Pierre Duhem's route towards an abstract thermodynamics

Stefano Bordoni – University of Bologna - Italy

In the last decades of the nineteenth century, two kinds of mechanics were available: mechanics as mechanical models like colliding elastic molecules or aethereal vortices on the one hand, and mechanics as a formal language for physical sciences on the other hand. Two different traditions of research emerged from Rudolf Clausius's version of thermodynamics. While James Clerk Maxwell and Ludwig Boltzmann pursued the integration of thermodynamics with the kinetic theory of gases, others relied on a macroscopic and more abstract approach that set aside specific mechanical models. This second approach blossomed in about two decades in different countries of Europe and in the United States. François Massieu, Josiah Willard Gibbs, Hermann Helmholtz, and then Pierre Duhem explored the connections between the contents of thermodynamics and the formal structures of analytical mechanics. Others like the young Max Planck and Arthur von Oettingen pursued a sort of formal symmetry between thermal and mechanical variables. In the British Isles, Joseph John Thomson developed a *dynamical* approach to physics and chemistry, making use of the tools of abstract mechanics without excluding microscopic motions. Some developments were logically interconnected, as it was for Massieu's, Gibbs's, Helmholtz's, and Duhem's, even though they occurred in a largely independent manner. Duhem put forward the most original and most systematic reinterpretation of thermodynamics, which involved a bold upgrading of analytical mechanics and a bold mathematical unification of physics and chemistry. A strong commitment to unification was one of the hallmarks of all these theoretical researches.

My purpose is to analyse this abstract, potential-based approach to thermodynamics, its roots in Rudolf Clausius's and William Macquorn Rankine's researches in the mid-nineteenth century, the important developments that took place in the 1870s and 1880s, and lastly Pierre Duhem's very general *Energetics*, which led to a mathematical unification of different fields of physics. Different routes towards an abstract thermodynamics were taken by physicists who had different attitudes towards mechanics. If something like "the crisis of mechanics" crossed the late nineteenth century, it did not dwell at the homes of Massieu, Gibbs, Helmholtz, Planck, Oettingen, and Duhem. These physicists offered *mechanical* theories of heat that relied on fruitful connections between the mathematical language of mechanics and the specific contents of thermodynamics.

KEY WORDS: mechanics, thermodynamics, potentials, work, heat, energy, Lagrange's equations, energetics.