

low temperature. By doing work, as also by conduction, and radiation with absorption, this inequality of temperature is spent, *i.e.*, lost. Clausius and Thomson alone seem to have grasped the value of this conception. The difficulty was to put it into mathematical language—into calculable terms. Each did this independently. Thomson, more than any other thinker, put the problem into common-sense language, brought the subject home to the practical reason; at the same time he put it into mathematical language, allowing the conceptions of waste¹ and of value and of availability (or usefulness) of energy to be scientifically—that is, measurably—defined. In 1851 he put the axiom upon which Carnot's reasoning is based (without knowing the words of Carnot quoted above) into the following words:² "It is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects." He saw at once, when adopting Joule's doctrine of the convertibility of heat and mechanical work, that, if all processes in the world be reduced to those of a perfect

¹ The term "wasted," as distinguished from "annihilated," is first introduced in Part 1 of the "Dynamical Theory of Heat," 1851, p. 189 of 'Math. and Phys. Papers,' vol. i.; and in the following year, in a paper read before the Royal Society of Edinburgh on the 19th of April, entitled, "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy," the subject is brought home to the general understanding by a succession of short theses referring to the dissipation and possible limited

restoration of energy ('Papers,' vol. i. p. 511, &c.)

² 'Math. and Phys. Papers,' vol. i. pp. 179, 511. Helmholtz ('Vorträge und Reden,' vol. i. p. 43) said in 1854: "In any case we must admire the acumen of Thomson, who could read between the letters of a mathematical equation, for some time known, which spoke only of heat, volume, and pressure of bodies, conclusions which threaten the universe, though indeed only in infinite time, with eternal death."