# QUIZ 3

## Part One: True or False

T 1. For gas reacting with liquid, either phase can be a macro- or microfluid depending on the contacting scheme being used.

T 2. Each flow pattern of fluid through a vessel has associated with it a definite clearly defined residence time distribution(RTD), or exit age distribution function E.

T 3. When the RTD is close to that of plug flow, the state of segregation of fluid as well as early or late mixing of fluid has little effect on conversion. However, when the RTD approaches the exponential decay of mixed flow, then the state of segregation and earliness of mixing become increasing important.

T 4. At low conversion levels $X_A$ is insensitive 不敏感的 to RTD, earliness of mixing, and segregation. At intermediate 中间的 conversion levels, the RTD begins to influence $X_A$, however, earliness and segregation still have little effect. At high conversion levels all these factors may play important roles.

F 5. Segregation 分离 plays no role in ~~mixed flow~~ PF; however, it increasingly affects the reactor performance as the RTD shifts from mixed to plug flow.

F 6. In a real reactor, macrofluids and late mixing microfluids give higher conversions than early mixing microfluids for reaction orders greater than ~~zero~~ 1.

## Part Two: Gap Fillling or Multiple Choice

1. For microfluids, late mixing favors reactions where the order of the reaction n (>0/<0/>1/<1), early mixing favors reactions where the order of the reaction n (>0/<0/>1/<1)

2. For small deviations 偏离 from plug flow dispersion 轴向扩散 model and tanks-in-series 多釜串联 model could be used; for laminar flow 层流 in short tubes or laminar flow of viscous materials 粘性材料, the convection 层流 model could be used.

3. For a tube reactor, if pulse experiments showed that the spread od tracer grows linearly with distance,i.e., $\sigma \propto L$ , then, convection model should be used.

4. The mean residence time 平均停留时间 of a flow reactor obtained from the step experiment tracer curves is less than $V_R / v_0$ , the possible non-ideal flow pattern is (short-circuiting, dead spaces, axial diffusion)

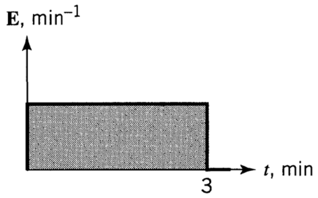
5. In a mixed flow reactor, the fraction of exit stream older than the mean residence time is 36.8 %, younger than the mean residence time is 63.2 %

## Part Three: Calculation

### A

1. A liquid macrofluid reacts according to A → R as it flows through a vessel. Find the conversion of A for the following flow pattern and kinetics.

$$C_{A0} = 6 \text{ mol/liter}$$
$$-r_A = k$$
$$k = 3 \text{ mol/liter}\cdot\text{min}$$




$A = E\cdot 3 = 1 \Rightarrow E = \frac{1}{3}\,min^{-1}$

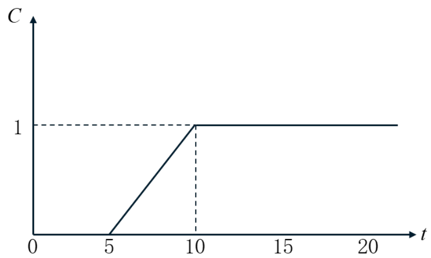
$C_A=0 \quad t=2$ 0级反应

$\frac{C_A}{C_{A0}} = [1+(n-1)C_{A0}^{n-1}kt]^{\frac{1}{1-n}} = 1-\frac{t}{2}$

$\frac{\bar{C}_A}{C_{A0}} = \int_0^{+\infty}\frac{C_A}{C_{A0}}E\,dt = \int_0^{2}\frac{1}{3}(1-\frac{t}{2})\,dt = 1-\frac{9}{12} = \frac{1}{4}$ $\quad \frac{2}{3}-\frac{1}{3} = \frac{1}{3}$

$\bar{X}_A = \cancel{\frac{3}{4}}\ \frac{2}{3}$

2. A step experiment is made on a non-ideal reactor. The results are shown in the following figure.




(a) Find the mean residence time $\bar{t}$ and the variance $\sigma_t^2$

(b) Assuming that the disperation model (open vessel boundary conditions) is a good representation of flow in the reactor, find $\frac{D}{\mu L}$

(a) $\bar{t} = \frac{\int_5^{10} c\,t\,dt}{\int_5^{10} c\,dt} = \frac{\frac{125}{6}}{2.5} = \frac{50}{6} = 8.33$

$\sigma_t^2 = \frac{\int_5^{10} c\,t^2 dt}{\int_5^{10} c\,dt} - \bar{t}^2 = \frac{\frac{2125}{12}}{2.5} - (\frac{25}{3})^2 = 1.23$

(b) $\sigma_\theta^2 = \frac{\sigma_t^2}{\bar{t}^2} = 46.8$

$\frac{D}{\mu L} = \frac{1}{Pe} = \frac{\sigma_\theta^2}{2} = 23.4$

(a) $\bar{t} = \frac{1}{C_{max}}\int_0^{C_{max}} t\,dC_s = 7.5s$

$C_{step} = \begin{cases} 0, & t<5 \\ \frac{1}{5}t-1, & 5<t<10 \\ 1, & t>10 \end{cases}$

$C_{pause} = \frac{dC_{step}}{dt} = \begin{cases} 0, & t<5 / t>10 \\ \frac{1}{5}, & 5<t<10 \end{cases}$

$\sigma_t^2 = \frac{\int_0^\infty t^2 c\,dt}{\int_0^\infty c\,dt} - \bar{t}^2 = \frac{475}{6} - \frac{225}{4} = \frac{175}{12}$

$\sigma_\theta^2 = \frac{\sigma_t^2}{\bar{t}^2} = 2\frac{D}{\mu L} + 8(\frac{D}{\mu L})^2 = \frac{7}{27}$

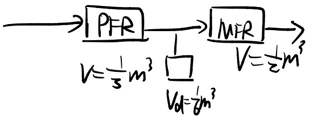
$\frac{D}{\mu L} = 0.094$

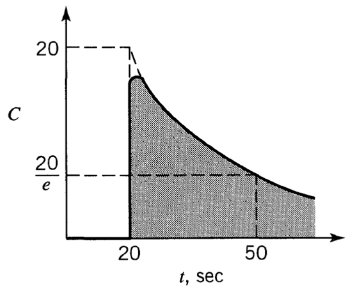
3. A pulse of cencentrated NaCl solution is introduced as tracer into the fluid entering a vessel ( $V = 1\text{m}^3$ , $v = 1\text{m}^3/\text{min}$ ) and the concentration of tracer is measured in the fluid leaving the vessel. Develop a flow model to represent the vessel from the tracer output data sketched below.

$\bar{t}_p = 20s$  $\bar{t}_m = 50-20 = 30s$

$\bar{t} = \frac{V_a}{v} = \bar{t}_p + \bar{t}_m$  $V_a = \frac{5}{6}m^3$  $V_d = \frac{1}{6}m^3$

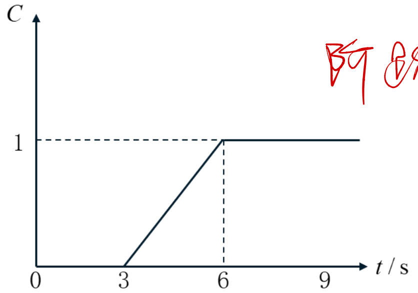
$V_p = \frac{1}{3}m^3$  $V_m = \frac{1}{2}m^3$




**B**

1. A step experiment is made on a non-ideal reactor. The results are shown in the following figure.

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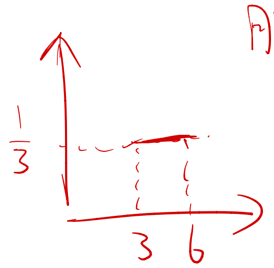


脉冲

(a) Find the mean residence time $\bar{t}$ and the variance $\sigma_t^2$

(b) Assuming that the disperration model (open vessel boundary conditions) is a good representation of flow in the reactor, find Pe.

$\bar{t} = \frac{3+6}{2} = 4.5s$

$\sigma_t^2 = \frac{\int_3^6 t^2 c\,dt}{\int_3^6 c\,dt} - \bar{t}^2 =$

Cpulse

$\sigma_\theta^2 = \frac{\sigma_t^2}{\bar{t}^2} = f(Pe)$

2. Assuming Plug flow, a tubular reactoe 12m long would give 96% conversion of A for zero-order reaction A $\rightarrow$ R. For convection model, how long should the reactor be to insure 96% conversion of A ?

zero-order PFR $\frac{C_A}{C_{A0}} = 1 - X_A = 1 - \frac{k\tau}{C_{A0}}$ $\quad \frac{k\tau}{C_{A0}} = 0.96$

Convection $\frac{C_A}{C_{A0}} = (1 - \frac{k\tau'}{2C_{A0}})^2 = 0.04$ $\quad \frac{k\tau'}{2C_{A0}} = 0.8$ $\quad \frac{k\tau'}{C_{A0}} = 1.6$

$\frac{\tau'}{\tau} = \frac{5}{3}$ $\quad L' = \frac{5}{3} L = 20m$

3. A first order irreversible reaction with rate constant of 9 min$^{-1}$ proceeds in two mixed flow reactors which have equal size and are in series. The conversion of reaction is 99%. Find the conversion when stream is a macrofluid.

$k = 9 min^{-1}$

$\frac{C_A}{C_{A0}} = \frac{1}{(1+\frac{k\bar{t}}{N})^N} = \frac{1}{(1+\frac{9\bar{t}}{2})^2} = 0.01$ $\quad \bar{t} = 2min$

0.25

$\frac{\bar{C_A}}{C_{A0}} = \frac{N^N}{(N-1)!\,\bar{t}_N} \int_0^{+\infty} \frac{C_A}{C_{A0}} t^{N-1} e^{-tN/\bar{t}} dt = \frac{4}{2} \int_0^{+\infty} 0.01\, t\, e^{-2t} dt$

4 $\quad$ 2 $\quad$ 2

$= 0.02$

$te^{-t}$

$(1+t)e^{-t}$

1

k=9

$te^{-2t}$

$(0.25+0.5t)e^{-2t}$

$-0.5-t+0.5$