NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
BACHELOR OF SCIENCE HONOURS DEGREE
SUPPLEMENTARY EXAMINATIONS – AUGUST 2014
REACTOR TECHNOLOGY – SCH 4208
TIME: 3 HOURS

Instructions to candidates:

1. Answer all questions in Section A and any three questions in Section B.
2. Show all your steps clearly in any calculation
3. Start the answers for each question on a new page.

Additional material:

Graph paper

SECTION A

1 (a) (i) State the law of conservation of mass
(ii) In what circumstances is the law of conservation of mass restricted. [8]

(b) 2000 kg of a 5 per cent slurry of calcium hydroxide in water is to be prepared by diluting a 20 per cent slurry. Calculate the quantities required. The percentages are by weight. [12]

2 (a) (i) With the aid of examples, distinguish between elementary and non-elementary reactions. [8]

(ii) In a process for the production of hydrogen required for the manufacture of ammonia, natural gas is to be reformed with steam according to the reactions:

$$CH_4 + H_2O \rightleftharpoons CO + 3H_2, \quad K_p(\text{at } 1173 \text{ K}) = 1.43 \times 10^{13} \text{ N}^2/\text{m}^4$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2, \quad K_p(\text{at } 1173 \text{ K}) = 0.784$$

The natural gas is mixed with steam in the mole ratio $1CH_4 : 5H_2O$ and passed into a catalytic reactor which operates at a pressure of 3 MN/m^2(30 bar). The gases leave the reactor virtually at equilibrium at 1173 K.
Show that for every 1 mole of CH_4 entering the reactor, 0.950 mole reacts, and 0.44 mole of CO_2 formed. [12]

SECTION B

3 (a) With the aid of a diagram describe the main features of a batch reactor. [5]

(b) Ethyl formate is to be produced from ethanol and formic acid in a continuous flow tubular reactor operated at a constant temperature of 303 K. The reactants will be fed to the reactor in the proportions 1 mole HCOOH: 5 moles C_2H_5OH at a combined flowrate of 0.0002 m^3/s (0.72 m^3/h).
The reaction will be catalysed by a small amount of sulphuric acid. At the temperature, mole ratio, and catalyst concentration to be used, the rate equation determined from small-scale batch experiments has been found to be:

$$\mathscr{R} = \boldsymbol{k} C_F^2$$

where: $\mathscr{R}$ is formic acid reacting/(kmol/m^3s)

C_F is concentration of formic acid kmol/m^3, and

$\boldsymbol{k} = 2.8 \times 10^{-4}$ m^3/kmol s.

(i) Estimate the volume of the reactor required to convert 70 per cent of the formic acid to the ester.

(ii) If the reactor consists of a pipe of 50 mm i.d. what will be the total length required?

(iii) Determine also whether the flow will be laminar or turbulent and comment on the significance of this in relation to the estimate of reactor volume. The viscosity of the solution is 1.4×10^{-3}N s/m^2.

[15]

4 (a) Fixed-bed reactors and fluidized-bed reactors are some of the most important industrial reactors. With the aid of sketch diagrams explain their mode of operation and where they are applied. [8]

(b) Derive the performance equation of an ideal batch reactor with a sinlge reaction occurring.

[12]

5 (a) (i) Explain the term **mixed flow** as applied to mixed flow reactors.
(ii) Give another name that is commonly used for mixed flow reactor. [5]

(b) Pure gaseous reactant A (C_{A0} = 100 millimol/l) is fed at a steady rate into a CSTR, of volume 0.1 litre, where it dimerises according to the reaction (2A $\longrightarrow$ R). For different gas feed rates the following data is obtained:

Run number	1	2	3	4
v_0 (litre/hr)	10.0	3.0	1.2	0.5
C_{af} (millimol/litre)	85.7	66.7	50.0	33.4

Find the rate equation. [15]

6(a) List five experimental methods for exploring the kinetics of catalytic reactions that you have studied. [5]

(b) The catalytic reaction A $\longrightarrow$ 4R is run at 4.1 atm and 112^{o}C in a plug flow reactor which contains 0.015kg of catalyst and uses a feed consisting of the partially converted product of 22 liters/hour of pure unreacted A. The results are as follows:

Run	1	2	3	4
C_{Ain}, mol/liter	0.100	0.080	0.060	0.040
C_{Aout}, mol/liter	0.084	0.070	0.055	0.038

Use a graphical method to find the rate equation to represent this reaction. [15]

End of question Paper!!!