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Natural thermodynamics

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HIGHLIGHTS

- Thermodynamics is founded on the notion of quantum.
- Entropy is derived from statistical mechanics of open systems.
- The principle of increasing entropy equals the imperative of decreasing free energy.

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ABSTRACT

The principle of increasing entropy is derived from statistical physics of open systems assuming that quanta of actions, as undividable basic build blocks, embody everything. According to this tenet, all systems evolve from one state to another either by acquiring quanta from their surroundings or by discarding quanta to the surroundings in order to attain energetic balance in least time. These natural processes result in ubiquitous scale-free patterns: skewed distributions that accumulate in a sigmoid manner and hence span log–log scales mostly as straight lines. Moreover, the equation for least-time motions reveals that evolution is by nature a non-deterministic process. Although the obtained insight in thermodynamics from the notion of quanta in motion yields nothing new, it accentuates that contemporary comprehension is impaired when modeling evolution as a computable process by imposing conservation of energy and thereby ignoring that quantum of actions are the carriers of energy from the system to its surroundings.

1. Introduction

Thermodynamics speaks about nature in energetic terms. Since energy can be assigned to anything, thermodynamics addresses everything. However, energy as such does not exist. It is an attribute of its carrier. Energy is carried, for instance, by a photon. Thus, when quantifying the state of a system, its carrier composition – not its energy – ought to be examined in the first place. Likewise, when describing the system in transformations from one state to another, motions of carriers – not changes in energy – ought to be explained in the first place. This assertion that the carrier is a more fundamental notion than energy may though seem superfluous, because the equation for the carriers in motion, as will be shown below, turns out to be equivalent to the equation for energy in motion [1–6]. Yet, we will argue that thermodynamics, as a concise and consistent theory, follows naturally from the concept of the quantum.

Fermat's principle says the photon will propagate along the path of least time. When moving along that path, the photon will, by carrying energy, diminish an energy difference, known as free energy, between the state of departure and the state of arrival. In other words the photon's least-time trajectory trails along the energy gradient where the change in momentum

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points along the force, i.e., $\mathbf{F} = d_t\mathbf{p}$. This means that Fermat's and Newton's accounts on motions are equivalent, as they should be.

Moreover, it is not only the photon but any other embodiment of energy that moves alike along a geodesic, i.e., the trajectory where free energy will be consumed in least time. For instance, water runs down along the steepest descents on a hill slope thereby consuming free energy in the form of a gravitational energy gradient in the least time. If this were not to the case, then there would be a change in momentum, i.e., an effect without a force, i.e., water would linger without a reason. Likewise, a stock of animals grows by consuming surrounding chemical potentials in the form of food in the least time. Of course, it may though appear to an observer as if this were not the case, when a force, i.e., a reason goes unrecognized. For instance, browsers' fear for predators may redirect them on a detour. When that force is taken into account, the observed behavior is indeed found motivated, i.e., to obey the least-time principle.

The universal least-time imperative, known as the principle of least action, is the generalization of Fermat's principle. So it turns out that transformations from one state to another of any kind whether given in terms of action or in terms of energy are equivalent, as they should be. Nevertheless it is worthwhile to ask, what exactly is the action that carries energy?

The quantum of action, specifically the quantum of light, is the most elementary action. Its unit, joule seconds (Js), informs us that energy E and a period of time t are attributes of the quantum of action so that their product is an invariant measure known as Planck's constant

$$h = Et. \tag{1}$$

This equation is, of course, mathematically equivalent to the familiar textbook form

$$E = hf \tag{2}$$

where $f = 1/t$ is the photon's frequency. Yet the former (Eq. (1)) stresses that the photon is the basic building block of nature with energy and time as its compound attributes whereas the latter (Eq. (2)) places emphasis on the photon's energy attribute. The units imply that Planck's constant is not only an invariant number but it measures a physical entity, namely the quantum of action.

Here we adopt the old atomistic tenet by regarding the quantum of action as the invariant and elementary unit of nature [7]. This tenet differs from that in modern physics where the quantum of light, i.e., the photon, as a gauge boson, is deemed also as a non-conserved virtual particle [8]. Put differently, according to the atomistic idea the photon is the indivisible quantum of action whereas the modern doctrine declares that energy is quantized. This tension between the old and new ways of thinking about the physical basis requires for a resolution.

2. The notion of quantum

Let us begin by postulating that indeed everything is ultimately composed of the quanta of actions, and explore its consequences. However, first we had better make sure that the postulate is not in an obvious conflict with observations. Since even one exception to the rule would jeopardize the tenet's consistency and logic, we must analyze also phenomena and substances that are traditionally remote from thermodynamics.

2.1. Correspondence with observations

Every chemical reaction will either emit or absorb at least one photon, as light or heat depending on energy of dissipation (Eq. (2)). Nuclear reactions dissipate likewise, albeit then the quanta carry higher energy. Also annihilation of a particle with its antiparticle yields photons. Conversely, pair production proceeds from photons to particles. All this implies to us, just as Newton conceived, that matter is ultimately made of photons [9]. This tenet can be falsified, for instance, by presenting a material entity whose annihilation would yield something that, in turn, would not annihilate to mere photons.

This resolution of everything being composed of the same basic building blocks is motivated further by models that present elementary particles in terms quantized actions [5,10]. These models reproduce particles' measured properties and comply with their oscillations and decay schemes. Still some changes of state, such as a body falling from a height on the ground, are not outwardly dissipative. Yet, we continue arguing by considering the reverse reaction that also the transformation from one place to another entails either absorption or emission of quanta of actions. When the body is lifted up from the ground back up on the height, some form of free energy will be consumed. Here on Earth the required fuel for the reverse transformation is ultimately produced by absorbing photons from insolation. Thus, the reversibility in transformation points to the irrefutable conclusion: photons are emitted when the body is falling down because photons are absorbed when the body is lifted up. This resolution raises another question. Why are the emitted photons not detected?

To answer, let us examine a well-known phenomenon involving photons where no light is observed. Namely, the double slit experiment yields bright and dark bands for constructive and destructive interference. At a dark band where two photons have combined with opposite polarizations, we see nothing. The cancellation of electromagnetic fields, i.e., forces, however, does not mean that the photons themselves would have vanished into nothing. The net force vanishes when all forces balance each other. When there is no net electromagnetic force, nothing will drive detection, i.e., a charge-coupled transformation in the detector. Nevertheless, the lack of electromagnetic energy gradient does not imply a nil potential.