National Exams December 2019

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 **CLOSE BOOK EXAM.** One aid sheet allowed written on both sides. A Casio or Sharp approved 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. Some questions require an answer in essay format. Clarity and organization of the answer are important.

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

Note: For some questions 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.

To calculate degree of reduction (γ) of an organic material or biomass, the number of available electrons is needed for various elements. These are 4 for C, 1 for H, -2 for O, and -3 for N.

1. Giving suitable figures, describe how from a morphological point of view, organization of the plant and animal material is related to physical handling and processing of these materials. (20 marks)

2. A well-mixed fed-batch fermenter (bioreactor) of volume V contains cells initially at concentration x_o. A sterile feed enters the fermenter with volumetric flow rate F. The concentration of substrate in the feed is s_i. The equation for rate of cell growth is: $r_x = k_1 x$; and the expression for rate of substrate consumption is: $r_s = k_2 x$; where k_1 and k_2 are rate constants with dimensions 1/h; r_x and r_s are dimensions of kg/(l.h), and x is the concentration of cells in the fermenter. (a) Derive a differential equation for the unsteady state mass balance of cells. (10 marks) (b) From this equation, what must be the relationship between F, k_1 and the volume of liquid in the fermenter at steady state? (4 marks) (c) Solve the differential equation to obtain an expression for cell concentration in the fermenter as a function of time. (6 marks).

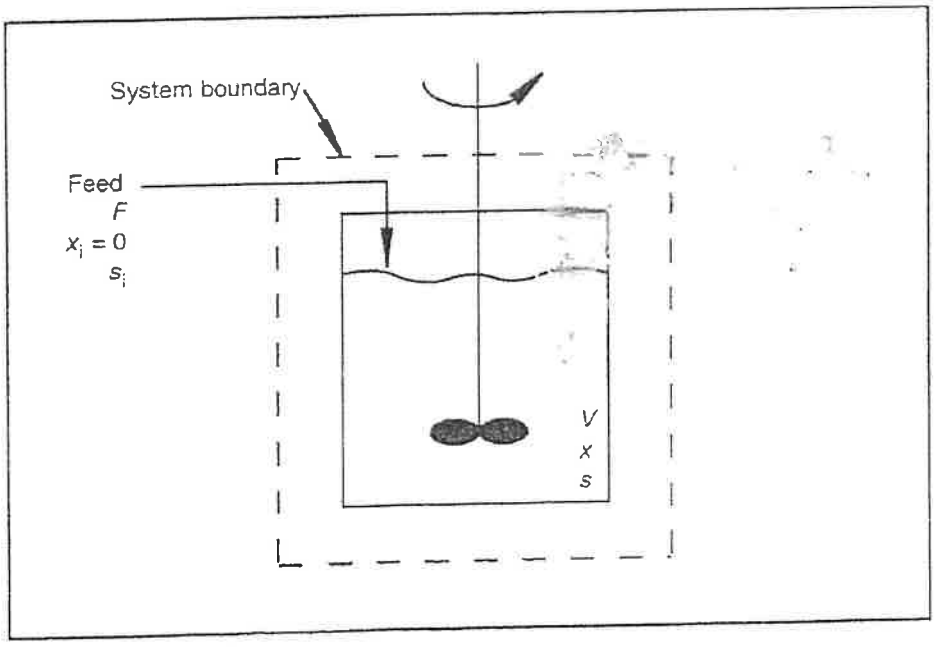

Fig. for question 2

3. Fumaric acid is produced from malic acid using the enzyme, fumarase. Calculate the standard heat of reaction for the following enzyme transformation:

$C_4H_6O_5$ (malic acid) $\rightarrow C_4H_4O_4 + H_2O$

The heats of combustion (Δh_c°) for various products are as:
Δh_c° for liquid water = 0 kJ/gmol
Δh_c° for malic acid = -1328.8 kJ/gmol
Δh_c° for fumaric acid = -1334.0 kJ/gmol

(20 marks)

4. Production of single cell protein from hexadecane is described by the following stoichiometric equation:

$C_{16}H_{34} + a\ O_2 + b\ NH_3$ -----> $c(C_{4.4}H_{7.3}N_{0.86}O_{1.2}) + d\ H_2O + e\ CO_2$

Where $C_{4.4}H_{7.3}N_{0.86}O_{1.2}$ represents the biomass. If cells can convert 2/3 (w/w) of the substrate carbon to biomass, (a) determine the stoichiometric coefficients for the above biological equation (10 marks). (b) Calculate the yield coefficients $Y_{X/S}$ (g biomass/g substrate) and $Y_{X/O2}$ ((g biomass/g oxygen). (10 marks)

5. *Celllomonas* bacteria ($CH_{1.56}N_{0.16}O_{0.54}$) used as single cell protein for human or animal food are produced from glucose under anaerobic conditions. All carbon in the substrate is converted into biomass; ammonia is used as nitrogen source. Cells contain 5% ash. How does the yield of biomass from substrate in mass and molar terms compare with the maximum possible biomass yield? (20 marks)

$C_6H_{12}O6$ (glucose) + 0.96 $NH_3 \rightarrow 6(CH_{1.56}N_{0.16}O_{0.54}) + 3\ H_2O$

Degree of reduction (γ_s) for glucose = 4, w (carbon atom in substrate) = 6.

6. Aerobic growth of *S. cerevisiae* on ethanol is given by:

$C_2H_5OH + aO_2 + bNH_3 \rightarrow cCH_{1.704}\ N_{0.149}\ O_{0.408} + dCO_2 + eH_2O$

(a) Determine the coefficients a, b, c and d, where respiratory quotient (RQ, i.e. ration of moles of CO_2 produces and moles of O_2 consumed) = 0.66. (12 marks)
(b) Determine the biomass yield coefficient, and oxygen yield coefficient on mass basis. (8 marks)

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

7. (a) List five major characteristics currently used in the classification of bacteria. (6 marks)

(b) What is fungal spore? List and describe five types of asexual fungal spores. (8 marks)

(c) Why do some bacteria have multiple plasmids and others none? (6 marks)

8. Below (Fig. 1) is a growth curve for *Listeria* in broth culture. Draw the growth curve on the above graph when the:
(a) incubation temperature is increased to 37°C (Aw 0.99, pH 6.8), (7 marks)
(b) water activity (Aw) is decreased to 0.42 in combination with a 37°C incubation, (7 marks)
(c) 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)

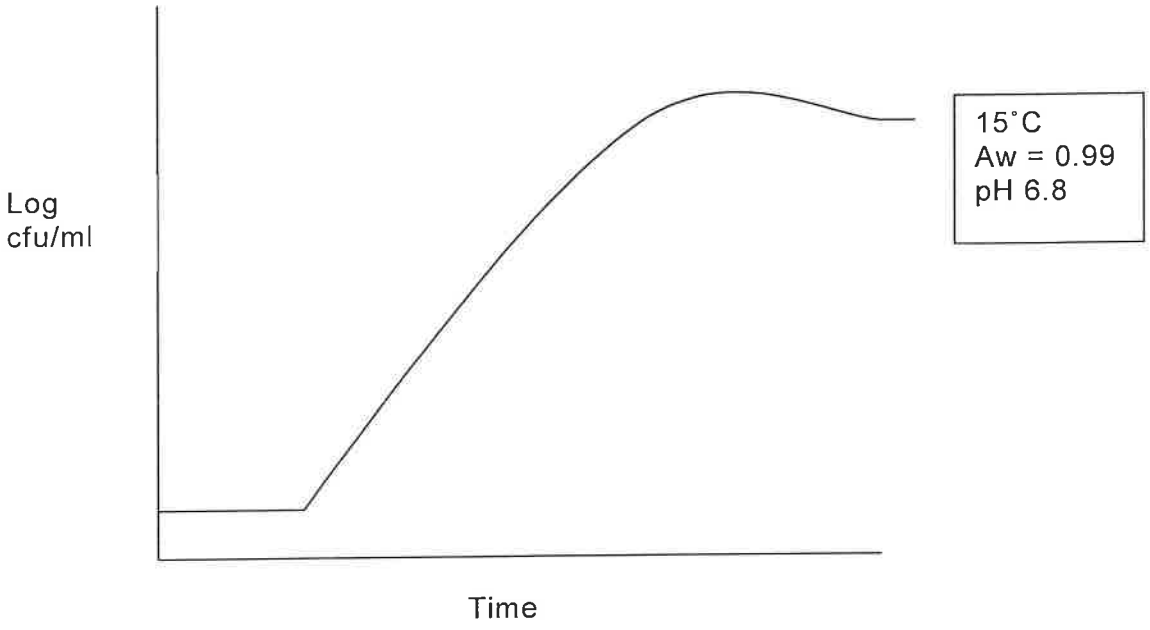

Figure for problem 8

9. Data for cell concentration (x) versus time (t) are plotted on a semilog paper. Points (t_1 = 0.5 h, x_1 = 3.5 g/l) and (t_2 = 15 h, x_2 = 10.6 g/l) fall on a straight line passing through the data.

(a) Determine the equation relating x and t. (15 marks)
(b) What is the value of the specific growth rate for the culture? (5 marks)