Bioengineering Study Program – School of Life Science and Technology – ITB

Mid Semester Exam

BE-2101 Introduction to Bioengineering

(Pengantar Rekayasa Hayati)

Date: September 25, 2017

Hours: 10.00 – 12.00 (120 minutes)

Closed book and notes. Only text book of Bioengineering Fundamentals (Ann-Saterbak et al) is allowed be opened

---

1. Surfactant, a complex mixture of phospholipids, proteins, and ions, plays an important role in decreasing the surface tension of water on the alveolar surface. If surfactant is not present or is present but in less than normal quantities, then the attraction of water molecules for each other (and hence the surface tension) increases. An increased surface tension leads to an increased pressure in the alveoli that can lead to their collapse. The surface tension of normal fluids that line the alveoli with normal amounts of surfactant is 5-30 dyne/cm. The surface tension of normal fluids that line the alveoli without surfactant is 50 dyne/cm. Surface tension is related to the pressure, P, as follows:

$$P = \frac{2\sigma}{r}$$

   Where σ is the surface tension and r is the radius of the alveolus. Report all answers in units of mmHg.
   a. If the average-sized alveolus has a radius of about 100 μm, what is the surface-tension pressure for an adult when surfactant is present?
   b. What is the pressure for an adult with average-sized alveoli without surfactant?
   c. Premature babies usually have alveoli with radii one-quarter the size of normal adults. In addition, since surfactant does not usually begin to be secreted into alveoli until the six month of gestation, premature babies usually do not have surfactant. Estimate surface-tension pressure for a premature baby.

2. A 40-year-old man comes into the hospital complaining of fever, cough, chills, and malaise. Subsequently, he is diagnosed with pneumonia. You decide to treat him with Antibiotic X. Initially you dose him with 5882 mg. In this patient, antibiotic X has a volume distribution (V_d) of 10 L. The volume of distribution is the volume of blood and plasma in which the drug distributes. The clearance rate (C_L) of the drug is 0.1 L/min. The clearance rate is the volumetric rate of elimination of the drug in the volume of distribution. Antibiotic X has a bioavailabilty of 85% (i.e., 15% of the drug is not available to be used by the body).
   a. To prepare an injection, you dilute the initial drug the initial drug dose of 5882 mg in 5 mL of water. What is the drug concentration in mol/L? The molecular weight of Antibiotic X is 372 g/mol.

b. What is the effective concentration in mg/L of this drug in the body after dosing?

3. The body needs a constant supply of energy in order to survive. The minimum level of energy required just to perform chemical reactions in the body and maintain essential activities of the central nervous system, heart, kidney, and other organs is known as the basal metabolic rate (BMR). However, if an individual is to engage in such activities as eating and walking, additional energy must be available. On average, an individual performing normal daily activities expends 2750 kcal/day. The daily energy expenditure is comprised of maintaining the BMR, digesting and processing food (220 kcal), nonexercise activities such as maintaining body temperature (190 kcal), and purposeful physical activity (690 kcal).
   a. Given that breathing accounts for 5% of the BMR, calculate the energy required for an individual at rest to breathe. Report your answer in units of joules/breath
   b. Heavy exercise can increase the daily expenditure to 7000 kcal. In addition, exercise can increase the energy requirements for breathing about 20-fold. Calculate the energy expended for purposeful physical activity when exercising.

4. Mammalian cells are cultured (grown) in a bioreactor. The chemical building blocks of cells are carbon, hydrogen, nitrogen, and oxygen; cells are often modeled as $CH_\alpha N_\beta O_\delta$
   a. To begin a batch process, 50 L of cells at 100 g/L are initially added to the reactor. After operation, the cell concentration is 25 g/L and the cell mass fills the entire reactor volume of 1000 L. Determine the amount of $(NH_4)_2SO_4$ to be supplied, assuming that the cells are 12 wt% nitrogen and that $(NH_4)_2SO_4$ is the only nitrogen source.
   b. During a continuous operation, the steady-state cell concentration in the reactor is 20 g/L, and the cell mass fills the entire reactor volume of 1000 L. Assume that no cells enter the reactor and that the product stream containing the cells leaves the reactor at a rate of 20 L/day. Determine the mass flow rate of $(NH_4)_2SO_4$ to be supplied in the feed stream, assuming that the cells are 12 wt% nitrogen and that $(NH_4)_2SO_4$ is the only nitrogen source.
   c. During batch and continuous operations in the real world, the added nitrogen source is in 20% excess of stoichiometric needs. Redo the calculation for (b), assuming that a 20% excess of nitrogen is supplied in the feed stream.