enzyme loading need to be optimized, and a support material with the correct surface characteristics must be selected.
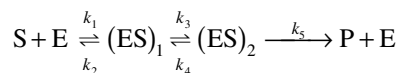
Enzymes are widely used in industry and have significant medical applications. Among the most widely used enzymes are proteases (papain, trypsin, subtilisin); amylases (starch hydrolysis); rennet (cheese manufacturing); glucose isomerase (glucose-to-fructose conversion); glucose oxidase (glucose-to-gluconic acid conversion); lipases (lipid hydrolysis), and pectinases (pectin hydrolysis). Enzyme production and utilization are a multibillion-dollar business with a great potential for expansion.

SUGGESTIONS FOR FURTHER READING

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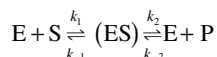STINSON, S. C., Counting on Chiral Drugs, *Chemical & Engineering News* (Sept. 21), 83–104, 1998.

PROBLEMS

3.1. Consider the following reaction sequence:

$$S + E \underset{k_2}{\overset{k_1}{\rightleftharpoons}} (ES)_1 \underset{k_4}{\overset{k_3}{\rightleftharpoons}} (ES)_2 \xrightarrow{k_5} P + E$$

Develop a suitable rate expression for production formation $[v = k_5(ES)_2]$ by using (a) the equilibrium approach, and (b) the quasi-steady-state approach.

3.2. Consider the reversible product-formation reaction in an enzyme-catalyzed bioreaction:

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

Develop a rate expression for product-formation using the quasi-steady-state approximation and show that

$$v = \frac{d[P]}{dt} = \frac{(v_s/K_m)[S] - (v_p/K_p)[P]}{1 + \dfrac{[S]}{K_m} + \dfrac{[P]}{K_p}}$$