FOREWORD

Lack of experience diminishes our power of taking a comprehensive view of the admitted facts. Hence those who dwell in intimate association with nature and its phenomena grow more and more able to formulate, as the foundation of their theories, principles such as to admit of a wide and coherent development; while those whom devotion to abstract discussions has rendered unobservant of the facts are too ready to dogmatize on the basis of a few observations.[1]

IN THIS BOOK, I consider the varieties of methods and styles in the thought and practice of some of the many people who investigated the general properties of matter, the specific properties of material objects (including living organisms), and the phenomena exhibited when such objects are subjected to artificial treatment. Over the centuries, the efforts of these people, belonging to different professions—physicians, natural philosophers, alchemists, pharmacists, metallurgists, mineralogists, and in modern times, chemists, physicists, and biologists of various kinds—contributed to the development of the field of scientific inquiry we now call "chemistry."

The word "style" has come to have many different meanings in various contexts—haute couture, the literary, visual, and musical arts, as well as politics and other social activities. It has also been used as a euphemism for personal idiosyncracy.[2] I use "style" as a neutral term denoting the manner in which chemical investigation was conducted. Its meaning is not restricted to the aesthetic attributes (simplicity, symmetry) of particular chemical theories, to their "truth" or "falsity," or to the clarity of their exposition. Nor is "style" applied solely to chemical practice in which exceptional originality, skill, ingenuity, or precision was exhibited in the use and development of experimental methods. Such elegance was rightly hailed by contemporaries and by later historians, but imaginative (often illogical) thought, as well as routine or imprecise laboratory work, have also played a significant role in the historical development of chemical knowledge.

In the conduct of their chemical studies, and in the interpretation of the results, the investigators were influenced by preconceptions derived from many sources, among them religious belief, philosophical and technical tradition, previous education and practical experience, and social custom. As Stephen Toulmin put it:

> However objective and open-minded a scientist may be, his questions necessarily involve the use of preformed concepts. In this sense, he relies on preconceived ideas; but it is a sense which emphatically does not involve any suggestion of dogmatism. For these concepts are the common coin of scientific discussion in a given period, the basis of common understanding between scientists and of their language; they are essential if there is to be any agreement between scientists about what questions are relevant, sensible, even intelligible.[3]

In what follows, I consider the thought and action of these people, whether or not they are now considered to have been "scientists," to form a continuum in the development of chemical knowledge, leading to the multiplicity of specialties and sub-specialties that now constitute the chemical sciences. In connection with the changes in the conceptual structure of an area of chemical inquiry, I emphasize the practice that led to the discovery of previously unknown natural objects and phenomena, to the performance of fruitful experiments, to the invention of new or better methods, tools, and instruments, and to changes in classification, nomenclature and symbolism. I also consider, where appropriate, biographical data relevant to the theme of this essay. In denoting the preconceptions of an individual, I do not use the terms "naive realist," "empiricist," "positivist," "presentist," "pragmatist," "whig," "conventionalist," etc., which are frequently used (and misused) by historians. All too often, what they have taken to be an intellectual commitment may have been, for the scientist, a "working hypothesis." Nor do I use the currently fashionable (but frequently misapplied) phrases "material culture" or "moral economy." Scientist-historians such as I have been chastised by some professional historians of science as being indifferent to archival sources, especially personal correspondence, and I agree that the critical study of such material is essential in historical research, as will be evident in later pages of this book. I must add, however, that it is by no means certain in all cases that the selected correspondence of a noted scientist reveals more about his or her method and style of thought and work than a well-informed and thorough examination of the entire published scientific output.[4]

Distinctions have been made between the styles of scientific thought in German-speaking, French-speaking, and English-speaking nations.[5] Also, much attention has been paid to the idea of a "Denkstil," offered by the serologist Ludwik Fleck, and derived from the writings of the sociologist Karl Mannheim.[6] The most influential recent theory is the one presented by Thomas Kuhn, who set forth stimulating views about what he called "normal science," characterized by "puzzle-solving" along lines set by prevailing concepts ("paradigms") in a scientific community, and the appearance of "anomalies" whose explanation led to a revolution and to the adoption of new paradigms.[7] The recent discussion of the eighteenth-century Chemical Revolution (of which more later) has raised questions about the applicability of Kuhn's theory to the historical development of the chemical sciences. Moreover, in relation to the theme of this book, the concept of a scientific community, in which particular paradigms prevail, glosses over the differences in the methods and styles of the individual members of that community.[8] I was reminded of the warning by Pieter Geyl that a modern historian should be

> on his guard against . . . intellectually satisfying schemes which may hedge in or distort the view. . . . He will not too readily identify a period with an idea; behind the idea he will look for the unruly, struggling men. Behind the anonymity of a class, of a nation, of a sect he will search for various shadings, for individual peculiarities.[9]

For my purpose, a more valuable guide has been the recent magisterial three-volume treatise by the late historian Alistair Crombie,[10] in which he traced the emergence in Europe of six styles of scientific reasoning: mathematical, experimental, analogical modeling, taxonomic, probabilistic and statistical, and historical:

> These six styles and their objects are all different, sometimes incommensurable, assuming fundamentally different worlds, but frequently they are combined in any particular research. By identifying the regularities that become its object of inquiry, and by defining its questions and acceptable evidence and answers, a style both creates its own subject-matter and is created by it. A change of style introduces not only new subject-matter, but also new questions about the same subject-matter. . . . Different styles introduce new questions about the existence of their theoretical objects; are these real or products of methods of measurement or sampling, or even of language?[11]

In his treatise, Crombie discusses in considerable detail examples drawn largely from the physics and physiology developed by European investigators before the end of the nineteenth century. As will be evident in what follows, each of the six styles is represented in the historical development of chemical knowledge, but the rapidity and extent of the transformation of chemistry after 1800 led many investigators to change the style of their research. For this reason, I deem it necessary to retell some of what is well known to professional historians of chemistry, in order to provide the context in which the individual styles were expressed. Also, since I will consider the styles of several chemists active during the twentieth century, when the award of Nobel Prizes has often affected historical judgment, some of the relevant theoretical and practical background will also need retelling.

To the styles of thinking listed by Crombie might be added some less well-defined mental attributes, such as imagination or intuition in the choice of chemical problems, of experimental attack and interpretation of experimental results, or of nomenclature and symbolism.[12] Among the styles related to chemical practice, one might include features such as technical skill, ingenuity, precision, or even dependence on group effort in the laboratory. Each chemical style has had its own standards in the evaluation of theories and of experimental data. With the development of a research field, these standards have changed, although vestiges of older styles, such as Pythagorean numerology or the laboratory operations of medieval alchemists, may have been retained.

This book deals, therefore, primarily with the methods and styles of individual scientists in the formulation of their theories, in the conduct of the experimental work in their laboratories, in the presentation of the results of their thought and action, as well as in their acknowledgment of prior work on the problem at hand, and in their response to contemporary critics. Clearly, the differences in style depended to some degree on the extent and quality of their early education, which was related to the social status of their parents or guardians. The men from wealthy families went to leading universities, or had competent private tutors, and often were provided with private laboratories. The less fortunate ones, who emerged from poverty, were largely self-educated, learned laboratory methods as apprentices, and likely were sustained by religious belief. The majority came from middle-class families, and frequently tended to be more competitive than those in the two other groups.

To the above introductory remarks, I should add that professional historians of the natural sciences have differed in their preconceptions of what constitutes "good history."[13] In recent decades there has been argument about such matters as "internalism" versus "externalism," "presentism," "instrumentalism," the "Whig interpretation of history," and the "social construction of scientific knowledge."[14] The debate has now lessened somewhat in intensity, with the acceptance of the view that valuable insight into the complexity and special nature of the development of the natural sciences may be gained from different approaches—philosophical, technical, sociological, and biographical. What still divides professional historians from scientists who study the historical development of their specialty is the tendency of many of the former to overgeneralize their interpretation of selected historical data, and the tendency of the latter to emphasize the theoretical and empirical aspects of particular scientific problems, without consideration of their "cultural" significance.

It has recently become fashionable among philosophers and historians to write about the "disunity of science" and to call attention to the differences in thought and practice among the areas of scientific investigation now denoted as separate "disciplines."[15] Such differences were recognized by Auguste Comte and William Whewell, but the attraction of the idea of the "unity of science" (implicit in the natural philosophy of Aristotle) became pervasive at the end of the nineteenth century. Among its proponents were the scientists Hermann Helmholtz and Ernst Mach (both physicists and physiologists), and their views inspired the so-called Vienna Circle of "logical positivists."

One consequence of the adoption of the idea of the unity of science has been the present-day institutional classification of chemistry as a "physical science." During most of the nineteenth century, however, the dominant chemical specialty was "organic" chemistry, defined by Jöns Jacob Berzelius as dealing with the study of "organized" matter, with close links to animal and plant anatomy and physiology.[16] This tie to what came to be called "biology" (now often termed "life sciences") was also evident in the various schemes for the classification of the innumerable known chemical substances, both "organic" and "inorganic." The relationship of chemistry to physics was expressed during the seventeenth and eighteenth centuries and the first half of the nineteenth century in the term "philosophical chemistry," which included experimental study of heat and electricity.[17] The emergence after about 1850 of the mathematical treatment of "energy" (thermodynamics) and of electromagnetism led to the establishment of "physical chemistry" (or "theoretical chemistry") as a distinctive institutional discipline,[18] the links to experimental physics having been established earlier in the century, most notably by Michael Faraday. During the twentieth century, with the application of quantum theory and wave mechanics to problems of chemical structure, some physicists preferred the term "chemical physics." In similar fashion, later in the century, many biologists preferred "molecular biology" to "biochemistry."[19]

Implicit in the idea of the "unity of science" is the question of whether chemistry has been (or can be) "reduced" to physics, or whether biology has been (or can be) "reduced" to chemistry.[20] The philosophers and philosophically-minded scientists who have argued about this question have largely focused attention on the theoretical physics or physical chemistry of their time, or on biological problems arising from the study of evolution or genetics. Although they may have recognized that chemistry — the study of the specific properties ("forms and qualities") and transformations of the millions of substances found in nature and those made by man — fits into a continuum of scientific knowledge that ranges from the general properties of matter to the specific properties of living organisms, relatively few modern philosophers have ventured to examine the philosophical aspects of the development of chemical thought and practice, and appear to have followed Kant in denying to chemistry the status of a "science."[21]

Another recent fashion has been the "laboratory study" of scientific practice, especially the nature of experiment, as a reaction to the past tendency to emphasize the development of scientific thought.[22] Most of the "case studies" were drawn from the work of physicists and biologists, and only occasionally from that of chemists. This new interest in scientific practice was in part an outgrowth of the attempt of some sociologists to show that scientific knowledge is "socially constructed."[23] The members of this group disparaged the important studies of Robert Merton and others on the social customs and conduct of scientists.[24]