The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (3) | (0915561)

Liquid Liquid Extraction

Experiment Number (4)

short Report

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1. ABSTRACT

The liquid-liquid extraction experiment focuses on optimizing the separation of compounds from a model mixture using appropriate solvent systems. Key parameters such as solvent-to-sample ratio and extraction time are systematically varied to assess their impact on extraction efficiency. Analytical techniques are employed to quantify target compound concentrations in each phase, contributing to a comprehensive understanding of liquid-liquid extraction for potential applications in pharmaceuticals, environmental analysis, and biochemistry. The results aid in refining extraction protocols and designing scalable processes with improved selectivity and reduced environmental impact. The main result of this experiment is that in laminar flow, characterized by smooth fluid motion, the mass transfer coefficient (k) generally increases with an increasing liquid flow rate, and the concentration of benzoic acid in raffinate (Toluene) decreases as the water flow rate increases.

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2. RESULTS

Table 1:Raw Data

Conc. of aqueous NaOH (M)	0.025		
Conc. of ethanolic NaOH (M)	0.15		
Hight of Packing (m)	1.1		
Diameter of Packing (m)	0.05		
Area (m2)	0.0019625		
Volume of Sample (ml)	10		
Run	1	2	3
water flow rate (ml/min)	200	175	145
water flow rate (m^3/s)	0.0000033	0.0000029	0.0000024
volume of ethanolic NaOH for feed (ml)	5.6	5.6	5.6
volume of ethanolic NaOH for Raffinate (ml)	4.4	4.5	4.6
volume of aqeous NaOH for extract (ml)	1.5	1.7	1.9

Table 2:Concentration of benzoic acid in three samples

Conc. of benzoic acid in inlet water ($lbmol/ft^3$)	0	0	0
Conc. of benzoic acid in outlet water ($lbmol/ft^3$)	0.00023	0.00027	0.00030
Conc. of benzoic acid in Toluene feed ($lbmol/ft^3$)	0.0052	0.0052	0.0052
Conc. of benzoic acid in Raffinate Toluene ($lbmol/ft^3$)	0.00412	0.00421	0.00431
Eq. Conc. of inlet benzoic acid ($lbmol/ft^3$)	0.00147	0.00147	0.00147
Eq. Conc. of outlet benzoic acid ($lbmol/ft^3$)	0.00147	0.00147	0.00147
$\Delta C1$ inlet	0.00147	0.00147	0.00147
$\Delta C2$ out	0.00123	0.00120	0.00117
ΔCE	0.00135	0.00133	0.00131
Mass transfer coefficient (1/s)	0.00027	0.00027	0.00025

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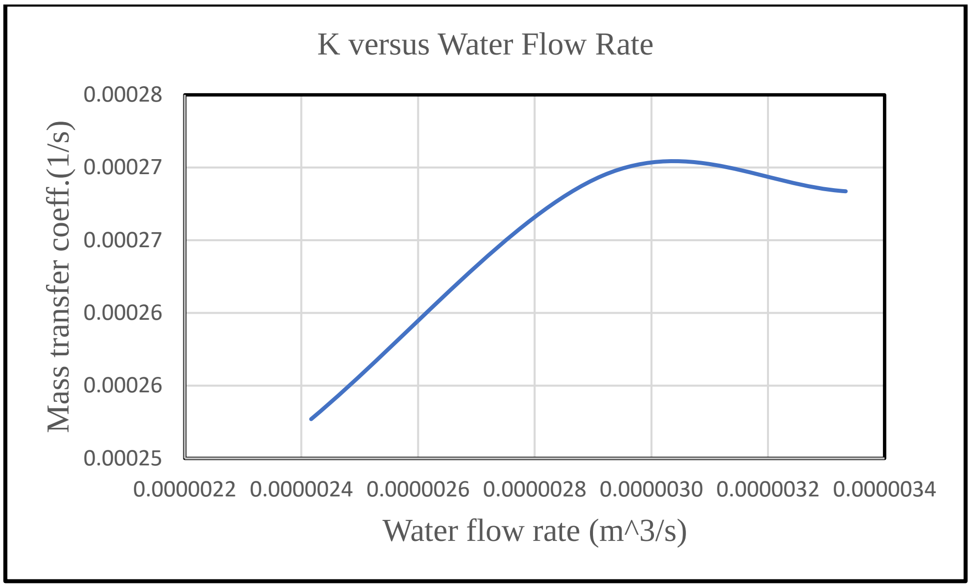

Figure 1:Mass transfer Coeff. k(1/s) versus Water flow rate

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3. DISCUSSION

This experimental investigation's main goal is to clarify how increased water flow rates affect the extraction process of benzoic acid. While the experimental data do not provide a clear explanation for the underlying processes, some trends become apparent, indicating a continuous decrease in the solvent's benzoic acid content throughout the experiment. This observed event supports our theory, which states that increasing the flow rate of water—which functions as the solvent in this case—will lead to a higher extraction rate of benzoic acid, based on Figure (1), as the water flow rate increases, k which is the mass transfer coefficient increases too.

However, if we look at the benzoic acid concentration with runs, Table(3) demonstrates that as the flowrate increased, the benzoic acid concentration decreased and there is no proof that the mass that is extracted is the cause of the decreased concentration, The primary reason is that the amount of water in the mixture dilutes the benzoic acid, which leads us to the importance of choosing the right solvent for extraction processes.

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4. CONCLUSION

By conducting this experiment on different water flow rates, we can conclude that:

- Since the lab's performance contained several errors that produced inaccurate data, it is very difficult to draw firm conclusions about how the flow rate impacted the toluene's overall benzoic acid removal efficiency.
- The mass transfer coefficient increases and the concentration of benzoic acid in raffinate (Toluene) decreases as the water flow rate increases.
- The solvent in a liquid-liquid extraction process must almost be taken out of the extract, raffinate, or both.
- A packed column leads to high extraction efficiency due to the high surface area that the packing makes.

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5. REFERENCES

- Separation process principles: chemical and biochemical operations / J. D. Seader, Ernest J. Henley, D. Keith Roper. —3rd ed.
- Chemical engineering laboratory “3” (0915561); University of Jordan; faculty of engineering and Technology; Department of Chemical engineering.

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6. APPENDIX

- Sample of calculation:

For run 1:

Conc. of aqueous NaOH (M) = 0.025

Conc. of ethanolic NaOH (M) = 0.15

Hight of Packing (m) = 1.1

Area (m^2) = 0.0019625

Water flow rate (ml/min) = 200

Water flow rate (m^3/s) = $\frac{\text{Water flow rate}\left(\frac{ml}{min}\right)*10^{-6}}{60} = \frac{200*10^{-6}}{60} = 0.0000033$

Volume of ethanolic NaOH for feed (ml) = 5.6

Volume of ethanolic NaOH for Raffinate (ml) = 4.4

Volume of aqueous NaOH for extract (ml) = 1.5

Conc. of benzoic acid in inlet water ($lbmol/ft^3$) = 0

- ✓ Conc. of benzoic acid in outlet water ($lbmol/ft^3$) (Cb1):

Cb1 = $\frac{\text{Conc.of aqueous NaOH (M)}*\text{Volume of aqueous NaOH for extract (ml)}*2.204*28.317}{10*1000} = 0.00023$

- ✓ Conc. of benzoic acid in Toluene feed ($lbmol/ft^3$) (Cb2):

Cb2 = $\frac{\text{Conc.of ethanolic NaOH (M)}*\text{Volume of ethanolic NaOH for feed (ml)}*2.204*28.317}{10*1000} = 0.0052$

- ✓ Conc. of benzoic acid in Raffinate Toluene ($lbmol/ft^3$) (Cb3):

Cb3= $\frac{\text{Conc.of ethanolic NaOH (M)}*\text{Volume of ethanolic NaOH for Raffinate (ml)}*2.204*28.317}{10*1000} = 0.00412$

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From Chart:

Eq. Conc. benzoic acid (lbmol/ft³) = -0.0167 C^2 + 0.8763 C + 1.463

Where C is the Conc. benzoic acid.

- ✓ Eq. Conc. of inlet benzoic acid (lbmol/ft³):

Eq. Conc. benzoic acid (lbmol/ft³) = -0.0167* 0.0052^2 + 0.8763C*0.0025 + 1.463 =0.00147

- ✓ Eq. Conc. of outlet benzoic acid (lbmol/ft³):

Eq. Conc. benzoic acid (lbmol/ft³) = -0.0167* 0.00412^2 + 0.8763C*0.00412 + 1.463 =0.00147

- ✓ ΔC1 inlet:

ΔC1= Eq. Conc. of inlet benzoic acid (lbmol/ft³) - Conc. of benzoic acid in inlet water (lbmol/ft³)

ΔC1= 0.00147 -0 = 0.00147 lbmol/ft³

- ✓ ΔC2 out:

ΔC2= Eq. Conc. of outlet benzoic acid (lbmol/ft³)- Conc. of benzoic acid in outlet water (lbmol/ft³)

ΔC2= 0.00147 -0.00032 = 0.00123 lbmol/ft³

- ✓ ΔCE:

ΔCE= $\frac{\Delta C1 - \Delta C2}{\ln\left(\frac{\Delta C1}{\Delta C2}\right)} = \frac{0.00147 - 0.00123}{\ln\ln\left(\frac{0.00147}{0.00134}\right)}$ = 0.00135 lbmol/ft³

- ✓ Mass transfer coefficient (K) (1/s):

$$= \frac{\text{water flow rate}\left(\frac{m3}{s}\right) * (\text{Conc.of benzoic acid in outlet water} - \text{Conc.of benzoic acid in inlet water})\left(\frac{lbmol}{ft3}\right)}{CE * Area * Hight\ of\ packing}$$

$$= \frac{0.0000033 * (0.00023 - 0)}{0.00135 * 0.0019625 * 1.1} = 0.00027\ \ 1/s$$

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