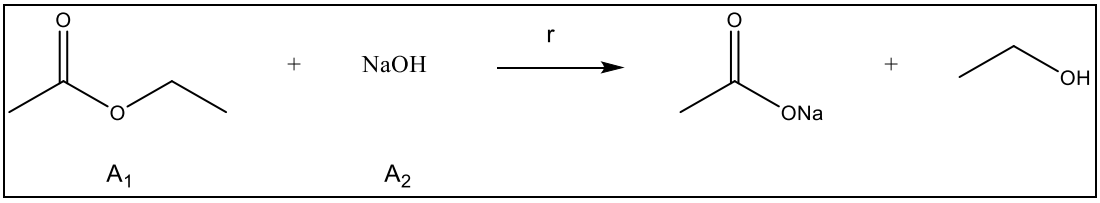
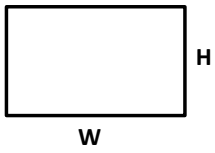
Exercise 18

It is planned to carry out the liquid-phase hydrolysis of ethyl acetate in a square microchannel.



Data

Channel geometry: $H = W$



Rate constants as a function of temperature:

$T\ (K)$	303	323	343
$k\ (m^3 mol^{-1} s^{-1})$	$1.90\ 10^{-4}$	$5.80\ 10^{-4}$	$1.60\ 10^{-3}$

Rate equation: $r = kc_1c_2$

Initial concentrations: $c_{10} = c_{20} = 400\ mol \cdot m^{-3}$

Desired conversion of ethyl acetate: $X = 90\%$

Diffusion coefficient: $D_m = 10^{-9}\ m^2 \cdot s^{-1}$

Questions

1. For each temperature, calculate the channel height required to avoid the influence of mass transfer supposing stratified flow ($Re < 10$)
2. For each temperature, calculate the space-time required to reach the specified conversion assuming plug-flow behavior

Solution

Maximum mixing time for negligible effect of segregation: $t_{mx} = 0.1 \cdot t_r$

Hydraulic diameter ($H = W$): $d_h = 4\frac{\text{cross-sectional area}}{\text{perimeter}} = 2\frac{HW}{(H+W)} = 2\frac{H^2}{2H} = H$

$t_{mx} = t_{diff} = A\frac{\left(\frac{d_h}{2}\right)^2}{D_m} = A\frac{\left(\frac{H}{2}\right)^2}{D_m}$ with $A = \frac{1}{3} \rightarrow H = \sqrt{\frac{4D_m t_{mx}}{A}} = \sqrt{12 D_m t_{mx}} = \sqrt{1.2 D_m t_r}$

PFR with 2nd order kinetics: $DaI = \frac{\tau}{t_r} = \frac{X}{1-X} = 9$

$\tau = DaI \cdot t_r$

A	0.33		
DaI	9.0		
T (K)	303	323	343
k (m^3/mol s)	1.90E-04	5.80E-04	1.60E-03
tr (s)	13.2	4.3	1.6
tmx (s)	1.32	0.43	0.16
H (m)	1.26E-04	7.19E-05	4.33E-05
H (um)	125.7	71.9	43.3
Tau (s)	118.4	38.8	14.1