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Separation and Purification Technology 41 (2005) 237–266

Separation and Purification Technology

www.elsevier.com/locate/seppur

Review

Recovery and separation of organic acids by membrane-based solvent extraction and pertraction☆
An overview with a case study on recovery of MPCA

Š. Schlosser*, R. Kertész, J. Marták

Department of Chemical and Biochemical Engineering, Slovak University of Technology, Radlinského 9, 81237 Bratislava, Slovakia

Received 20 October 2003; received in revised form 14 July 2004; accepted 16 July 2004

Abstract

Various possibilities of the application of membrane-based solvent extraction (MBSE) and pertraction in recovery and separation of organic acids, and in biotransformations are discussed. A short overview of the subject literature is presented. Factors, which have to be considered in the development of MBSE application, will be discussed. Hybrid processes employing MBSE will be covered as well. Mass-transfer characteristics of hollow fiber contactors for MBSE of organic acids are presented. The kinetics of formation and decomposition of the permeant–extractant complex may influence greatly the mass-transfer rate and should be taken into account in modelling. A case study on recovery of 5-methyl-2-pyrazinecarboxylic acid (MPCA) by simultaneous MBSE and membrane-based solvent stripping shows potential of this process. Optimised process parameters for MPCA are suggested on bases of simulations. Outlook for future applications of HF contactors in extraction separations is discussed and potential for progress is envisaged, especially for higher value acids and integrated or hybrid reaction-separation systems.

Keywords: Recovery; Separation; Organic acids; 5-Methyl-2-pyrazinecarboxylic acid; Solvents; Liquid membranes; Membrane-based solvent extraction; Membrane-based solvent stripping; Pertraction; Hollow fiber contactors; Simulation

Contents

☆ Presented in part at the membrane science and technology conference PERMEA 2003, Tatranské Matliare, Slovakia, September 7–11, 2003 (http://sschi.chtf.stuba.sk/permea/).
* Corresponding author. Tel.: +421 2 524 96743; fax: +421 2 524 96920.
E-mail address: schlosser@cvt.stuba.sk (Š. Schlosser).

1383-5866/$ – see front matter
doi:10.1016/j.seppur.2004.07.019

Nomenclature

A	surface area (m^2)
A_w	arithmetic mean value of the inner and outer geometric surface areas of fibers (m^2)
c	molar concentration of the solute (undissociated acid or acid in the complex) ($mol\,m^{-3}$)
D	distribution coefficient (–)
k	individual mass-transfer coefficient ($m\,s^{-1}$)
K_e	overall mass-transfer coefficient in the extractor ($m\,s^{-1}$)
K_s	overall mass-transfer coefficient in the stripper ($m\,s^{-1}$)
$\dot{n}$	molar flux ($mol\,s^{-1}$)
N_{cs}	number of contactors in series (–)
N_{ct}	total number of contactors (both in parallel and series) (–)
r_e	rate constant of the extraction reaction, Eq. (3) ($m\,s^{-1}$)
r_s	rate constant of the stripping reaction, Eq. (4) ($m\,s^{-1}$)
R	overall mass-transfer resistance ($s\,m^{-1}$)
Re	Reynolds number (–)
u	linear velocity of the flow ($m\,s^{-1}$)
$\dot{V}$	volumetric flowrate ($m^3\,s^{-1}$)
$Y_{MA/OA}$	ratio of mineral acid to organic acid flux (–)
Z	concentration factor of the solute in the concentrate (output from the stripper) defined by relation $Z = c_{R,n+1}/c_{F1}$ (–)
β_{n+1}	concentration ratio $\beta_{n+1} = c_{S,n+1}/c^*_{S,n+1}$ (approach to an equilibrium on the raffinate end of the contactor in MBSE, $c^*_{S,n+1} = D_F c_{F,n+1}$) (–)
ε	porosity of the wall (–)
η_e	yield of the solute in extraction (–)
η_{conv}	conversion of the reagent in the stripping solution (–)

Subscripts

0	initial value
1	feed or stripping solution inlet end of a HF contactor or a series of contactors
2	raffinate or stripping solution outlet end of a HF contactor or a series of contactors
b	boundary layer in the bulk phase
e	extractor (MBSE)
F	feed phase, feed boundary layer
i	inner surface of the fiber wall
n	number of the contactor segments
o	outside surface of the fiber wall
R	stripping solution; stripping interface
s	stripper (MBSS)
S	solvent phase, boundary layer in the solvent
w	fiber wall

Abbreviations

6-APA	6-aminopenicillanic acid
AOT	sodium di(2-ethylhexyl)sulfosuccinate (anionic surfactant)
BLM	bulk liquid membrane
CF HF	cross-flow hollow fiber contactor
D2EHPA	di(2-ethylhexyl)phosphoric acid
DLC	double Lewis cell with layered BLM
DNNSA	dinonylnaphtalenesulfonic acid
EC	equilibrium cell for contacting two liquids
ELM	emulsion liquid membrane
EXT	solvent extraction
FSC	flat sheet contactor
HF	hollow fiber
MBSE	membrane-based solvent extraction
MBSS	membrane-based solvent stripping
MHS	multimembrane hybrid system (LM between two ion-exchange membranes)
MIBK	methylisobutylketone