

reaction, Y_C , and consequently the final selectivities, X , defined by equation (10.9), are higher in the first mixer. Considering these results and the fact that the mean residence time in mixer **I** is 2.3 times longer than in mixer **II** for the same values of Re and a , one can conclude that mixture in the second mixer is more homogeneous (less segregated) than in the first one. This results from the fact that distribution of the rate of deformation of fluid elements in the system is more uniform in mixer **II** than in mixer **I**, where mixing of reactants streams takes place mainly at the end of the mixer.

Table 10.IIIc presents results of computations performed for mixer **I**, for the same value of the mean residence time as in mixer **II**. To obtain equal values of the mean residence time Reynolds number was set to 2.3 in mixer **I**. Again one can see that mixing in the second reactor is better, because for the same mean residence time the

Table 10.IIIc. Conversions and selectivities in competitive-parallel reactions; mixer I, $Re=2.3$, $Sc=1000$, $\bar{Da}=1000$, $\dot{N}_{A0}=\dot{N}_{B0}=\dot{N}_{C0}$.

a	Y_A [%]	Y_B [%]	Y_C [%]	X [%]
9	10.31	9.81	0.50	4.87
19	9.42	8.62	0.80	8.52
49	8.57	7.45	1.12	13.03
99	8.02	6.79	1.24	15.44

conversions of the limiting substrate, Y_A , are approximately 40% lower in mixer **I** than in mixer **II**. Smaller conversion in the first system results also in smaller selectivity than in the second system. However, a comparison of selectivities obtained in both reactors does not say much about the quality of mixing in both systems. The selectivity can be applied as a measure of mixing efficiency only for the systems with the same degree of conversion of the substrate remaining in stoichiometric deficiency.

The above results can be useful for design and determination of operating conditions of chemical reactors when one has to avoid side reactions leading to excessive consumption of the main substrate or producing impurities lowering quality of the final product.

10.3. Degrees of Segregation.

The common definition of the degree of segregation [8,9] is based on the distribution of dimensionless concentrations of non-reacting species $f_A=c_A/c_{A0}$ and $f_B=c_B/c_{B0}$ (usually $f_B \cong 1 - f_A$)

$$I_S = \frac{\overline{(f_A')^2}}{\bar{f}_A \cdot (1 - \bar{f}_A)} = \frac{\overline{(f_B')^2}}{\bar{f}_B \cdot (1 - \bar{f}_B)} = -\frac{\overline{f_A' \cdot f_B'}}{\bar{f}_A \cdot \bar{f}_B} = 1 - \frac{\overline{f_A \cdot f_B}}{\bar{f}_A \cdot \bar{f}_B}. \quad (10.12)$$

Table 10.IV presents the values of I_s obtained for mixer I and II by averaging over the entire volumes of the reactors contained within interval $0 \leq z/d \leq 1.5$ (Volume) and over outlet surfaces $z=1.5 \cdot d$ (Outlet). Data presented in this table show

Table 10.IV. I_s ; Re=1, Sc=1000.

a	Volume		Outlet	
	Mixer I	Mixer II	Mixer I	Mixer II
9	0.8073	0.7921	0.5914	0.5887
19	0.7552	0.7360	0.4658	0.4637
49	0.6590	0.6391	0.2782	0.2757
99	0.5703	0.5598	0.1634	0.1593

that increasing volume ratio decreases the degree of segregation in the systems, which is quite opposite to the results obtained for the competitive-parallel reactions (tables 10.III) and reveals the weakness of definition outlined in equation (10.12) to characterize the course of complex reactions.

Another possibility is to relate the definition of intensity of segregation to the process considered using, however, the local concentrations of passive tracers. For example for the reaction $A + B \rightarrow P$ the intensity of segregation based on knowledge of the passive tracer concentration can include stoichiometry of the reaction considered

$$I_{SR} = \frac{f_A \cdot (\eta \cdot \bar{f}_B + \bar{f}_A) - \bar{f}_A}{2 \cdot \bar{f}_A \cdot \bar{f}_B} - \frac{\eta - 1}{2} = \frac{f_A \cdot [\eta \cdot (1 - \bar{f}_A) + \bar{f}_A] - \bar{f}_A}{2 \cdot \bar{f}_A \cdot (1 - \bar{f}_A)} - \frac{\eta - 1}{2}, \quad (10.13)$$

where η denotes the global stoichiometric ratio of reactants (in our case $\eta = \dot{N}_{A0}/\dot{N}_{B0}$). Degree of segregation calculated from expression (10.13) is equal to that obtained from Käppel definition [87] in the specific case when $\eta=1$. Table 10.V presents values of I_{SR} computed for three different global stoichiometric ratios.

Table 10.V. I_{SR} ; mixer I, Re=1, Sc=1000.

a	Volume			Output		
	$\eta=0.5$	$\eta=1$	$\eta=2$	$\eta=0.5$	$\eta=1$	$\eta=2$
9	0.9731	0.9678	0.9625	0.8777	0.8434	0.8082
19	0.9736	0.9691	0.9644	0.8854	0.8578	0.8294
49	0.9760	0.9720	0.9673	0.8932	0.8707	0.8477
99	0.9772	0.9733	0.9696	0.8971	0.8772	0.8572

As it can be seen, the effect of volume ratio on I_{SR} is similar to that observed for conversion in an instantaneous reaction and selectivity in competitive-parallel reactions; increasing a

decreases mixedness in the system. On the other hand, the higher stoichiometric ratio η , the lower value of I_{SE} . This is so, because heightening the initial concentration of reactant A in the central stream increases the concentration gradient of this substrate and improves mixing in the reactor.

Obviously, both degrees of segregation computed from definitions (10.12) and (10.13) provide very little information about the history of mixing.

This disadvantage does not refer to the next proposition, which includes earliness of mixing:

$$I_{SE} = 1 - \frac{\int_0^{t''} \frac{d}{dt'} (f_A \cdot f_B) \cdot (t'' - t') dt'}{\left(\bar{t}_{res} \cdot \bar{f}_A \cdot \bar{f}_B \right)}, \quad (10.14)$$

where t' , t'' , \bar{t}_{res} denote respectively the age, the residence time of a particulate liquid element and the mean residence time in the system. For unpremixed feed integration by parts gives

$$\int_0^{t''} \frac{d}{dt'} (f_A \cdot f_B) \cdot (t'' - t') dt' = \int_0^{t''} f_A \cdot f_B dt', \quad (10.15)$$

which simplifies calculations.

The results of calculations presented in table 10.VI indicate that the earliest mixing occurs for highest volume ratios when the central feeding stream does not expand significantly after leaving the dosing pipe and is relatively quickly stretched by the annular flow (see figures 10.5 and 10.6) and consequently mixed with annular flowing solution. The early mixing gives more time for the reaction - this explains why conversion of the fast reaction increases with the increasing of the volume ratio.

To sum up, let us emphasize how important it is to understand an investigated process so that to choose a proper definition of the intensity of segregation reflecting phenomena governing mixing.

Table 10.VI. I_{SE} . $Re=1$, $Sc=1000$.

a	Mixer I	Mixer II
9	0.9299	0.8926
19	0.8903	0.8480
49	0.8157	0.7618
99	0.7354	0.6658