16-CHEM-A4, CHEMICAL REACTOR ENGINEERING

DECEMBER 2018

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 – a) 9 points, b) 13 points, c) 3 points
5. 25 points – a) 10 points, b) 15 points

QUESTION 1

The following data was obtained for thermal decomposition of hydrogen iodide (HI) given by the equation $2HI \rightarrow H_2 + I_2$:

Temperature (in °C)	Reaction Rate Constant (in $cm^3/mol.s$)
283	9.42×10^{-7}
356	8.09×10^{-5}
393	5.88×10^{-4}
427	3.1×10^{-3}
508	0.1059

Find the complete rate equation for this reaction as a function of temperature.

QUESTION 2

Gaseous-phase reaction **A → 2B** is carried out in a constant-volume batch reactor and the following was obtained:

Time (hr)	Total Pressure (atm)
0.0	1.31
0.5	1.50
1.0	1.65
1.5	1.76
2.0	1.84
2.5	1.90
3.0	1.95
3.5	1.99
4.0	2.025
5.0	2.08
6.0	2.12
7.0	2.15
8.0	2.175

The reaction mixture, at 1 atm and 14 °C, contains 76.94% by volume of reactant A and the remaining inerts. The reaction is initiated by dropping the reactor into a constant-temperature bath at 100 °C. Find a rate expression to represent the reaction.

QUESTION 3

The aqueous decomposition of **A** is studied in an experimental mixed flow reactor and the following data was obtained at steady-state:

Concentration of A in Feed (in moles/liter)	**Concentration of A in Exit Stream** (in moles/liter)	**Holding Time** (in sec)
2.00	0.65	300
2.00	0.92	240
2.00	1.00	250
1.00	0.56	110
1.00	0.37	360
0.48	0.42	24
0.48	0.28	200
0.48	0.20	560

For a feed rate C_{A0} of 0.8 moles/liter and a conversion of 75%, what holding time is needed in a plug flow reactor?

QUESTION 4

An irreversible first-order reaction, **A → B**, was carried out in a laboratory packed bed reactor (H_m = 10 cm high). The superficial gas velocity in the packed bed was 2 cm/s and a conversion of 97% was obtained.

(a) Determine the reaction rate constant in m^3 per m^3 of catalyst per second.

(b) The same reaction is now carried out in a larger fluidized bed reactor (H_m = 100 cm high) with superficial gas velocity of 20 cm/s. What would the conversion be for an estimated bubble size of 8 cm?

(c) What would be the conversion in a packed bed reactor with H_m = 100 cm and superficial gas velocity of 20 cm/s?

DATA:

Minimum fluidization velocity (u_{mf}) = 3.2 cm/s

Void fraction at minimum fluidization conditions ($\varepsilon_{mf} = \varepsilon_m$) = 0.5

Effective diffusivity (D_e) = 3 x 10^{-5} cm/s

Wake factor (α) = volume of wake/volume of bubble = 0.34

QUESTION 5

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

Time (in min)	**Effluent Concentration of Tracer** (in g/cm^3)
0.0	0.25
0.1	0.20
0.2	0.17
1.0	0.15
2.0	0.125
5.0	0.07
10.0	0.02
30.0	0.001

(a) Evaluate the mean residence time.

(b) Plot the residence time distribution (RTD) and compare with that of an ideal mixed flow reactor.