UNIVERSITY OF GHANA


BSC. ENGINEERING FIRST SEMESTER EXAMINATIONS: 2018/2019
DEPARTMENT OF BIOMEDICAL ENGINEERING
BMEN 401: ENGINEERING PRINCIPLES OF HUMAN PHYSIOLOGY AND ANATOMY (3 Credits)

**INSTRUCTIONS:**

ANSWER **ANY THREE** QUESTIONS

**TIME ALLOWED**: TWO (2) HOURS

1. Following a 650 mg i.v bolus dose of a drug to a 65 kg subject, the plasma drug concentration is found to decline biexponentially. The equation that best described the drug kinetics is:

$$C = 65e^{-14t} + 35e^{-3t}$$

where C is drug concentration at any given time in μg/ml.

Assume that the two-compartment kinetics model equation for the concentration is

$$C = Ae^{-\propto t} + Be^{-\beta t},$$

where A and B are the hybrid constants, α and β are first order constants for rapid distribution
phase and slow elimination phase.

a. Calculate the volume of the central compartment $V_c$ (5 marks)

b. Calculate the transfer rates $k_{12}$ and $k_{21}$ between the two compartments, given that these transfer rates are related to the hybrid first order constants α and β as follows: (8 marks)

$$k_{12} = \frac{AB(\beta - \propto)^2}{C_0(A\beta + B \propto)}$$

$$k_{21} = \frac{A\beta + B \propto}{C_0}$$

c. Calculate the elimination rate constant $K_E$ for the disposal of the drug from the central compartment which is expressed in terms of the hybrid constants as

$$K_E = \frac{\propto \beta C_0}{A\beta + B\alpha}$$

( 4 marks)

d. Calculate the plasma level of the drug after 30 minutes of intravenous dose ( 7 marks)

e. On the same axes sketch suitable graphs of the amount of drug remaining to be absorbed (ARA)
against time for a drug whose rate of absorption follows
(i) .zero –order (3 marks)

(ii) first order (3 marks)

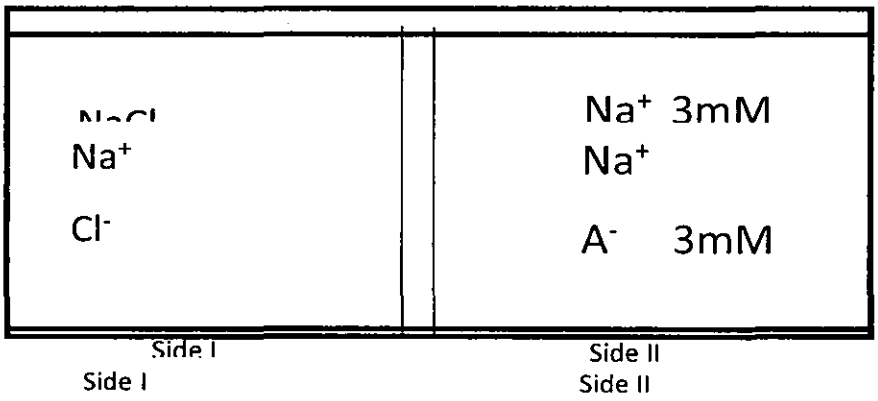
~~kinetics assuming the drug is administered extravascularly.~~

2 (a) What is Gibbs-Donnan Equilibrium and how is it different from thermodynamic equilibrium? ( 4 marks)

a. Name two effects of the Gibbs- Donnan Equilibrium in a cell and how these effects can be reduced or cancelled. ( 6 marks)

b. The diagram below shows two compartments separated by a biological membrane with 3 mMole /LNaCl solution in one compartment on one side and 3 mMole/L NaA solutions on the other compartment on the other side. If the membrane is impermeable to $A^-$, Calculate the concentrations of ions in sides 1 and II after the Gibbs –Donnan Equilibrium.

(10 marks)




c. Calculate the membrane potential at the Gibbs-Donnan Equlibrium at 37 ° C. (5 marks)

d. The initial plasma concentration of a drug given by intravenous infusion at 9.00 am is 250 mg/ml. If the half-life of the drug is 6 hours, what would be the plasma concentration at 9.00 pm that same day? (5 marks)

3a. The Table below gives the plasma drug concentrations (Cp) obtained following an intravenous bolus administration of a 250 mg dose of a drug that exhibited the characteristics of a one-compartment model and was eliminated exclusively by urinary excretion.

| Time (h) | Plasma Concentration (ug/ml) |
|---|---|
| 0.5 | 68.0 |
| 1.0 | 54.0 |
| 2.0 | 30.0 |
| 3.0 | 18.5 |
| 5.0 | 6.0 |
| 7.0 | 1.8 |

Plot a suitable graph of the data ( 7 marks)

Using the graph, determine the following:

b. The elimination half-life ($t_{1/2}$) (4 marks)

c. The overall elimination rate constant (K) (4 marks)

d. The initial plasma concentration, (Cpo) ( 5 marks)

e. The apparent volume of distribution (V)

( 5 mark)

f. The drug plasma concentration at 75 min following the administration of a 2.5 mg $kg^{-1}$ dose to a subject weighing 70 kg ( 5 marks)

4 a. The rate at which drug accumulates in urine is given by

$$\frac{dM_{urine}}{dt} = k_{renal} V_{app} C$$

where $k_{renal}$ is the elimination path rate through the kidneys and $\boldsymbol{V_{app}}$ and $\boldsymbol{C}$ are the apparent volume distribution and the concentration of the drug respectively. By considering the bolus intravenous injection, derive the expression for the mass of the drug in the urine

i. At any time ( 6 marks)

ii. After sufficiently long period of time (4 marks)

b. Prove that if the only drug elimination pathway is through the kidneys, then the total amount of drug collected in the urine is equal to the total drug dose. (7 marks)

c. A penicillin solution has a half-life of 6 days $(t_{1/2} = 6\ days)$. How long will it take for the concentration to drop to 70% of the initial concentration? (7 marks)

e. A patient visits her doctor with symptoms typical of bladder infection. She is immediately prescribed a 400 mg dose of antibiotic $(t_{1/2} = 12\ h)$. The corresponding plasma concentration of the drug is found to be 96 µg/ml. What is the volume of distribution of this drug? (6 marks)

Q5 2. a. Briefly describe the Glucose Tolerance Test (GTT). (5 marks)

b. The deviation **g(t)** of a subject's blood glucose concentration **G(t)** from its baseline value **Go**, satisfies the second order differential equation below;

$$\frac{d^2g}{dt^2} + (P_1 + P_4)\frac{dg}{dt} + (P_2P_3 + P_1P_4)g = P_4j + \frac{dj}{dt}$$

where $P_i(i = 1,2,3,4)$ are positive constants which represents feedback mechanism parameters in the process and **j** is the rate of glucose infusion from the intestines. If the effects of exercise and hypoglycemic medication are lumped as a dumping factor **α** which is related to the feedback parameters as

$$\alpha = \frac{P_1 + P_4}{2}$$

and the system natural frequency $w_o$ is also related to the feedback parameters as

$$w_o = \sqrt{P_2P_3 + P_1P_4}$$

and the input glucose impulse function

$$Q(t) = P_4J + \frac{dJ}{dt}$$

Assuming the impulse function Q*(t)* satisfies the Dirac delta function, solve for the possible outcomes or the solutions of *g(t)* after GTT. (15 marks)

c (b.) How is the general Diabetologist's theory apply to distinguish between a healthy individual and a diabetic patient? (5 marks)

d (c) Sketch on the same axis the graphs of blood glucose concentration and plasma insulin concentration for a non-diabetic person and a diabetic patient if both are given a high amount of glucose and their blood glucose rose to 250 mg/dL. Assume that the normal blood glucose is within the range 64.8 - 104.4 mg/dL. (5 marks)