	2.93
Benzene (C_6H_6)	5.4	5.12	80.2	2.53
Chloroform (CHCl3)	-63.5	4.68	61.3	3.63
Ethanol (C_2H_5OH)	-114.1	1.99	78.4	1.22
Water (H_2O)	0.0	1.86	100.0	0.51
Naphthalene ($C_{10}H_8$)	80.6	6.90	218	Xxx

PROCEDURES:

A: Determining The Boiling Point Constant of Water

1. Calculate the mass of sodium chloride necessary to make about 200mL of a 1-*m* solution. Show your calculation to your instructor before continuing.

2. Measure out three samples of salt of the calculated mass.

3. Bring 200mL of deionized water to boil in a 400mL beaker. Record the temperature of the water.

4. Carefully add the first sample of salt to the boiling water and allow to boil. Make sure you do not have salt sticking to the sides of the beaker and that it is all dissolved. Record the temperature and the molality.

5. Carefully add the second sample to the boiling solution and allow to boil. Record the temperature and molality.

6. Carefully add the third sample to the boiling solution and allow to boil. Record the temperature and molality.

7. Construct a graph of T (y-axis) vs. *m* (x-axis). Calculate the slope, intercept, and equation of the graph. Show your calculations on the graph.

B: Determination of The Molecular Weight of an Unknown

1. Record which unknown you are using.

2. Measure out one sample of the unknown roughly equal to the mass of one of the samples you used in part A.

3. Bring 200mL of deionized water to boil in a 400mL beaker. Record the temperature of the boiling water.

4. Carefully add the unknown sample to the boiling water and allow to boil. Record the temperature.

5. Calculate the molecular weight of the unknown salt. Your instructor will tell you how many ions per formula are produced for your particular unknown.

Student ___________________________________

REPORT FORM FOR COLLIGATIVE PROPERTIES LAB

PART A:

1. Volume of Water ____________________
2. Mass of salt sample 1____________________
3. T ____________________ *m*____________________

   (show molality calculation)

4. Mass of salt sample 2_____________________
5. T____________________ *m*____________________

   (show molality calculation)

6. Mass of salt sample 3______________________
7. T____________________ *m*____________________

   (show molality calculation)

8. Attach graph of T vs. *m*.

PART B:

9. Unknown ____________ #Ions/Formula______________
10. Mass of Unknown______________________
11. Volume of water______________________
12. Boiling T________________
13. T after addition of unknown sample___________________
14. Molecular weight of Unknown_____________________
    (show molecular weight calculations)

POST LAB QUESTIONS

1. What is the greatest source of error in this experiment?

2. What effect would ignoring the number of ions per formula have on the molecular weight calculated?

3. If the thermometer you used was not calibrated and consistently read 0.5^{o}C lower than the actual temperature, what effect would this have on the calculated molecular weight?

4. Which of the following solutions would have a larger freezing point depression: 1-m HCl in benzene or 1-m HCl in water? Why?

5. Calculate the molality of commercial HCl solution which is 12.1M, has a density of 1.19 g/mL, and is 37.2 wt.% HCl.