Ex/PG/BPE/T/112A/2024

**M.E. Bio-Process Engineering - First Year - First Semester 2024**

**Bioreaction Engineering and Bioreactor Design**

Time : Three hours | Full Marks : 100

**Answer any five questions**

***All symbols have usual meaning***

***Assume any missing data***

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| 1. a) A $6m^3$ fermenter is operated continuously with feed substrate concentration of $15kg.m^{-3}$. The microorganism has the following growth kinetic characteristics: $\mu_{max} = 0.45h^{-1}$; $K_S = \frac{0.8g}{L}$; $Y_{X/S} = 0.55$<br>(i) What is the feed flow rate required to achieve 90% substrate conversion?<br>(ii) How does the biomass productivity at 90% conversion compare with the maximum one?<br>1. (b) State the mechanism and derive the rate equation for the competitively inhibited enzymatic reaction. | 15<br><br><br><br><br>5 |
| 2. a) A microbial strain is cultured in a $10m^3$stirred fermenter. The value of $k_la$ *is* $0.17min^{-1}$. Oxygen solubility in the broth is $8\ g.m^{-3}$.<br>a) If the specific rate of oxygen uptake is 10mmol/g/h, what is the maximum possiblecell concentration?<br>b) Bacteria suffer growth inhibition when copper sulphate is accidentally added to the broth. This causes a reduction in the oxygen uptake rate to 3mmol/g/h. What maximum cell concentration can now be achieved?<br>2. b) Describe Feedback control loop | 15<br><br><br><br><br>5 |
| 3.A single pass shell-and-tube heat exchanger is used to heat a dilute salt solution used in a large scale protein chromatography. $25m^3$ /h solution passes through 40 parallel tubes inside the heat exchanger. The tubes are of 15mm diameter and 4m length. The viscosity of the salt solution = $10^{-3}kgm^{-1}s^{-1}$; density=$1010kgm^{-3}$; average heat capacity = $4kJkg^{-1}{}^oC^{-1}$ and thermal conductivity = $0.64Wm^{-1}{}^oC^{-1}$. $N_{Nu} = 0.023N_{Re}^{0.8}N_{Pr}^{0.4}$<br>In another case, a stirred fermenter of diameter 5m contains an internal helical coil for heat transfer. The fermenter is mixed using turbine impeller of 1.8m diameter, operated at 50rpm. The fermenter broth has viscosity = $5x10^{-3}$ Pa-s; density =$1000kgm^{-3}$; average heat capacity =$4.2kJkg^{-1}{}^oC^{-1}$; thermal conductivity =0.7 $Wm^{-1}{}^oC^{-1}$. $N_{Nu} = 0.87N_{Pr}^{0.62}N_{Pr}^{0.33}$<br>Calculate the heat transfer coefficients for both the cases. | 20 |
| 4. In a two stage chemostat arrangement, the volumes of 1st and the second reactors are 500L and 300L respectively. The first reactor is used for cell production and the second is used for antibiotic production. The volumetric feed rate is 200L/h and the glucose concentration is 5g/L. The growth kinetic data of the microbe used in the reactor are as follows: $\mu_{max} = 0.5h^{-1}$; $K_S = \frac{0.1g}{L}$; $Y_{X/S} = 0.4$.<br>Determine cell and glucose concentrations in the effluent of the first reactor. Assuming negligible growth of cells in the second reactor, determine the product and substrate concentrations at the effluent of the second reactor if $q_p = 0.02g/gcell/h$ *and* $YP/s = 0.5$.<br>compare with the maximum one? | 20 |
| 5. In a chemostat with cell recycle, the feed flow rate and culture volume of 100mL/h and V=1L respectively. The system is operated under glucose limitation and the yield coefficient $Y_{X/S}$ is 0.5kg/kg. Glucose concentration in the feed is 10g/L. The $\mu_{max} = 0.2h^{-1}$; The value of | 20 |

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| concentration factor, c is 1.5 and the recycle ratio is 0.7. The system is under steady state. Find the substrate concentration in the recycle stream. Find the biomass concentration inthe recycle stream and in the separator effluent. | |
| 6. Penicillin is produced by *P. chrysogenum* in a fed-batch culture with the intermittent addition of glucose solution to the culture medium. The initial culture volume at quasi-steady state is $V_0 = 500L$, and glucose-containing nutrient solution is added with a flow rate of 50 L/h. Glucose concentration in the feed solution and initial cell concentration are $C_{S0} = 300g/L$ and $C_{X0} = 20$ g/l, respectively. The kinetic and yield coefficients of the organism are $\mu_m = 0.2h^{-1}$, $K_S = 0.5g/L$, and $Y_{X/S} = 0.3$. (i) Determine the culture volume at t = 10 h; (ii) Determine the concentration of glucose at $t = 10h$ at quasi-steady state; (iii) Determine the concentration and total amount of cells at quasi-steady state when t = 10 h; (iv) If $q_P = 0.05g\ product.\ (g\ biomass)^{-1}\ h^{-1}$ and $C_{P0} = 0.1g/L$ , determine the product concentration in the vessel at $t = 10h$. | 20 |
| 7. Discuss on<br>(a) Continuous sterilization<br>(b) Bubble column bioreactor | 10<br>+<br>10 |