

04-BS-13, Biology/December 2018

National Exams December 2018

04-BS-13, Biology

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. One aid sheet allowed written on both sides. One of two calculators is permitted; any Casio or Sharp approved model.
3. FIVE (5) questions constitute a complete exam paper; i.e. **three (3) from Part 1 and two (2) from Part 11.**
The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

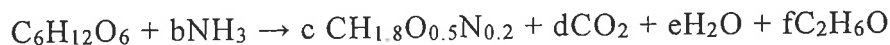
Part I: Solve any 3 questions out of the following 5 questions (20 marks for each)

Note: For some questions in order to calculate molecular weights of biomasses, products and substrates, elemental atomic masses will be needed. These are: for C = 12, for H = 1, for N = 14, and for O = 16.

1. (a) *Pseudomonas* 5401 is to be used for production of single cell protein for animal feed. The substrate is fuel oil. The composition of *Pseudomonas* 5401 is $\text{CH}_{1.83}\text{N}_{0.25}\text{O}_{0.55}$. Neglect ash content in biomass when calculating its MW. If the final cell concentration is 25 g/L, what minimum concentration of $(\text{NH}_4)_2\text{SO}_4$ (MW = 132.1) must be provided in the medium if $(\text{NH}_4)_2\text{SO}_4$ is the sole nitrogen source. (10 marks)

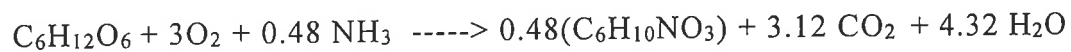
(b) Ethanol production by bacteria:

Zymomonas mobilis bacteria produce ethanol ($\text{C}_2\text{H}_6\text{O}$) from glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) under anaerobic conditions without external electron acceptors. The biomass yield from glucose is 0.05 g/g. The nitrogen source is NH_3 . Cell composition is represented by the formula $\text{CH}_{1.8}\text{O}_{0.5}\text{N}_{0.2}$. Assume 5% ash in the biomass. (Glucose degree of reduction (γ) = 4; ethanol degree of reduction (γ) = 6). This process is represented by:



- (i) What is the yield of ethanol from glucose? (8 marks)
 (ii) How do the yield calculated in (i) compare with the thermodynamic maximum? (2 marks)

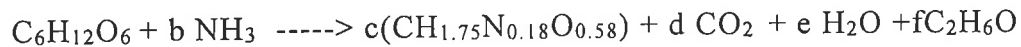
2. The growth of Baker's yeast (*S. cerevisiae*, $\text{C}_6\text{H}_{10}\text{NO}_3$, MW = 144) on glucose ($\text{C}_6\text{H}_{12}\text{O}_6$, MW = 180) is described by



In a batch reactor of volume 10^5 L, the final desired yeast concentration is 50 g biomass/L.

- (a) Determine the minimum initial concentrations (g/L) and total amounts (g) of glucose and NH_3 (MW = 17) needed in the nutrient media.
 (b) Determine the yield coefficients (g/g) $Y_{X/S}$ and Y_{X/O_2} .
 (c) Determine the total amount (g) of oxygen (MW = 32) required.
 (d) If the rate of growth at exponential phase is $r_x = 0.7$ g biomass/(L.h), determine the rate of O_2 consumption in g of O_2 /(L.h). (5 marks of each section)

3. A crude fermenter is set up in a shed in the backyard of a suburban house. Under anaerobic conditions with ammonia (NH₃) as nitrogen source, about 0.45 g ethanol (C₂H₆O, MW = 46.1) are formed per g glucose (C₆H₁₂O₆, MW = 180.2) consumed. At steady state, the production rate of ethanol averages 0.4 kg/h. The owner of this enterprise decided to reduce his electric bill by using the heat released during the fermentation to warm water as an adjunct to the household hot water system. 2.5 L/h cold water at 10°C is fed into a jacket surrounding the fermenter. To what temperature is the water heated? Heat losses from the system are negligible. Use a biomass composition of CH_{1.75}O_{0.58}N_{0.18} plus 8% ash. The stoichiometric equation is as:



The heats of combustion (Δh_c°) for various products are as:

Δh_c° for glucose = -2805 kJ/gmol

Δh_c° for NH₃ = -382.6 kJ/gmol

Δh_c° for biomass = -21.2 kJ/gmol

Δh_c° for ethanol = -1366. kJ/gmol

Density of water = 1 kg/L, specific heat of water = 75.4 J/(gmol. °C), MW of water = 18

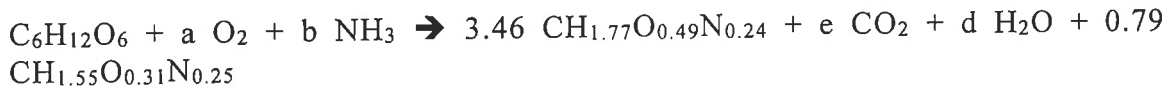
(20 marks)

4. (a) Estimate the theoretical growth and product yield coefficients ($Y_{X/S}$, $Y_{P/S}$) for ethanol fermentation by *S. cerevisiae* as described by:



$Y_{X/ATP}$ = 10.5 g biomass/mol ATP; and glycolysis yields 2 mol ATP/mol of glucose in biomass. MW of glucose = 180, MW of CO₂ = 44, and MW of C₂H₅OH = 46. (8 marks)

(b) A recombinant protein (CH_{1.55}O_{0.31}N_{0.25}, MW = 22.03) is being produced by *E. coli* (CH_{1.77}O_{0.49}N_{0.24}, MW = 25) using ammonia (NH₃) as nitrogen source and glucose (C₆H₁₂O₆, MW = 180) as substrate, and is described by the following stoichiometric equation:



Considering $\mu = \mu_{max} = 0.4 h^{-1}$, $m_s = 0.2 h^{-1}$, $m_P = 0.1 h^{-1}$, protein as desired product, calculate $Y_{X/S}$, $Y_{P/S}$, $Y'_{X/S}$ and $Y'_{P/S}$ in g/g.

(12 marks)

5. (a) How rheological properties of biological material are influenced by size, shape and volume of the cells and the physical nature and characteristics of the intercellular spaces. (10 marks)

(b) How the gross structure of a plant or animal product affects its further processing in useful products? Discuss with a few examples after providing cell gross structures. (10 marks)

Part II. Answer any 2 questions out of the following 3 questions (20 marks for each question)

1. (a) What uses do bacteria make of carbon source? What other nutrients might bacteria require, and why? How do selective, differential, and enrichment media differ? (10 marks)

(b) Discuss how materials move into and out of cells. What are the different transport mechanisms in prokaryotic and eukaryotic cells? Describe the differences in cell wall structure between Gram-positive and Gram-negative bacteria. (10 marks)

2. (a) What is a pure culture? Why do we place such importance on obtaining and maintaining pure cultures? Describe three methods for isolating pure cultures of microorganisms. (10 marks)

(b) What is the difference between fermentation and respiration? What is the difference between aerobic and anaerobic respiration? Why so many type of microbiological media used in the laboratory in the culture of microorganisms? (10 marks)

3. (a). What are the advantages and limitations of the following processes for sterilization? (i) Boiling, (ii) autoclaving, (iii) irradiation, (iv) dry heat, (v) ethylene oxide, and (vi) filtration. (15 marks)

(b). Why it is necessary to refrigerate milk that has been pasteurized? (5 marks)