

Exercise 15

The Villermaux-Dushman protocol was used to characterize the mixing in a circular micro-channel.

Experimental data

Flowrate (ml/min)	4	6	8	10	12
Absorbance (-)	0.623	0.463	0.355	0.320	0.258

Physical properties and geometric factors

Temperature: $T = 298\text{ K}$

Kinematic viscosity: $\nu = 10^{-6}\text{ m}^2 \cdot \text{s}^{-1}$

Concentration set used: 2b

Optical path length: $l = 10\text{ mm}$

Micro-channel diameter: $d_t = 0.5\text{ mm}$

Equal volumetric flowrates of both solutions

Questions

For each of the experimental data, calculate:

- The segregation index
- The power dissipation
- The mixing time

Plot the mixing time as function of the power dissipation.

Compare the $t_{mx} = f(\varepsilon)$ data with the general relationships found for micromixers.

Solution

Procedure:

1. $K_B = 10^{\left(\frac{555}{T} + 7.355 - 2.575 \log_{10} T\right)}$
2. $c_{I_3^-} = \frac{A}{\varepsilon_{353} l} [\text{mol} \cdot \text{m}^{-3}]$ with $\varepsilon_{353} = 2606\text{ m}^2 \text{mol}^{-1}$
3. $-\frac{5}{3} c_{I_2}^2 + \left(c_{I^-,0} - \frac{8}{3} c_{I_3^-}\right) c_{I_2} - \frac{c_{I_3^-}}{K_B} = 0 \rightarrow c_{I_2} = \frac{-\left(c_{I^-,0} - \frac{8}{3} c_{I_3^-}\right) + \sqrt{\left(c_{I^-,0} - \frac{8}{3} c_{I_3^-}\right)^2 - 4 \cdot \frac{5}{3} \frac{c_{I_3^-}}{K_B}}}{-2 \cdot \frac{5}{3}}$
4. $Y = \frac{4(c_{I_2} + c_{I_3^-})}{c_{H^+,0}}$
5. $Y_{CS} = \frac{6c_{IO_3^-,0}}{6c_{IO_3^-,0} + c_{H_2BO_3^-,0}}$
6. $X_S = \frac{Y}{Y_{CS}}$
7. $t_{mx} = 0.33 A' c_{H^+,0}^{-4.55} c_{I^-,0}^{-1.5} c_{IO_3^-,0}^{5.8} c_{NaOH,0}^{-2} c_{H_3BO_3,0}^{-2}$ where $A' = \frac{A}{l}$

8. $\varepsilon = \frac{32 \cdot v \cdot u_m^2}{d_t^2}$ (circular channel)

c_I-, 0	1.60E-02	mol/l
c_H+, 0	3.00E-02	mol/l
c_IO3-, 0	3.00E-03	mol/l
c_H2BO3-, 0	4.50E-02	mol/l
c_NaOH, 0	4.50E-02	mol/l
Kc	7.02E+02	
Ycs	2.86E-01	

Flowrate (ml/min)	4	6	8	10	12
A	0.623	0.463	0.355	0.32	0.258
c_I3- (mol/l)	2.39E-05	1.78E-05	1.36E-05	1.23E-05	9.90E-06
c_I2 (mol/l)	2.14E-06	1.59E-06	1.22E-06	1.10E-06	8.83E-07
Y	3.47E-03	2.58E-03	1.98E-03	1.78E-03	1.44E-03
Xs	1.22E-02	9.03E-03	6.92E-03	6.24E-03	5.03E-03
A'	6.23E-02	4.63E-02	3.55E-02	3.20E-02	2.58E-02
tmx (s)	0.049	0.036	0.028	0.025	0.020
u (m/s)	0.34	0.51	0.68	0.85	1.02
eps (W/kg)	14.8	33.2	59.0	92.2	132.8

