MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: REACTOR DESIGN AND ANALYSIS III

CODE: CHEP 314

SESSIONAL EXAMINATIONS
APRIL 2023

DURATION: 3 HOURS

EXAMINER: MR C.K. SIMENDE

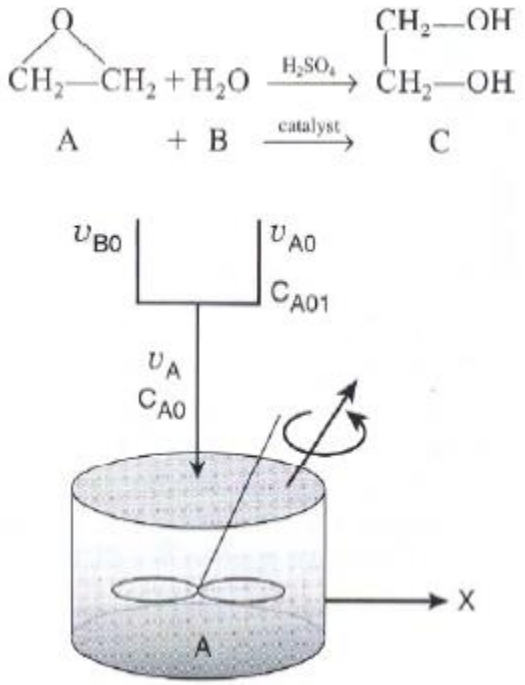
INSTRUCTIONS

1. *Answer **any four** questions*
2. *Start a new question on a fresh page*
3. *Total marks 100*

Additional material(s): *Calculator, Graph paper*

QUESTION 1

a) It is desired to produce 200×10^6 pounds per year of ethylene glycol(EG). The reactor is to be operated isothermally. A 1 lb mol/ft^3 solution of ethylene oxide (EO) in water is fed to the reactor together with an equal volumetric solution of water containing 0.9 wt% of the catalyst H_2SO_4. The specific reaction rate constant is 0.311 min^{-1}. The reaction proceeds as shown in Scheme 1.



Scheme 1: Single CSTR

Additional information

Molecular Weight of EG = 62

Molecular Weight of EO = 58

i) If 80% conversion is to be achieved, determine the necessary CSTR volume. [16]

ii) If two 800-gal reactors were arranged in parallel, what is the corresponding conversion? [5]

iii) If two 800-gal reactors were arranged in series, what is the corresponding conversion? [4]

QUESTION 2

a) Describe the steps of a catalytic reaction using the aid of fully labeled diagrams. [5]

b) Equation (1) is a catalytic reaction to improve the octane number of gasoline:

$$\mathrm{n-pentane} \underset{\substack{75\%\ \mathrm{Pt} \\ \mathrm{on}\ Al_2O_3}}{\Longleftrightarrow} \mathrm{i-pentane} \ldots\ldots\ldots (1)$$

The steps in this reaction are as follows:

$$\mathrm{n-pentene} \overset{-H_2\ (P_t)}{\Longleftrightarrow} \mathrm{n-pentene} \underset{Al_2O_3}{\Longleftrightarrow} \mathrm{i-pentene} \overset{+H_2\ (P_t)}{\Longleftrightarrow} \mathrm{i-pentane}$$

Show that:

$$-r'_N = \frac{k_s K_N C_T [P_N - \frac{P_I}{K_r}]}{1 + K_N P_N + K_2 P_2} \quad [15]$$

c) Write down the reaction rate equation for the following surface mechanisms:

i) Single site [1]

ii) Dual site [2]

iii) Eley-Rideal [2]

QUESTION 3

a) Describe and explain the three main types of catalyst deactivation. [9]

b) Outline the mechanism of catalysts deactivation. [4]

c) The first-order isomerization $A \rightarrow B$ is being carried out isothermally in a batch reactor on a catalyst that is decaying as a result of aging. Derive an equation for conversion as a function of time. [12]

QUESTION 4

a) Distinguish between physical adsorption and chemical adsorption. [5]

b) The result of kinetic runs on the reaction A → R made in an experimental packed bed reactor using a fixed feed rate F_{Ao} = 10 kmol/h are as shown in table 1:

Table 1

W, kg catalyst	1	2	3	4	5	6	7
X_A	0.12	0.20	0.27	0.33	0.37	0.41	0.44

i) Find the reaction rate at 40% conversion. [10]

ii) For a feed rate of 400 kmol/ h to large scale packed bed reactor find the amount of catalyst needed for 40% conversion. [5]

iii) Find the amount of catalyst that would be needed in part (II) if the reactor employed a very large recycle of product stream. [5]

QUESTION 5

a) Describe and explain the contact (adsorption) theory using the hydrogenation of ethylene in the presence of a nickel catalyst as an example. [8]

b) Using the results in Table 2 plot the BET isotherm and hence find S_g using the BET equation. [5]

Table 2: Equilibrium data

P(kP)	0.8	3.3	18.7	30.7	38.0	42.7	57.3	67.3
V(cc at STP/gm)	6.1	12.7	17.0	19.7	21.5	23.0	27.7	33.5

c) Derive the BET adsorption isotherm equation with the help of following equilibrium equations:

$$M + S \rightleftharpoons MS$$

$$M + MS \rightleftharpoons M_2S$$

$$M + M_2S \rightleftharpoons M_3S$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$M + M_{n-1}S \rightleftharpoons M_nS$$

Where *M* is the unadsorbed gas molecules, *S* is the active site on the adsorbent surface, *MS* is the single complex formed, M_2S is the double complex formed, and so on. [12]

END OF EXAMINATION