National Exams December 2012

04-Chem-B4, Biochemical Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is CLOSED BOOK EXAM.
   One of two calculators is permitted, any Casio or Sharp approved models

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1(a) Use simplified flow diagrams to explain the difference between anaerobic and aerobic pathways for the metabolism of glucose to provide energy and cell growth. **(10 marks)**

Question 1(b) Draw schematic diagrams of a prokaryotic and eucariotic cell and describe the important components and their functions in each type of cell. **(10 marks)**

Question 2(a) Show the structure and explain the biological functions of each biochemical compound: DNA, RNA, Adenosine Triphosphate (ATP), phospholipids. **(10 marks)**

Question 2(b) For the following bacteria types, identify the carbon source, electron donor, electron acceptor, and main metabolic products: aerobic heterotrophic, aerobic autotrophic, anaerobic heterotrophic. **(10 marks)**

Question 3 The Monod equation is used to correlate the cell growth rate as a function of limiting substrate concentration. Calculate the cell growth rate of Saccharomyces cerevisiae (yeast) under aerobic conditions with glucose as the limiting substrate. The following Monod parameters are available:
Max. specific growth rate = 0.5 per hour
Saturation constant = 25 mg glucose per Litre
Glucose concentration = 40 g glucose per Litre
Cell concentration = 5 g dry weight per Litre
(20 marks)

Question 4

List a minimum of six scale-up criteria for stirred tank bioreactor design. Explain which scale-up criterion would you use in the following cases of cell growth:

a) shear sensitive mammalian cells

b) highly aerobic procaryotic cells that have high oxygen requirements

c) thermophilic cells whose growth requires strict control of bioreactor temperature

(20 marks)

Question 5

Consider a single air bubble and a single microbial cell in a fermentation medium. Explain the step-by-step physical transfer of oxygen molecules from air bubble to the cytoplasm of the cell and identify the various mass transfer resistances in series. Which mass transfer resistance is usually the rate-limiting step in the oxygen mass transfer? **(10 marks)**

Define the following parameters and give their units and explain their significance in aerobic fermentation:

1. Respiration rate coefficient and how it is related to critical dissolved oxygen concentration and other parameters
2. Individual liquid film mass transfer coefficient and how it is related to molecular diffusivity of oxygen and thickness of liquid film boundary layer surrounding an air bubble
3. Volumetric mass transfer coefficient and its dependence on power per unit volume and superficial air velocity.

(10 marks)

Question 6

Consider a unit liquid volume in a bioreactor with air bubbles in the presence of living cells. Using a mass balance of oxygen show how the rate of accumulation of oxygen is related to cell concentration, the volumetric mass transfer coefficient and other variables. For an aerobic bioreactor at steady-state with 20 g dry wt. cells/L, it was found that the rate of oxygen uptake by the cells was 1,000 mg O_2 per L per h. Assuming that the saturation oxygen concentration is 5 mg O_2/L and a near zero dissolved oxygen concentration, find the following: the volumetric mass transfer coefficient and the respiration rate coefficient.
(20 marks)