National Exams May 2013

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 a CLOSED BOOK EXAM.
   Any non-communicating calculator is permitted.
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 (20 marks)

Consider a continuous, aerobic bacterial culture in a continuous stirred tank bioreactor fed with sterile fermentation medium. Three different dilution rates D are tested, and the biomass concentration x and glucose concentration S in the exit stream are measured. The results are as follows:

D (h^{-1})	x (g/L)	S (mM)
0.05	0.248	0.067
0.5	0.208	1.667
5	0	10

A) Calculate the glucose yield coefficient $Y_{x/s}$ (g biomass/mole glucose).
B) Assuming Monod growth kinetics, calculate the maximum specific growth rate μ_{max} (h^{-1}) and the Monod constant K_S (mM). (mM = millimolar)

Question 2 (20 marks)

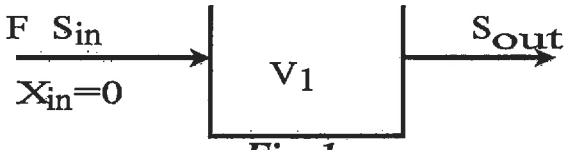

Fig. 1a

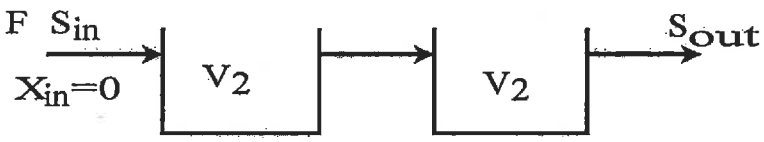

Fig. 1b

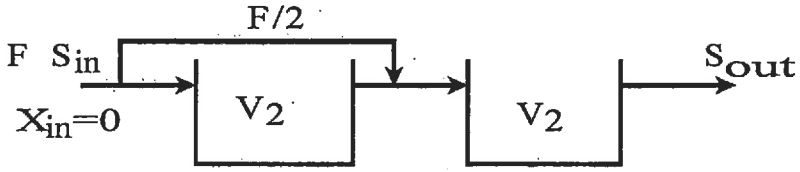

Fig. 1c

Figures 1a, 1b and 1c show three different bioreactor configurations: a single stage (1a), two bioreactors in series (1b) and two bioreactors in series with half of the feed being fed to the second bioreactor (1c). In all three bioreactor configurations the volumetric flow rate of the sterile medium F and the inlet substrate concentration S_{in} are the same; F=15 L/h and S_{in}=10 kg/m^3. In Figure 1a, the reactor volume V_1=0.1 m^3, and in Fig. 1b and 1c the bioreactor volumes are V_2=0.5V_1. The microbial process follows the Monod kinetics with: □$_{max}$=0.2 h^{-1}, K_s=2 kg/m^3 and $Y_{x/s}$=0.5 g/g. Calculate the substrate conversion [(S_{in}-S_{out})/S_{in}] for each of the bioreactor configurations and compare them.

Question 3 (20 marks)

Consider the growth of a microorganism in batch culture, inoculated at a concentration of 0.1 g/L, growing on glucose as the limiting substrate with initial concentration S_0 = 10 g/L. After a lag time of 3 h, the culture grows exponentially, with a doubling time of 2 h. Stationary phase is reached after a total time of 14 h. Assume that there was no decline phase.
Calculate:

- μ_{max} (h^{-1})
- $Y_{X/S}$ (g/g)
- The total time in culture to reach stationary phase if S_0 were 2 g/L, assuming that this concentration is also sufficient to support maximal growth (i.e. $S >> K_s$ during the entire fermentation).

Question 4 (20 marks)

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)

B) Draw a schematic diagram of a prokaryotic and eukaryotic cell and describe the important components and their functions in each type of cell. (10 marks)

Question 5 (20 marks)

A) Show the structure and explain the biological functions of each biochemical compound: Protein, DNA, RNA, Adenosine Triphoshate (ATP), phospholipids. (10 marks)

B) For the following bacteria types, identify the carbon source, electron donor, electron acceptor, and main metabolic products: (1) aerobic heterotrophic, (2) aerobic autotrophic, (3) anaerobic hetertrophic. (10 marks)

Question 6 (20 marks)

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