National Exams May 2017

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. Approved calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper. THREE (3) from Part I and TWO (2) from Part II. The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

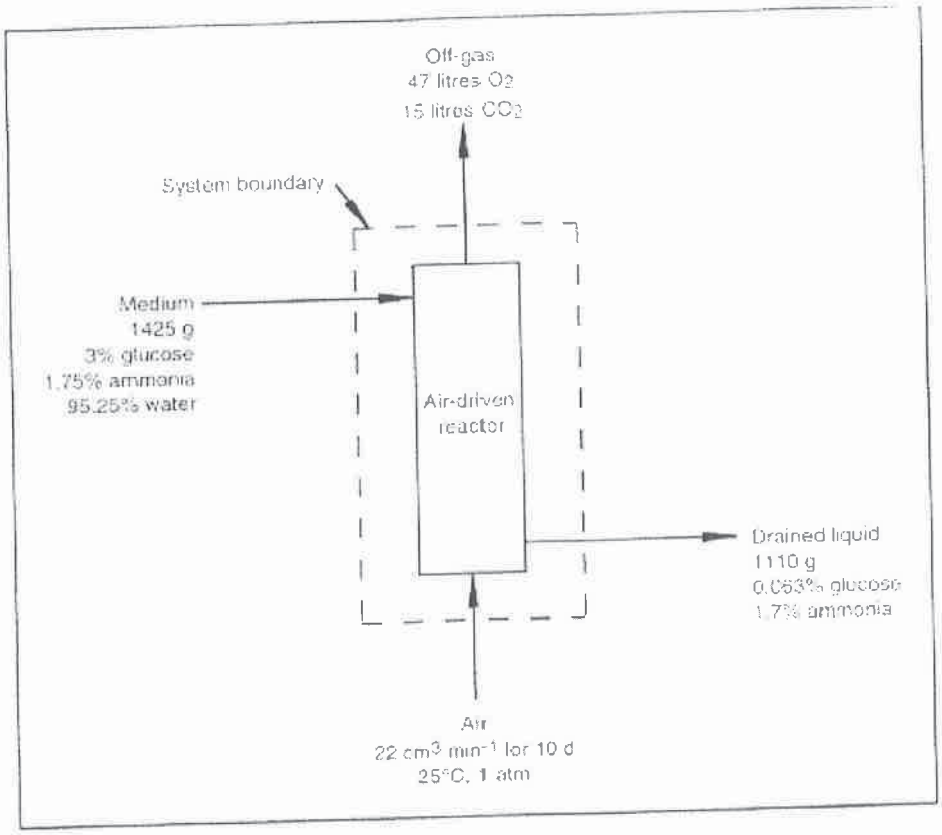
5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

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. Ethanol (C_2H_6O, MW = 46.1) is produced by anaerobic fermentation of glucose ($C_6H_{12}O_6$, MW = 180.2) by *Saccharomyces cerevisiae*. For the particular strain of *S. cerevisiae* employed, the maintenance coefficient is 0.18 kg/kg, Y_{XS} is 0.11 kg/kg. Y_{PX} is 3.9 kg/kg and μ_{max} is 0.4/h. It is decided to investigate the possibility of using *Zymomonas mobilis* bacteria instead of yeast for making ethanol. *Z. mobilis* is known to produce ethanol under anaerobic conditions using a different metabolic pathway to that employed by yeast. Typical values of Y_{XS} are lower than for yeast at about 0.06 kg/kg; on the other hand, the maintenance coefficient is higher at 2.2 kg/(kg h). Y_{PX} for *Z. mobilis* is 7.7 kg/kg; μ_{max} is 0.3/h.
   (a) From stoichiometry, what is the maximum theoretical yield of ethanol from glucose? The reaction equation for fermentation of glucose to ethanol without cell growth is:
   $C_6H_{12}O_6$ -----> $2C_2H_6O + 2\ CO_2$ (4 marks)
   (b) Y_{PS}' is maximum and equal to the theoretical yield when there is zero growth and all substrate entering the cell is used for maintenance activities. If ethanol is the sole extracellular product of energy yielding metabolism, calculate m_P for each organism. (5 marks)
   (c) *S. cerevisiae* and *Z. mobilis* are cultured in batch fermenters. Predict the observed product yield from substrate for the two cultures. (5 marks)
   (d) What is the efficiency of ethanol production by the two organisms? Efficiency is defined as the observed product yield from substrate divided by the maximum or theoretical product yield. (3 marks)
   (e) What does the specific rate of ethanol production by *Z. mobilis* compare with that by *S. cerevisiae*? (3 marks)

2. Plant roots produce valuable chemicals *in vitro*. A batch culture of *Atropa belladonna* roots at 25°C is established in an air-driven reactor as shown in figure below. Because roots can not be removed during operation of the reactor, it is proposed to monitor growth using mass balance.



1425 g nutrient medium containing 3% glucose ($C_6H_{12}O_6$) and 1.75% NH_3 is fed into the reactor; the remainder of the medium can be considered water. Air at 25°C and 1 atm pressure is sparged into the fermenter at a rate of 22 cm^3/min. During a 10-day culture period, 47 liters O_2 and 15 liters CO_2 are collected in the off-gas. After 10 days, 1110 g liquid containing 0.063% glucose and 1.7 % dissolved NH_3 is drained from the vessel. The ratio of fresh weight to dry weight for roots is known to be 14:1. (a) What dry mass of roots is produced in 10 days? (5 marks) (b) Write down the reaction equation for growth, indicating the approximate chemical formula for the roots, $CH_\alpha O_\beta N_\gamma$ (10 marks). (c) What is the limiting substrate? (2 marks) (d) What is the yield of roots from glucose? (3 marks)

The stoichiometric equation for aerobic growth is:

$C_6H_{12}O_6 + a\ O_2 + b\ NH_3$ -----> $c(CH_\alpha N_\beta O_\gamma) + d\ CO_2 + e\ H_2O$

Composition of air = 21% O_2 and 79% N_2 by volume; Gas constant (R) = 82.057 cm^3 atm/(K gmol)

3. *Propionibacterium* species are tested for commercial-scale production of propionic acid. Propionic and other acids are synthesized in anaerobic culture using sucrose ($C_{12}H_{22}O_{11}$, MW = 342.3) as substrate and ammonia (NH_3) as nitrogen source. Overall yields (w/w) from sucrose are as follows: Propionic acid ($C_3H_6O_2$, MW = 74.1) 40%, Acetic acid ($C_2H_4O_2$,

MW = 60.1) 20%, Butyric acid ($C_4H_8O_2$, MW = 88.1) 5%, lactic acid ($C_3H_6O_3$, MW = 90.1) 3.4%, and biomass ($CH_{1.8}O_{0.5}N_{0.2}$, MW = 25.9) 12%. Bacteria are inoculated into a vessel containing sucrose and ammonia; a total 30 kg sucrose is consumed over a period of 10 days. What are the cooling requirements? The stoichiometric equation is as:
$C_{12}H_{22}O_{11}$ + b NH_3 -----> c($CH_{1.8}N_{0.5}O_{0.2}$) + d CO_2 + e H_2O +f_1 $C_3H_6O_2$ + f_2 $C_2H_4O_2$ + f_3 $C_4H_8O_2$ + f_4 $C_3H_6O_3$

The heats of combustion (Δh_c^o) for various products are as:
Δh_c^o for sucrose = -5644.9 kJ/gmol
Δh_c^o for NH_3 = -382.6 kJ/gmol
Δh_c^o for biomass= -552 kJ/gmol
Δh_c^o for propionic acid = -1527.3 kJ/gmol
Δh_c^o for acetic acid = -874.2 kJ/gmol
Δh_c^o for butyric acid = -2183.6 kJ/gmol
Δh_c^o for lactic acid = -1368.3 kJ/gmol
(20 marks)

4. During exponential phase in batch culture, the growth rate of a culture is proportional to the concentration of cells present. When *Streptococcus lactis* bacteria are cultured in milk, the concentration of cells doubles in 45 min. If this rate of growth is maintained for 12 h, what is the final concentration of cells relative to the inoculum level? There is no loss of cells from the system. The volume of the reactor is constant.
(20 marks)

5. (a) How the mechanical properties of cell wall in plant material reflect the mechanical properties of plant tissues. Discuss this in relation to cellulose microfibrils embedded in an amorphous matrix (number and arrangements). Provide figures where needed. (10 marks)

(b) Describe protective tissues, conductive tissues and ground tissues. How these are related the material properties of plant and animal tissues? Provide figures where possible. (10 marks)

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

6. (a) How does each of the following factors affect growth in bacteria – pH, temperature, moisture, hydrostatic pressure, and radiation (8 marks)

(b) Describe 3 forms of bacteria (4 marks)

(c) Name two important genera of endospore forming bacteria encountered in foods (4 marks)

(d) Lactic acid may be produced by industrial fermentation. Indicate the role of lactic acid as a food additive and how do cells respond in environments in the presence of high concentrations of the organic acid. (4 marks)

7. Define the following terms and when there is more than one, compare and contrast their general characteristics with those of others in the same group.

(a) Cell wall, plasma membrane, and endoplasmic reticulum (5 marks)

(b) Protozoa, algae, mycelia, and amoeba (6 marks)

(c) Budding, sexual fusion, fission, and sporulation (6 marks)

(d) Why are so many types of microbiological media employed in laboratories for the culture of microorganisms? (3 marks)

8. A simple, batch fermentation of an aerobic bacterium growing on methanol gave the results shown in the table below. Calculate:

(a) Maximum growth rate (μ_{max}) (5 marks), (b) yield on substrate (Y_{XS}) (4 marks), (c) mass doubling time (t_d) (4 marks), (d) saturation constant (K_s) (3 marks), and (e) specific growth rate (μ_{net}) at t = 10 h (4 marks).

Time, h	Cell concentration, g/l	Substrate concentration, g/l
0	0.2	9.23
2	0.211	9.21
4	0.305	9.07
8	0.98	8.03
10	1.77	6.8
12	3.2	4.6
14	5.6	0.92
16	6.15	0.077
18	6.2	0.0

Use the regular graph paper provided for data plotting after converting cell concentration into log values or use semilog paper provided without converting to log values.