An Investigation of a Greener Method to Use Freezing Point Depression to Determine Molar Mass

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Academic Honesty Statement

I have read and agree to the terms of the Academic Honesty Statement.

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**Abstract**

The experiment examined the use of freezing point depression to determine the molar mass and therefore identity of an unknown fatty acid. This process works because freezing point is a property that is dependent on amount present, not what is present. The freezing points were determined by melting the fatty acids, as both purely steric acid and as a solution of the steric acid and the fatty acid, slowly cooling it down while measuring the temperature as it cools for six minutes, and used the data collected to graph two lines where the intersection is the experimental freezing point. The experimental value for the molar mass was ± 57.43024528 g/mol which had an uncertainty too wide for an answer more definite than the unknown acid being any of the three (lauric, myristic, palmitic) acids. Unfortunately due to the large uncertainty, no meaningful conclusion can be determined and the results ultimately do not align with the hypothesis.

**Introduction**

This report explores colligative properties, like boiling point and freezing point, which are properties determined by concentration (Sanders, 2020). Through the understanding of freezing point depression and boiling point elevation, the molar mass of an unknown fat with a known mass can be determined. This report, however, will be focusing on freezing point depression as it is the data collected. The equations for freezing point depression (FPD) is

FPD: (1)

In this experiment, the molar mass and therefore identity of an unknown fatty acid, in this experiment unknown A, will be discovered through the use of FPD with steric acid being the known solvent. The fatty acid used will be limited to one of three acids; dodecanoic acid (lauric acid), tetradecanoic acid (myristic acid), and hexadecenoic acid (palmitic acid); which have twelve (“Lauric acid”, 2020), fourteen (“Myristic acid”, 2020), and sixteen (“Palmitic acid”, 2020) carbon chains respectively. The i and kf of the equation will be known as kf is given and i can be assumed to be 1 because the unknown fatty acid is limited to being three potential fatty acids; dodecanoic acid (lauric acid), tetradecanoic acid (myristic acid), and hexadecenoic acid (palmitic acid), all of which do not dissociate into ions. The identity of the unknown fatty acid can be determined after determining the change in freezing point before solving for molality through the use of equation 1. With molality, the moles and molar mass of the unknown fatty acid can be determined.

**Methods**

The freezing point of the known steric acid was determined by melting approximately 9 grams of steric acid in a test tube in a hot water bath at 85˚C (Sanders, 2020). The test tube was moved to a graduated cylinder for insulation to have its temperature measured for 6 minutes (Sanders, 2020). This process was repeated for a total of 3 trials (Sanders, 2020). The FPD of the solution of steric acid and an unknown fatty acid was determined by adding approximately 2 grams of the unknown fatty acid and repeating the steps above, this was also repeated for a total of 3 trials (Sanders, 2020). The freezing points of steric acid and the solution were determined by determining the intersection of the two graphs made by the collected data as seen below in the results section (Sanders, 2020). Using the freezing point depression determined by the graphs, equation 1 was used to acquire the molality that could be multiplied by mass of solvent and divided by the mass of the solute to acquire moles and mass respectively (Sanders, 2020).

**Results**

Figure 1.1 Trial 1 of steric acid freezing point determination

Figure 1.2 Trial 1 of solution freezing point determination

Calculation 1.1 Freezing point of trial 1 steric acid

Tf1 = -0.284x + 83.662 = -0.0005x + 68.716

x = 52.7195767

-0.284(52.7195767) + 83.662 = 68.68964021 = -0.0005(52.7195767) + 68.716

Calculation 1.2 Freezing point of trial 1 solution

Tf1 = -0.5053x + 85.931= -0.0034x + 64.096

x = 43.50468221

-0.5053(43.50468221) + 85.931 = 63.94808408 = -0.0034(43.50468221) + 64.096

Calculation 1.3 Example ∆T calculation using trail 1 steric acid and solution

68.68964021 - 63.94808408 = 4.74155613

**Discussion**

The results suggest unknown acid a being myristic acid as the calculated value is closest to its literature value; however, due to the uncertainty being so large, the true identity of the acid could be any of the acids as they all fall within the range. The experimental molar mass was ± 57.43024528 g/mol which was wide enough to encompass the literature values of all possible unknowns of 200.32 g/mol for lauric acid, 228.37 g/mol for myristic acid, and 256.26 g/mol for palmitic acid (Sanders, 2020). In the experiment, it was assumed that the unknown acid and the steric acid would not dissociate and would keep the value of i in equation 1 at 1. The value of kf is assumed to be 4.5 ± 0.01 because it is a value that was given (Sanders, 2020). The scale used had an uncertainty of ±0.001g. The propagation of uncertainty was done by doubling the standard deviation to be certain that the freezing points would lie within the range, and the remaining uncertainty propagation is done with the relevant random uncertainty equations (Sanders, 2020). The experiment could be improved if the solution could be mixed more thoroughly so the cooling curve would be more consistent like the curve of steric acid. This could lead to a smaller standard deviation which could lead to a smaller final uncertainty for molar mass. The unknown acid could not be determined with certainty in this experiment as all potential unknowns fell within the range due to the uncertainty.

**References**

A Greener Approach to Molar Mass Determination Using Freezing Point Depression. In *Laboratory Manual for CHM 1220,* 3rd Ed.; Sanders, L.J., Underwood, K. A., Clark, T.B., Dolson, D. A., Aga, R. S.; Van Griner: Cincinnati, OH, 2020; pp 33-47

Appendix A: Treatment of Data. In *Laboratory Manual for CHM 1220,* 3rd Ed.; Sanders, L.J., Underwood, K. A., Clark, T.B., Dolson, D. A., Aga, R. S.; Van Griner: Cincinnati, OH, 2020; pp 213-220

National Center for Biotechnology Information. PubChem Database. Lauric acid, CID=3893, https://pubchem.ncbi.nlm.nih.gov/compound/Lauric-acid (accessed on Feb. 11, 2020)

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**Appendix A: Graphs and values of measured properties and the kf value**

Figure A.1 Trial 1 of steric acid freezing point determination

Figure A.2 Trial 2 of steric acid freezing point determination

Figure A.3 Trial 3 of steric acid freezing point determination

Figure A.4 Trial 1 of Solution freezing point determination

Figure A.5 Trial 2 of Solution freezing point determination

Figure A.6 Trial 3 of Solution freezing point determination

Table A.1 Values and uncertainty of measured properties and the kf value

|  |  |  |
| --- | --- | --- |
|  | Value | Uncertainty |
| Kf of steric acid | 4.5 | 0.01 |
| mass of solvent (kg) | 0.008863 | 0.001 |
| mass of solute (g) | 1.935 | 0.001 |

**Appendix B: Calculations**

Steric Acid

Tf1 = -0.284x + 83.662 = -0.0005x + 68.716

x = 52.7195767

-0.284(52.7195767) + 83.662 = 68.68964021 = -0.0005(52.7195767) + 68.716

Tf2 = -0.3195x + 84.431 = -0.0004x + 68.695

x = 49.31369477

-0.3195(49.31369477) + 84.431 = 68.67527452 = -0.0004(49.31369477) + 68.695

Tf3 = -0.2766x + 83.412 = -0.0001x + 68.615

x = 53.51537071

-0.2766(53.51537071) + 83.412 = 68.60964846 = -0.0001(53.51537071) + 68.615

Tfavg = (68.68964021 + 68.67527452 + 68.60964846)/3 = 68.65818773

2\*Standard Deviation:

= 0.085291002

Avg Tf (solvent) ± 2x Std. Dev: 68.658 ± 0.085

Solution

Tf1 = -0.5053x + 85.931= -0.0034x + 64.096

x = 43.50468221

-0.5053(43.50468221) + 85.931 = 63.94808408 = -0.0034(43.50468221) + 64.096

Tf2 = -0.4878x + 86.172 = -0.0043x + 64.794

x = 44.21509824

-0.4878(44.21509824) + 86.172 = 64.60387508 = -0.0043(44.21509824) + 64.794

Tf3 = -0.3311x + 81.672= -0.0065x + 65.155

x = 50.88416513

-0.3311(50.88416513) + 81.672 = 64.82425293 = -0.0065(50.88416513) + 65.155

Tfavg = (63.94808408 + 64.60387508 + 64.82425293)/3 = 64.45873736

2\*Standard Deviation:

= 0.911518906

Avg Tf (solvent) ± 2x Std. Dev: 64.459 ± 0.912

∆Tf

Value: 68.65818773-64.45873736 = 4.199450371

Uncertainty: = 0.915500558

∆Tf ± uncertainty: 4.199 ± 0.916

Molality

Value: 4.199450371/4.50 = 0.933211193

Uncertainty: = 0.203455138

Molality ± uncertainty: 0.933 ± 0.203

Moles

Value: 0.933211193\*0.008863 = 0.008271051

Uncertainty:

= 0.002030393

Moles ± uncertainty: 0.00827 ± 0.00203

Molar Mass

Value: 1.935/0.008271051 = 233.9485085

Uncertainty:

= 57.43024528