**Laboratory 10 — Evaporation & Intermolecular Forces**

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**Abstract**

This experiment was conducted to determine the temperature changes caused by the evaporation of five liquids and relate the changes in temperature to the strength of the intermolecular forces of each liquid. The substances tested in this experiment included *n*-pentane, 1-propanol, 1- butanol, 1- pentanol, and 2- pentanone. To collect the data needed to make the comparison, temperature probes were placed into beakers of the different liquids and then removed. Once removed, the change in temperature was recorded once the temperature began to increase. The results demonstrated that the liquid with the weakest intermolecular force had the highest change in temperature whereas the liquid with the strongest intermolecular force had the lowest change in temperature.

**Introduction**

 The purpose of this experiment was to learn about how the intermolecular forces affect different aspects of the molecule. This experiment was conducted to determine how intermolecular forces contribute to certain characteristics of a molecule and to relate the change of temperature to the strength of the intermolecular forces present in each of the molecules tested. Intermolecular forces are the forces which control the interaction between different molecules including the attraction and repulsion between molecules. The three types of intermolecular forces seen in this experiment were London dispersion forces, hydrogen bonds, and dipole-dipole bonds. London dispersion forces exist between any two molecules and the strength of the London dispersion forces increases as the molar mass of the molecule

fluoride. dipole-dipole bonds are only present in polar molecules in which the negative end of a polar molecule is attracted to the positive end of another polar molecule.

**Procedure**

 Before the experiment was conducted, the Lewis Structure, molar mass, boiling point in degrees Celsius and the intermolecular forces exhibited by each substance was determined. Before coming into contact with the materials, proper personal protective equipment was utilized. The temperature probe was connected to the computer to collect data using the Logger Lite software. Next, the distal end of the probe was wrapped with a square piece of filter paper to create a cylinder around the end of the probe. A rubber band was then applied to the end of the probe to secure the filter paper. The probe was then inserted into a large test tube inside of a beaker to prevent the tube from tipping over. The probe was then held in the liquid for 30 seconds to allow the filter paper to absorb the liquid. The initial temperature was taken when the temperature obtained by the probe became constant. Next, the probe was removed from the liquid and placed on the edge of the lab station so that the tip of the probe extended past the edge of the table to allow the liquid to evaporate effectively. The temperature was recorded until the temperature reached a minimum and then began to increase. The minimum temperature was recorded, and then the change of temperature during evaporation was determined by subtracting the minimum temperature from the initial temperature. The filter and rubber band were then removed from the probe, and the process was repeated for each liquid that was tested.

**Results and Discussion**

This experiment yielded the result that the liquid with the weakest intermolecular force and the lowest boiling point produced the most significant change in temperature during evaporation. As shown in Table 1, *n*-pentane which experiences London dispersion forces has the lowest boiling point and the most significant change in temperature among the substances. 1-pentanol experiences hydrogen bonding, possess the highest boiling point and the least change in temperature. This demonstrates that molecules with a stronger intermolecular force and a higher boiling point experience a smaller change in temperature during evaporation then substances with a weaker intermolecular force and a lower boiling point. Substances with a lower molar mass tend to see more of a change in temperature than ones with a higher molar mass, but the strength of the bonds also contributes highly to this process. Even though *n*-pentane and 1-butanol have a nearly identical molar mass, the forces experienced by *n*-pentane and 1-butanol are entirely different. 1-butanol experiences hydrogen bonding requires more energy to separate the bonds whereas *n*-pentane experiences London dispersion forces which are the weakest of the three bonds and takes less energy to separate the bonds.

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| **Substance** | **Molar Mass (g/mol)** | **Boiling Point (˚C)** | ***T*1 (max) (˚C)** | ***T*2 (min) (˚C)** | **Δ*T* (*T*1– *T*2) (˚C)** |
| *n*-pentane | 72 (g/mol) | 36 ˚C | 25.2 ˚C | -2.0 ˚C | 27.2 ˚C  |
| 1-propanol | 60 (g/mol) | 97 ˚C | 25.5 ˚C |  18.4 ˚C | 7.1 ˚C |
| 1-butanol | 74 (g/mol) | 118 ˚C | 26.4 ˚C | 19.1 ˚C | 7.3 ˚C |
| 1-pentanol | 88 (g/mol) | 138 ˚C | 25.2 ˚C | 23.5 ˚C | 2.3 ˚C |
| 2-pentanone | 86 (g/mol) | 101 ˚C | 26.2 ˚C | 15.9 ˚C | 10.3 ˚C |

Table 1

 The three alcohols that were tested in this experiment were 1- propanol, 1-butanol, and 1- pentanol. Even though all alcohols experience hydrogen bonding, not all have the same boiling point. 1-pentanol has the highest boiling point with the lowest change in temperature whereas 1-propanol has the lowest boiling point of the three alcohols and the most change in temperature among the alcohol. The data plotted in Figure-1 also demonstrates that not only the intermolecular forces and the boiling point affect the change in temperature but also the molar mass. The data plotted in Figure-1 indicates that the lower the molar mass of a substance is, the difference in temperature is more significant.

Figure 1

 This data can be utilized to predict the change in temperature during the evaporation of other substances. For example, the difference in temperature experienced when methanol (CH₃OH) evaporates can be expected to be more significant because the molar mass of methanol is 32.04 (g/mol). The change in temperature of hexanol (C6H13OH) can be expected to lower because the molar mass of hexanol is 102.162 (g/mol). Both hexanol and methanol experience hydrogen bonding because both contain a hydrogen atom that is bonded directly to an oxygen atom which is a characteristic of all alcohols. Based on the data collected in the experiment, the substance with the strongest intermolecular force present is 1-pentanol, followed by 2- pentanone with *n-*pentane experiencing the weakest intermolecular force.

**Conclusions**

 Based on the data collected during this experiment, molecules with a stronger intermolecular force, a higher boiling point, and a high molar mass, when evaporated, do not demonstrate a steep change in temperature compared to substances with a weak intermolecular force, a lower boiling point, and a low molar mass. The results obtained from this lab are to be expected due to the known characteristics of each intermolecular force.