Liquid-Liquid Extraction Unit Operation
Introduction into ChE 415 Curriculum

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Figure 6. Johnson Hall at Oregon State University. LLE unit installed in John 214.

Objective:
Introduce Liquid-Liquid Extraction to Chemical Engineering Senior Lab

- Develop equilibrium distribution plot for ternary system of kerosene-acetic acid-water
- Install/Characterize Armfield UOP5-MKII Liquid-Liquid Extraction (LLE) Unit
- Develop Standard Operating Procedure and project assignment for use in ChE 415

Background:
Liquid-Liquid Extraction (LLE) is a unit operation that uses mass transfer as the driving force for separation. There are two solvents involved and a solute which is transferred from one to the other. In our case, this is a continuous process in which deionized water removes acetic acid that is initially mixed in kerosene.

F_S - feed solvent mass flow rate
x'_F - weight fraction of solute in feed solvent
x'_{Np} - weight fraction remaining in feed solvent
S_S - extract solvent mass flow rate
y'_S - weight fraction of solute initially in extract solvent
y'_1 - weight fraction in extraction solvent of solute

Mass Balance for solute: $x'_F F_S + y'_S S_S = x'_{Np} F_S + y'_1 S_S$

Operating line equation: $\frac{F_S}{S_S} = \frac{y'_1 - y'_S}{x'_F - x'_{Np}}$

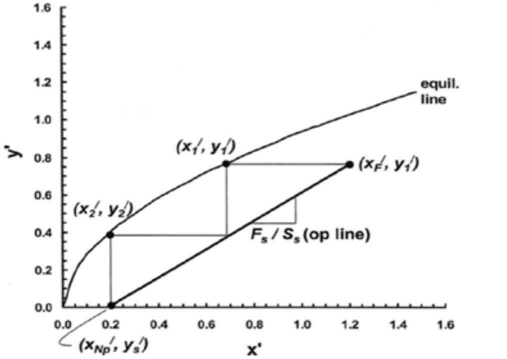

Figure 1. Stagewise continuous LLE – method of analysis for immiscible system. Diagram courtesy of Dr. Gregory Rorrer, OSU ChE 411

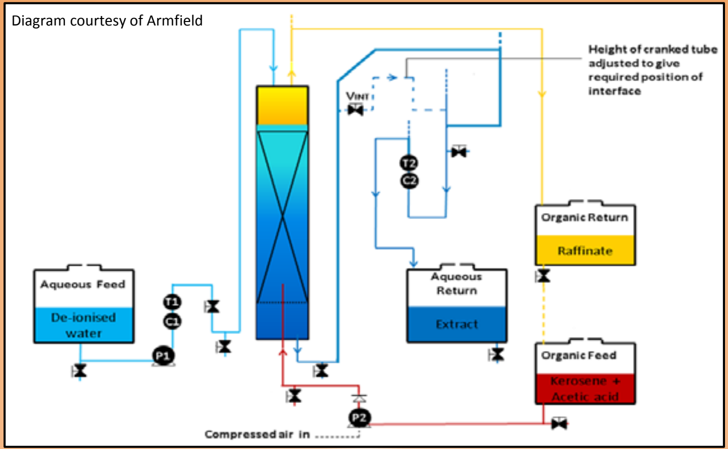

Figure 2. Process Flow Diagram obtained from Armfield Instruction Manual showing a continuous, counter-current flow process. DI water flows down and kerosene flows up the column due to differences in density. Concentration of acetic acid is measured at the DI water inlet and outlet by conductivity probes.

Figure 3. UOP5-MKII in Johnson Hall Laboratory. The unit included the extraction column, controller, and four reservoirs (feed, solvent, and two returns)

Figure 4. (Left) Snapshot at top of column, kerosene set at 80 mL/min. (Right) Snapshot at middle of column, kerosene set at 240 mL/min.

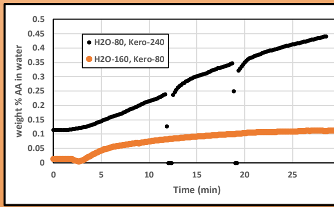

Figure 5. (Black) Weight percent of acetic acid in water vs time data collected from LLE unit. Kerosene flow at 80 mL/min, DI water flow at 160 mL/min. (Orange) Kerosene flow at 240 mL/min, DI water at 80 mL/min.

Student Deliverables
- Measure concentration of acetic acid removed
- Calculation of overall mass transfer coefficient ($K_L a$)
- Find number of theoretical stages
- Scale up of design to industrial size

Conclusions Thus Far:
- Using the system in the continuous aqueous phase (kerosene droplets) design yields the highest mass transfer of acetic acid
- Higher flow rates of non-continuous phase increase the mass transfer area by decreasing the droplet size and increasing the amount of droplets flowing through the column

Future Work:
- Collect and analyze multiple trials of experimental data
- Determine overall mass transfer coefficients ($K_L a$) as a function of flow
- Determine kerosene recycling feasibility
- Determine ranges of operating conditions (flow rates & concentrations)
- Revise Standard Operating Procedure and project assignment

Acknowledgements:
- Oregon State University, CBEE Department for the funding for our project
- John Cochran and Andy Brickman for their assistance in the installation of the LLE unit
- Ese Ono-Sorhue: Armfield Project development lead
- Dr. Philip Harding for his guidance