KATHMANDU UNIVERSITY
End Semester Examination [C]
July, 2017

JUL 0 7 2017

Level	: B. Tech.	Course	: BIOT 204
Year	: II	Semester	: I
Time	: 2 hrs. 30 mins.	F. M.	: 55

SECTION "C"
[5Q × 5 = 25 marks]

Answer *ANY FIVE* questions.

1. Production of single-cell protein from hexadecane is described by the following reaction equation:

$$C_{16}H_{34} + aO_2 + bNH_3 \rightarrow cCH_{1.66}O_{0.27}N_{0.20} + dCO_2 + eH_2O$$

where $CH_{1.66}O_{0.27}N_{0.20}$ represents the biomass. If respiratory quotient (RQ) = 0.43, determine the stoichiometric coefficients. [5]

2. In downstream processing of gluconic acid, concentrated fermentation broth containing 20% (w/w) gluconic acid is cooled in a heat exchanger prior to crystallisation. 2000 kg/h liquid leaving an evaporator at 90 °C must be cooled to 6 °C. Cooling is achieved by heat exchange with 2700 kg/h water initially at 2 °C. If the final temperature of the cooling water is 50 °C. What is the rate of heat loss from the gluconic acid solution to the surroundings? Assume the heat capacity of gluconic acid is 0.35 cal/g/°C. Use the provided standard tables. [5]

3. Describe cone-and-plate and coaxial-cylinder rotary viscometers with their biotechnological applications and limitations. [5]

4. How can a mixing effectiveness be assessed? Describe your assessment procedure assuming a stirred tank reactor with a dye as a tracer. [5]

5. Describe the kinetics of substrate uptake in cell culture, with and without product formations. [5]

6. *Serratiamarcescens* is cultured in a minimal medium reactor. Oxygen consumption is measured at a cell concentration of 22.7 g/L dry weight.

Time (min)	**Oxygen Concentration (mmol/L)**
0	0.25
2	0.23
4	0.21
8	0.20
10	0.18
12	0.16
14	0.15

a. Determine the best kinetic model fit to the data. [1]
b. Determine the rate constant. [2]
c. If the cell concentration is reduced to 12 g/L, what is the value of the rate constant? [2]

SECTION "D"

[3Q × 10 = 30 marks]

Attempt *ANY THREE* questions.

7. 1.5 kg salt is dissolved in water to make 100 litres. Pure water runs into a tank containing this solution at a rate of 5 L/min; salt solution overflows at the same rate. The tank is well mixed.
   a) How much salt is in the tank at the end of 15 min? Assume the density of salt solution is constant and equal to that of water. [5]
   b) Assume that a reaction in the tank consumes salt, at a rate given by the first-order equation:

   $$\mathbf{r = k_l\, C_A}$$

   where k_l is the first-order reaction constant and C_A is the concentration of salt in the tank. Derive an expression for C_A as a function of time. If k_l is 0.02 min^{-1}, how long does it take for the concentration of salt to fall to a value 1/20 the initial level? [5]

8. A fermentation slurry containing *Streptomyces kanamyceticus* cells is filtered using a continuous rotary vacuum filter. 120 kg/h slurry is fed to the filter; 1 kg slurry contains 60 g cell solids. To improve filtration rates, particles of diatomaceous-earth filter aid are added at a rate of 10 kg/h. The concentration of kanamycin in the slurry is 0.05% by weight. Liquid filtrate is collected at a rate of 112 kg/h; the concentration of kanamycin in the filtrate is 0.045% (w/w). Filter cake containing cells and filter aid is continuously removed from the filter cloth.
   a) What percentage liquid is the filter cake?
   b) If the concentration of kanamycin in the filter-cake liquid is the same as in the filtrate, how much kanamycin is absorbed per kg filter aid?

   Draw a flow diagram and mention the necessary assumptions. [10]

9. a) Describes the factors that can effect the rheology of fermentation broths. [5]
   b) A reactoris used to culture an anaerobic organism that does notrequire gas sparging. The broth can be assumed Newtonian.As the cells grow, the viscosity of the broth increases. In this condition, how can an increasing viscosity in biochemical process affects the power requirements? [5]

10. Describe (using examples, equations and/or figures)
   (a) Total rate [2]
   (b) First-order Kinetics [2]
   (c) Phases of cell growth in batch [2]
   (d) Theoretical and observed yields [2]
   (e) Effect of culture conditions on cell kinetics [2]

Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ kg^{-1}) Saturated liquid	Evaporation (Δh_v)	Saturated vapour
72	33.96	301.4	2329.0	2630.3
74	36.96	309.7	2324.0	2633.7
76	40.19	318.1	2318.9	2637.1
78	43.65	326.5	2313.9	2640.4
80	47.36	334.9	2308.8	2643.8
82	51.33	343.3	2303.8	2647.1
84	55.57	351.7	2298.6	2650.4
86	60.11	360.1	2293.5	2653.6
88	64.95	368.5	2288.4	2656.9
90	70.11	376.9	2283.2	2660.1
92	75.61	385.4	2278.0	2663.4
94	81.46	393.8	2272.8	2666.6
96	87.69	402.2	2267.5	2669.7
98	94.30	410.6	2262.2	2672.9
100 (Boiling point)	101.325	419.1	2256.9	2676.0

Table C.2 Enthalpy of saturated water and steam

(Pressures from 0.6112 kPa to 22 120 kPa)

Reference state: Triple point of water: 0.01°C, 0.6112 kPa.

Pressure (kPa)	Temperature (°C)	Specific enthalpy (kJ kg^{-1}) Saturated liquid	Evaporation (Δh_v)	Saturated vapour
0.6112 (Triple point)	0.01	+0.0	2501.6	2501.6
0.8	3.8	15.8	2492.6	2508.5
1.0	7.0	29.3	2485.0	2514.4
1.4	12.0	50.3	2473.2	2523.5
1.8	15.9	66.5	2464.1	2530.6
2.0	17.5	73.5	2460.2	2533.6
2.4	20.4	85.7	2453.3	2539.0
2.8	23.0	96.2	2447.3	2543.6
3.0	24.1	101.0	2444.6	2545.6
3.5	26.7	111.8	2438.5	2550.4
4.0	29.0	121.4	2433.1	2554.5
4.5	31.0	130.0	2428.2	2558.2
5.0	32.9	137.8	2423.8	2561.6
6	36.2	151.5	2416.0	2567.5
7	39.0	163.4	2409.2	2572.6
8	41.5	173.9	2403.2	2577.1
9	43.8	183.3	2397.9	2581.1
10	45.8	191.8	2392.9	2584.8
12	49.4	206.9	2384.3	2591.2
14	52.6	220.0	2376.7	2596.7
16	55.3	231.6	2370.0	2601.6
18	57.8	242.0	2363.9	2605.9
20	60.1	251.5	2358.4	2609.9

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Steam Tables

(From R.W. Haywood, *Thermodynamic Tables in SI (Metric) Units*, 1972, 2nd edn, Cambridge University Press, Cambridge)

Table C.1 Enthalpy of saturated water and steam (Temperatures from 0.01°C to 100°C)

Reference state: Triple point of water: 0.01°C, 0.6112 kPa.

Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ kg^{-1}) Saturated liquid	Evaporation (Δh_v)	Saturated vapour
0.01 (Triple point)	0.611	+0.0	2501.6	2501.6
2	0.705	8.4	2496.8	2505.2
4	0.813	16.8	2492.1	2508.9
6	0.935	25.2	2487.4	2512.6
8	1.072	33.6	2482.6	2516.2
10	1.227	42.0	2477.9	2519.9
12	1.401	50.4	2473.2	2523.6
14	1.597	58.8	2468.5	2527.2
16	1.817	67.1	2463.8	2530.9
18	2.062	75.5	2459.0	2534.5
20	2.34	83.9	2454.3	2538.2
22	2.64	83.9	2454.3	2538.2
24	2.98	100.6	2444.9	2545.5
25	3.17	104.8	2442.5	2547.3
26	3.36	108.9	2440.2	2549.1
28	3.78	117.3	2435.4	2552.7
30	4.24	125.7	2430.7	2556.4
32	4.75	134.0	2425.9	2560.0
34	5.32	142.4	2421.2	2563.6
36	5.94	150.7	2416.4	2567.2
38	6.62	159.1	2411.7	2570.8
40	7.38	167.5	2406.9	2574.4
42	8.20	175.8	2402.1	2577.9
44	9.10	184.2	2397.3	2581.5
46	10.09	192.5	2392.5	2585.1
48	11.16	200.9	2387.7	2588.6
50	12.34	209.3	2382.9	2592.2
52	13.61	217.6	2378.1	2595.7
54	15.00	226.0	2373.2	2599.2
56	16.51	234.4	2368.4	2602.7
58	18.15	242.7	2363.5	2606.2
60	19.92	251.1	2358.6	2609.7
62	21.84	259.5	2353.7	2613.2
64	23.91	267.8	2348.8	2616.6
66	26.15	276.2	2343.9	2620.1
68	28.56	284.6	2338.9	2623.5
70	31.16	293.0	2334.0	2626.9