Thermodynamics of adaptation and the Le Chatelier principle

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A major limitation of many thermodynamic devices (catalysts, heat engines) is that their functioning demands external fitting between the environmental parameters and internal parameters of the device. Here we explore thermodynamic limits of adaptation, where this fitting is achieved automatically. These limits are based on the Le Chatelier principle, whose implications for adaptation will be briefly reviewed. Within our minimal model of catalysis, particles are transferred from a higher chemical potential reservoir to a lower one. The catalyst is supposed to function with the maximal current under uncertain chemical potentials: if they change, the machine tunes its own structure fitting it to the maximal current under new conditions. This adaptation is possible under two limitations: (i) The degree of freedom that controls the device structure has to have stored energy (described via a negative temperature). (ii) The device has to malfunction in a constant environment due to structural fluctuations, whose relative magnitude is controlled solely by the stored energy. We argue that several features of the adaptive machine are similar to those of living organisms (energy storage, aging).