UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2010/2011 Academic Session

April/May 2011

EKC 533 – Industrial Catalysis and Reactor Engineering

Duration : 3 hours

Please ensure that this examination paper contains FOUR printed pages before you begin the examination.

Instruction: Answer **ALL** questions.

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1. [a] What are the technical limitations that exist in typical process of catalytic ammonia synthesis? Explain each limitation involved in the process.

[8 marks]

[b] What are the various feedstocks from which methanol could be produced? Explain the types of catalysts, their operating limitations in each of synthesis methods.

[9 marks]

[c] Why "hydrotreating" process is important for gas oil feedstocks? What are the types of catalysts involved in various stages of hydrotreating and compare?

[8 marks]

2. [a] A particular catalyst has a surface area S = 100 m^2/g, a density ρ_c= 3 g/cm^3, and a void fraction ε = 0.30.

[i] The pseudo-homogeneous rate of the irreversible reaction $A \rightarrow B$ in a test of this catalyst was $1x10^{-2}$ mol/l.s when the reactant concentration was 1 mol/l and $2.5x10^{-3}$ when the reactant concentration was 0.5 mol/l. What is the surface reaction rate expression in mol/(cm^2.s)?

[6 marks]

[ii] What reactor volume will be necessary to process 100 liters/sec of 2 molar A to 90% conversion in a packed-bed reactor?

[8 marks]

[b] For the highly endothermic steam reforming of methane on a Ni/Ca-alumina catalyst, describe and sketch the basic features of a suitable industrial reactor (e.g. fixed or fluidized bed, single or multistage, heating or cooling arrangements). Briefly justify your choices listing advantages of your system versus the advantages and disadvantages of other possible systems. Illustrate the temperature versus conversion progression for the suitable system. You may assume the catalyst has a long life.

[6 marks]

[c] Give an example of a parallel deactivation network and write the rate equations, which describe this system.

[2 marks]

[d] Why are the measurements of surface area, pore size and pore volume of catalysts important?

[3 marks]

3. [a] A packed bed has spherical pellets that pack in a square close-packed configuration.

[i] What is the void fraction in the reactor?

[2 marks]

[ii] Calculate the external surface area per liter of fluid volume for pellets of diameter of 1/4, 1/8, 1/16, 1/32, and 1/64 in.

[2 marks]

[iii] A first-order irreversible reaction $A \rightarrow Products$ occurs on 1/16 inch pellets with a conversion of 90%. What conversions would be obtained for each of these pellet diameters, assuming that the reaction is always reaction limited? Comment on the results.

[4 marks]

[b] In an automobile's catalytic converter, carbon monoxide and hydrocarbons present in the exhaust gases are oxidized. Unfortunately the effectiveness of these units decreases with use. The phenomenon was studied by a researcher by means of an accelerated aging test on a palladium impregnated porous pellet packed bed converter. From the reported data on hydrocarbon conversion shown in Table Q.3.[b], develop an expression to represent the deactivation rate of this catalyst.

Table Q.3.[b].

Time, hr	5	10	15	20	25	30	35	40
$X_{hydrocarbon}$	0.57	0.53	0.52	0.50	0.48	0.45	0.43	0.41

[12 marks]

[c] What are the objectives of catalyst characterization?

[3 marks]

[d] What is the difference between incipient wetness and wet impregnation method?

[2 marks]

4. [a] Discuss in detail about the advantages and disadvantages of the following sulphuric acid manufacturing processes:

[i] Lead chamber process
[ii] Contact process
[iii] Double-contact absorption process

[9 marks]

[b] Desribe the following:

[i] Thermal NO_x
[ii] Fuel NO_x
[iii] Prompt NO_x

[8 marks]

[c] Compare the advantages and limitations of the following VOC control technologies.

[i] Cryogenic condensation
[ii] Biofiltration
[iii] Thermal oxidation

[8 marks]

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