

Department of Chemical Engineering

Major Exam CHL727 / CLL727 (Heterogeneous catalysis and Catalytic Reactors)

M.M 40

Time: 13:00 – 15:00 HRS

Date : 06/05/16

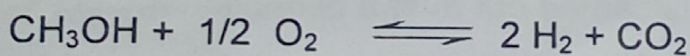
Venue: LH 410

1. Answer the following briefly.

(2x3=6)

- Why do monolith and honeycomb catalysts have to be coated before they are loaded with catalyst? Compare a monolith with a packed bed catalyst reactor.
- Write down all the reaction steps involved in regeneration of cracking catalysts.
- What are the most important factors to be considered in the design of multi phase reactors.

2. (a) Hydrogen as a feed for fuel cells can be produced from methanol by steam reforming with CuO/ZnO/Al₂O₃ catalysts at 200–300 °C. The following reactions occur:



In addition to CO₂ and H₂ the produced gas stream contains ~2% CO and coke on catalyst. Give the reason for the same and possible steps to stop it. (3)

(b) Compare trickle-bed and suspension reactors according to the following criteria:

- Temperature distribution
- Selectivity
- Residence-time behaviour of the liquid
- Catalyst particle diameter
- Catalyst effectiveness factor
- Catalyst performance

(3)

3. (a) Discuss the various transport steps involved in the design of a slurry bubble column reactor. Why slurry bubble column reactors are preferred over a trickle bed reactor. (3)

(b) Stating the project title and group members' name, give two most significant conclusions of your design project. (3)

(3)

4. In a laboratory packed bed reactor with 150 micron zeolite particles the catalyst bed height (L_m) is 10 cm, and the superficial gas velocity (u_0) is 2 cm/s. The reaction is first-order reaction ($A \rightarrow R$) and the volumetric rate constant (k''') for this reaction is 1.40 s^{-1} .

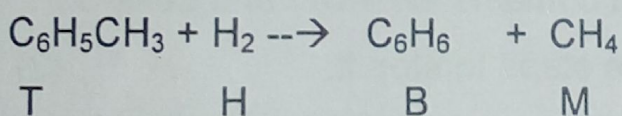
(a) Determine the conversion in the packed bed reactor. (5)

(b) Calculate the conversion in a larger fluidized bed pilot plant in which the catalyst bed height (L_m) is 100 cm, gas superficial velocity $u_0 = 20 \text{ cm/s}$ and the estimated bubble size is (d_b) 8 cm. (8)

Data: From experiment, the minimum fluidized bed velocity, $u_{mf} = 3.2 \text{ cm/s}$, and packed bed void fraction (ϵ_m) is 0.5, which is similar to the bed void fraction at minimum fluidization (ϵ_{mf}).

The volume fraction of solids per unit volume of bed in bubble (f_b), cloud and wake (f_c), and emulsion (f_e), were 0.001, 0.063 and 0.330 respectively. Also the calculated values of coefficients of interchange gas between bubble and cloud (K_{bc}) and cloud wake and emulsion (K_{ce}) 3.312 s^{-1} and 0.92 s^{-1} respectively. (calculated based on unit volume of bubble). State clearly all the assumptions made and any other data assumed.

5. The catalytic hydro dealkylation of toluene is carried out over a bifunctional catalyst at 660°C and 30 bar:



The reaction follows a rate law of the Langmuir-Hinshelwood type and is given as :

$$r = \frac{kK_T P_T P_H}{1 + K_T P_T + K_B P_B}$$

At 660°C , The values of rate parameters are : $k = 0.202 \text{ mol kg}^{-1} \text{ bar}^{-1} \text{ h}^{-1}$, $K_T = 0.9 \text{ bar}^{-1}$, $K_B = 1.0 \text{ bar}^{-1}$

The molar ratio of toluene ($M.W = 92$) to hydrogen in the initial mixture is 1/10.

Calculate the catalyst mass for a reactor handling 2000 t/a toluene with 60 % conversion. (1 year = 8000 operating hours). (9)