04-CHEM-A4, CHEMICAL REACTOR ENGINEERING

December 2014

3 hours Duration

1. If doubt exists as to the interpretation of any question, please submit with your answer a clear statement of any assumption(s) you make. If possible, please underline or enclose any such statement in a box.

2. This is an OPEN BOOK EXAM. You may bring to this exam

   - the official designated textbook by Fogler – any edition – annotated in margins, etc. as desired. No loose notes allowed.
   - your own unit conversion tables and/or mathematical tables such as a CRC Handbook.
   - a non-communicating, programmable electronic calculator using a small operating guide. Please write the name and model of your calculator on the first inside left-hand sheet of the exam workbook.

3. Graph paper will be provided.

4. Any **four** questions constitute a complete paper and, unless you indicate otherwise, only the first four answers as they appear in your answer booklet will be marked.

5. Each question is worth 20 points. Marking schemes are provided in brackets after each question.

6. Technical content is the key ingredient in your answers. However, no credit will be given for deriving rate expressions, or standard formulas that are available in the textbook. Clear writing is essential, particularly when explanations are required.

7. It will help the examiner if you could cite the origin of significant formula used – e.g., Fogler, eq. (3-44).

Marking Scheme – Four questions comprise a complete exam.

1. 20 points
2. 20 points – a) 7 points, b) 6 points, c) 7 points
3. 20 points – a) 7 points, b) 6 points, c) 7 points
4. 20 points – a) 8 points, b) 12 points
5. 20 points

QUESTION 1

The room temperature hydrolysis of sucrose by the catalytic action of an enzyme is given by the equation

$$\text{Sucrose} \rightarrow \text{Products}$$

For a sucrose initial concentration (C_{A0}) of 1.0 millimoles/liter and an enzyme initial concentration (C_{E0}) of 1.0 millimoles/liter, the following kinetic data was obtained in a batch reactor:

Concentration, C_A (in millimoles/liter)	Time, t (in hours)
0.84	1
0.68	2
0.53	3
0.38	4
0.27	5
0.16	6
0.09	7
0.04	8
0.018	9
0.006	10
0.0025	11

Evaluate the constants k_3 and M assuming that the above data can be reasonably fitted by the kinetic equation

$$-r_A = -\,dC_A/dt = (k_3\, C_A\, C_{E0})/(C_A + M)$$

where M is a constant.

QUESTION 2

The kinetic data for the following liquid phase reaction is given below:

$$A \rightarrow R$$

Concentration, C_A (in mol/L)	Reaction Rate, $-r_A$ (in mol/L min)
0.1	0.1
0.2	0.3
0.3	0.5
0.4	0.6
0.5	0.5
0.6	0.25
0.7	0.1
0.8	0.06
1.0	0.05
1.3	0.045
2.0	0.042

a) How long must the reaction proceed in a batch reactor for the concentration to drop from C_{A0} = 1.3 mol/L to C_{Af} = 0.3 mol/L?

b) What size of plug flow reactor would be needed for 80% conversion of a feed stream of 1000 moles of A per hour at C_{A0} = 1.5 mol/L?

c) What size of mixed flow reactor is needed for 75% conversion of a feed stream of 1000 moles of A per hour at C_{A0} = 1.2 mol/L?

QUESTION 3

We wish to explore various reactor setups for the transformation of A into R. The feed contains 99% A and 1% R, and the desired product is to consist of 10% A and 90% R. The transformation takes place by means of the elementary reaction

$$A + R \rightarrow R + R$$

with rate constant k = 1 L/mol min. The concentration of the active materials throughout the reaction is

$$C_{A0} + C_{R0} = C_A + C_R = C_0 = 1 \text{ mol/L}$$

What holding time will yield a product in which C_R = 0.9 mol/L f or each of the following:

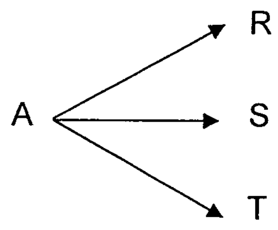
a) plug flow reactor

b) mixed flow reactor

c) minimum-size setup involving a plug flow reactor and a mixed flow reactor

QUESTION 4

Under ultraviolet radiation, reactant A (C_{A0} = 10 kmol/m^3) in a process stream (volumetric flow rate = 1 m^3/min) decomposes as follows:



$r_R = 16C_A^{0.5}$ kmol/m^3 min

$r_S = 12C_A$ kmol/m^3 min

$r_T = C_A^2$ kmol/m^3 min

Calculate the concentration of the desired product as well as the volume of the reactor needed for each of the following:

a) R is the desired product using a continuous stirred tank reactor

b) T is the desired product using a plug flow reactor

QUESTION 5

Pure gaseous A (C_{A0} = 120 mmol/L) is fed into a 1-liter continuous stirred tank reactor (CSTR) at various volumetric flow rates. There it decomposes given by the equation

$$A \rightarrow 3R$$

The exit concentration of A is measured for each flow rate given below:

Volumetric Flow Rate, V_0 (in L/min)	Concentration, C_A (in mmol/L)
0.06	30
0.48	60
1.5	80
8.1	105

Using the above data, find a rate equation to represent the kinetics of the decomposition of A. Assume that reactant A alone affects the rate.