National Exams May 2019

16-Chem-B4, Biochemical Engineering

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. An approved Casio or Sharp calculator is permitted.**

3. **FIVE (5) questions constitute a complete exam paper. ANSWER ALL FIVE QUESTIONS.**

4. **Each question is of equal value.**

5. **If questions require an answer in short essay format, clarity and organization of the answer are important.**

Question 1 (20 marks)

Microorganisms are being applied in a well mixed stirred tank system of working volume (V_L) 10 m^3 to treat the wastewater. A single Rushton turbine impeller is applied for mixing. The impeller diameter is 0.936 m and the rotational speed is 1 RPS. Assume the density and viscosity of the broth are 1000 kg/m3 and 10^{-3} Pa.s respectively. Assume the power number $N_p = 6$ and the ratio of gassed power to total power supplied is 0.6. What is the maximum volumetric flux of oxygen (in g O_2 per m^3 per h) which can be supplied to the water?

Given the following information:

The solubility of oxygen in water is given by the following equation

DO (ppm) = $\frac{(P-p)\times 0.678}{35+t}$ **$0\ ^\circ C < t < 30\ ^\circ C$ and P, p = total and partial pressure (oxygen) in Torr, DO stands for dissolved oxygen and t is temperature in deg C.**

Assume that the the mole fraction of oxygen in air is 0.21 and the total pressure is 1 atmosphere (760 Torr) and temperature is 20 degree Celsius.

$$k_L a = 9.09 \times 10^{-4} \left(\frac{P_g}{V_L}\right)^{0.7}$$

Here P_g/V_L is in kW/m^3 and k_La is in s^{-1}

Also given: Power number = $N_P = P g_c/n^3 D_i^5 \rho$ where P is in Watts (for SI units); Reynolds number = $N_{Rc} = nD_i^2\rho/\mu$. Where all symbols have their usual meaning

Question 2 (20 marks)

Derive the Michaelis-Menten Equation ($v = v_m S/ (K_m + S)$ } for enzyme kinetics from first principles. All symbols have their usual meaning.

Question 3 (20 marks)

If the observed rate of reaction for immobilized spherical catalyst particles of diameter 1 mm is 200 micromol/(cm^3 of catalyst).min, and the initial substrate concentration S_0 is 100 mol/m^3 and the observable Thiele modulus is 4.3, what is the effective diffusivity of the substrate (in m^2/s) in the immobilized enzyme particle.

Question 4 (20 marks)

The cultivation of a cell culture is to be scaled up from a 0.01 m^3 volume bioreactor to a 50 m^3 bioreactor. For the smaller bioreactor, the impeller diameter is 0.1 m and the bioreactor diameter is 0.3 m. The smaller bioreactor is operated at 100 RPM. Assume the density and viscosity of the broth are 1000 kg/m^3 and 10^{-3} Pa.s respectively. What is the the diameter of the vessel and impeller for the larger bioreactor and alsocCalculate the rotational speed of the impeller in the larger bioreactor assuming equal impeller tip speed in the smaller and llarger bioreactors Assume the same tank height to tank diameter ratio for both bioreactors as a geometrical similarity condition.

Question 5 (20 marks)

Sketch, with appropriate descriptive labels, the process schematics for two different approaches for high temperature, short time (HTST) sterilization. Briefly compare advantages and disadvantages of each.