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| Experiment 5: Surface Tension of Solutions |
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# Abstract

In this experiment, the effect of isopropanol and sodium chloride in different concentrations on the surface tension of their solutions was tested with a duNuoy ring apparatus. Solutions of 0.8, 0.6, 0.4, 0.2, and 0.1 M isopropanol and 4, 3, 2, and 1 M solutions of NaCl were tested. A densitometer was used to measure the density of the solutions, which was input into a tensiometer to automatically conduct the surface tension measurements, averaging the surface tension over three trials. It was found that as the concentration of isopropanol increased, the measured surface tension decreased, while with increasing concentrations of NaCl, the surface tension increased. This can be explained by the contribution of intramolecular forces each of the solutes bring. Isopropanol, with weaker intramolecular forces than water, weaken the overall intramolecular forces at the surface, lowering the surface tension. NaCl, with stronger ionic intramolecular forces, interact more strongly with water, and increase the strength at the surface, increasing the surface tension.

# Introduction

In this experiment, a duNuoy ring apparatus will be used to measure the surface tension of solutions. Generally, properties of molecules in the system are proportional to volume, which represents the interactions of molecules with other molecules surrounding it. However, when said molecule is near the surface, the molecule is no longer completely surrounded by molecules; it is exposed to the surface surroundings. These properties can thus be written as the following equation in equation 1:

Where V and A are the total volume and surface area, and the associated Q terms are adjusting for molecules below and above, respectively. Applying this to Gibbs energy, the following equation is derived:

The first term represents the contribution from the total volume, the molecules buried deep below the surface, and the second term represents the contribution from molecules near the surface. Gamma represents the surface tension in this case: gamma being negative means that free energy can be minimized by minimizing surface tension. This is observed as a sphere, for example, when a liquid is observed in absence of gravity.

When applying the property Q to number of moles of solute, the QA term now represents the surface concentration, and measures the quantity of solute molecules at the surface in a thin layer. This changes the surface tension, and a relationship called Gibbs isotherm is derived to form this relationship.

To investigate this relationship, the duNuoy ring apparatus will be used to measure the surface tension of different solutions with different amounts of solute.

# Experimental

To begin this experiment, a 0.8 M isopropanol solution was prepared in a 100 mL volumetric flask by adding 6.11 mL of isopropanol and filling the flask with distilled water. Another solution of 100 mL 4.0 M NaCl was prepared by adding 23.376 grams NaCl to a volumetric flask and dissolving it in 100 mL distilled water.

Next, the tensiometer was calibrated, and 20 mL of the 0.8 M isopropanol solution was added to a small beaker. A densitometer was used to measure the density of the solution, which was recorded and entered into the tensiometer. Then, the beaker was placed on top of the elevator platform. The elevator platform was brought up and the balance was brought downward until the ring was almost submerged into the solution. The machine was then set to run three trials to take an average, and the start button was pressed.

During operation, the elevator platform was then automatically adjusted upward until the ring was fully submerged into the solution by about 1/8 inch. Then, the elevator was lowered as the tension measurements were observed on the machine. The maximum number was recorded. This was repeated 3 times to obtain an average.

This process was repeated with 0.6 M, 0.4 M, 0.2 M, and 0.1 M isopropanol solutions, as well as 4 M, 3 M, 2 M, and 1 M NaCl solutions by diluting the original solution.

# Results

The machine reported two values for the density. For this experiment, only the Huh-Mason adjusted values were used for the experimental data. For each trial, the concentration of the solute, the density of the solution, and the Huh-Mason adjusted surface tension was recorded, as well as the standard deviation during the trial. The measured data for the Isopropanol set of trials is seen below. The NaCl trials can be found in the attached data sheet in the appendix.

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| Isopropanol | | | | |
| Concentration (M) | density g/cm^3 | **Huh-Mason** | Units | STD |
| 0.8 | 0.9898 | 46.7 | mN/m | 0.06 |
| 0.6 | 0.9911 | 48.13 | mN/m | 0.09 |
| 0.4 | 0.9937 | 53.45 | mN/m | 0.14 |
| 0.2 | 0.9958 | 59.14 | mN/m | 0.1 |
| 0.1 | 0.9968 | 63.26 | mN/m | 0.23 |
| water | 0.998 | 69.32 | mN/m | 0.23 |

Table : Experimental Data for Isopropanol Solution Surface Tension Trials

With the experimental data for the NaCl solutions and the isopropanol solutions, a plot of log(concentration) against the surface tension was created, and a best fit line was drawn through the points. Notice the slope of the best fit line through these plots as the concentration of the solute increases.

Figure : Log(concentration) against Surface Tension Plot for NaCl Solutions

Figure : Log(concentration) against Surface Tension Plot for Isopropanol Solutions

In the plots, an increased concentration of NaCl resulted in an increase in surface tension, while an increased concentration of isopropanol resulted in a decrease in surface tension.

# Discussion

As mentioned in the introduction, the surface tension is related to the number of solute molecules on the surface of the solution. However, through this experiment, it is clear that the relationship is not direct – more molecules on the surface of the solution does not always constitute an increase in surface tension. This can be explained with the concept of intramolecular forces. The stronger the average intramolecular forces between the molecules on the surface of the solution, whether it be from the solute or the solution, the greater the surface tension, as the ring would need to exert more force to break the stronger intramolecular forces to breach the surface of the solution.

Isopropanol, with its structure given below, is capable of forming van der Waals interactions, dipole-dipole interactions, and hydrogen bonds. However, its non-polar carbons compared to the structure of water mean that the hydrogen bonding capabilities of isopropanol are weaker than that of water, and therefore, weaker intramolecular forces are expected in isopropanol. This fact is confirmed with the boiling point of isopropanol, which is 82.5°C, compared to water’s boiling point of 100°C at STP. Therefore, as the concentration of isopropanol increases, the average strength of the intramolecular forces at the surface of the solution decrease, as there are more isopropanol molecules. This means that the ring would need less force to break through the tension at the surface, which coincides with the data.

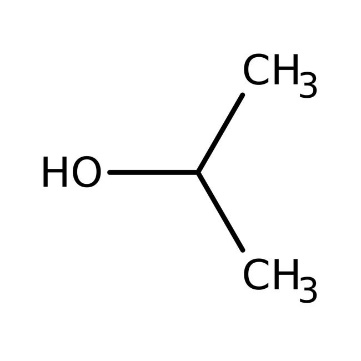


Figure : Structure of Isopropanol

Sodium chloride, on the other hand, disassociates in water to form sodium and chloride ions. While incapable of forming hydrogen bonds, these ions are capable of forming the even stronger ionic interactions with each other as well as ion-dipole interactions with water. Thus, the addition of NaCl to a solution would increase the overall strength of intramolecular forces. This is consistent with the data, as an increase in the concentration of NaCl in solution saw an increase in the measured surface tension. Thus, through this experiment, we support a relationship and explanation that trends in surface tension are directly related to the average strength of intramolecular forces at a solution’s surface.

# Appendix

Experiment Datasheet 