THERMODYNAMICS AND RELATIVITY*

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1. *Introduction.* We have met to do honor to the memory of Josiah Willard Gibbs. By the labors of this master, the classical principles of thermodynamics were given their most complete and comprehensive expression. As the subject for the tenth memorial lecture, it seems appropriate to discuss the extensions to these classical principles which have since been made necessary by Einstein's discovery of the special and general theories of relativity.

The need for an extension of thermodynamics to relativity arises in two ways. In the first place, the classical thermodynamics was—perhaps unintentionally but nevertheless actually—only developed for systems which were tacitly assumed to be at rest with respect to the observer, and further investigation is necessary for the treatment of thermodynamic systems which are moving relative to the spatial coordinates in use. This further investigation must be carried out with the help of those principles for the inter-comparison of measurements—made by observers in uniform relative motion to each other—which form the subject matter of the special theory of relativity.

In the second place, the older thermodynamics tacitly assumed that the behavior of thermodynamic systems could be described with the help of ideas as to the nature of space and time which we now know to be approximately valid only for a limited range of space-time and in the absence of strong gravitational fields. The considerations of the classical thermodynamics were thus actually limited to the treatment of small enough systems and weak enough gravitational fields so that the deviations from this kind of space-time could be neglected, and the Newtonian theory of gravitation could be applied as a close enough approximation. In order, however, to investigate the thermodynamic behavior of large portions of the universe as we may

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