An undergraduate experience for studying the diffusion of a solute in an aqueous solution

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Molecular diffusion driven by concentration gradients is the most common type of diffusion in chemical separation processes, such as liquid-liquid extraction, stripping, and adsorption. To better understand molecular diffusion, a fundamental knowledge of Fick's law of diffusion is crucial. In the Spring 2021 semester, I participated in the Special Problem Course offered by Dr. Souto, in which we developed a new undergraduate laboratory experience. This experience consisted of a hands-on experimental work and data analysis to study the diffusion of salt in an aqueous media. This new experiment will be incorporated in the Chemical Engineering Senior Laboratory in the Fall 2021 semester, where currently, there are no experiments for students to study molecular diffusion. This project was funded by the 2020 AIChE Separations Division Education and Outreach award.

The work consisted of preparing a concentrated sodium chloride solution, arming the equipment set-up, collecting and analyzing the data. Additionally, we prepared the experimental handout and a video demonstration. This video demonstration could also be useful in other chemical engineering courses. Also, during summer 2021, we expanded this project to study the repeatability of the experiment. We performed multiple experimental runs at different concentrations of sodium chloride (1 M and 2 M).

The equipment that we used is the Armfield's liquid diffusion apparatus. It consists of a diffusion cell, a diffusion vessel, a magnetic stirrer, and a conductivity meter. The diffusion cell consists of a honeycomb of accurately dimensioned cylindrical pores that allows the diffusion of the salt into the diffusion vessel. The diffusion was studied by measuring the change in conductivity of the pure water in the diffusion vessel as the salt solution diffuses into the water through the diffusion cell. The pure water was in continuous agitation that ensures that the salt concentration in the vessel stays well mixed. The salt diffuses from the diffusion cell into the diffusion vessel due to the presence of a concentration gradient.

The diffusion coefficient of the salt was determined using an equation based on Fick's law of diffusion and taking the following assumptions: perfectly mixed solutions, negligible volume available to the solute within the capillaries, and pseudo-steady-state conditions throughout the experiment [1]. Our work resulted in the determination of a range of acceptable values for the diffusion coefficient that is obtained using this apparatus, the experimental conditions being investigated, and the assumptions used for the calculations. Also, we determined the experimental conditions that provided optimal results, such as the agitation rate, the time collecting data, and the handling of the diffusion cell.

These results will be implemented in the experimental handout of the experiment such that when chemical engineering students enrolled in the laboratory course perform the experiments, they have a reference. In addition, the video we prepared describing the diffusion experiment and how to perform the calculations will be useful for the students, particularly if we need to pivot to remote learning. In conclusion, this work demonstrates how students can use this experimental setup to study the fundamental concepts of diffusion and how different experimental conditions can influence the calculation of the diffusion coefficient.

References

[1] *Liquid Diffusion Coefficient Apparatus Instruction Manual for Product Code CERB*, Issue 13, Armfield Limited, Ringwood, Hampshire, England, 2019, pp. 32–34.

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