NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
BACHELOR OF SCIENCE HONOURS DEGREE
END OF FIRST SEMESTER EXAMINATIONS – JANUARY 2011
REACTOR TECHNOLOGY – SCH 4208
TIME: 3 HOURS

INSTRUCTIONS TO CANDIDATES

Answer *all* questions in Section A *and any 3* questions in Section B. Total marks - 100.

SECTION A

1. (a) What is the main aim in designing a chemical reactor? [3 marks]

   (b) State the performance equation of a chemical reactor. [2 marks]

   (c) List ***three*** principal features of the reactor. [3 marks]

2. (a) List ***six*** types of catalysis. [6 marks]

   (b) State ***two*** methods of measuring reactor performance. [2 marks]

3. (a) There are two complicating factors that must be accounted for beyond what is normally considered in homogeneous systems. State these factors and explain the reason why they are considered complicating factors. [4 marks]

   (b) Fluid-solid reactions are numerous and of great industrial importance. They are those in which the solid does not appreciably change in size and those that appreciably change in size during reaction. Give two industrial examples of each. [4 marks]

4. (a) State the Arrhenius equation. [2 marks]

(b) A human being *(75* kg) consumes about 6000 kJ of food per day. Assume that the food is all glucose and that the overall reaction is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O, \quad -\Delta H_r = 2816 \text{ kJ}$$

from air (↑ O_2) breathed out (↑ CO_2)

Find 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. [6 marks]

5. Consider a gas-phase reaction $2A \rightarrow R + 2s$ with unknown kinetics. If a space-velocity of l/min is needed for 90% conversion of A in a plug flow reactor, find the corresponding

(i) space-time and [4 marks]

(ii) mean residence time or holding time of fluid in the plug flow reactor. [4 marks]

SECTION B

6. (a) Consumption of reactants to give unwanted and unmarketable byproducts is wasteful and affects negatively the operating expenses of a chemical production process. Using suitable examples where possible, explain why it is of utmost importance to ascertain the exact nature and amount of byproducts formed in a reaction when designing a reactor. [8 marks]

(b) State and explain the ***three*** reasons why a semi-batch reactor may be a suitable choice for a chemical reactor, with the aid of suitable examples. [9 marks]

(c) Deduce the material balance of a batch reactor. [3 marks]

7. (a) With the aid of a diagram, give a detailed account of ***one*** industrial use of continuous stirred tank reactors in Zimbabwe. [7 marks]

(b) Determine the time required for 80% conversion of 7.5 mol A in a 15-L constant-volume batch reactor operating isothermally at 300 K. The reaction is first-order with respect to A, with $k_A = 0.05$ min^{-1} at 300 K. [5 marks]

(c) Compare and contrast a batch reactor to continuous reactor. [8 marks]

8. (a) Yagi et al. (1951) roasted pyrrholite iron sulfide dispersed in asbestos fibres and found that the time for complete conversion was related to particle size as follows:

$$\tau \propto R^{1.5}$$

Particles remained as hard solids of unchanging size during the reaction. A fluidized-bed reactor is planned to convert pyrrholite ore to the corresponding oxide. The feed is to be uniform in size $\tau = 20$ min, with mean residence time $\bar{t} = 60$ min in the reactor. What fraction of original sulfide ore remains unconverted? [10 marks]

(b) With the aid of a diagram, and relevant industrial applications explain the shrinking core model for a non-catalytic reaction of particles with surrounding fluid. [10 marks]

9. Achieving sustainable processes that allow us at present to fully meet our needs without impairing the ability of future generations to do so, is an important goal for current and future engineers. In production of new materials, chemicals, and pharmaceuticals sustainable processes certainly require the most efficient use of raw materials and energy, preferably from renewable sources, and prevention of

generation and release of toxic materials. Advancing the state of the art of chemical reaction engineering (CRE) is the key element needed for development of such environmentally friendly and sustainable chemical processes.

Discuss the role of chemical reaction engineering in sustainable process development.

[10 marks]