substrate to form an [ES] complex, we can use the equilibrium coefficient to express [ES] in terms of [S].

The equilibrium constant is

$$K'_m = \frac{k_{-1}}{k_1} = \frac{[\mathrm{E}][\mathrm{S}]}{[\mathrm{ES}]} \tag{3.5}$$

Since $[\mathrm{E}] = [\mathrm{E}_0] - [\mathrm{ES}]$ if enzyme is conserved, then

$$[\mathrm{ES}] = \frac{[\mathrm{E}_0][\mathrm{S}]}{(k_{-1}/k_1) + [\mathrm{S}]} \tag{3.6}$$

$$[\mathrm{ES}] = \frac{[\mathrm{E}_0][\mathrm{S}]}{K'_m + [\mathrm{S}]} \tag{3.7}$$

where $K'_m = k_{-1}/k_1$, which is the dissociation constant of the ES complex. Substituting eq. 3.7 into eq. 3.2 yields

$$v = \frac{d[\mathrm{P}]}{dt} = k_2 \frac{[\mathrm{E}_0][\mathrm{S}]}{K'_m + [\mathrm{S}]} = \frac{V_m[\mathrm{S}]}{K'_m + [\mathrm{S}]} \tag{3.8}$$

where $V_m = k_2[\mathrm{E}_0]$.

In this case, the maximum forward velocity of the reaction is V_m. V_m changes if more enzyme is added, but the addition of more substrate has no influence on V_m. K'_m is often called the Michaelis–Menten constant, and the prime reminds us that it was derived by assuming rapid equilibrium in the first step. A low value of K'_m suggests that the enzyme has a high affinity for the substrate. Also, K'_m corresponds to the substrate concentration, giving the half-maximal reaction velocity.

An equation of exactly the same form as eq. 3.8 can be derived with a different, more general assumption applied to the reaction scheme in eq. 3.1.

3.3.2.2. The quasi-steady-state assumption. In many cases the assumption of rapid equilibrium following mass-action kinetics is not valid, although the enzyme–substrate reaction still shows saturation-type kinetics.

G. E. Briggs and J. B. S. Haldane first proposed using the quasi-steady-state assumption. In most experimental systems a closed system (batch reactor) is used in which the initial substrate concentration greatly exceeds the initial enzyme concentration. They suggest that since $[\mathrm{E}_0]$ was small, $d[\mathrm{ES}]/dt \approx 0$. (This logic is flawed. Do you see why?) Computer simulations of the actual time course represented by eqs. 3.2, 3.3, and 3.4 have shown that *in a closed system the quasi-steady-state hypothesis holds* after a brief transient *if* $[\mathrm{S}_0] \gg [\mathrm{E}_0]$ (for example, 100×). Figure 3.4 displays one such time course.

By applying the quasi-steady-state assumption to eq. 3.3, we find

$$[\mathrm{ES}] = \frac{k_1[\mathrm{E}][\mathrm{S}]}{k_{-1} + k_2} \tag{3.9}$$

Substituting the enzyme conservation eq. 3.4 in eq. 3.9 yields

$$[\mathrm{ES}] = \frac{k_1([\mathrm{E}_0] - [\mathrm{ES}])[\mathrm{S}]}{k_{-1} + k_2} \tag{3.10}$$