NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

Chemical Reaction Engineering II

ECE/TCE 3102

Supplementary Examination Paper

August/Sept 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

INSTRUCTIONS

1. Answer **All** questions
2. Each question carries 25 marks
3. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
1	25
2	25
3	25
4	25
TOTAL ATTAINABLE	100

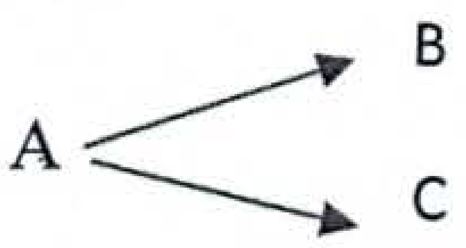
Answer all questions

QUESTION 1

a) Explain how the following are affected by strong pore diffusion resistance. NB: use of equations is expected.

i) Rate of reaction at different particle sizes. **[4]**

i) The selectivity (rB/rC) of the reaction is given below. **[6]**



Where $r_A = k_1C_A$ and $r_B = k_2C_A$

b) Review the importance of Hatta Number in fluid-fluid systems. **[4]**

c) State and explain three factors that determine the approach for a fluid-fluid reaction process. **[6]**

d) Explain the significance of these terms i) Effectiveness factor and Thiele modulus. **[5]**

QUESTION 2

a) Langmuir-Hinshelwood kinetics is used to come up with reaction rates for adsorbing species on solid surfaces. In the production of ammonia, dissociate adsorption of nitrogen molecule is the rate determining step. Make use of a diagram and equations to describe this process. **[5]**

b) To remove oxides of nitrogen (assumed to be NO) from automobile exhaust, a scheme has been proposed that uses not completely burn carbon, carbon monoxide, according to the reaction

$$CO + NO \leftrightarrow Products(N_2, CO_2)$$

Experimental data for a particular solid catalyst indicate that the reaction rate can be represented by;

$$-r_N = \frac{kP_NP_C}{[1 + K_1P_N + K_2P_C]^2}$$

Where P_N = gas-phase partial pressure of NO, P_C = gas-phase partial pressure CO

k, K_1, K_2 = Coefficients depending only on temperature

i)Proposed an adsorption-surface reaction-desorption mechanism that will explain the experimentally observed kinetics and prove it. **[15]**

ii) A certain engineer thinks that it would be desirable to operate with very large stoichiometric excess of CO to minimize reactor volume. Do you agree or disagree? Explain. **[5]**

QUESTION 3

a) Discuss challenges encountered during heterogeneous catalysis. **[5]**

b) The first-order decomposition of A is run in an experimental mixed-flow reactor. Find the role played by pore diffusion in these runs; in effect, determine whether the runs were made under diffusion-free, strong resistance, or intermediate conditions. **[9]**

d_p	W	C_{AO}	v	X_A
4	1	300	60	0.8
12	3	100	160	0.6

c) A packed bed reactor converts A to R by a first-order catalytic reaction, $A \rightarrow R$ With 9-mm pellets, the reactor operates in the strong pore diffusion resistance regime and gives 63.2% conversion. How would this affect the conversion if these pellets were replaced with 18-mm pellets (to reduce pressure drop)? **[11]**

QUESTION 4

a) Discuss factors three factors that control the design of a fluid-solid reactor. **[6]**

b) What is the aim of coming up with a model? **[4]**

c) Outline applications of fluid-solid reactions; use of examples is encouraged. **[5]**

d) Spherical solid particles containing B are roasted isothermally in an oven with gas of constant composition. Solids are converted to a firm, nonflaking product according to the SCM as follows:

dp	X_B	t, sec
2	0.875	1
1	1	1

The following conversion data determine the rate controlling mechanism for the solid transformation. **[10]**

Table 4.1 : Conversion-Time expression for various shapes

	Film Diffusion Controls	Ash Diffusion Controls	Reaction Controls
Flat plate $X_B = 1 - \frac{1}{L}$ L = half thickness	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B L}{b k_g C_{Ag}}$	$\frac{t}{\tau} = X_B^2$ $\tau = \frac{\rho_B L^2}{2b\mathscr{D}_e C_{Ag}}$	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B L}{b k'' C_{Ag}}$
Cylinder $X_B = 1 - \left(\frac{r_c}{R}\right)^2$	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B R}{2b k_g C_{Ag}}$	$\frac{t}{\tau} = X_B + (1 - X_B)\ln(1 - X_B)$ $\tau = \frac{\rho_B R^2}{4b\mathscr{D}_e C_{Ag}}$	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/2}$ $\tau = \frac{\rho_B R}{b k'' C_{Ag}}$
Sphere $X_B = 1 - \left(\frac{r_c}{R}\right)^3$	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B R}{3b k_g C_{Ag}}$	$\frac{t}{\tau} = 1 - 3(1 - X_B)^{2/3} + 2(1 - X_B)$ $\tau = \frac{\rho_B R^2}{6b\mathscr{D}_e C_{Ag}}$	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/3}$ $\tau = \frac{\rho_B R}{b k'' C_{Ag}}$

(END OF PAPER)