$1/k_B T = 0$ axis. If the quantity measured is the frequency of a process, as is often the case in solid-state physics, the prefactor A can be called the attempt frequency, with A^{-1} being the limiting time required to surmount the activation barrier as the temperature approaches infinity. In textbook examples, for small E_a, this approach yields plausible values for such frequencies. Further, if the E_a of such a process is modified only slightly, the intercept does not change.

Starting with reports by Frederick Hurn Constable[1] in 1925 and by Wilfried Meyer and Hans Neldel[2] in 1937, researchers have done a great number of experiments on sets of closely related materials and systems in which the prefactor of Arrhenius plots of a related set varies systematically with E_a. While care must be taken to avoid artifacts, it has been clear for some time that the phenomenon is real.[3] For a wide-ranging variety of sets of related physical, geological, biological, and chemical phenomena, the logarithms of those intercepts vary linearly with E_a. That also means the Arrhenius fit lines cross at an isokinetic temperature at which the rate is independent of E_a. Those observations have various names: the isokinetic rule, the compensation law (because the increase in the prefactor partially compensates for the increase in E_a), and the Meyer–Neldel rule.

The meaning and explanation of the Meyer–Neldel rule were long considered to be a mystery, but work by a number of groups in the final decades of the past millennium provided a clear theoretical framework for both kinetic and equilibrium systems. The key to activation is not the energy or enthalpy; it is the free-energy change, which includes an entropy term. When the activation barrier is large, the entropy change increases with E_a, and that increases A.

In 2006 one of us (Yelon) coauthored a review of the state of the art in experiment and theory,[4] which have continued to evolve since. Systematic studies yield information concerning the characteristic energy of the collective excitations—phonons or local vibrations—that are aggregated to surmount the activation barrier.[5] In some cases, notably studies of electronic or ionic conductivity, important information concerning mechanisms can be obtained. Like the Arrhenius relation that spawned it, the Meyer–Neldel rule is an elegant way to gain insight into the fundamental interactions governing temperature-dependent processes.

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Axel Lorke's Quick Study (PHYSICS TODAY, May 2021, page 66) discusses underlying connections between seemingly unrelated phenomena. His brief reminder of Svante Arrhenius's major contributions to science—and in particular, his now-famous empirical relation describing the rate of thermally activated processes—is thought-provoking.

There is, however, a minor point appearing in the caption of figure 2, showing electron density versus inverse temperature, that needs clarification. If we concentrate on the high-temperature (left) portion of the graph, the "reaction" involved is the generation of an electron–hole pair (analogous to electron–positron pair production in particle physics), for which the Gibbs free-energy change is what is known as the energy gap E_g. For that reaction, the product of the electron density n and hole density p is given by $np \propto \exp(-E_g/k_B T)$, where k_B is the Boltzmann constant and T is absolute temperature.[1] At the high temperatures on the left side of the graph, the semiconductor is nearly intrinsic, so $n \approx p \propto \exp(-E_g/2k_B T)$, which is where the factor of two in the denominator of the slope originates.

The caption states that the "factor of two in the denominator arises because electrons obey Fermi–Dirac statistics rather than classical Boltzmann distribution." But at such high temperatures, Fermi–Dirac statistics approximates the Boltzmann distribution, so it cannot be the reason for the factor of two as the caption states. A similar explanation applies to the ionization of neutral donors.[2]

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Another way to define physics

In his letter "But what is physics?" (Physics Today, April 2021, page 12), Peter Zimmerman raises an interesting question about physics and physicists. He recalls the definition given by his former professor Leonard Schiff: "Physics is whatever physicists do."

Schiff's definition, however, seems like a tautology. I prefer one given by Gabriel Weinreich:

> Physics is delineated, not by its subject matter, but by the methods of thought that a physicist uses.[1]

Additionally, in their December 1995 article in Physics Today (page 25), Sol Gruner, James Langer, Phil Nelson, and Viola Vogel provide a definition of physicist that I still treasure:

> The physicist is most cogently identified, not by the subject studied, but by the way in which a subject is studied and by the nature of the information being sought.

Both definitions point to the methods involved.

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