NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF APPLIED CHEMISTRY

END OF SECOND SEMESTER EXAMINATIONS - MAY 2003

REACTOR TECHNOLOGY - SCH 4208

TIME - 3 HOURS

INSTRUCTIONS TO CANDIDATES
Answer only five (5) questions.

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1. (a) How do you classify Chemical reactions useful in Reactor design? (10marks)

   (b) Distinguish between an elementary and non-elementary reaction. (6marks)

   (c) What type of reactor is preferred if the rate of heat of evolution is very high? Support your answer. (4marks)

2. (a) Phosphine decomposes by the following stoichiometric equation:

   $$4PH_{3(g)} \rightarrow P_{4(g)} + 6H_{2(g)}$$

   At a given instant phosphine decomposes at the rate of $10x10^{-5}gmols^{-1}L^{-1}$. Let the rate of reaction for phosphine be defined in terms of disappearance, ie;

   $$r_{PH3} = \frac{\text{gmoles of } PH_3 \text{ disappearing}}{\text{sec.liter}} = 10x10^{-5}$$

   (i) Compute the rates of appearance of phosphorous (P_4) and hydrogen (H_2). (4marks)

   (ii) Compute the rates of disappearance of phosphorous (P_4) and hydrogen (H_2) and the rate of appearance of phosphine. (6marks)

   (b) Derive the rate equation for a variable Batch Reactor in terms of conversion, X. (10marks)

3. (a) The decomposition of nitrous oxide in glass or silica vessels is generally a homogeneous 2nd order reaction. In the presence of a goldwire at high temperature. The decomposition of nitrous oxide was found by Hinshelwood and Prichard to be 1st order, ie, the stoichiometry is given by;

   $2N_2O \rightarrow 2N_2 + O_2$ and the rate of reaction is given by;

r_{N2O} = gmoles of N_2O disappearing/(sec.cm^3) = $k_e C_{N2O}$

at 900°C, Hinshelwood et al found that $k_e = 0.013 sec^{-1}$.

Calculate the corresponding value of k_p (gmoles/(sec.cm^3.atm).

R = 82.05 atm.cm^3/(gmol.K) (6marks)

(b) With reference to gas-solid non-catalytic reactors, discuss:

(i) the shrinking core reaction model (7marks)
(ii) progressive conversion reaction model. (7marks)

4. (a) The irreversible reaction $2A \rightarrow B$ is carried out at high temperature in a reactor with constant volume, V. If the reactor is initially charged with a concentration, C_{Ai}, obtain an expression for the concentration of A as a function of time. If we assume an elementary reaction, the rate of consumption can be expressed by

$r_A = k_1 C_A^2$. (6marks)

(b) A saponification reaction, which is carried out in the lab, is the reaction of ethyl acetate in an aqueous solution of NaOH,

$CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$

In 1906 Walker investigated this reaction at 25°C by commencing with equal concentrations (0.01 gmol/liter) of ethyl acetate and NaOH and the following course of the reaction by the electrical conductance method. Some of his results follow:

t(min)	5	9	13	20	25	33	37
gmol of NaOH per liter	0.00755	0.00633	0.00541	0.00434	0.00385	0.00320	0.00296

On the basis of these data, determine the order of the reaction and evaluate the rate constant.(14 marks)

5. (a) Continuous stirred tank reactor and a plug flow reactor are two types of continuous flow reactors. Discuss the advantages and limitations of each type of reactor. (8marks)

(b) The liquid reaction $A + B \rightarrow R + S$ is to be carried out at constant volume and

temperature in a batch reactor. The reaction is almost irreversible and its rate equation is $r_A = -kC_AC_B$, where the rate constant has a value of $0.45x10^{-3}m^3/(kmol.s)$. The initial concentration of A and B are $2.5kmol/m^3$ respectively. Calculate the reaction time required for a turnover of 96.5% and the smallest volume needed for a production of 1.5t/day of product R. The charging, maintenance and cleaning is approximately 1hr. The molecular weight of R is 150kg/kmol.

(12marks)

6. (a) Milk is pasteurised if it is heated to 67°C for 25 min, but if it is heated to 78°C it only needs 12 seconds for the same result. Find the activation energy for this sterilisation process.

(8marks)

(b) Yagi et al. (1951) roasted pyrrhotite (iron sulfide) particles dispersed in asbestos fibers and found that the time for complete conversion was related to particle size as follows: $\tau = R^{1.5}$. Particles remained as hard solids during reaction. A fluidised-bed reactor is planned to convert pyrrhotite ore to the corresponding oxide. The feed is to be uniform in size, $\tau = 25min$, with mean residence time, $t = 75$ min the reactor. What fraction of the original sulfide ore remains unconverted?

(12 marks)

7. (a) (i) What is meant by auto-catalytic reactions? (4marks)

(ii) Describe catalytic poisoning. (4marks)

(b) Fixed bed -reactors and fluidised bed- reactors are some of the most important Industrial Reactors. With the aid of sketch diagrams explain the mode of operation and their industrial applications, advantages and limitations.

(12marks)

END OF QUESTION PAPER!!!