

ture remaining constant), he gave the name of free energy. He showed that in a state of equilibrium the free or available energy must be a minimum. He also showed the connection in which the available or free energy stands to the quantity introduced by Rankine and Clausius, the entropy which measures the unavailable or hidden energy. By making chemical changes depend on the increase or decrease of a definite measurable quantity a parallel was established between chemical and mechanical processes, the latter always taking place in the direction of a decrease of potential energy. Free energy has thus been appropriately termed by M. Duhem the thermo-dynamic potential.

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Helmholtz's
"free
energy."

Helmholtz did not apply this fruitful view to chemical processes on any extensive scale, but his explanations have done much to establish that correcter and more comprehensive way of treating such questions which has since become general. Horstmann had indeed led up to this view, Willard Gibbs had applied it before, and Lord Rayleigh had suggested it.¹ The conception of

¹ The general use of the conception of useful or free energy must be dated from the remarkably lucid expositions of Helmholtz, though it is now recognised by all who have studied the history of this fertile conception that the physical notion of available energy goes back to Thomson (see Tait, 'Thermodynamics,' 1868, p. 100) and Maxwell ('Heat,' p. 187, 8th ed.; Duhem, 'Mécanique chimique,' vol. i. p. 92; Le Chatelier in 'Journal de Physique,' 1894, p. 291); that the mathematical formulæ were given by Massieu (quoted by Duhem, 'Le Potential Thermodynamique,' 1886, pp. v.

and 11), and more definitely explained and applied to the physical phenomena of dissociation by Gibbs ('Thermodynamische Studien,' ed. Ostwald, p. 66, &c.; 'Amer. Journ. of Sciences and Arts,' 1879); and that it is especially owing to the labours of Duhem that the subject has received the attention of chemists. M. Duhem, in the introduction to the work of 1886, gives a very valuable and lucid historical exposition, and subsequently in his large work in four volumes ('Mécanique chimique,' 1897-1900) a vast number of applications. For the history of thought the import-