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An English translation of the paper of Max Planck (1943) about “Zur Geschichte der Ausdeutung des physikalischen Wirkungsquantums: or: The history of the discovery of the physical quantum of action” to provide a readable version of the German content.

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Since the appearance of the elementary quantum of action marks the beginning of a new epoch in physical science, I feel the need and the obligation towards the physicists of a later generation to describe in a summarising presentation, to the best of my knowledge, the repeatedly tortuous path by which I arrived at the calculation of this universal constant, as it is reflected in my memory.

1 Section-I (Thermodynamics and entropy) (p.153-154)

For this purpose, I must first go back a little further, to my university years. What has always interested me most in physics were the great general laws that have significance for all natural processes, regardless of the properties of the bodies involved in the processes and of the ideas one forms about their structure. I was therefore particularly fascinated by the two laws of thermodynamics. However, while the first law, the law of conservation of energy, has a very simple and easily comprehensible meaning and therefore requires no special explanation, the correct understanding of the second law requires detailed study. I learnt this principle (second law) in my last year of study (1878) by reading the writings of R. Clausius, which particularly attracted me anyway because of the excellent clarity and persuasiveness of the language.

Clausius derived the proof of his second law from the hypothesis that heat does not pass automatically from a colder to a warmer body. However, this hypothesis requires a special explanation, because it is not only intended to express the fact that heat does not pass directly from a colder to a warmer body, but also that it is not possible in any way to transfer heat from a colder body to a warmer body, for example through a suitably devised circular-(cyclic) process, without any other change occurring in nature that serves as compensation, which has the property that it cannot be reversed without leaving behind another permanent change. Only if one makes this further assertion of the hypothesis a prerequisite is it possible to provide the general proof of the second law. The multiple attacks that Clausius' proof has received are largely based on a misunderstanding of the complete content of his hypothesis.

In an effort to gain as much clarity as possible on this point, I came up with a formulation of the hypothesis that seemed to me to be simpler and more convenient. It reads: "The process of heat conduction cannot be completely reversed in any way ." This expresses the same thing as the Clausius version without the need for any special explanation. You just have to pay careful attention to the words "in any way" and "completely." They want to say that in the attempt to reverse the process, one may use any means at all, mechanical, thermal, electrical, chemical, only on the condition that after the end of the process used, the means used are again in exactly the same state as at the beginning, when they were used. I called a process that cannot be completely reversed in any way natural , today it is called irreversible. But the mistake that one commits by interpreting Clausius' theorem too narrowly, and which I have tried to combat all my life, has, it seems, still not been eradicated for the time being. Because to this day I still encounter the following definition of irreversibility in addition to the above one: Irreversible is a process that cannot run in the opposite direction. This is not sufficient. Because from the outset, it is quite conceivable that a process that cannot run in the opposite direction can be completely reversed in some way by suitably constructed machinery. It is precisely this deeper meaning of irreversibility that makes the second law significant not only for thermal phenomena, but for all natural processes. According to the above definition, all processes in nature fall into two classes: reversible and irreversible processes (I used to say neutral and natural processes), depending on whether or not they can be completely reversed in some way. From this it follows, which is now the essential point, that the decision as to whether a natural process is irreversible or reversible depends only on the nature of the initial state and the final state. There is no need to know anything about the nature and course of the process. In the first case, that of irreversible processes, the final state is in a certain sense distinguished from the initial state, and nature has a greater preference for it, so to speak. In the second case, that of reversible processes, the two states have equal status. Clausius' entropy was found to be a measure of the magnitude of this preference, and the meaning of the second law is the law that in every natural process the sum of the entropies of all bodies involved in the process increases, and in the limiting case, for a reversible process, remains unchanged. I used the above statements for my Munich doctoral dissertation .

They probably only let it pass as a dissertation because they knew me from my other work in the practical course in physics and in the mathematics seminar. But even among physicists who were closer to the subject, I found no interest, let alone applause. Helmholtz had probably not read the paper at all, and Kirchhoff explicitly rejected its content, stating that the concept of entropy, whose magnitude can only be measured and therefore defined by a reversible process, should not be

applied to irreversible processes. I was unable to get close to Clausius, who was very reserved in his personal relationship. An attempt I made once to introduce myself to him in Bonn was unsuccessful, because I didn't meet him at home.

However, such experiences did not prevent me, deeply imbued with the importance of this task, from continuing the study of entropy, which I regarded, along with energy, to be the most important property of a physical entity. Since its maximum denotes the final equilibrium, knowledge of entropy gave rise to all the laws of physical and chemical equilibrium. In the following years I carried this out in detail in various works, first for changes in the state of matter, then for gas mixtures and finally for solutions. Fruitful results were obtained everywhere. Unfortunately, however, as I only discovered later, the great American theorist John Willard Gibbs, who had formulated the same theorems earlier, even in a more general version, had beaten me to it 3 years, so that I was not particularly successful in this field either.

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