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Manfred Raff

Mass Transfer Models in Membrane Processes

Applications in Artificial Organs

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Preface

The scientific focus of my professional life is membrane technology. It started 1976 at University of Stuttgart, Germany, with a cooperative project between university, nephrology and industry, during which I developed a prototype of a new dialysis machine, which should be steam sterilisable, to be used with a car battery and avoid leakages in piston pumps.

As an employee of Gambro Dialyzers, Germany (since 2012 Baxter), between 1982 and 1991, I was involved in research, development and production of membranes and modules for kidney and liver dialysis, plasmapheresis and oxygenation.

Between 1991 and 2014, I worked as Professor at Furtwangen University, first in the "Department of Process Engineering", and later as Dean of the faculties "Mechanical and Process Engineering" and "Medical and Life Sciences". In cooperation with industry, during that time I carried out various membrane projects and offered the topic of membrane processes in elective and compulsory lectures in the bachelor and master education. Since 2014, I am retired but still working for 2 further years as Assistant Professor at the Cooperative State University Stuttgart (lecture: "process engineering") and for further 4 years at Furtwangen University (lecture: "artificial organs").

I would like to express my sincere thanks to the companies Baxter and Fresenius for their support with literature, brochures and pictures for this book. Many thanks also to all scientists and publishers, supporting me by the permission to reprint figures from their publications.

And last but not least, I would especially thank my wife Monika for always actively supporting me in living my professional dreams.

Bisingen, Germany Manfred Raff

Contents

Symbols

A^m	Membrane surface area (m^2)
A^s	Surface of polymer particles (m^2)
A^g	Cross section of membrane pore (m^2)
A_q	Cross section of flow channel (m^2)
c	Concentration (g/l)
Δc_m	Mean logarithmic concentration difference (g/l)
Cl	Clearance (ml/min)
d_i	Inner diameter of a hollow fibre membrane (m)
d_h	Hydraulic diameter (m)
d_E	Equivalent diameter (m)
D	Diffusion coefficient (m^2/s)
E	Enhancement factor
f	Free fraction of a component in the plasma
He	Henry coefficient (Pa)
k	Boltzmann constant ($= 1.381 \cdot 10^{23}$ kg $\cdot$ $m^2/(K \cdot s^2)$)
K_0	Overall mass transfer coefficient (m/s)
K_A	Equilibrium constant (M^{-1})
L_{eff}	Length of the hollow fibre membranes between the potting (m)
L_p	Hydraulic permeability (m/(s $\cdot$ Pa))
$\check{M}$	Molar mass (g/mol)
$\dot{m}$	Mass flow density (kg/s/m^2)
$\dot{M}$	Mass flow (kg/s)
N	Number of hollow fibre membranes in the module
p	Pressure (Pa)
P_i^m	Diffusive permeability of comp. i in the membrane (m/s)
Q	Volume flow (ml/min)
r_i	Molecular radius of comp. i (m)
R_i	Rejection coefficient of comp. i
R^b	Mass transfer resistance of blood boundary layer (s/m)
R^d	Mass transfer resistance of dialysate boundary layer (s/m)