Stochastic thermodynamic analysis of the Michaelis-Menten kinetics

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Introduction

Stochastic thermodynamics (ST) deals with the interaction of mesoscopic, nonequilibrium physical systems with heat reservoirs in equilibrium.[1] Such interactions are assumed to be the source of the randomness in the dynamics of the system, assigning to it a probability $p_x(t)$ of being in the state x at time t.

- We will use the Michaelis-Menten kinetics as case of study for the ST.

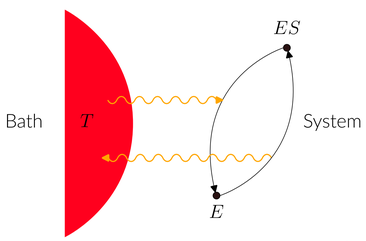
Michaelis-Menten kinetics (MM)

The system (MM) is composed by a single molecule of enzyme E. We assume the enzyme processes a single molecule of substrate S per time. Then the system can be in two states: free enzyme E and complexed ES.

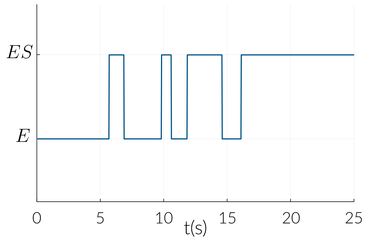
- The reaction network that models the kinetics is:

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} E + P \tag{1}$$

- The substrate S and the product P are **chemostated**.



(a) Representation of the MM[Massimiliano REF?].



(b) Single realization of the system.

The system is kept in contact with a heat bath with temperature T.

- The changes in state of the system are due to energy exchanges with the bath.

References

[1] Luca Peliti and Simone Pigolotti.
Stochastic Thermodynamics: An Introduction.
Princeton University Press, 2021.