UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

EKC 533 – Industrial Catalysis and Reactor Engineering

Duration : 3 hours

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

Instruction: Answer **ALL** questions.

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1. [a] The following second-order liquid-phase catalytic reaction

$$A \rightarrow P$$

is conducted isothermally at 373 K in a mixed-flow reactor with void volume of 1L and containing 3 gm of catalyst. The initial concentration C_{Ao} and exit concentration C_{Aout} are 2 mol/L and 0.5 mol/L, respectively. The feed rate is 1 L/h.

[i] Find the rate constant for the reaction. *[5 marks]*

[ii] Find the amount of catalyst needed in a packed-bed reactor in order to achieve 80% conversion of 1000 L/h of feed of concentration C_{Ao} = 1 mol/L. *[5 marks]*

[iii] If the reactor used in part [ii] is packed with one part of catalyst to four parts inert solid of same particle size. Does using inert solid affect the reaction rate equation? *[2 marks]*

[b] Sketch the conversion (X_A) versus temperature (T) diagram for the following two packed-bed reactors system as shown in Figure Q.1.[b].

Given:
The reaction is exothermic
Conversion: X_{A1} = 0.6 and X_{A2} = 0.9
Recycle ratio: R_1 = 2 and R_2 = 1
The heat exchangers cool the reacting fluid.

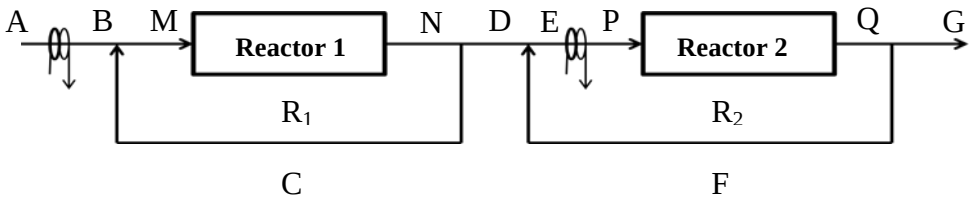

Figure Q.1.[b].

[5 marks]

[c] Cerium oxide (CeO_2) is very interesting metal oxide used as the support of Au for carbon monoxide oxidation. For this purpose, it is desired to synthesize 1% Au/CeO_2 catalyst by co-precipitation method. Summarize the steps of the preparation method using block diagram. The following chemicals are available:

- Hydrogen tetrachloroaurate (III) hydrate ($HAuCl_4.xH_2O$)
- Cerium nitrate ($Ce(NO_3)_3 \cdot 6H_2O$)
- Nickel(II) nitrate hexahydrate ($Ni(NO_3)_2 \cdot 6H_2O$)

[5 marks]

…3/-

[d] It is important to characterize the catalyst in part [c] above for its chemical composition, structure, texture and other properties. What are the properties that can be revealed from the following analytical instruments?

[i] Transmission electron microscopy (TEM)

[ii] X-ray Diffraction (XRD)

[iii] Scanning electron microscope (SEM) *[3 marks]*

2. [a] Cumene is cracked over silica-alumina catalyst to form benzene and propylene ($A \rightarrow R + S$). When the impurity cumene hydroperoxide (CHP) is present in trace amounts in the cumene feedstream, it can deactivate the catalyst. The feed consists of cumene and trace (0.08 mol%) of CHP. The following data were taken at 1 atm and 420 ^{o}C in a differential reactor.

Time, t (s)	0	50	100	150	200	300	400	500
Benzene in exit stream (mol%)	2	1.62	1.31	1.06	0.85	0.56	0.37	0.24

Determine the order of catalyst decay and the decay constant. *[15 marks]*

[b] List four disadvantages of fluidized bed reactor? *[4 marks]*

[c] What are the problem and cause of catalyst deactivation by sintering and how to minimize it? *[6 marks]*

3. [a] What are the catalysts used for the process of ammonia synthesis. Briefly describe them. Catalyst deactivation can also occur during the process. What are the potential poisons for the catalysts. *[9 marks]*

[b] What are the five different groups of catalysts that are normally used in dehydrogenation process. What are the potential cause of deactivation for these catalysts. *[8 marks]*

[c] Briefly discuss the catalyst and the process used in the hydrogenation of acetylene to ethylene. *[8 marks]*

4. [a] Briefly discuss the 'contact process' in the production of sulfuric acid including the catalyst used and the acid production steps. *[9 marks]*

[b] Pt-Rh based catalysts are commonly used in the production of nitric acid. Briefly discuss the advantages of these catalysts. *[7 marks]*

[c] Briefly discuss Non-Selective Catalytic Reduction (NSCR) and Selective Catalytic Reduction (SCR) for NOx reduction technology. *[9 marks]*