Bioseparation Engineering

BBL 731

Major – Maximum marks 40

Note. In this question paper, YZ refer to the following. If your entry no. is 2016BB10018 and Y is 1 and Z is 8. If your entry no. is 2019BEZ10453 then Y is 5 and Z is 3. When it is written YZ, that means 18 for the former and 53 for later. If it is written Y.Z than means 1.8 for former and 5.3 for later. If it is written 125+Y+Z, then it is 125+1+8 = 134 for former and 125+5+3 = 133 for later.

1. A process engineer needs to crystallize the solution of monosodium glutamate in a 1 L reactor. You performed thermocalorimetry experiments and found that the solution has energy of 112 KJ/mole at 298K. From the literature, you know that super saturated solution of the same compound has energy of 112KJ/mole, while metastable energy was 125+Y+Z KJ/mole while saturated solution has energy of 100 KJ/mole. Considering above,

(a) what energy should be imparted to the solution for the crystallization? (1 mark)

After imparting of this energy, you decided to accelerate the process by means of adding YZ nucleating agents with side of 10 nm and are in shape of a cube. The rate of the nucleation varies by

$$\frac{dN}{dt} = K_n(C - C^*)$$

Where C and C* are concentration in solution and at saturation. The value of K_n is Y.ZX10^{-4} L/(mg X seconds) at 298 K, concentration at supersaturation was 50+Y+Z g/L while the concentration at saturation can be maximum of 30 g/L.

(b) What will be the initial rate of nucleation? (1 marks)

Now 20 second after the crystallization operations, temperature drops by 10 K as chiller start to work properly. Now the temperature is 288 K. At this temperature, the maximum solubility of monosodium glutamate is 1g/L. In the first 20 second, the average nucleation rate is 25% of the initial rate per unit nucleating agents. In our process, all the nuclei grow as a single crystal. The growth of crystals are in shape of cubes and given by

$$\frac{dM}{dt} = kA(C - C^*)$$

Where M is the mass of each crystal, k = 4.5 X 10^{-9} L/(m^2 second) is mass transfer coefficient, A is area of the crystal and C and C* are concentration in solution and at saturation.

(c) What will be the initial rate of crystal growth? (1 mark)

(d) Considering that the average crystal growth rate is 40% of the initial growth, what will be the initial nucleation rate at temperature 288 K. Note that the K_n increases linearly with every 0.1 increase in the temperature in Kelvin (2 marks).

(e) At this stage, you came to know that another impurity who saturated concentration at 298 K is 45 g/L while at 288 K is 0.002 g/L. The concentration of this impurity is 1 g/L in the solution. What will be the purity of the crystal formed? (1 mark)

(f) Your supervisor comes and ask you whether you can model the size of crystal with time. How will you do it? Show the derivation (2 marks).

Q2. Your solute has a diameter of 1+Y+Z X 10^{-15}m which follows Fick's first law of diffusion in a cylindrical tank with a diameter of 2 m and length of 10 m. he Fick's first law of diffusion is given by

$$J_A = \frac{D_v}{B_T}\left[C_{Ai} - C_A\right]$$

Where J_A is flux given in moles per unit area per unit time. D_v is the diffusion coefficient, B_T is the film thickness, C_{Ai} is the starting moles and C_A is the moles across the film. The D_v is given by -

$$D_v = \frac{KT}{6\pi r_0 \mu}$$

K is the Boltzmann constant, 1.380 X 10^{-23} J/K, T is the temperature in Kelvin, r_0 is molecular radius of the solute and μ is the viscosity is 8.90 X 10^{-4} Pa.Seconds. The temperature is 298 K.

You can consider the following assumption that the diffusion is taking place along the length of the reactor. C_A is 0 while C_{Ai} is 100 moles. The thickness of the film can be considered length of the reactor.

(a) Calculate the diffusion coefficient (1 mark)

(b) What is the initial flux? (1 mark)

(c) Assuming average flux is half the initial flux, calculate the time required to reach equilibrium? (2 marks)

(d) What should be the Power given the to ensure that the time of mixing is only 0.000001% of the time required for the mixing through only diffusion? (2 marks)

Q3. You are performing an electrophoresis experiment. As an experienced operator you know that the solute changes its charge with change in temperature. The empirical charge Z of the solute is given by the following equation:

$Z = (T-0.5)/T$

The temperature on the other hand follows step wise increase. Every 5 minutes of operation leads to increase in 10 K temperature.

Your life is further complicated by the fact that potential per cm increases by 1 unit after each 10 minutes run. You have a plate of 100 cm long.

(a) Calculate how long will it take the solute to reach till end? (3 marks). The initial temperature is 273+Y+Z Kelvin

(b) Draw the potential function with respective to the length of the plate. (1 mark)

(c) Draw charge function with respective to the length of the plate. (1 mark)

Your impurity on the other hand follows the following charge rule

$Z = (T+0.5)/T$ and every 5 minutes of operation leads to increase in 10 K temperature while the potential remains constant at 1 volt/cm for this impurity through-out.

(d) Where will you be your impurity when the sample is end of the plate? Where will you collect the impurity? (1 mark)

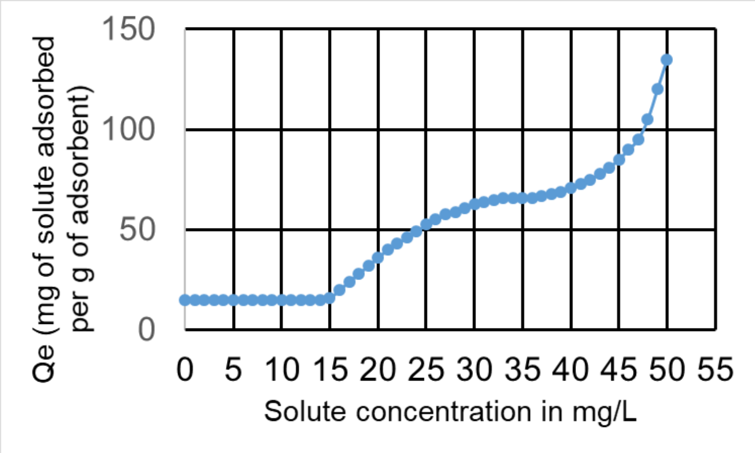
The diffusion coefficient is 7.8×10^{-7} cm^2/second and T = 298 K.

Q4. The adsorption of compound X is studied in a packed bed adsorption column. The parameters of test column are diameter = 4.5 cm, void fraction 0.YZ, length = 250 cm, density of adsorbent = 1.05 g/cm^3, feed concentration 30 mg/cm^3, breakthrough volume 3000 cm^3, exhaust volume is 4000 cm^3, feed velocity is 10 cm/minute, breakthrough concentration is 5% of feed and exhaust concentration is 90% of feed. Calculate time of breakthrough and time of exhaust. (a) What is the amount of X adsorbed in equilibrium zone and adsorption zone considering the linear increase in concentration of X in both the zones (4 marks)? If the feed concentration is increased to 90 mg/cm^3, (b) what will be the dimensions of the new column? (2 marks)

Q5. In the below adsorption graph, there are three distinct region –

(a) What are these three regions? (1 mark)

(b) Write three different equation to describe all the three regions separately? (3 mark) Find out the parameters for those equations.



Q6. You have been tasked to recover enzyme synthase with limited resources. A already available chromatography column in the company is giving the following concentrations when loading the compound of interest:

Y = 0 at t <2 minutes; Y = 1, when t is 2 < t < 3 in minutes; Y = 2 + (t-3), when t is 3 < t <4 in minutes; Y = 2 – (t-4), when t is 4 < t < 5 in minutes; Y = 1, when t is 5 < t < 6 in minutes and y = 0 at t >6

However, the impurity dextran is giving following output:

X = 1, at 1 < t <3 minutes and X = 0 at t > 3 minutes.

You need a minimum of 90% purity and 90% yield. (a) What will be the time from which you will start collecting the fraction (4 marks)? (b) Will you need another column (1 mark)? All units are SI.

Q7. You are filtering a beer which contains two species: bacterial cells 7 X 10^{-4} cm in diameter and spores 0.3 X 10^{-4} cm in diameter. You have measured the specific cake resistance of each species:

$\mu\alpha\rho_0$ (bacteria) = Y.Z X 10^9 kg/sec m^3

$\mu\alpha\rho_0$ (spore) = 2 times of bacteria

Other experiments show that for a mixed culture,

$\mu\alpha\rho_0 = (\Sigma\phi_i (\mu\alpha\rho)^{1/2})^2$

Where ϕ_i is the fraction of solute I in all the solutes. The present beer contains half the concentration of bacteria as spores.

(a) How long will it take to filter 850 liters of combined beer in a filter of negligible resistance, a pressure drop of 10^5 N/m^2 and 4.0 m^2 area? (2 marks)

(b) Would it be faster to first filter the bacteria (with a filter medium which passes the spores) and then filter the spores? (1 mark)