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Theory for electron-phonon systems at high levels of Joule heating: Spontaneous symmetry breaking with possible applications to chemical systems.

Thursday 12 June 2025 17:00 (15 minutes)

Recent work on dissipative electron-phonon type systems will be reviewed. A Boltzmann transport equation was formulated which accounts for second order collisions with an electron-phonon vertex and a three-phonon vertex. This approach reveals the existence of two forces perpendicular to the primary direction of electrical current, equally and oppositely acting on electrons and phonons. Solutions for stationary states confirm that charge and thermal energy become separated. The phonon force leads to a modified Guyer-Krumhansl equation. If enough power is dissipated, the electron and phonon dynamics can experience spontaneous symmetry breaking.

More recently, the same approach was taken for chemical reaction-diffusion systems.
Again, scattering processes up to second order are taken into account and again, two forces emerge when a spatial gradient exists, one force on reactants and products, the other force on phonons. The forces are equal and opposite and have the tendency for separation of the phonons away from the reactants and products. These forces are capable of creating the types of instabilities that can lead to the formation of Turing patterns. The existence of these forces allows for exergonic conversion where not all of the released energy from reactions and diffusion becomes heat. In the realm of high-energy explosions, calculations show that reactants and products can be accelerated laterally to the direction of a TNT reaction front up to speeds near 1000 m/s. This acceleration is in opposition to diffusion and represents active transport. Calculations also show that active transport observed in biological systems such as bacteria, mitochondria, and chloroplasts may be explained by this second-order transport theory. Using reasonable values for key parameters, calculations show that up to one-third of the available chemical energy can be converted toward pumping protons uphill to a potential of 50 mV. This gives a physical understanding for Mitchell's general chemiosmotic mechanism which is an important concept in biochemistry.

S.N. Patitsas, Phys. Rev. E \textbf{108}, 024201 (2023)

Keyword-1

electron-phonon scattering

Keyword-2

Geyer-Krumhansl equation

Keyword-3

spontaneous symmetry breaking

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