CHEM 106
GENERAL CHEMISTRY

Experiment 3
Molecular Weight Determination from Freezing Point Depression

Purpose: To learn colligative properties and to determine the molecular weight of sulfur by using one of the colligative properties.

Prelaboratory Work

Before the experiment in the laboratory, you should be able to answer these questions.

1. List the colligative properties.
2. What is the molality of a solution that contains 1.5 g of urea (molar mass = 60 g/mol) in 200 g of benzene?
3. Calculate the freezing point of a solution containing 5.85 g of NaCl in 200 g of water? (Na: 23 g/mol; Cl:35.5 g/mol)
4. A solution containing 1.00 g of an unknown substance in 12.5 g of naphthalene was found to freeze at 75.4°C. What is the molar mass of the unknown substance?
5. Define molality and molarity.

Theory

Some of the physical properties of solutions are independent of the nature of the solute and depend only upon the solute amount. These properties are called “colligative properties”. Vapor-pressure lowering, Boiling point elevation, Freezing-point depression and osmotic pressure are colligative properties.

Those effects introduced above are familiar to us in our daily life. In this experiment, freezing point depression property will be used. That’s why it is better to give examples or explanations related with this property.

Anti-freeze solution is used for lowering the freezing point of water in automobiles. (This solution is made by mixing water and ethylene glycol or water and methanol or water and another one.) When something is added to water, freezing point of water decreases automatically. The increasing addition amount decreases the freezing point more.

Another example is pouring salt onto the snow on the roads to prevent freezing in winter days. When salt is added to water, the resulting solution has lower freezing point (and also higher boiling point). Increasing the amount of salt decreases the freezing point more. Freezing point and boiling point of a solution differ from those of the pure solvent by amounts that are directly proportional to the molal concentration of the solute and can be expressed with the equation below:

$$\Delta \mathbf{T} = \mathbf{K} \cdot \mathbf{m}$$

where $\Delta \mathbf{T}$ is the freezing-point lowering or boiling-point elevation, **K** is molal freezing (or boiling) constant which is specific for each solvent, **m** is the molality of the solution (number of moles of solute /kg of solvent).

Some representative constants, boiling points, and freezing points are given in Table 1. For naphthalene, the solvent used in this experiment, the molal freezing constant (Kf) has a value of 6.90 ^{o}C/m.

TABLE 1. Molal Freezing-Point and Boiling-Point Constants

Solvent	Freezing point (˚C)	K_{fp} (°C/m)	Boiling point (˚C)	K_{bp} (°C/m)
CH_3COOH (acetic acid)	16.6	3.90	118.1	2.93
C_6H_6 (benzene)	5.4	5.12	80.2	2.53
C_2H_5OH (ethyl alcohol)	-114.1	-	78.4	1.22
H_20 (water)	0.0	1.86	100.0	0.51
$C_{10}H_8$(naphthalene)	80.6	6.9	218	-

Example: What would be the freezing point of a solution containing 19.5 g of biphenyl ($C_{12}H_{10}$) dissolved in 100 g of naphthalene if the normal freezing point of naphthalene is 80.6°C?

Solution:

$$\text{moles of } C_{12}H_{10} = \frac{19.5\text{ g}}{154\text{ g/mol}} = 0.127\text{ mol}$$

$$\frac{\text{moles of } C_{12}H_{10}}{\text{kg of naphthalene}} = \frac{0.127\text{ mol}}{0.1\text{ kg}} = 1.27\text{ molal (m)}$$

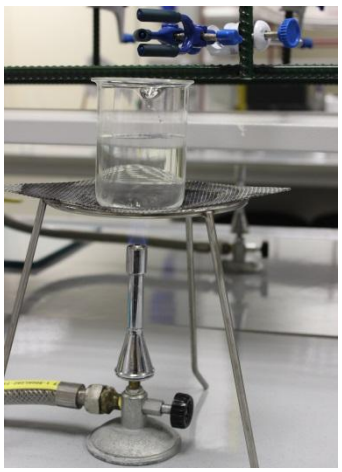
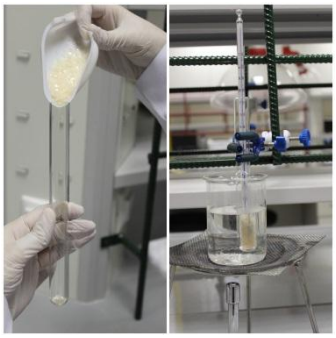
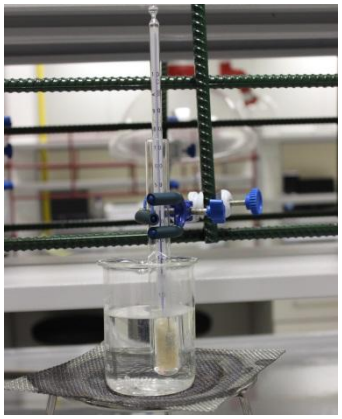
$\Delta T = (6.91\ ^\circ C/m) \times (1.27\ m) = 8.8\ ^\circ C$

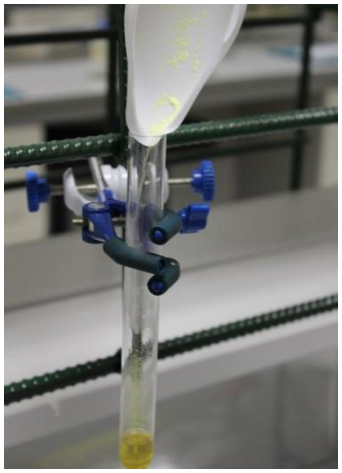
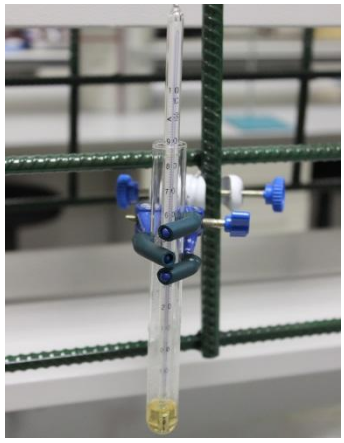
Since the freezing point is lowered, the observed freezing point of the solution will be $T_{pure} - T_{solution} = 80.6℃-8.8℃=71.8℃$

Materials

Naphthalene	Large test tube	600-mL beaker
Sulfur	Clamp	Bunsen burner
Thermometer	Ring and ring stand	

Procedure

PART A: Cooling Curve for Pure Naphthalene	
1. Fill your 600-mL beaker nearly full of water and heat it to about 85 ^{o}C. Clamp the test tube in the water bath as shown in figure.	
2. Weigh 3 g of naphthalene and put the naphthalene in the test tube. Then insert the thermometer into the test tube-naphthalene as shown in figure above. Wait for naphthalene melts. When all of the naphthalene has melted, stop heating, remove the test tube out of water.	
3. Starting with 85 ^{o}C; record temperature readings every 30 s. Shake the test tube slightly at every temperature reading. When the freezing point is reached, crystals will start to form, and the temperature will remain constant. After all the naphthalene freeze, temperature lowering will start again.	

PART B: Determination of the Molar Mass of Sulfur	
1. Weigh 0.5 g of sulfur.	
2. Replace the test tube in the water bath and heat until all the naphthalene has melted. Add the sulfur into the test tube. Shake the test tube until all the sulfur has dissolved.	
3. Remove the test tube out of the water bath, record the temperature every 30 s until all the naphthalene has solidified. Do not forget to shake the test tube at each temperature readings. Using the data above, draw two cooling graph and find ΔT.	

DATA SHEET

Molecular Weight Determination from Freezing Point Depression

Student's Name : Date:

Laboratory Section/Group No :

Assistant's Name and Signature:

1. Weight of Naphthalene: ……..g

2. Weight of Sulfur:……..g

3. Freezing point of pure naphthalene, T_{pure} :……. ^{o}C

4. Freezing point of solution (napht. + sulfur), $T_{solution}$:……. ^{o}C

5. $\Delta T = T_{pure} - T_{solution}$= ……..$^{o}C$

6. Molality of Sulfur: ……..molal (m). ***(Show calculations below..)***

7. Molar mass of unknown Sulfur:……..g/mol ***(Show calculations below..)***

COOLING CURVE		
Pure naphtalene		**Naphtalene + Sulfur (S)**
Temperature (°C)	**Time (sec.)**	**Temperature (°C)**