MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: REACTOR DESIGN AND ANALYSIS III/REACTOR DESIGN

CODE: CHEP 314/HCHE 324

SESSIONAL EXAMINATIONS
DECEMBER 2022

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) Define the following terms and give an example in each case:

i) Catalyst [2]

ii) Catalysis [1]

iii) Homogeneous catalysis [2]

iv) Heterogeneous catalysis [2]

v) Catalyst support [3]

vi) Promoter [2]

b) List and explain the general characteristics of catalysts. [10]

c) The Fisher - Tropsch synthesis was studied using a commercial 0.5 wt % Ru on γ-Al_2O_3. The equation for the reaction is:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

The catalyst dispersion percentage of atoms exposed determined from hydrogen chemisorptions was found to be 49 %. At a pressure of 988 kPa and a temperature of 475 K, a turnover frequency of 0.044 s^{-1} was reported for methane. What is the rate of formation of methane in mol/s.g of catalyst (metal plus support)? [3]

QUESTION 2

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 follows:

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 3

a) Define the following terms:

i) Adsorption [2]

ii) Adsorbate [1]

iii) Adsorbent [2]

b) Describe the factors which affect the rate of adsorption. [8]

c) Derive the Langmuir adsorption isotherm using the aid of a fully labelled diagram. [12]

QUESTION 4

a) Describe the Shrinking-Core Model (SCM) for fluid-solid reactions using fully labeled diagrams. [15]

b) In a fluidized bed reactor, particles of iron sulphide of uniform size are to be roasted. The time required for complete conversion is 20 min. The mean residence time of particles in the fluidized bed is 60 min. The particles remained as hard solids during reaction. τ and R relationship found to be $\tau \infty R^{1.5}$ .Calculate the fraction of original iron sulphide remaining unreacted. [10]

QUESTION 5

a) The gas-phase cracking reaction:

$$\text{Gas oil (g)} \rightarrow \text{Products (g)}$$

$$A \rightarrow B + C$$

is carried out in a *fluidized* CSTR reactor. The feed stream contains 80 % gas oil (A) and 20 % inert I. The gas oil contains sulfur compounds, which poison the catalyst. The volumetric feed rate to the reactor is 5000 m^3/h. There are 50,000 kg of catalyst in the reactor and the bulk density is 500 kg/m^3. Assuming that the bed can be modeled as a well-mixed CSTR, determine the reactor volume and space time (τ). [5]

b) Calculate the time required for complete burning of particles of graphite (size: R_0 = 5 mm, density: ρ_B = 2.2 g/cm^3) in an 8 % oxygen stream at 900 ºC and 1 atm. For the high gas velocity used assume that film diffusion does not offer any resistance to transfer and reaction. [10]

Data: Rate constant k” = 20 cm/s

c) Consider the catalyzed reaction:

$$A + B \rightarrow B + C$$

with the second-order rate constant 1.15 x 10^{-3} m^3/mol/ksec. The rate law is :

$$r = k[A][B].$$

What volume of CSTR would be necessary to give 40 % conversion of species A if the feed concentration of A is 96.5 mol/m^3, the feed concentration of B is 6.63 mol/m^3, and the flow rate is 0.5 m^3/ksec? [10]

END OF EXAMINATION