16-CHEM-A4, CHEMICAL REACTOR ENGINEERING

MAY 2017

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. However only the items listed below are permitted into the exam.
   - One textbook of your choice with notations listed on the margins etc but no loose notes are permitted into the exam.
   - 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. Answering any **four** questions will constitute a complete paper. Unless you indicate otherwise, only the first four answers as they appear in your answer booklet will be marked.

4. Each question is worth 25 points. Marking schemes are provided in brackets after each question.

5. 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.

6. 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.

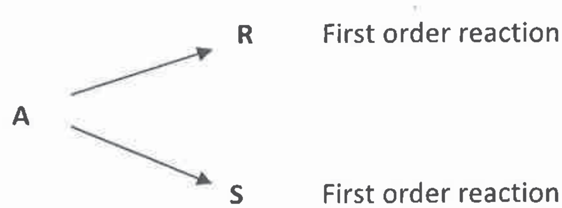
1. 25 points
2. 25 points
3. 25 points
4. 25 points
5. 25 points – a) 18 points, b) 7 points

QUESTION 1

A zero-order homogeneous gas-reaction **A → rR** proceeds in a constant volume batch reactor containing 20% inerts, and the pressure rises from 1 atm to 1.3 atm in 2 minutes. If the same reaction takes place in a constant pressure batch reactor and feed is at 3 atm and contains 40% inerts, what is fractional volume change in 4 minutes?

QUESTION 2

Substance A in a liquid reactor produces R and S as follows:



A feed ($C_{A0} = 1$, $C_{R0} = C_{S0} = 0$) enters two mixed flow reactors in series ($\tau_1 = 2.5$ min, $\tau_2 = 5$ min). The composition of the exit stream leaving the first reactor is $C_{A1} = 0.4$, $C_{R1} = 0.4$, $C_{S1} = 0.2$. Find the composition of the exit stream leaving the second reactor.

QUESTION 3

A catalytic reaction **A → 4R** takes place in plug flow reactor at 3.2 bars pressure and a temperature of 115°C with 20 liters/hr of pure A. The following data was obtained for concentration of A (C_A) in the effluent stream for various amounts of catalyst:

Catalyst used, kg x 10^3	C_A, mole/liter x 10^3
20	74
40	60
80	44
120	35
160	29

Develop a rate equation for this reaction.

QUESTION 4

In a dilute aqueous solution where a large excess of water is present, acetic anhydride is hydrolyzed to produce acetic acid as per the following equation:

$$(CH_3CO)_2O + H_2O \rightarrow 2CH_3COOH$$

The reaction is irreversible, exothermic and pseudo first-order with respect to acetic anhydride. The variation of the pseudo first-order rate constant (k) with temperature is given below:

Temperature, °C	k, $sec^{-1} \times 10^3$
15	1.34
20	1.88
25	2.63
30	3.51

A batch reactor is charged with an anhydride solution containing 300 mol/m^3 at 15°C. The specific heat and density of the reaction mixture are 3.8 kJ/kg.K and 1070 kg/m^3, respectively, and they are constant throughout the course of the reaction. The heat of reaction of acetic anhydride is 210 MJ/kg. If the reactor is operated adiabatically, estimate the time required for the hydrolysis of 80% of the acetic anhydride to acetic acid.

QUESTION 5

A sample of tracer was injected as a pulse to a reactor and effluent concentration (C) measured as a function of time shown in the following data:

Time (sec)	Effluent Concentration of Tracer (g/cm^3)
0	0
10	0.2
20	0.4
30	0.7
40	1.5
50	1.8
60	1.2
70	0.8
80	0.4
90	0.3
100	0.1
110	0

a) Evaluate the mean residence time.

b) Determine the number of stirred-tank reactors if tanks-in-series model is used to approximate the data