Preface

EVERY AUTHOR will be familiar with that most common and difficult question, "What is your book about?" During the several years I have worked on this project, I have experimented with several answers. Perhaps the simplest and most satisfactory is that it is an inquiry into how and why a new scientific discipline took root, grew, and flourished in a particular social setting. The discipline is physical chemistry; the setting is America in the decades around the turn of the century.

But such a bald statement demands some explication. Why study the history of entities as disorderly, ill-defined, and common as scientific disciplines? Why select a science as technically demanding and politically inert as physical chemistry? Why focus on the United States when it is well known that this science had its origins in Europe? And why end the story in the early 1930s, a time when some would say that things were just getting interesting?

Ruthlessly honest answers would demand the acknowledgment of chance. Like many if not most books, this one went through several lives and was shaped by all manner of accidental factors that now can hardly concern a reader. But as any student of science knows, just because the context of discovery differs from the context of justification, it does not follow that justifications are unimportant. With this in mind, let me explain, as best I can, the scope and design of this book.

It is about a discipline, and by that I mean a family-like grouping of individuals sharing intellectual ancestry and united at any given time by an interest in common or overlapping problems, techniques, and institutions. There is much ambiguity in this definition. It says nothing about size, for example, or about the degree to which individuals must be "related" in order to qualify as members of the same discipline. Yet to be more precise would be to exaggerate the exactness of the phenomenon. Disciplines may enroll a few dozen scientists or thousands. They may be tightly focused on a few questions and techniques, or they may be so diffuse as to challenge the skill of the best textbook writer. Some are happy families, with little controversy over methods and goals. Others are fractured into many research schools, each with a different agenda, each evolving its own traditions of thought and work, and each competing for resources and recognition. A single discipline may be all of these things at various points in its history.

Disciplines are difficult to define, but they are important in the intellectual and social life of scientists and scholars, especially those in academe. We publish in disciplinary journals; we work in departments that reflect present or

past disciplinary contours; we take and teach courses bearing titles like "history of science" and "organic chemistry"; we identify ourselves at cocktail parties and in biographical directories by discipline; our applications for grants and fellowships are read and evaluated by peers, meaning other members of our discipline. With few exceptions, the more actively engaged we are in the production and transmission of knowledge, the more powerfully disciplines influence our behavior and self-images. We are, of course, more than members of a discipline, but our professional lives revolve around these entities; they help us define our ambitions, successes, and failures.

Despite or perhaps because of this ubiquity, disciplines have not enjoyed a favorable press in recent years. They have been described as purely political entities dedicated to serving the interests of small elites and as repressive institutions that stifle creative impulses and impose artificial limits on the growth of knowledge. For some proponents of "interdisciplinary" education, the discipline is something to be overcome.

Yet the discipline not only confines, it also liberates. The successful discipline affords its practitioners social and intellectual security, institutional support, and a sense of direction and opportunity. Although a small elite may exert great influence within a discipline, it would be a grave mistake to assume that its motives must be nefarious, its goals self-serving, and its influence retrograde. The discipline is not dysfunctional; it is functional. There is a nearly universal tendency for scholars, even those who set out to break disciplinary molds, to organize themselves into such units.

The reason is not far to seek. Disciplines not only lend structure and meaning to lives, they also bring order and significance to knowledge. To appreciate this, it is necessary only to try to imagine a world that ignores them. Any glimpse of unity that a schooling without specialties might afford could hardly compensate for its barrenness and sterility. Few if any of us could flourish on the boundless sea that is knowledge without categories. With no reason to drop anchor here rather than there, with no coordinates or landmarks to mark and communicate positions, a word like exploration would lose all meaning. Specialization, which is as important to science and scholarship as to pin production, would be impossible. Disciplines may shrink our horizons, but they compensate by giving us means by which we can make our knowledge productive.

Disciplines play important roles in all kinds of intellectual activity, but nowhere are they as important as in the sciences. Essential to the sustained accumulation of facts, the elaboration of ideas, and the transmission of technique, disciplines are at least partly responsible for giving modern science its cumulative and progressive character. As Thomas S. Kuhn has suggested, it would be surprising if some form of progress did not result from the concentration of effort on selected problems. Disciplines are lenses that focus individual effort. Scientific disciplines, with their textbooks, journals, abstracting services, review articles, societies, and powerful sanctions against amateurs,

are especially powerful lenses. They are strikingly efficient in identifying soluble problems and in bringing resources to bear on such problems.

Of all the scientific disciplines one could write about, physical chemistry is perhaps not the first to come to mind. It is not as flamboyant as molecular biology or particle physics. Its practice does not command headlines or prompt Congressional inquiries; its concepts seldom attract popular attention; its story offers comparatively few opportunities to explore issues central to modern political history. Chemists find this discipline difficult to define; physicists sometimes look upon it as a trivial application of their subject; undergraduate chemistry majors tend to see it as the bane of their existence—a forbidding hurdle standing between them and a degree. All will grant the usefulness of physical chemistry and the virtues of knowing it, but few develop much affection for it.

Yet physical chemistry was not always dowdy. In the early twentieth century, it was nearly as chic and exciting as molecular biology is today. The names of its progenitors, Ostwald, van't Hoff, Arrhenius, and Nernst, were familiar to the scientifically literate. Their studies of solutions and chemical thermodynamics transformed scientists' understanding of chemical affinity. A generation later, their successors would effect another revolution by using quantum theory to generate new pictures of the molecule and chemical bond. Physical chemists' striking success in exploring the terrain between chemistry and physics inspired other scientists who were dissatisfied with traditional disciplinary boundaries and helped stimulate the growth of such other borderland specialties as biochemistry and geochemistry. Their science helped launch the high-technology industries of the day—petroleum cracking and nitrogen fixation. Its name could be invoked by a novelist like Sinclair Lewis as a symbol of the progressiveness, power, and difficulty of modern science.

One reason for writing about the history of physical chemistry, then, is simply because its story, while much less known than that of molecular biology or particle physics, has been no less important to the history of twentieth-century science.

But there is another reason as well. The fate of most successful disciplines is fragmentation into smaller and more cohesive specialties. Coalescing around a few tightly focused research schools, they expand and diversify until dismembered by the forces generated by their own growth. The name of the parent field may endure, but more for the convenience of educators and bibliographers than as a cohesive and vital category of scientific research.

Physical chemistry presents us with a poignant illustration of this process. Born out of a revolt against the disciplinary structure of the physical sciences in the late nineteenth century, it soon acquired all the trappings of a discipline itself. Taking form in the 1880s, it grew explosively until, by 1930, it had given rise to a half-dozen or more specialties that, more and more, were coming to serve as the principal reference frames for their members. Older physi-

cal chemists lamented the fragmentation of their science; younger ones, who now considered themselves primarily colloid chemists, kineticists, or crystallographers, celebrated the progress that accompanied specialization. Ironically, one of these descendants, variously called chemical physics, structural chemistry, or quantum chemistry, would perform the broad integrative functions that the founders of physical chemistry had aspired to fulfill. These developments—the coalescence of physical chemistry in the 1880s and the emergence of a new chemical physics in the 1930s—frame the book that follows. The first was associated most directly with the career of Wilhelm Ostwald, the second with that of Linus Pauling.

A few words must be said about what some readers may find to be a disturbing emphasis on the history of this discipline in America. Physical chemistry as a network of ideas is not American any more than it is German or French. And if this were a work of straightforward intellectual history, my concentration on American institutions and scientists would be unforgivable.

But disciplines are more than simply aggregates of disembodied ideas. They find leaders who are imbued not only with the norms of science but also with the values of national cultures; they draw on traditions of thought and activity that may vary from country to country, and within countries from locale to locale; they are propagated by journals and textbooks that are written in particular languages; in each nation and region they meet peculiar economic and social conditions, which may favor or hinder their development, or which may channel it along particular lines; and for reasons of convenience, and sometimes necessity, practitioners usually respect national boundaries when they organize themselves, either formally and informally. Even today, in an age of air travel and global telephone connections, distance produces subtle but significant variations in the practice of science. In earlier times, when long-distance communication was more laborious and western culture less homogeneous, opportunities for variation and divergence were greater and national and local styles more prominent.

For the historian, this dual nature of disciplines constitutes a dilemma. To concentrate on the universal by relating the history of a discipline without attention to national boundaries all but necessitates the sacrifice of the local details that may prove essential to understanding how and why the discipline flourished in particular places. The result may be a beautiful account of intellectual development, but one that provides little insight into the economic and cultural conditions that made such development possible. Alternatively, to focus exclusively on the history of a disciplinary community in one nation precludes any meaningful discussion of the content of the science. At best, we get sketchy summaries of conceptual developments; at worst, we lose all touch with ideas—the very things that give disciplines their *raison d'être*. In either case, the integrity of the historical subject—the discipline in its intellectual and conceptual totality—is destroyed.

I do not pretend to have solved this dilemma. It is impossible in the confines of a single volume to do justice to the history of a modern discipline in all its complexity. Yet, by what I hope are judicious compromises I have sought to retain the strengths and avoid the weaknesses of the two approaches outlined above. The origins of physical chemistry are in Europe, and in the first two chapters I describe those origins at some length. Subsequently, I allude to developments in Europe as they impinged on American scientists, elaborating only where it seems necessary to follow the work of selected research schools on this side of the Atlantic. The schools on which I focus are those of Arthur A. Noyes, G. N. Lewis, and Wilder D. Bancroft. Not only were these scientists among the most prominent American physical chemists of their generation, they were also critically important teachers and institution-builders. The study of their lives and labor, supplemented by a broader but shallower survey of the community in which they worked, is the best route I have discovered to explore both the expansion and diversification of physical chemistry in the early twentieth century and the path that led from the physical chemistry of Ostwald to the chemical physics of Pauling.