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Nonequilibrium response of a voltage gated sodium ion channel and biophysical characterization of dynamic hysteresis

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Abstract

Here we have studied the dynamic as well as the non-equilibrium thermodynamic response properties of voltage-gated Na-ion channel. Using sinusoidally oscillating external voltage protocol we have both kinetically and energetically studied the non-equilibrium steady state properties of dynamic hysteresis in details. We have introduced a method of estimating the work done associated with the dynamic memory due to a cycle of oscillating voltage.We have quantitatively characterised the loop area of ionic current which gives information about the work done to sustain the dynamic memory only for ion conduction, while the loop area of total entropy production rate gives the estimate of work done for overall gating dynamics. The maximum dynamic memory of Na-channel not only depends on the frequency and amplitude but it also depends sensitively on the mean of the oscillating voltage and here we have shown how the system optimize the dynamic memory itself in the biophysical range of field parameters. The relation between the average ionic current with increasing frequency corresponds to the nature of the average dissipative work done at steady state. It is also important to understand that the utilization of the energy from the external field can not be directly obtained only from the measurement of ionic current but also requires nonequilibrium thermodynamic study.

Keywords: `Sodium ion channel, Nonequilibrium response spectroscopy, Memristor, Nonequilibrium thermodynamics, Dynamic hysteresis.`
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