NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
BACHELOR OF SCIENCE HONOURS DEGREE
END OF FIRST SEMESTER EXAMINATIONS – FEBRUARY 2010
REACTOR TECHNOLOGY – SCH 4208
TIME: 3 HOURS

INSTRUCTIONS TO CANDIDATES

Additional Material:
Graph Paper

Answer all questions in Section A and only 3 in Section B. Total marks are 100.
R = 82.06 atm $cm^3 gmol^{-1} K^{-1}$. also R = 8.314$J mol^{-1} K^{-1}$

SECTION A

1. a) State 3 factors that affect reactor performance. [3]

   b) State the general performance equation of a chemical reactor. [1]

   c) What are the advantages of duct reactors relative to fixed-bed packed catalytic tubular reactors. [4]

2. a) State the material balance for a mixed flow reactor [2]

   b) For a gas reaction at 400K the rate is reported as

$$-\frac{dp_A}{dt} = 3.66 p_a^2 \qquad \text{atm/hr}$$

   i) What are the units of the rate constant) [2]

   ii) What is the value of the rate constant for this reaction if the rate equation is expressed as

$$-r_A = -\frac{1}{V}\frac{dN_A}{dt} = kC_A^2$$

[4]

3. a) State the Arrhenius equation. [2]

b) A rocket engine, Fig. El.l, burns a stoichiometric mixture of fuel (liquid hydrogen) in oxidant (liquid oxygen). The combustion chamber is cylindrical, 75 cm long and 60 cm in diameter, and the combustion process produces 108 kg/s of exhaust gases. If combustion is complete, find the rate of reaction of hydrogen and of oxygen.

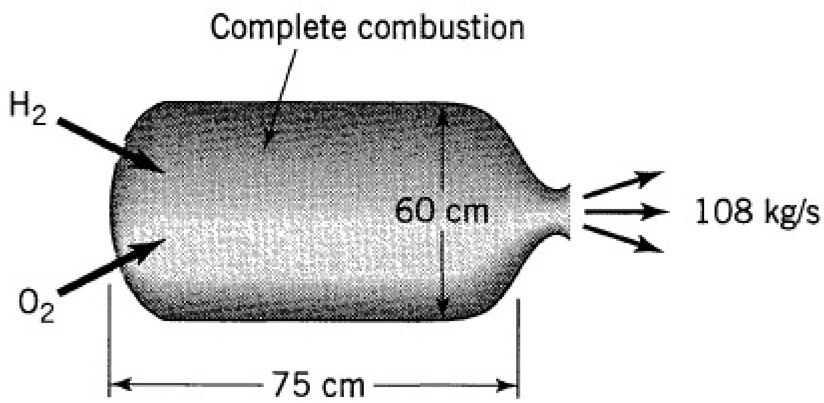


Figure E1.1 [6]

4. a) Define molecularity. [2]

b) To explain the kinetics of non-elementary reactions we assume that a sequence of elementary reactions is actually occurring but that we cannot measure or observe the intermediates formed because they are only present in very minute quantities. List three types of intermediates that can be postulated and give a suitable example for each intermediate. [6]

5. a) List any two assumptions made in the Bernoulli equation. [2]

b) In an isothermal batch reactor 70% of a liquid reactant is converted in 13min. What space-time and space-velocity are needed to effect this conversion in a plug flow reactor and in a mixed flow reactor? [6]

SECTION B

6. a) (i) What is the effect of heat and mass transfer on determination of the rate of heterogeneous reactions? Give suitable examples. [4]

(ii) With the aid of diagrams, explain the difference between a parallel reaction and a series reaction. [2]

b) Given that, for batch and flow systems of gases of changing density but with temperature and pressure constant

$$X_A = \frac{C_{A0} - C_A}{C_{A0} + \varepsilon_A C_A}$$

$$\frac{C_A}{C_{A0}} = \frac{1 - X_A}{1 + \varepsilon_A X_A}$$

Show that the relationship between C_A and X_A for the products is

$$\frac{C_R}{C_{A0}} = \frac{(r/a)X_A + C_{R0}/C_{A0}}{1 + \varepsilon_A X_A}$$

[7]

c) ***A*** Commercial Popcorn Popping Popcorn Popper. We are constructing a 1-liter popcorn popper to be operated in steady flow. First tests in this unit show that 1 liter/min of raw corn feed stream produces 28 liter/min of mixed exit stream. Independent tests show that when raw corn pops its volume goes from 1 to 31. With] this information determine what fraction of raw corn is popped in the unit.

[7]

7. a) (i) State and explain the two step which are carried out when determining the rate equation. [4]

(ii) What is the role of Archimedes screw in a batch reactor? [2]

b) (i) With aid of a diagram, describes the progressive core model, for the noncatalytic reaction of particles with surrounding fluid. [4]

(ii) List four examples in which the reacting particle does not change in size in size as the reaction proceeds. [2]

c) Pure gaseous reactant A (C_{AO} = 100 millimol/liter) is fed at a steady rate into a mixed flow reactor (V = 0.1 liter) where it dimerizes (2A → R). For different gas feed rates the following data are obtained:

Run number	1	2	3	4
v_0, liter/hr	10.0	3.0	1.2	0.5
C_{Af}, millimol/liter	85.7	66.7	50	33.4

Find a rate equation for this reaction. [8]

8. a) Consider a gas-phase reaction 2A→R + 2S with unknown kinetics. If a space velocity of l/min is needed for 90% conversion of A in a plug flow reactor, find the corresponding space-time and mean residence time or holding time of fluid in the plug flow reactor. [6]

b) With the aid of a diagram, tell how many steps are involved when air bubbles through a tank of liquid which contains dispersed microbes and is taken up by the microbes to produce product material. [6]

c) The elementary liquid phase reaction

$$A + 2B \underset{k_2}{\overset{k_1}{\rightleftarrows}} R$$

With rate equation,

$$-r_A = -\frac{1}{2} r_B = (12.5 \text{ liter}^2/\text{mol}^2 \cdot \text{min}) C_A C_B^2 - (1.5 \text{ min}^{-1}) C_R, \qquad \left[\frac{\text{mol}}{\text{liter} \cdot \text{min}}\right]$$

is to take place in a 6-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 to be introduced at equal volumetric flow rates into the reactor, and 75% conversion of limiting component is desired (see Fig. 2). What should be the flow rate of each stream? Assume a constant density throughout. [8]

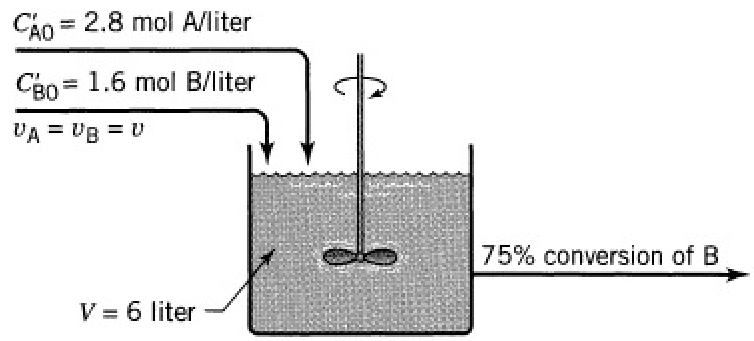


Fig 2.

9. a) The homogeneous gas decomposition of phosphine

$$4PH_3(g) \rightarrow P_4(g) + 6H_2$$

proceeds at 649°C with the first-order rate

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

What size of plug flow reactor operating at 649°C and 460 kPa can produce 80% conversion of a feed consisting of 40 mol of pure phosphine per hour? [8]

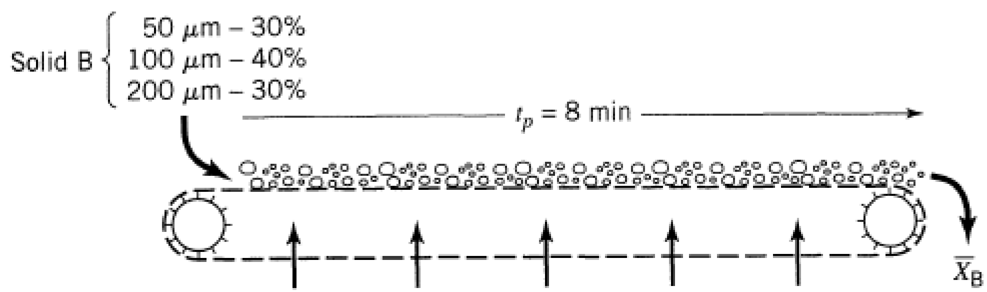
b) A feed consisting

30% of 50-μm-radius particles

40% of 100-μm-radius particles

30% of 200-μm-radius particles

is to be fed continuously in a thin layer onto a moving grate crosscurrent to a flow of reactant gas. For the planned operating conditions the time required for complete conversion is 5, 10, and 20 min for the three sizes of particles. Find the conversion of solids on the grate for a residence time of 8 min in the reactor.



[12]