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Walther Nernst and the Transition to Modern Physical Science

Primarily a scientific biography of Walther H. Nernst (1864–1941), one of Germany's most important, productive, and often controversial scientists, this book addresses a specific set of scientific problems that evolved at the intersection of physics, chemistry, and technology during one of the most revolutionary periods of modern physical science. Nernst, who won the 1920 Nobel Prize for Chemistry, was a key figure in the transition to a modern physical science, contributing to the study of solutions, of chemical equilibria, and of the behavior of matter at the extremes of temperature. A director of major research institutes, rector of Berlin University, and inventor of a new electric lamp, Nernst was at once the first "modern" physical chemist, an able scientific organizer, and a savvy entrepreneur. His career exemplified the increasing connection between German technical industry and academic science, between theory and experiment, between concepts and practice.

Diana Kormos Barkan was trained as a chemist in Romania and Israel before receiving a doctoral degree in the history of science at Harvard University in 1990. Her dissertation received the Prix Marc-Auguste Pictet of the Société de Physique et d'Histoire naturelle de Genève in 1992. She has been a member of the Institute for Advanced Study in Princeton and the recipient of NSF, NEH, and Sloan Foundation grants. She has carried out research in many European countries and has been an invited lecturer in Austria, England, Germany, and Israel. Her articles have been published in edited volumes and in *Science in Context* and *Perspectives on Science*.

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Preface

In his speech during the memorial festivities in honor of the University of Berlin's founder in August 1922, the new rector addressed assembled students, professors, and guests in a bold and unconventional manner: he offered a moving encomium to his murdered friend and longtime associate, the prominent German Jewish industrialist and politician Walther Rathenau, killed two months earlier by reactionary gangs in the Grunewald neighborhood of Berlin. Walther Hermann Nernst, distinguished Professor and Geheimrat, appealed to German academia and intellectuals to expunge violence and dogmatism from public life.

And yet, Nernst had his own record of involvement with violence. He had lost his two sons in the Great War, and had only recently been removed from a list of German war criminals because of his work on chemical warfare. A Prussian by birth and education and, at age fifty-eight, an academic personality of international reputation, Nernst had recently been awarded the Nobel Prize in Chemistry, to the opprobrium of the Allies' press. He had been one of the deposed Emperor's scientific advisors, and yet had become a trusted intellectual of the young Weimar Republic.

In its makeup and language, the speech reflected Nernst's complex and seemingly contradictory personality. A scientist and government employee, he was nonetheless speaking out in public about private friendship with a rather unpopular Jewish politician, drawing on Schiller and Shakespeare for eloquent odes to freedom and indictments of tyranny. He then shifted swiftly to an elaborate, detailed, and technical astrophysical lecture on the birth of new stars and their cosmology. Hence, the lecture comprised two completely different texts that confronted two distinct realms of social discourse: His views on public life were ruled by empathy, political partisanship, sense of civic duty, literature, and philosophy; the other, scientific view, described exploding novas and attempted to balance the energies of the universe and reconcile competing astrophysical hypotheses. Between the two sections, Nernst inserted some reflections on the tragic figure of the early modern astronomer Tycho Brahe, on whose tomb in the Teyn church in Prague is written: *Nec fasces, nec opes, solum artis sceptra perennant.*

"Neither raw force, nor riches, but only the scepter of the spirit lasts forever."

Upon his death almost two decades later in the midst of World War II, the *New York Times* portrayed Nernst as one of the last German scientists "free to think and to say what he pleased, [a] *Gelehrter* . . . honored and not regarded, as now, as an annoyance, from whom nothing socially useful can be expected."

This is primarily a scientific biography of Walther Nernst (1864–1941), one of Germany's most important, productive, and controversial modern scientists. His life and work have until now been treated as a minor chord in the accounts of the triumphant marching song of German theoretical physics and chemistry. I have sought to convey the flavor of daily existence of a German scientist who was immersed and enmeshed in the great scientific, educational, technological, and political debates of his time. His life was one of many rewards and punishments.

The book is designed mainly to address a specific set of scientific problems. When and how they became problems, how they were elucidated experimentally and theoretically, and how this understanding will promote our overall view of developments in modern physical science are the main questions at hand. The most substantive concerns the manner in which events leading to a total reformulation of modern physics may be seen as a complex process, extending synchronically across several disciplines and domains, as well as having their origins in diachronically diverse traditions. Moreover, by looking at Nernst, I expand the circle of scientists concerned with radiation, conductivity, and heat to include a number of chemists, physical chemists, and engineers who have been largely absent from the historiography of early quantum theory.

This approach raises an additional set of questions: In what particular ways are scientists, or groups of scientists, different from one another? That is, can we, or should we, isolate the work of, say, physicists from that of their colleagues simply because we know quantum theory to have been created by a physicist? What exactly was Max Planck's circle of colleagues in the years prior to his enunciation of the quantum hypothesis in 1900? How does the traffic in theories, methods, and instruments across fields affect disciplinary identity? Do even disciplines themselves exist beyond budgets and letterheads? In short, how are individual and group identities formed, and does all this matter at the end of the day?

To get at these questions, I found that I had to make this a book about alternatives and about the benefits of rereading. It tells the stories several times, in several incarnations, and explores ambiguities that ultimately resolve into a new narrative. It is, in many ways, a revisionist book. By focusing my attention on the often plodding reality of everyday scientific practice, I believe that the resulting picture will eventually modify our accounts on a number of issues, especially on the origin of the heat theorem and the relationship among physics, chemistry, and the needs arising from industrial practical application. This is neither a "privileged" account, nor does it seek to describe all aspects of scientific activity in late nineteenth-century physics and chemistry. My aim is to provide a "thicker" description of theory, experiment, and technology by addressing three major areas: the history of physical chemistry in Germany; the formulation of the third law of thermodynamics; and the relationship of physics, chemistry, and industrial concerns as present in the work of Nernst and his contemporaries.

In his later work, Thomas S. Kuhn struggled to understand how exactly we move from an old, established system to a new starting point. It was the study of "displacement" that had remained for him, and still remains for all of us, deeply problematic. In response to his critics, Kuhn still considered it necessary that a story be organized in a spiral way, that some of the points be covered several times. This form of organized reflexiveness, which he found indispensable, was not at the time anything close to the then–already fashionable reflexivity. The only way to explore these displacements is by small steps, not necessarily through microhistory, but by following the reincarnation of questions, methods, and tools in recurring problematic situations. But ultimately, as Kuhn insisted, it matters not where individuals are located but how thought and thought collectives move. By focusing on individuals and their specific re-understanding of the problem on which they are working, we ultimately attempt to explain general movement, that notorious undirected progress.

At the risk of losing the reader after the following introductory explanations, it is necessary at this point to provide a backbone to the book's structure. The various chapters are fairly technical and, although accessible to a nonspecialist, have a recursive pattern that might be opaque. In the tradition of puzzle solving, the book centers around one crucial anomaly: The work, which has been universally brushed aside if not outright derided by those who have known or described Nernst, is in need of "placement" into the context of his scientific career. Between 1894 and 1906, Nernst invented and developed a new electric bulb. This work has been seen as a business proposition, which it was, and as nothing else. The heat theorem, which was formulated at the end of 1905, was connected by biographers to a long-standing chemical theoretical problem: how to predict the feasibility of chemical equilibria. No connection whatsoever was made between the ongoing, intensive work on the lamp and this highly theoretical and hypothetical postulation of a new law of thermodynamics. Furthermore, Nernst immediately began making connections between his heat theorem and Planck's quantum theory of radiation, and he organized the First Solvay Congress in Physics in 1911, which was the first international meeting devoted to the new quantum physics. This move on his part, too, has been seen as a rather pragmatic, professional move, which it was as well, but without exploring why Nernst would be involved in a topic not his own. That is, within the historiography of quantum theory, the story is as follows: The insufficiency of existing radiation laws prompts by the end of the nineteenth century an examination of black-body radiation, which leads to Max Planck's postulation of the quantum theory in 1900. This is followed by seminal papers by Albert Einstein, who develops it into a more comprehensive quantum theory of light (1905) and matter (1907). In this chronology, Nernst's heat theorem is "confirmed" by Einstein's 1907 paper; eventually, Nernst's subsequent experiments at low temperatures are confirmation of Einstein's paper of 1907.

On the other hand, the traditional account of the postulation of the heat theorem revolves around a different chronology, according to which it evolved as a result of Nernst's attempt to solve a problem in chemistry: How do we evaluate chemical affinities and how can we predict on the basis of such knowledge the feasibility of a chemical reaction? Hence, Nernst devised dissociation experiments of gases at high temperatures and postulated the necessary conditions for understanding the relationship between chemical work (affinity) and heat. He then moved to low-temperature experiments to prove the heat theorem for the domain of solid substances.

In this scenario, Nernst's work on an electrolytic lamp is an anomaly, until now an amusing aside. What follows is a scrambling of the pieces and their reassembling:

The first part, which consists of chapters 1 through 5, sets the stage for Nernst's education, training, and early researches. It places him in an eclectic position, of a physicist involved in exploring traditional problems in physics and electrochemistry. It also introduces a scientific network of particular people with whose work and personalities Nernst would be involved throughout his career. Here we meet H. F. Weber, Fr. Kohlrausch, W. Ostwald, P. Drude, Max Planck, and S. Arrhenius.

The second part, comprising chapters 6 through 9, focuses on what I have called Nernst's high-temperature electrical work. The major problem to be solved was that of illumination, of obtaining a material which would emit the brightest light, withstand excessive temperatures, and consume lower amounts of energy than other available lamps. This involved many subproblems: electrical and electrolytic conduction, the behavior of solid conductors and nonconductors at high temperatures, the dissociation of gases at high temperatures, the behavior of solids and gases interacting at high temperatures, the problem of measuring extremely elevated temperatures, the design of materials for high temperatures, the design of instruments such as ovens, a calorimeter, photometer, and thermometer for such work. These were all intensely practical problems, each of which will be addressed in turn. The pattern will stay the same: We shall explore problems, the design of experiments, the design of instruments, and problems arising from such instruments.

I will argue that none of the aspects of Nernst's work could be solved – or properly understood – satisfactorily in isolation, and that scientists were enmeshed in a net of puzzle solving. From a theoretical standpoint, all existing tools had to be reevaluated: Matter theory, radiation laws, optics, gas theory, chemical equilibria, conductivity theory were all called to assist and were all found wanting. One central binding theme could be seen to be the problem of specific heats, which runs often invisibly, most often explicitly, throughout the book. Nernst's heat theorem, which is fundamentally about specific heats as well, emerges from these preoccupations, as does a deep sense he acquired of how things really are, that is, how matter behaves under given conditions.

The remaining chapters, 10 through 12, analyze the "canonization" of both quantum theory and the "heat theorem" in the larger scientific community, ultimately resulting in a Nobel Prize award to Nernst. The treatment is not complete. Important aspects of Nernst's late scientific career will be briefly mentioned, since the focus throughout has remained a set of particular problems and their practical resolution.

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Like the scientists with whose intellectual ancestry the book is repeatedly concerned, I too have elaborated upon the craft and preoccupations of my teachers. Yehuda Elkana opened the field to me and tried to inspire both vision and incisiveness. Erwin Hiebert, whose work on Nernst and on the history of physical chemistry was pathbreaking, may disagree with some of what I have to say, but I learned it all from him. Under no circumstances could I have completed this project without the patient and firm guidance and the genuine friendship of Daniel J. Kevles, to whom I am immensely grateful. Fiona Cowie was a tireless reader, and friend. I owe special gratitude to Martin Klein, for his thoughtful and acute criticism, advice, and support. I also thank Jed Buchwald, Moti Feingold, Peter Galison, Kostas Gavroglu, Mary Jo Nye, Norton Wise, and the anonymous readers at Cambridge University Press for valuable comments on sections of a rather undigested first draft. Alex Holzman, my editor, was especially patient and graceful. Thanks also to Phyllis Berk and Eric Newman at Cambridge. Charles Kormos struggled to smooth some of my prose and to keep me going.

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