With the assumption of dipole interaction with the membrane matrix, the dipole barrier under an applied field shows a minimum in its time transient. Kinetic equations governing the migration of ions are presented. $\mathbf{Na}^+$ activation, $\mathbf{Na}^+$ inactivation and $\mathbf{K}^+$ delay are all part of the same mechanism in this model with no other separate assumptions needed. Voltage Clamp equation and action potential equation are presented.

1. Introduction. The nerve impulse is a basic process in physiology, yet its mechanism is not clear. Hodgkin and Huxley's equations (1952a) enjoy a great popularity in discussing nerve impulse, and indeed they can describe many different experimental findings to certain accuracy (Huxley, 1959; Noble, 1966; Cole, 1968; Frankenhaeuser and Huxley, 1964), however the success of the equations relies on the parameters which have been chosen to be voltage dependent to conform to the experimental data, and these voltage dependent parameters seem not to have an easy interpretation.

Recently, Wei (1969a, b) proposed a dipole theory to explain the basic molecular process initiating the nerve impulse. It seems that many experimental facts conform to this theory (Wei, 1971, 1972). Thus, it is interesting to see what further progress can be done based on this idea. The purpose of this paper is to develop a molecular theory to explain the nerve impulse phenomenon and to derive a kinetic equation for $\mathbf{Na}^+$ activation, $\mathbf{Na}^+$ inactivation and $\mathbf{K}^+$ delay under the same physical principles. Using the law of motion, the voltage clamp equation and action potential equation can also be derived.

†Supported in part by Physics Research Center, National Science Council, The Republic of China.
2. Theory. In a previous paper (Lee and Chiang, 1976), nerve excitation has been explained with the assumption of coupling between the dipoles and the membrane matrix; the photons emitted from dipoles may be transferred to phonons, and the phonons may also excite the dipoles. As in the previous paper, we can write:

\[
\frac{dN_1}{dt} = -\omega_{12}N_1 + \omega_{21}N_2 - b(P - P_0),
\]

(1)

\[
\frac{dN_2}{dt} = \omega_{12}N_1 - \omega_{21}N_2 + b(P - P_0),
\]

(2)

\[
\frac{dP}{dt} = \beta \frac{dN_1}{dt} - b'(P - P_0),
\]

(3)

where \(N_1\) and \(N_2\) are the number of dipoles in state I with energy \(E_1\) and state II with energy \(E_2\) respectively \((E_2 > E_1)\); \(P\) is the number of phonons in the membrane matrix and \(P_0\) is the number of phonons in equilibrium condition; \(\omega_{12}\) and \(\omega_{21}\) are the probabilities per unit time for a dipole to jump from state I to state II and from state II to state I respectively; \(\beta\) is the percentage of photons emitted by the dipoles transferred to phonon, \(b\) and \(b'\) are constant. Similar to Lee and Chiang's paper (1976), \(\omega_{12}\) and \(\omega_{21}\) can be expressed as:

\[
\omega_{12}(F) = \frac{1}{2\tau} \exp\left[-(UW - pV)/WkT\right];
\]

(4)

\[
\omega_{21}(F) = \frac{1}{2\tau} \exp\left[(UW - pV)/WkT\right],
\]

where \(\tau\) is the average time required for a dipole to jump from one state to the other, \(p\) is the dipole moment, \(V\) is the voltage across the membrane (inside positive), \(W\) is the thickness of the membrane, \(k\) is the Boltzmann constant, \(T\) is the temperature and \(U\) is

\[
U = (E_2 - E_1)/2.
\]

(5)

Equations (1), (2) and (3) may be transformed into

\[
\frac{d\Delta N}{dt} = -(\omega_{21} + \omega_{12})\Delta N + (\omega_{21} - \omega_{12})N - 2b(P - P_0)
\]

(6)