CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

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Project Number

S0615

Project Title

Modeling of Liquid-Liquid Extraction Using Caffeine as the Model System

Abstract

Objectives/Goals

The liquid-liquid extraction process is an important process for chemical separation and purification. The purpose of this scientific research was to identify factors which affected the recovery percentage of the liquid-liquid extraction process and to create a mathematical model to characterize and optimize the process.

Methods/Materials

A caffeine solution and a non-toxic solvent, ethyl acetate, were chosen as the model chemical and extraction solvent for this study, respectively. Three parameters, solvent volume, extraction method, and salt concentration, were tested for impact on final extraction amounts. The study was divided into two separate phases: one focused upon the effect of increasing amounts of solvent and multiple extractions in comparison to single extractions, while the other phase focused upon the effect of the addition of salt to the aqueous solution.

Results

The control extraction was completed with 10 mL caffeine solution extracted by 10 mL ethyl acetate and yielded an average of 30%, with a variation of 5%. As the amount of solvent was increased to 40 mL in single extractions, the percentage of caffeine extracted increased to 74.5%. For the multiple extraction method, the percent of caffeine extracted increased to 79.5% by 10 mL solvent extractions repeated four times. In phase 2, the control extraction percentage increased from 30% to 39.5% when 0.5 g of salt was added into 10 mL of caffeine solution. The extraction percentage increased to 48.05% when 1 g of salt was added. When 2 g of salt was added, the extraction percentage decreased to 37%, and undissolvable white crystals were observed. Based on the results, a quadratic mathematical model was created to describe the extraction process.

Conclusions/Discussion

Multiple extraction method was more effective than singular extraction with the same amount of solvent. Salt addition was also able to increase extraction yields. However, a high salt concentration resulted in both caffeine and salt being unable to dissolve back into the aqueous phase as exemplified when 2 g of salt was added. The sudden decrease in caffeine extraction in result of the oversaturation of the aqueous solution was excluded from the final mathematical model fitting. In accordance to the mathematical model, the optimized caffeine extraction process is with multiple extractions and a controlled amount of salt.

Summary Statement

A Liquid-Liquid Extraction model was constructed based on three study factors, solvent volume, extraction method, and salt concentration, to calculate and optimize the extraction percentage for extraction process.

Help Received

My teacher lent me equipment for the experiment and helped me order chemicals, my father supervised me during the duration of the actual experiment itself.