10.542 – Biochemical Engineering
Spring 2005

Problem Set #5
Solutions should be written and submitted on your own paper. All pages should be stapled together.

1) Shuler & Kargi, Problem 9.2

2) Shuler & Kargi, Problem 9.11

3) Consider the thermophilic methanogen, *Methanococcus jannaschii*, grown in continuous culture at steady state. *M. jannaschii* produces methane according to the overall stoichiometric equation:

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

The gaseous substrates, H_2 and CO_2, are supplied in the entering gas stream, and the product methane is removed in the exiting gas stream.

(a) Write unsteady state mass balances for hydrogen and methane in both the gas and liquid phases. Write an unsteady state mass balance for biomass.

(b) In practice, a readily measurable parameter is p_{CH4}, the partial pressure of CH_4 in the exiting gas stream. Assuming steady state and neglecting the loss of methane in the exiting liquid phase, derive an expression for the specific methane production rate (q_{CH4}, in moles CH_4 (cell-hr)$^{-1}$) in terms of p_{CH4}, Q (the volumetric gas flow rate), V_L (the liquid volume), and X (the steady state biomass concentration).

4) The following C_{O2}(t) data were obtained in a 10 liter, air-sparged laboratory fermenter during the continuous cultivation at 0.5 hr^{-1} of *K. aerogenes* on glucose-based medium, at 37°C. The air was turned off at zero time and the surface of the liquid was swept with a nitrogen gas stream. After 2 minutes, aeration was recommenced. The concentration of *K. aerogenes* remained constant at 5.0 gm DCW/liter during this period. The solubility of oxygen in water at 37 °C is approximately 7 mg/L for air at atmospheric pressure (i.e., pO2 = 0.209 atm).

Detemine the specific oxygen uptake rate of *K. aerogenes* and the mass transfer coefficient under the agitation conditions employed.

Time (seconds)	***Probe reading (% sat)***	***Time (seconds)***	***Probe reading (% sat)***
0	80	130	23.7
10	73.6	150	49.2
20	67.2	170	63.0
30	60.8	190	70.7
40	54.4	210	74.9
60	41.2	230	77.2
80	29.2	250	78.5
100	15.5	290	79.5
110	10.2	350	80
120	4.1	400	80

(over)

5) Shuler & Kargi, Problem 10.6

6) Shuler & Kargi, Problem 10.8