UNIVERSITY OF GHANA

BSC ENGINEERING SECOND SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF FOOD PROCESS ENGINEERING

FPEN 306: CHEMICAL REACTION ENGINEERING (2 CREDITS)

INSTRUCTIONS:
ANSWER FOUR (4) QUESTIONS – TWO (2) QUESTIONS FROM EACH SECTION
Use separate Answer Booklet for each Section

Graph sheets required

TIME ALLOWED: TWO (2) HOURS

SECTION A

1.

a. Discuss the two methods of analysis of kinetic data obtain from a batch or flow reactor and compare and contrast the merits and demerits of each analytical technique.

b. Reactant A decomposes in a batch reactor according to the equation

$$A \longrightarrow \text{Products}$$

The composition of A in the reactor is measured at various times with results shown in the following columns 1 and 2.

Time, t (s)	Concentration, C_A (Mol/L)
0	10
20	8
40	6
60	5
120	3
180	2
300	1

Find a rate equation to represent the data using any appropriate kinetic analytical method.
For fractional life method assume F= 80% and C=10, 6 and 2

2.

a. The decomposition of A to produce B can be written as $A \rightarrow B$. When the initial concentration of A is 0.012 M, the rate is 0.0018M min^{-1} and when the initial concentration of A is 0.024 M, the rate is 0.0036M min^{-1}.

   i. Write the rate law for the reaction and find the rate constant.
   ii. If the activation energy for the reaction is 268 kJ mol^{-1} and the rate constant at 660 K is 8.1×10^{-3} sec^{-1} what will be the rate constant at 690 K?

b. The rate constant for the decomposition of N_2O_5 (g) at a certain temperature is 1.70×10^{-5} sec^{-1}. If the initial concentration of N_2O_5 is 0.200 mol/l,
   i. How long will it take for the concentration to fall to 0.175 mol/l
   ii. What will be the concentration of N_2O_5 be after 16 hours of reaction?

3.

a. Distinguish between the following terms with the aid of equations as they are used in chemical reaction engineering studies
   i. Molecularity and order of a reaction
   ii. Elementary and non-elementary reactions
   iii. Homogeneous and heterogeneous reactions

b. The decomposition of
   $Z \longrightarrow X + Y$
   Follows first order kinetics, at a constant temperature the rate constant is 1.60×10^{-5} sec^{-1}.
   i. What is the half-life for the disappearance of Z?
   ii. After 15.0 hours, what fraction of the initial Z remains?

SECTION B

4. Laboratory measurements made prior to the design of a chemical reactor for a reaction at 149°C and 10 atmospheres (1013 kPa) provided the following data:

X_A	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8
$-r_A$ (mol/dm^3.s) $\times 10^{-3}$	5.3	5.2	5.0	4.5	4.0	3.3	2.5	1.8	1.25	1.0

A gas mixture consisting of 50% A and 50% inerts enters the reactor at a flow rate of 10 dm^3/s.

   i. Calculate the entering concentration C_{AO} and entering molar flow rate F_{AO}
   ii. Calculate the sizes of two continuous stirred tank reactors (CSTRs) connected in series if the intermediate and final products have conversions of 40% and 80% respectively.

Assume the ideal gas constant $\boldsymbol{R} = 0.082\ dm^3.atm/mol.K$

5. The gas phase decomposition of phosphine with stoichiometry

$$4PH_3(g) = P_4(g) + 6H_2(g)$$

proceeds at 650^oC according to a first-order rate equation.

$$-r_{PH_3} = (10/hr)C_{PH_3}$$

The reaction is homogeneous and takes place in a plug flow reactor operating at 650^oC and 0.460 MPa and can produce 80% conversion of a feed consisting of 108 mol/hr of pure phosphine. Determine the expansion factor of the reaction and size of the plug flow reactor used. Assume the universal gas constant $\boldsymbol{R} = 8.314\ Pa.m^3/mol.K$

6. An elementary liquid-phase reversible reaction, A + 2B = R; with rate constants k_1 and k_2 for the forward and backward reactions respectively has the following rate equation:

$$-r_A = -\frac{1}{2}r_B = (25\,liter^2/mol^2.min)C_A C_B^2 - (3min^{-1})C_R, \quad \left[\frac{mol}{liter.min}\right]$$

The reaction take places in a 20-liter steady-state mixed flow reactor. Two feed streams, one containing 2.8 mol A/liter and the other containing 1.6 mol B/liter, are introduced at equal volumetric flow rates into the reactor, and 75% conversion of limiting component is desired. Draw a schematic diagram of the reactor.

i. Determine the performance equation of the reactor.
ii. Determine the flow rate of each stream?