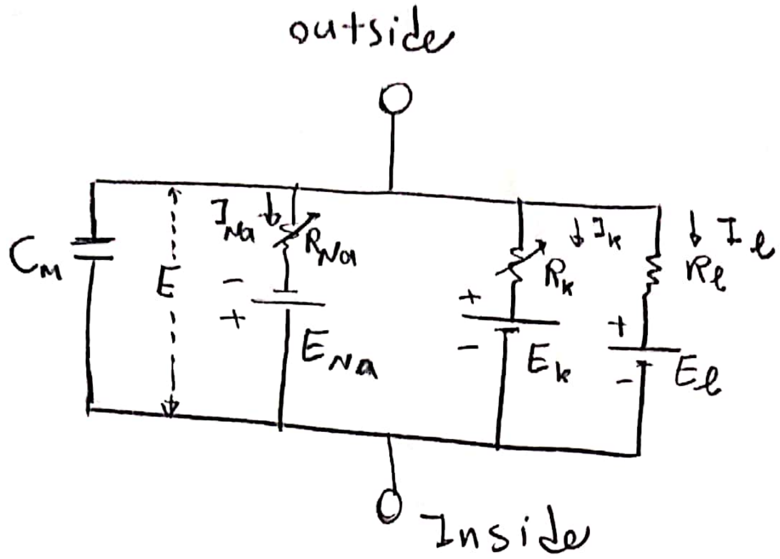

$$I = C_M \frac{dv}{dt} + I_i \quad (1)$$

$$I_{(i)} = I_{Na} + I_K + I_\ell \quad (2)$$

↳ leakage current

absolute of resting potential

$v = E - E_r$

$$\begin{cases} I_{Na} = g_{Na}(v - v_{Na}) & (3) \quad ; v_{Na} = E_{Na} - E_r \\ I_K = g_K(v - v_K) & (4) \quad ; v_K = E_K - E_r \\ I_\ell = \bar{g}_\ell(v - v_\ell) & (5) \quad ; v_\ell = E_\ell - E_r \end{cases}$$

$$g_K = \bar{g}_K n^4 \quad (6)$$

$$\frac{dn}{dt} = \alpha_n (1-n) - \beta_n n \quad (7)$$

α_n: vary with voltage (time)$^{-1}$

rate of outside to inside

n: dimention less, $0 < n < 1$

β_n: vary with voltage (time^{-1})

if the particle has a ⊖ charge α_n increase.

if the membrane is depolarized β_n decrease.

in resting state → $v = 0$

$$n_0 = \frac{\alpha_{n0}}{\alpha_{n0} + \beta_{n0}}$$

Solution for (7): using: if $t = 0 \rightarrow n = n_0$

$$n = n_\infty - (n_\infty - n_0)\exp\left(-\frac{t}{\tau_n}\right) \quad (8)$$

$$n_\infty = \frac{\alpha_n}{\alpha_n + \beta_n} \quad (9)$$

$$\tau_n = \frac{1}{\alpha_n + \beta_n} \quad (10)$$

$$g_K = \left\{(g_{K\infty})^{1/4} - \left[(g_{K\infty})^{1/4} - (g_{K0})^{1/4}\right]\exp\left(-\frac{t}{\tau_n}\right)\right\}^4 \quad (11)$$

رابطه‌ی α_n
و β_n با v $\Rightarrow$

$$\alpha_n = \frac{0.01\,(v+10)}{\exp\left(\frac{v+10}{10}\right)-1} \quad (12)$$

$$\beta_n = 0.125\exp\left(\frac{v}{80}\right) \quad (13)$$

$\alpha_n, \beta_n \left(\frac{1}{msec}\right)$

$v \rightarrow (mv)$

Sodium conductance

$$g_{Na} = \bar{g}_{Na} m^3 h \quad (14)$$

$$\frac{dm}{dt} = \alpha_m(1-m) - \beta_m m \quad (15)$$

$$\frac{dh}{dt} = \alpha_h(1-h) - \beta_h h \quad (16)$$

$$m = m_\infty - (m_\infty - m_0)\exp\left(-\frac{t}{\tau_m}\right) \quad (17) \quad \begin{cases} m_\infty = \dfrac{\alpha_m}{\alpha_m+\beta_m} \\ \tau_m = \dfrac{1}{\alpha_m+\beta_m} \end{cases}$$

$$h = h_\infty - (h_\infty - h_0)\exp\left(-\frac{t}{\tau_h}\right) \quad (18) \quad \begin{cases} h_\infty = \dfrac{\alpha_h}{\alpha_h+\beta_h} \\ \tau_h = \dfrac{1}{\alpha_h+\beta_h} \end{cases}$$

in resting Na conductance is very small. So we neglect m_0 if the depolarization is greater than 30 mv and neglect h_∞ if $v < -30$ mv.

$$\rightarrow g_{Na} = g'_{Na}\left[1-\exp\left(-\frac{t}{\tau_m}\right)\right]^3 \exp\left(-\frac{t}{\tau_h}\right) \quad (19) \quad ;\ g'_{Na} = \bar{g}_{Na} m_\infty^3 h_0$$

$$\alpha_m = \frac{0.1\,(v+25)}{\exp\left(\frac{v+25}{10}\right)-1} \quad (20)$$

$$\beta_m = 4\exp\left(\frac{v}{18}\right) \quad (21)$$

$\alpha_m, \beta_m \rightarrow \left(\frac{1}{msec}\right)$

$v \rightarrow mv$

$$m_\infty = \frac{\alpha_m}{\alpha_m+\beta_m} \qquad (22)$$

$$\alpha_h = \text{٠/٠٧} \exp\left(\frac{v}{20}\right) \qquad (23)$$

$$\beta_h = \frac{1}{\exp\left(\frac{v+\text{٣٠}}{10}\right)+1} \qquad (24)$$

$$h_\infty = \frac{\alpha_h}{\alpha_h+\beta_h} \qquad (25)$$

Summary:

$$I = C_M \frac{dv}{dt} + \bar{g}_K n^4 (v - v_K) + \bar{g}_{Na} m^3 h (v - v_{Na}) + \bar{g}_l (v - v_l) \qquad (26)$$

$$\begin{cases} \frac{dn}{dt} = \alpha_n (1-n) - \beta_n n \\ \frac{dm}{dt} = \alpha_m (1-m) - \beta_m m \\ \frac{dh}{dt} = \alpha_h (1-h) - \beta_h h \end{cases}$$

$$\begin{cases} \alpha_n(v), \beta_n(v) \checkmark \\ \alpha_m(v), \beta_m(v) \checkmark \\ \alpha_h(v), \beta_h(v) \checkmark \end{cases}$$

$$\alpha_n = \frac{\text{٠/٠١}(v+10)}{\exp\left(\frac{v+10}{10}\right)-1} \qquad \beta_n = \text{٠/١٢٥} \exp\left(\frac{v}{\text{٨٠}}\right)$$

$$\alpha_m = \frac{\text{٠/١}(v+\text{٢٥})}{\exp\left(\frac{v+\text{٢٥}}{10}\right)-1} \qquad \beta_m = \text{٤} \exp\left(\frac{v}{\text{١٨}}\right)$$

$$\alpha_h = \text{٠/٠٧} \exp\left(\frac{v}{\text{٢٠}}\right) \qquad \beta_h = \frac{1}{\exp\left(\frac{v+\text{٣٠}}{10}\right)+1}$$