Dynamics and Kinetics. Exercise 5

Problem 1

Suppose that the enzymatic catalysis may be represented by the following mechanism:

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} E + P$$

where E is the enzyme, S is the substrate and P the product of the reaction. (It is a slight generalization of the Michaelis-Menten mechanism.) Use the steady-state approximation.

a) Find the rate of production of P as a function of the concentrations of S, P and the total concentration of enzyme. To simplify the problem, you can use $K_s = (k_{-1} + k_2)/k_1$ and $K_p = (k_{-1} + k_2)/k_{-2}$

b) Show that for short times, the result of part a) reduces to the Michaelis-Menten equation.

c) Assume that the reaction is now inhibited. Give the new description for this reaction using the same scheme given above in the case of competitive inhibition (the action of the inhibitor on the enzyme, with the rate constants k_3 and k_{-3}). Compute the rate of reaction for short times.

Consider the hydrolysis of benzoylglycylglycyl-L-phenylalanine (Bz-Gly-Gly-Phe) by 1.0 x10^{-5} M of zinc carboxypeptidase where the inhibitor is the glycyl-L-tyrosine 2.0 x 10^{-4} M. Which type of inhibition is this? (I.e., competitive, non-competitive or incompetitive?) Give the characteristics. (I.e., compute as many kinetic parameters as you can.) The rates below are at short times when [P] ≈ 0.

Conc. of substrate (10^{-4} M)	2.0	5.0	10.0
Rate without inhibitor (10^{-5} M·s^{-1})	4.0	7.7	11.1
Rate with inhibitor (10^{-5} M·s^{-1})	1.6	3.6	6.1

Problem 2

The recombination of iodine atoms in the presence of argon is a third order reaction, that has been extensively studied using techniques such as flash photolysis.

$$\mathrm{I} + \mathrm{I} + \mathrm{Ar} \xrightarrow{k} \mathrm{I}_2 + \mathrm{Ar}$$

a) In an experiment, the concentration of argon is $1 \cdot 10^{-2}$ mol/l, and the initial concentration of iodine atoms is $6 \cdot 10^{-5}$ mol/l. At a temperature of 298 K, the half-life of the iodine atoms is 238 µs. Calculate the rate constant.

b) At a temperature of 350 K, but otherwise identical initial conditions as in a), the half-life of the iodine atoms is 342 µs. Calculate the activation energy of the reaction.

c) The following reaction mechanism has been suggested for the recombination of iodine atoms. First, the van-der-Waals complex IAr is formed in a weakly exothermic reaction that is reversible.

$$\mathrm{I} + \mathrm{Ar} \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} \mathrm{IAr}$$

In a second step, collision with another iodine atom leads to the formation of I_2.

$$\mathrm{IAr} + \mathrm{I} \xrightarrow{k_2} \mathrm{I}_2 + \mathrm{Ar}$$

The activation energy for this second step is zero. Since this second step is rate limiting, a pre-equilibrium exists for the formation of the complex IAr in the first step.

Write down the rate equation for the formation of I_2 under the assumption of a pre-equilibrium for the complex IAr and explain why the recombination of iodine atoms has a negative activation energy. Hint: Consider the temperature dependence of the effective rate constant.