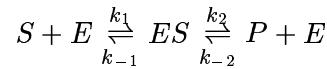
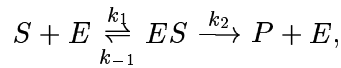


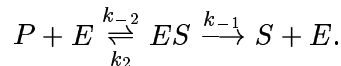
1. Consider a reversible enzyme reaction



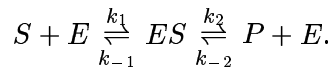
in which there is only one enzyme molecule, and the concentrations for substrate  $S$  and product  $P$  are kept at constant  $c_S$  and  $c_P$ . The enzyme can go either forward and complete a cycle, turning an  $S$  to a  $P$ :



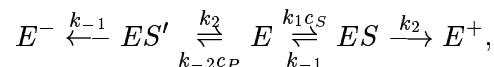
or backward and complete a cycle, turning a  $P$  to an  $S$ :



- (a) With constant  $c_S$  and  $c_P$  and treating  $E$  and  $ES$  as two states of the enzyme, write the transition probability matrix for the 2-state Markov system.
- (b) Compute the steady state probabilities of states  $E$  and  $ES$ , as well as the net forward flux of the single enzyme in steady state.
2. The enzyme kinetics shown below is known as reversible Michaelis-Menten-Briggs-Haldane mechanism:



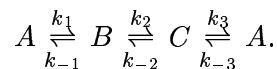
Let us consider that there is one enzyme molecule, and constant concentrations for  $S$  and  $P$ , at  $c_S$  and  $c_P$ . Again, as discussed in Problem 1, the enzyme can either cycle forward or backward. To compute the times and probabilities of the two types of cycles, one considers the following “extended scheme”



in which we denote  $ES'$  as the enzyme-product complex formed by the enzyme binds a product.

Compute the probability distributions for the forward and backward cycle times, as well as the probability of cycling forward  $p^+$  and backward  $p^- = 1 - p^+$ .

3. Consider the 3-state Markov system



- (a) The probabilities for the states,  $\mathbf{p} = (p_A, p_B, p_C)$ , satisfies a differential equation

$$\frac{d}{dt}\mathbf{p} = \mathbf{p}\mathbf{Q},$$

where  $\mathbf{Q}$  is a  $3 \times 3$  matrix. Write the  $\mathbf{Q}$  out in terms of the  $k$ 's.

- (b) Compute the steady state probabilities  $p_A^{ss}$ ,  $p_B^{ss}$ , and  $p_C^{ss}$ , and the steady state flux  $J^{ss}$ .
- (c) What is the condition for  $J^{ss} = 0$ ?