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)**

a) 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.

b) Write down all the reaction steps involved in regeneration of cracking catalysts.

c) 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 $CuO/ZnO/Al_2O_3$ catalysts at 200–300 ^{0}C. The following reactions occur:

$$CH_3OH + H_2O \rightleftharpoons 3\,H_2 + CO_2$$

$$CH_3OH + 1/2\ O_2 \rightleftharpoons 2\,H_2 + CO_2$$

In addition to CO_2 and H_2 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)

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 → 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 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 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 ^{0}C and 30 bar:

$C_6H_5CH_3 + H_2 \rightarrow C_6H_6 + CH_4$

T H B M

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^{0}C, The values of rate parameters are : k = 0.202 mol kg^{-1} bar $^{-1}h^{-1}$, K_T = 0.9 bar^{-1} , K_B = 1.0 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)