Experiment #4
Using Freezing-Point Depression to Find Molecular Weight

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Goal of the Experiment

Using the known quantity of a solute and the colligative property of freezing-point depression the objective of the experiment is to find the molecular weight of a known chemical compound, naphthalene, and comparing it to the accepted weight of naphthalene based on its chemical formula, $C_{10}H_8$. The expectation is that the freezing temperature of the solution will be lowered in proportion to the number of moles of solute added to the pure substance.

Chemistry Principle

Molecular weight of a substance can be determined using any of the colligative properties -- boiling point elevation, freezing point depression, or osmotic pressure. This experiment takes advantage of the relatively high freezing point of stearic acid to illustrate freezing point depression without the need for specialized equipment.

The formula $\Delta T = iK_f m$ which shows the freezing-point depression mathematically. The given K_f value of stearic acid is 4.89℃/m. Based on the chemical formula of naphthalene, $C_{10}H_8$, it can be determined that it is a covalent molecule and will therefore not dissociate. This means the value of i, the vant Hoff factor, is one and there will not be a potential source of error because of the difference between the theoretical and actual vant Hoff factor.

Results and Discussion

An initial mass of 10.0353g of stearic acid was melted in a water bath to 80℃. The accepted melting point of stearic acid is 69℃. The sample was then stirred constantly as it cooled to minimize supercooling of the sample. The stirrer was a copper wire in a test tube which also helped to minimize material loss. The sample did not freeze until it reached a temperature of 55.6℃. Since this value was unexpectedly low, the experiment was run again to verify this result. Upon the second heating and freezing of the sample, the freezing point was determined to be 55.4℃. Since the two tests were similar to each other the experiment was continued although the lower than expected freezing point was noted.

The pure stearic acid was melted again and 1.0085g of naphthalene was added. Using a computer generated cooling curve, the mean freezing point was calculated to be 52.09℃. The freezing point depression was calculated to be 3.41℃. Using the formula $\Delta T = iK_f m$ the experimental molar mass of the naphthalene was 144.1g/mol. Based on the accepted molar mass of 128.16g/mol, the percent error was calculated to be 12.45%.

The results of this experiment show a freezing point depression between pure stearic acid and a solution of stearic acid and naphthalene. Although the goal of the experiment was to find the molecular weight, the principles of colligative properties were still illustrated despite the margin of error.

Conclusion

The calculated percent of error of this trial is above the accepted threshold. Some sources of error could be material loss in the transfer of stearic acid or naphthalene during the experiment or during the stirring process. The setup in the lab also proved difficult. The temperature probe did not reach to the bottom of the sample of stearic acid and could have caused an inaccurate temperature reading. Because the initial freezing point was so far lower than expected, given more time the experiment would be run again with a fresh sample of stearic acid. Generally, the full experiment would be run again to ensure enough data points to reduce the effect of outliers.

Other potential tests could be boiling point increase and osmotic pressure of the solution. If these tests were going to be conducted with naphthalene as the solute, a different non-polar solvent would need to be used with a lower boiling point that would be more conducive to a standard laboratory environment since there are inherent risks dealing with a boiling point of 361℃.