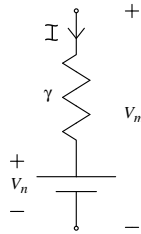


Model of ion channel has two parts

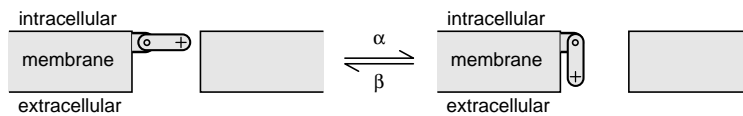
1. Two-state gate model of kinetics



2. Passive electrodiffusive model of permeation



First-order reversible reaction



Assume \mathcal{N} channels per unit area, of which $n(t)$ are open.

$$\frac{dn(t)}{dt} = \alpha(\mathcal{N} - n(t)) - \beta n(t)$$

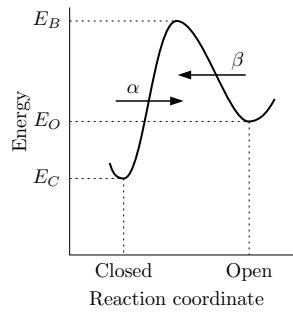
$$n(t) = n_{\infty} + (n(0) - n_{\infty}) e^{-t/\tau_x}; \quad n_{\infty} = \frac{\alpha}{\alpha + \beta} \mathcal{N}, \quad \tau_x = \frac{1}{\alpha + \beta}$$

Assume \mathcal{N} is large.

$$x(t) = \text{probability gate is open} \approx \frac{n(t)}{\mathcal{N}}$$

$$x(t) = x_{\infty} + (x(0) - x_{\infty}) e^{-t/\tau_x}; \quad x_{\infty} = \frac{\alpha}{\alpha + \beta}, \quad \tau_x = \frac{1}{\alpha + \beta}$$

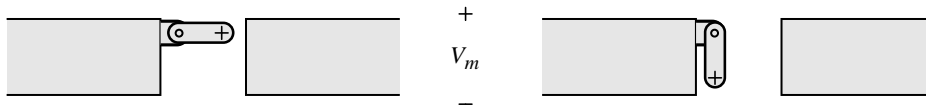
Theory of absolute reaction rates (volume 1, chapter 6)



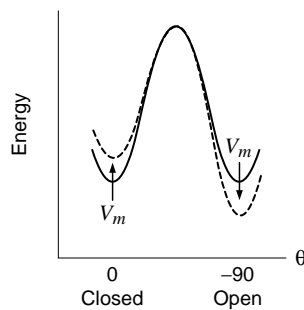
$$\alpha = Ae^{(E_C - E_B)/kT}$$

$$\beta = Ae^{(E_O - E_B)/kT}$$

Potential energy of an ion channel



The potential energy of an ion channel includes mechanical, chemical, and electrical contributions, each of which can be different in different conformations. Electrical potential energy depends on both the distribution of charge in the gate and on transmembrane potential. Therefore, E_B , E_O , and E_C depend on V_m .

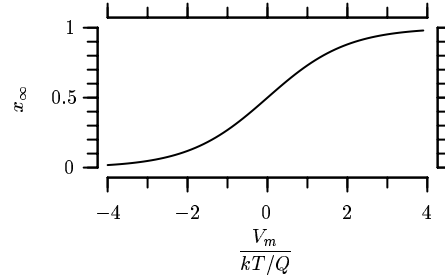


Example

$$E_B = \frac{1}{2}QV_B; \quad E_C = \frac{1}{2}QV_m; \quad E_O = -\frac{1}{2}QV_m$$

$$\alpha = A e^{\frac{1}{2}Q(V_m - V_B)/kT}; \quad \beta = A e^{-\frac{1}{2}Q(V_m + V_B)/kT}$$

$$x_\infty = \frac{\alpha}{\alpha + \beta} = \frac{1}{1 + \beta/\alpha} = \frac{1}{1 + e^{-QV_m/kT}}$$



$$\begin{aligned} \tau_x &= \frac{1}{\alpha + \beta} = \frac{1}{A(e^{\frac{1}{2}Q(V_m - V_B)/kT} + e^{-\frac{1}{2}Q(V_m + V_B)/kT})} \\ &= \frac{1}{Ae^{-\frac{1}{2}QV_B/kT}(e^{\frac{1}{2}QV_m/kT} + e^{-\frac{1}{2}QV_m/kT})} \end{aligned}$$

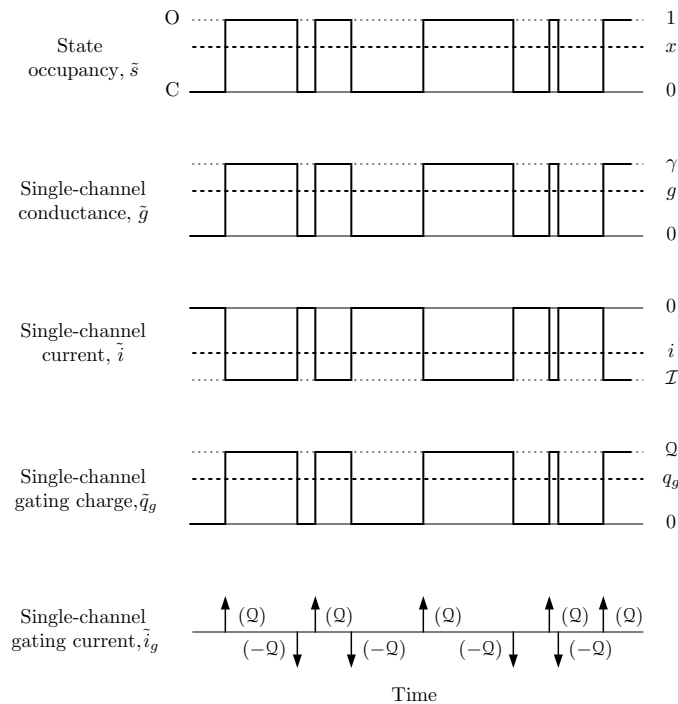
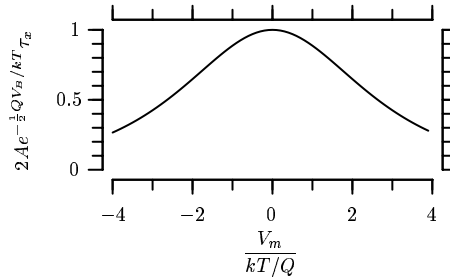


Figure 6.33

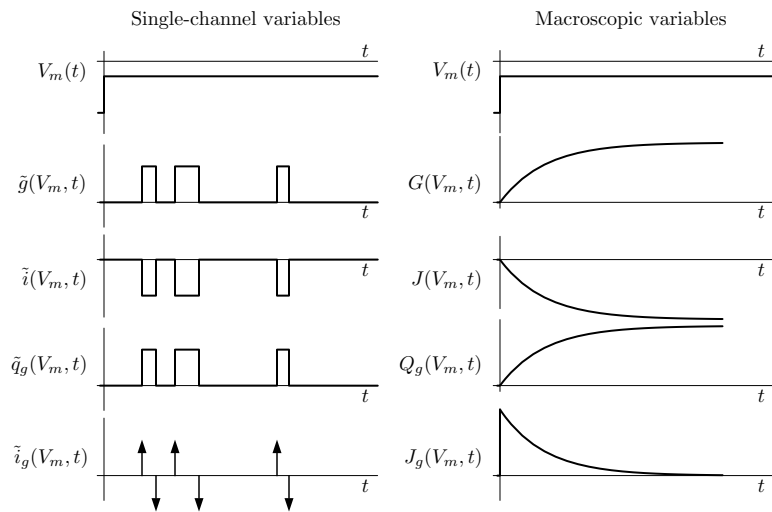


Figure 6.52

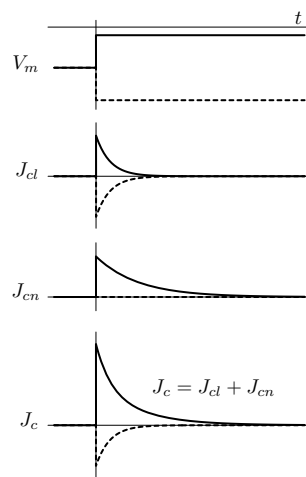


Figure 6.20

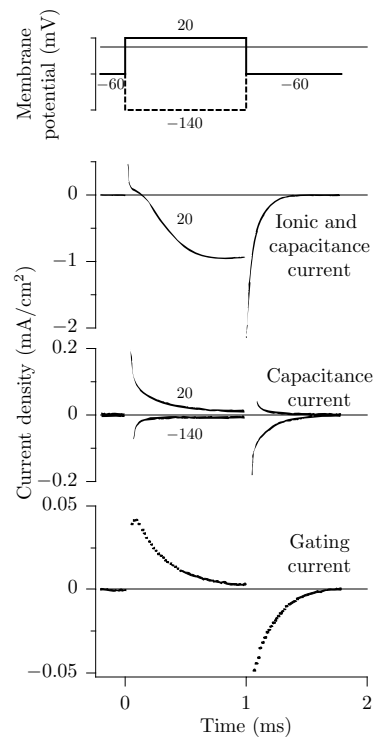


Figure 6.21

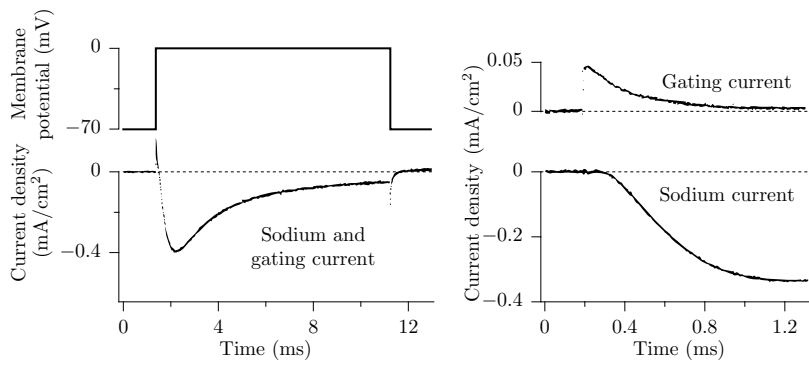


Figure 6.22

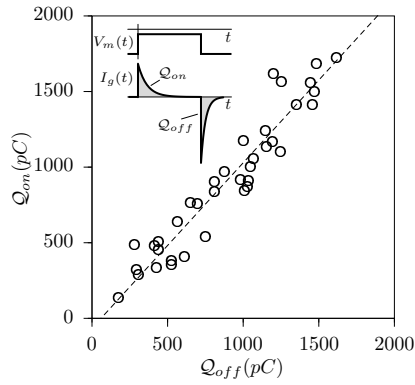


Figure 6.24

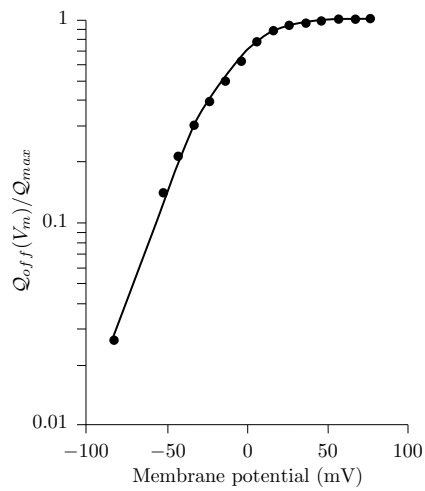


Figure 6.25

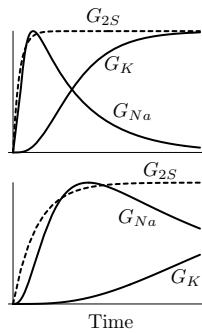


Figure 6.53

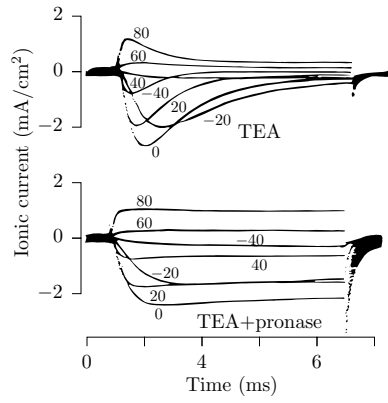
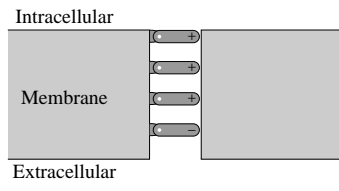


Figure 6.7

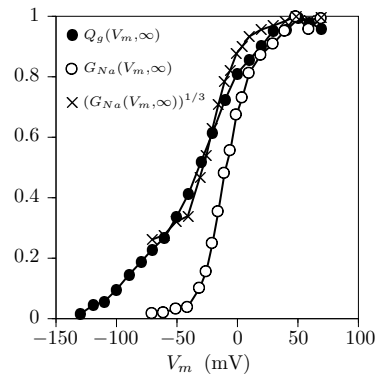


Figure 6.57

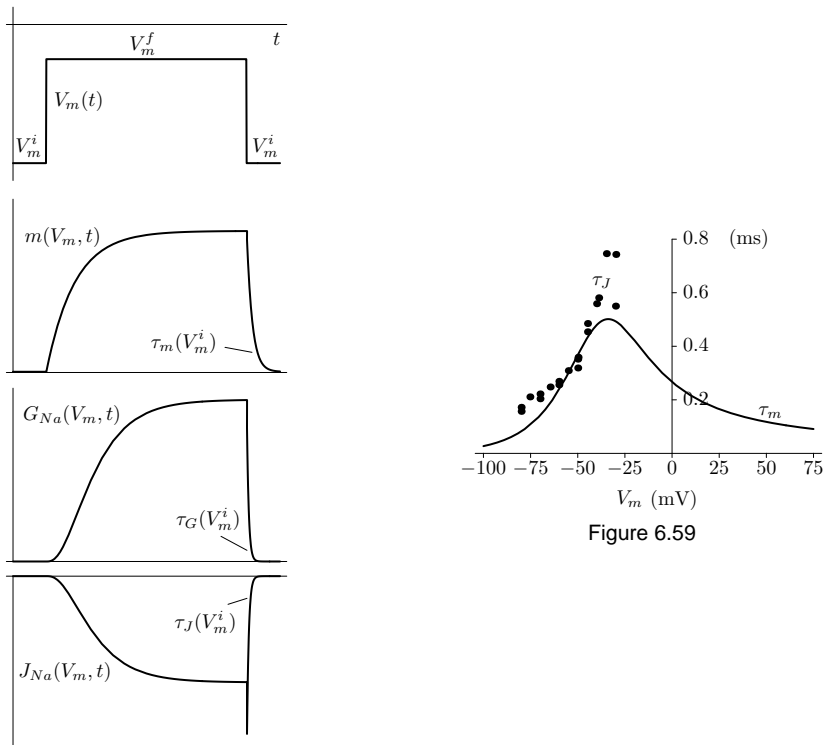


Figure 6.58

Figure 6.59