Zaiput Flow Technologies

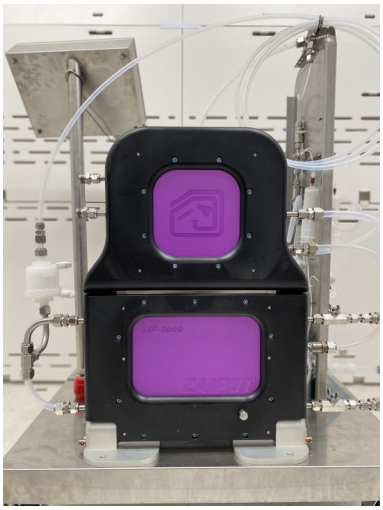
Separation made simple

ZFOX Extraction Platform

Solving the most challenging extraction problems

Sizing Guide

Overview



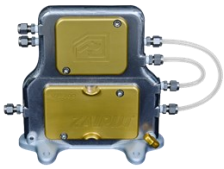
Liquid-liquid extraction (LLE) brings together mass transfer and phase separation to selectively remove substrates from one phase to the other. Traditionally, this is done in reactor vessels by mixing two phases together with an impeller for extended periods of time before allowing them to gravity separate. This, however, brings a host of inefficiencies including slow & unpredictable separation times, loss of reactor productivity, limited numbers of extractions and safety concerns for some compounds.

With Zaiput's Z-FOX extraction system, all of these worries are in the past. By coupling engineered mass transfer with in-line membrane driven phase separation, extractions can now be carried quickly, safely, and outside of a reactor -opening up more space to make your product. This guide can be used to properly size your extraction platform—made up of two primary components, a separator and mass transfer tubing

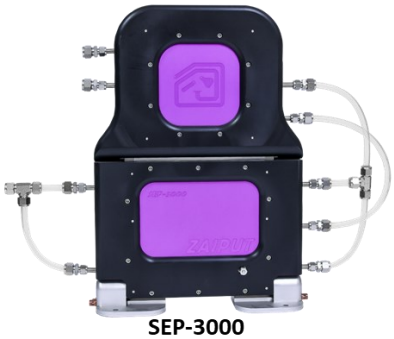
Separator Sizing

Sizing your membrane separator is an easy task as Zaiput has already determined the scaling. The proper device is based on your flow rate range— see the options below to find the right separator for you. These values are nominal based on a typical system, some systems will be able to operate at higher flow rates, while others at lower flow rates.

SEP-10



SEP-200



SEP-3000

Coming Soon

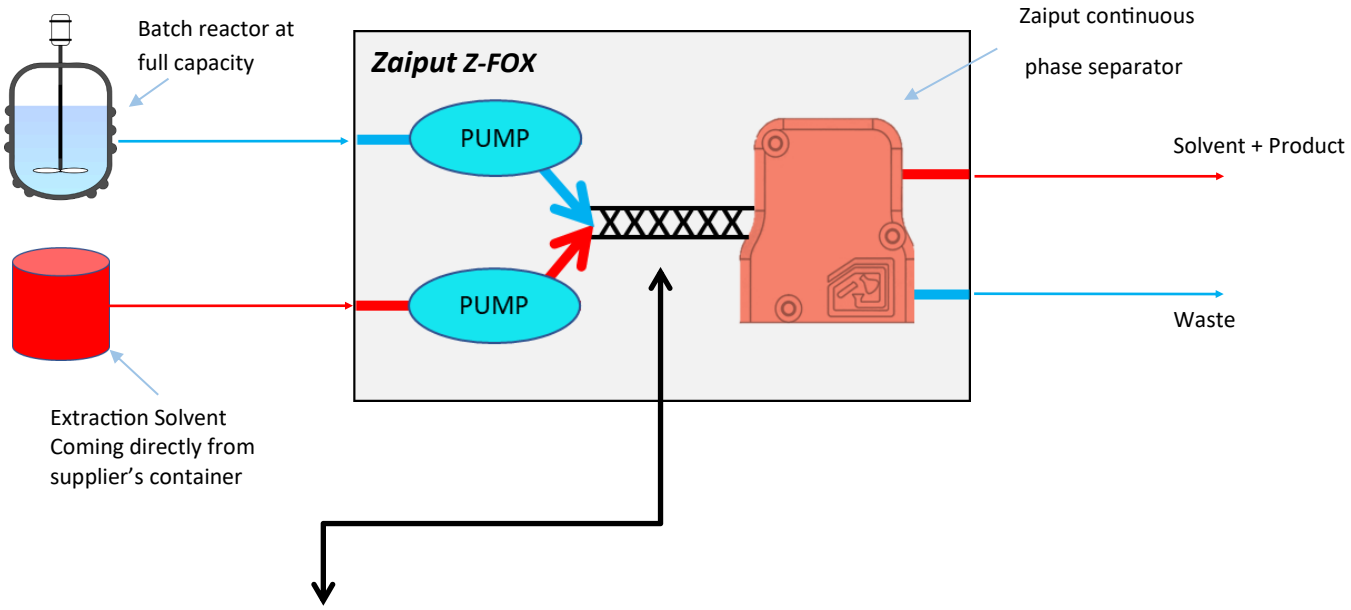
10 ml/min | 200 ml/min | 3,000 ml/min | 40,000 ml/min

The flow rate used with the lab device can be scaled to pilot with a 20X scaling factor, and to production with an additional 15X). For more information regarding the separator mechanism of separation, please visit www.zaiput.com or contact your Zaiput representative.

Batch Extraction

Quick Sizing of mass transfer for your application

To quickly size the mass transfer part of your Liquid-liquid extraction we have developed a model* that allows us to predict the number of static mixers and amount of residence time needed to reach complete equilibrium for any given system. We have used this model to generate a quick sizing procedure together with plots to make this process very fast and easy. This model has been extensively validated through experimentation to ensure accuracy.

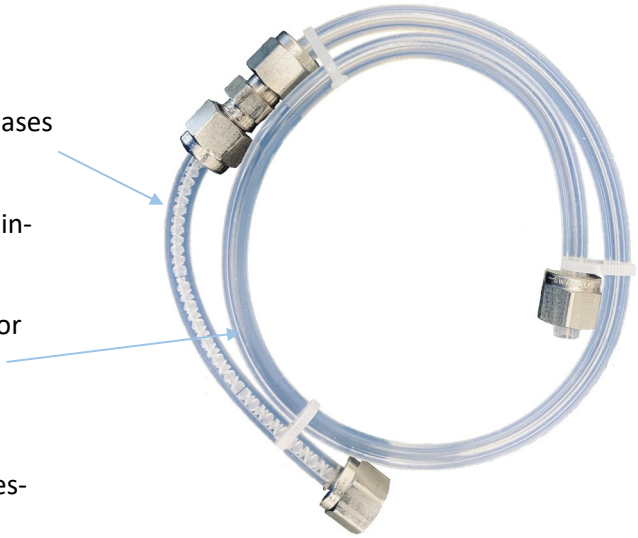


Engineered Mass Transfer

Sizing your application in 5 minutes:

Modular Mixing Unit

- Static Mixers foster mixing/ breakup of the immiscible phases into droplets.
- Diffusion driven Mass Transfer takes place at the droplet interface*
- Additional Tube length provides residence time needed for the mixed phases to reach equilibrium.



Modular Mixing Unit

The "Modular Mixing Unit" is repeated 1-5 times to prevent coalescence and ensure equilibrium is reached for your specific case.

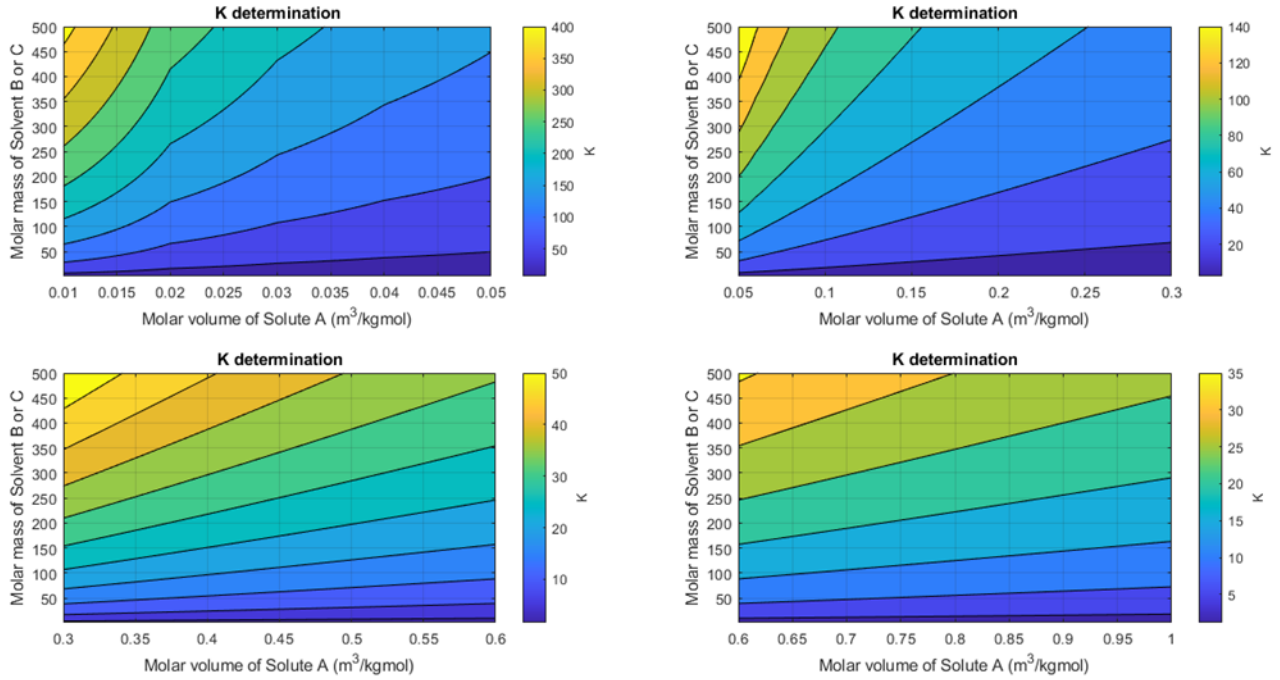
The number of "units" needed for equilibrium can be determined with the instructions on the next page by using the molar mass of the solvents, viscosity of the solvents, and molar volume of the solute (molar volume = molar mass/ density).

** Full details of the Mass Transfer model can be found on a whitepaper available on our website www.zaiput.com or from your Zaiput representative.*

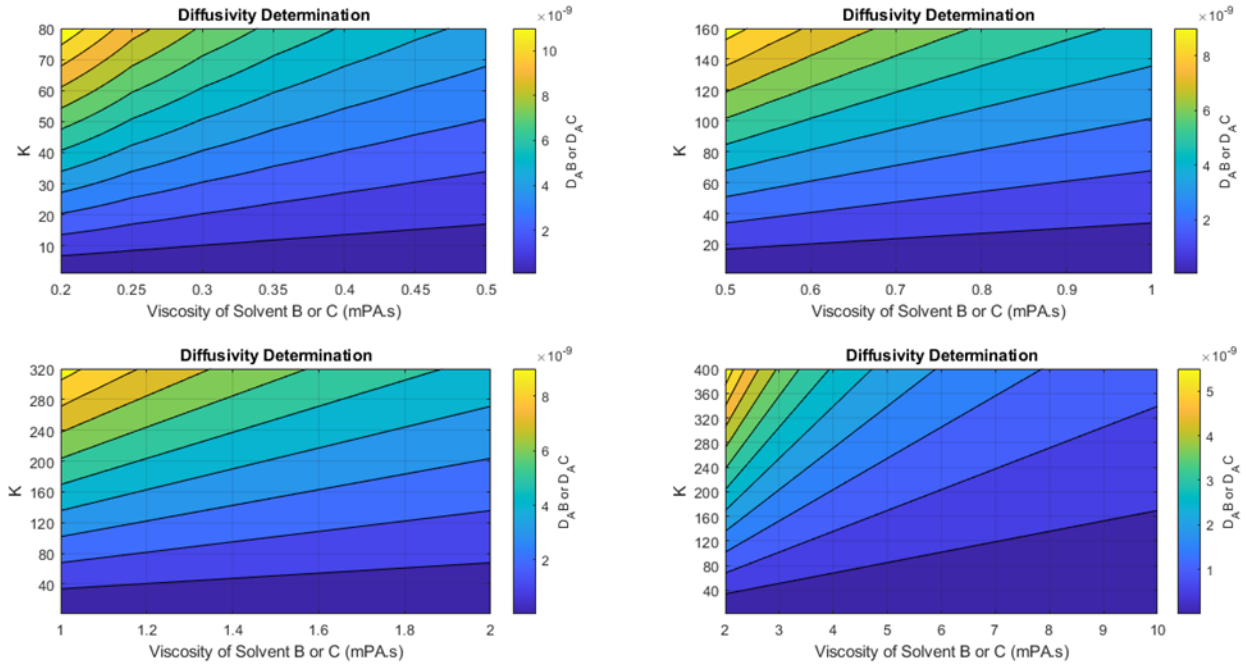
Determining number of Mass Transfer Units

Follow the steps to determine how many mixing units you need for your case. For a solute A present in liquid B that is being extracted with liquid C:

1. Determine the approximate value of parameter K for the solute in the phase B using the charts below. Different charts correspond to different ranges of values of Molar volume of A.



2) Determine the diffusivity of your solute in B using the viscosity of B and the parameter K .

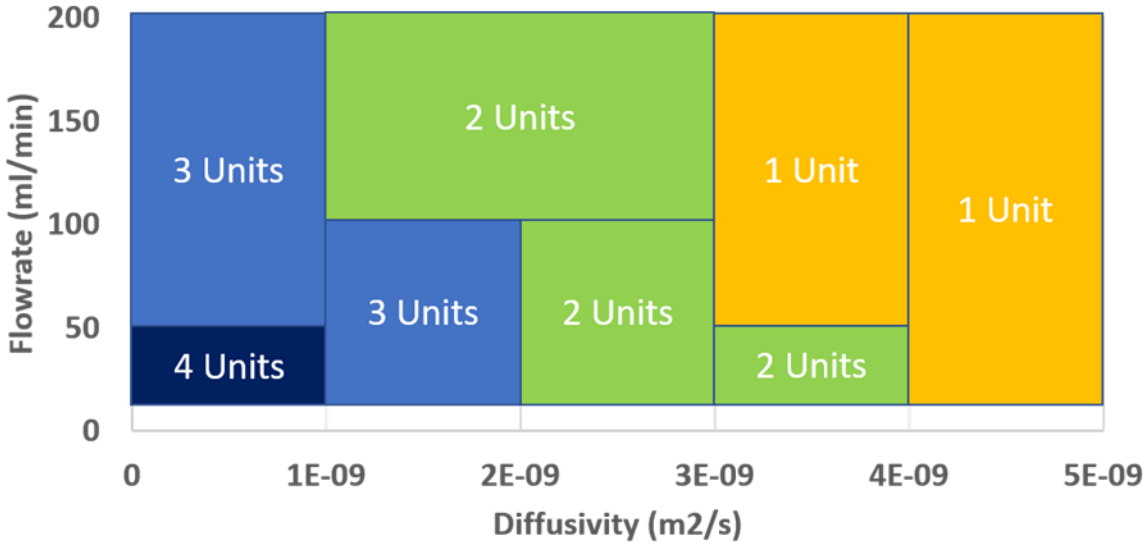


3) Repeat Steps 1 & 2 for solute A in liquid C.

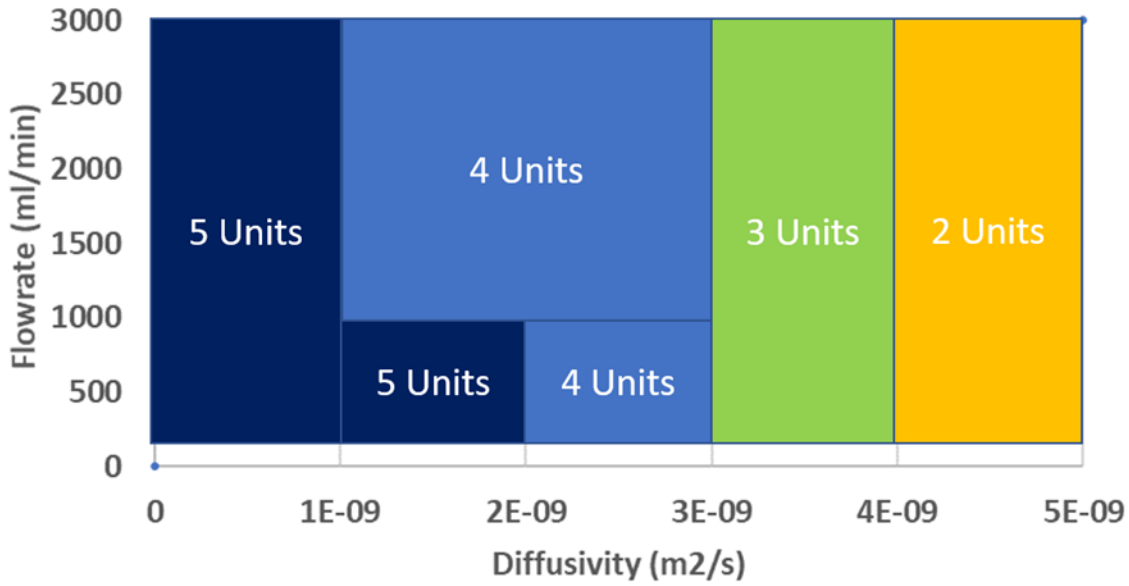
Determining number of Mass Transfer Units

4) Take a weighted average (weighted by phase ratio) of the two diffusivities to estimate the effective diffusivity.

5) Using the effective diffusivity and your total flow rate, determine how many "modular mixing units" you need for your case using the tables below. Each table refer to a different device scale.



This chart allows determination of the number of Modular Mixing Units needed for assigned Effective Diffusivity and flow rate. This chart refers to an application at the SEP-200 scale with 1/4" OD - 1/8" ID tubing with a 5" of Kenics Static Mixer.



This chart allows determination of the number of Modular Mixing Units needed for assigned Effective Diffusivity and flow rate. This chart refers to an application at the SEP-3000 scale with 1/2" OD - 3/8" ID tubing with a 8" of Kenics Static Mixer.

Ordering Information

Modular Mixing Unit

Zaiput offers ready Modular Mixing Units for your applications. Based on the size of the separator and findings from our sizing guide you can selected the aprt number that fits your needs

MMU-XXX- XX i.e.: MMU-200-FP

Device size

- 200 = SEP-200 scale
- 3000 = SEP-3000 scale

Material

- PP = Polypropylene
- FP = PTFE
- SS = Stainless Steel 316

Contact us if you need assistance with your application

Contact

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- **Zaiput Flow Technologies**, an MIT spin-out, is focused on bringing innovative separation technology and related tools to market.
- We are looking forward to assist you with your questions, support needs, or to discuss your application.

ZAIPUT

Selected Publications

70+ Publications

PNAS MIT Technology Review nature Science

- Weeranoppanant, N., Adamo, A., Saparbaiuly, G., Rose, E., Fleury, C., Schenkel, B., Jensen, K, Design of Multistage Counter-Current Liquid–Liquid Extraction for Small-Scale Applications ***Ind. Eng. Chem. Res.*** Apr 2017.
- Shen, Y, Weeranoppanant, N., Xie, L., Chen, Y, Lusardi M., Imbrogno J., . Bawendi, M., Jensen, K., Multistage extraction platform for highly efficient and fully continuous purification of nanoparticles ***Nanoscale*** Mar 2017.
- Peer, M., Weeranoppanant, N., Adamo, A., Zhang, Y., Jensen, K., Biphasic catalytic hydrogen peroxide oxidation of alcohols in flow: Scale up and extraction ***Org. Process Res. Dev.*** Aug 2016.

Contact

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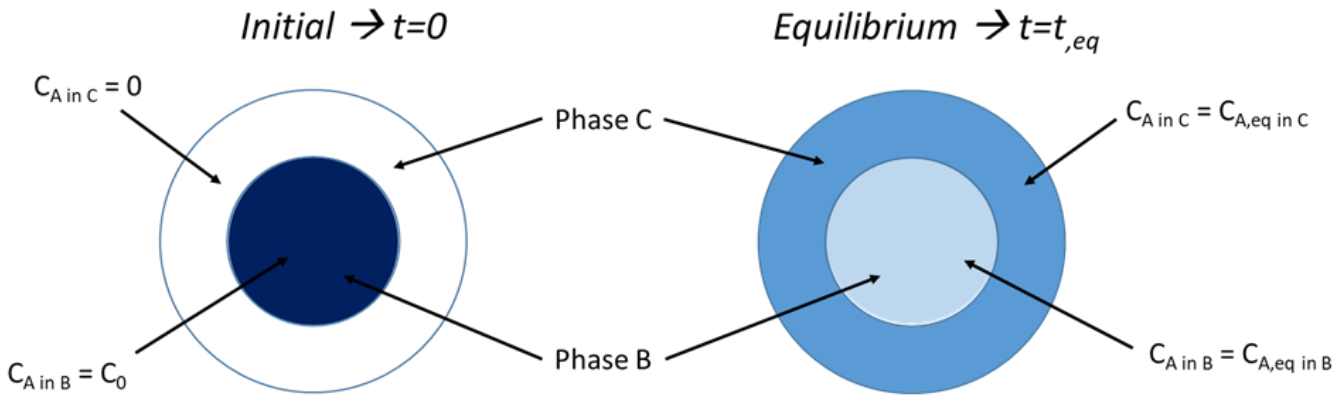
Mass Transfer Sizing

In liquid-liquid extraction, mass transfer is driven by difference in chemical potential to reach a more stable condition with lower free energy (chemical equilibrium). Diffusion of solutes is the most important principle in this mass transfer and as such we have built our model based on the diffusion rate of the solute within the solvents.



To speed up mass transfer for LLE in flow, static mixers are utilized to cause droplet breakup of the two immiscible phases. The increase in mass transfer with static mixers rate comes from a reduced length sale and increased interfacial area. Static mixers can be alternated with sections of empty tubing to enable high mass transfer rates with minimal coalescence, while reducing the cost of static mixers. The goal is to include enough static mixer length so that the system is no longer length scale limited but now diffusion limited. Based on diffusivity and flow rates, the number of static mixers + empty tubing (1 mass transfer unit) needs to be repeated up to 5 times.

Tubing Sizing

It is recommended that for flow rates up to 200 mL/min, a 1/4" OD 1/8" ID tubing section be used and for flow rates above 200 mL/min a 1/2" OD 3/8" ID tubing section be used. For each of these scales, 10-12 units of Kenics static mixers will provide sufficient droplet breakup for rapid mass transfer. The total length of static mixers can be found in the table below. The static mixers are followed by empty tubing for mass transfer and the length is also in the table below.

The number of mass transfer units required for a given extraction is based on the effective diffusivity of the solvent in each of the two phases and the flow rate of each phase. Effective diffusivity can be calculated with the molar mass of the solvents, viscosity of the solvents, and molar volume of the solute (molar volume = molar mass/ density). Please follow the charts on the upcoming pages to determine effective diffusivity and thus the number of mass transfer units necessary.

Device	SEP-10	SEP-200	SEP-3000
Flow Rate (ml/min)	0-10	10-200	200-3000
Tubing Size (OD)	1/16"	1/4"	1/2"
Mixer Length	(no mixers)	4-5"	8"
Mass Transfer Tubing length	79"	19-20"	28"