

04-BS-13, Biology

National Exams December 2013

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

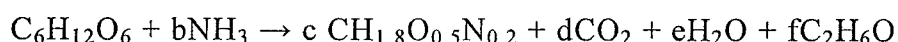
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Part I: Solve any 3 questions out of the following 6 questions (20 marks for each)

Note: For questions 1 to 4, 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. Ethanol production by yeast:

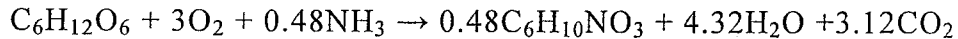
Saccharomyces cerevisiae produces ethanol (C_2H_6O) from glucose ($C_6H_{12}O_6$) under anaerobic conditions without external electron acceptors. The biomass yield from glucose is 0.11 g/g. The nitrogen source is NH_3 . Cell composition is represented by the formula $CH_{1.8}O_{0.5}N_{0.2}$. Assume 5% ash in the biomass. (Glucose degree of reduction (γ) = 4; ethanol degree of reduction (γ) = 6). This process is represented by:



- (a) What is the yield of ethanol from glucose? (15 marks)
(b) How do the yield calculated in (a) compare with the thermodynamic maximum? (5 marks)
2. Effect of cell growth on oxygen demand:
The biochemical reaction equation for conversion of ethanol (C_2H_6O) to acetic acid ($C_2H_4O_2$) is:
 $C_2H_6O + O_2 \rightarrow C_2H_4O_2 + H_2O$
Acetic acid is produced from ethanol during growth of *Acetobacter aceti*, which has the composition of $CH_{1.8}O_{0.5}N_{0.2}$. The biomass yield from the substrate is 0.14 g/g; product yield from the substrate is 0.92 g/g. Ammonia (NH_3) is used as nitrogen source. How does growth in this culture affect oxygen demand for acetic acid production? (Acetic acid degree of reduction (γ) = 4; ethanol degree of reduction (γ) = 6, γ for biomass = 4.2). (20 marks)
3. Production of Baker's yeast:
Baker's yeast is produced in a 50 000 litre (L) fermenter under aerobic conditions. The carbon substrate is sucrose ($C_{12}H_{22}O_{11}$); ammonia (NH_3) is provided as nitrogen source. The average biomass composition is $CH_{1.83}O_{0.55}N_{0.17}$ with 5% ash. The process is represented by:
 $C_{12}H_{22}O_{11} + aNH_3 + bO_2 \rightarrow cCH_{1.83}O_{0.55}N_{0.17} + dCO_2 + eH_2O$
Under efficient growth conditions, biomass is the only major product; and the biomass yield from sucrose is 0.5 g/g. If the specific growth rate is $0.45 h^{-1}$, estimate the rate of heat removal required to maintain constant temperature in the fermenter when the yeast concentration is 10 g/L. (20 marks)

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4. The growth of yeast (*S. cerevisiae*, X) on glucose (substrate, S) is described by:



In a batch reactor of volume 100 000 L, the final desired yeast concentration is 50 g biomass/L. Molecular weight of yeast = 144 g/mol, molecular weight of glucose = 180 g/mol, and molecular weight of ammonia = 17 g/mol.

- (a) Determine the yield coefficients Y_{XS} (g/g) and Y_{XO_2} (g/g). (10 marks)
 - (b) Determine the total amount of oxygen required. (5 marks)
 - (c) If the rate of growth at exponential phase is $r_x = 0.7$ g biomass/(L.h), determine the rate of oxygen consumption g/(L.h). (5 marks)
5. (a) In order to design a bioreactor for a process what type of data (10 important ones) you will need. (10 marks)
- (b) Why you will prefer the following bioreactors, give two reasons for each: Batch, Fed-batch, and Chemostat. (10 marks)
6. How does the gross cell structure of a plant or animal product affect its further processing into useful products? Discuss with a few examples after providing their cell structures. (20 marks)

Part II. Answer any 2 questions out of the following 4 questions (20 marks for each question)

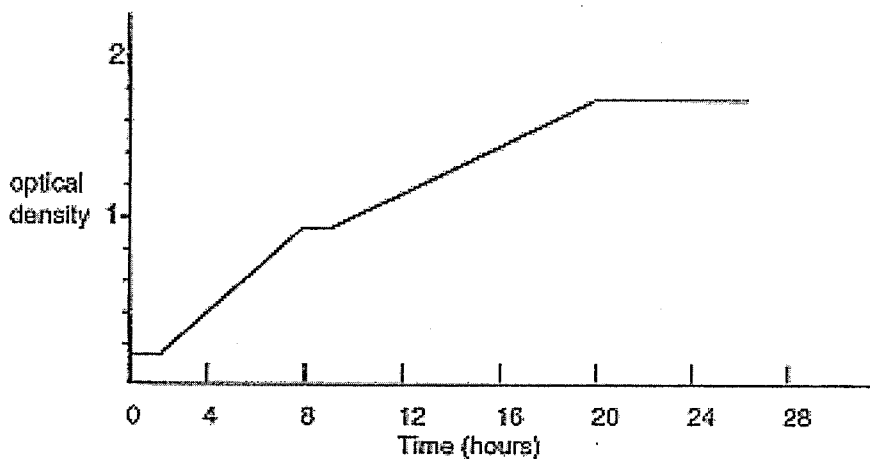
7. Hairy roots are produced by genetic transformation of plants using *Agrobacterium rhizogenes*. The following biomass and sugar concentration were obtained during batch culture of *Atropa belladonna* hairy roots in a bubble-column fermenter.

Time, d	0	5	10	15	20	25	30	35	40	45	50	55
Biomass concentration, g/L dry mass	0.64	1.95	4.21	5.54	6.98	9.5	10.3	12	12.7	13.1	13.5	13.7
Sugar concentration, g/L	30	27.4	23.6	21	18.4	14.8	13.3	9.7	8	6.8	5.7	5.1

- (a) Plot specific growth rate (μ) as a function of culture time. When is the growth rate constant? (10 marks)
- (b) Plot the specific rate of sugar uptake as a function of time. (8 marks)
- (c) What is the observed biomass yield (Y_{XS}) from substrate? (2 marks)

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8. Below (Fig. 1, page 5) is a growth curve for *Listeria* in broth culture. Draw the growth curve on the above graph when the:
- incubation temperature is increased to 37°C (A_w 0.99, pH 6.8), (7 marks)
 - the water activity (A_w) is decreased to 0.42 in combination with a 37°C incubation, (7 marks)
 - When the water activity is 0.99, incubation temperature of 15°C and pH 6.8 but the product stored under Modified Atmospheric Packaging (MAP; 20% carbon dioxide, 80% nitrogen). (6 marks)
9. Below is a growth curve for an *E. coli* culture growing on a glucose:lactose based medium. By referring to the curve answer the following questions



- The transcription of the beta-galactosidase and lactose permease genes begins at? (6 marks)
 - During what period of time do the bacteria utilize lactose as their sole source of carbon and energy? (7 marks)
 - During what period of time do the bacteria utilize glucose as a carbon-energy source? (7 marks)
10. (a) Describe the differences in cell wall structure between Gram-negative and Gram-positive bacteria. (7 marks)
- What are the similarities and differences between animal, plant and bacterial viruses? (7 marks)
 - What is the pure culture? Why do we place such importance on obtaining and maintaining pure culture? (6 marks)

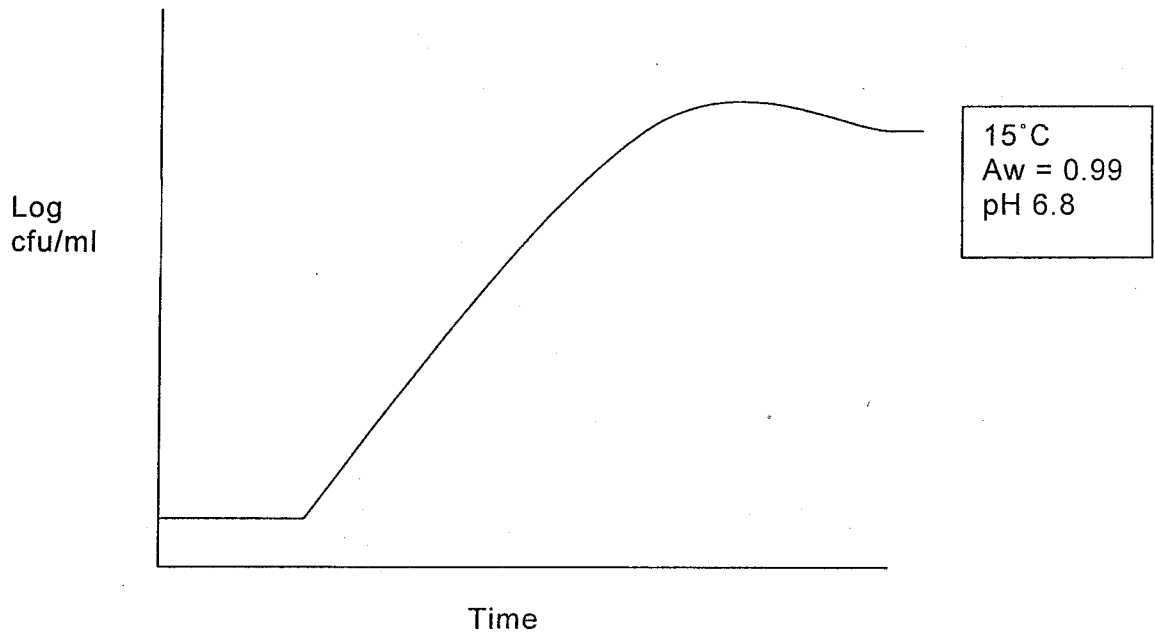


Figure 1 for problem 8

