NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
END OF SEMESTER TWO EXAMINATIONS – MAY 2005
REACTOR TECHNOLOGY – SCH 4208
TIME: 3 HOURS

INSTRUCTION TO CANDIDATES

Answer **four** questions only. Total marks are 100.

SECTION A

1. (a) Milk is pasteurized if it is heated to 63°C for 24min, but if it is heated to 74°C it only needs 12s for the same result. Find the activation energy of this sterilization process.R = 8.314J/mol.K (7marks)

(b) A homogenous gas decomposition of phosphine

$$4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$$

proceeds at 650°C with the first order rate; $-r_{PH3} = (12.5/hr)C_{PH3}$.
What size of plug flow reactor at 650°C and 11.4atm is needed for 75% conversion 10mol/hr of phosphine in a 2/3 phospohine -1/3 inert feed? (10marks)

(c) Show that for a variable-volume batch reactor;
$-r_A = C_{Ao}/(1 + \varepsilon_A X_A)dX_A dt$; $V = Vo(1 + \varepsilon_A X_A)$ (8marks)

2. (a) Setting out from 1st principles to investigate the dehydrogenation of ethylbenzene which is a well established process for manufacturing styrene:

$$C_6H_5.CH_2.CH_3 ===== C_6H_5.CH{:}CH_2 + H_2$$

There is available a catalyst which will give a suitable rate of reaction at 560oC. At this temperature the equilibrium constant for the reaction above is:

$$P_{St}xP_H/P_{Et} = Kp = 100mbar = 10^4 N/m^2$$

and if the feed to the process consists of ethylbenzene diluted with steam in the ratio 15moles steam: 1 mole ethylbenzene, determine the fractional conversion at equilibrium α_e, (12marks)

(b) A human being (75kg) consumes about 6000kJ of food per day. Assume that the food is all glucose and that the overall reaction is:
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H2O$, $-\Delta H_r = 2816kJ$, find the man's metabolic rate(the rate of living, loving and laughing) in terms of moles of oxygen used per m^3 of person per second.$\rho_{man} = 1000kgm^{-3}$ (8marks)

(c) Explain the differences between elementary and non elementary reactions citing an example for each reaction. (5marks)

3. (a) Chemical A is being converted into chemical Rin a vessel packed with non-porous, spherical catalyst beads. The specific surface area of the catalyst is 60m2/m3 of packed bed, its bulk density is 180kg/m3 of packed bed, and the porosity of the bed, ε = 0.40. The stoichiometric equation is
$A \rightarrow 2R$, and the rate of disappearance of A based on unit mass of catalyst is proportional to the concentration of A present in the gas.

$$-r_A''' = -1/W dN_A/dt = 0{:}1C_A$$

The negative sign shows that the rate of change of A is negative, or that A disappears.

(i) write out rate equation given, showing the units of the various terms
(ii) find r_A', the rate based on unit volume of reactor
(iii) findr_A, the rate based on unit volume of the fluid
(iv) find r_A'', the rate based on the unit surface of catalyst (16marks)

(b) For a bimolecular type second order reaction, $2A \rightarrow$ products; $C_{Ao} = C_{Bo}$
Show that;

$$\int_o^{XA}(1+\varepsilon_A X_A)/(1-X_A)^2 dX_A=(1+\varepsilon_A)X_A/(1-X_A)+ \varepsilon_A \ln(1-X_A) = kC_{Ao}t$$ (9marks)

4. (a) A liquid reaction $A + B \rightarrow R + S$ is to be carried out at constant volume and temperature out in an ideal tube reactor. The reaction is almost totally irreversible and its rate equation is $r_A = -kC_AC_B$, where the rate equation constant has the value of $0.65.10^{-3}s^{-1}kmol^{-1}m^3$.The initial concentration of A and B are $2.5kmolm^{-3}$, respectively. Calculate the reaction time needed for a turnover of 92.5% and the smallest reactor volume needed. The molecular-weight for R is $150kgkmol^{-1}$ and the density for the solution is $900kgm^{-3}$.Also calculate the volume of a tank reactor operating at the same conditions. (15marks)

(b) Compare between a tank reactor and a tube reactor, giving the advantages and disadvantages, area of applications and also use sketch diagrams to explain concentration and reaction rate for each reactor. (10marks)

5. (a) A feed consisting 25% of 50-μm- radius particles;50% of 100- μm- radius particles; 25% of 200- μm- radius particles is to be reacted in a fluidized-bed steady-state flow reactor constructed from a vertical 2-m long 20-cm ID pipe. The fluidizing gas is the gas phase reactant, and at the planned operating conditions the time required for complete conversion is 6, 12, and 24min for the three sizes of feed. Find the conversion of solids in the reactor for a feed rate of 1.2kgsolids/min if the bed contains 12kg solids.

Additional information:
The solids are had and unchanged in size and weight during reaction. A cyclone separator is used to separate and return to the bed any solids that may be entrained by the gas. The change in gas phase composition in the bed is small.
(13marks)

(b) One liter per minute of liquid containing A and B (C_{Ao} = 0.15mol/liter, C_{Bo} = 0.015mol/liter) flow into a mixed reactor of volume V= 1liter. The materials react in a complex manner for which the stoichiometry is unknown. The outlet stream from the reactor contains A, B, and C (C_{Af} = 0.025 mol/liter, C_{Bf} = 0.035mol/liter, C_{Cf} = 0.045mol/liter). Find the rate of reaction of A, B and C for the conditions within the reactor, sketch the process diagram labeling it fully. (12marks)

End of question Paper!!!