Cathedrals of Science

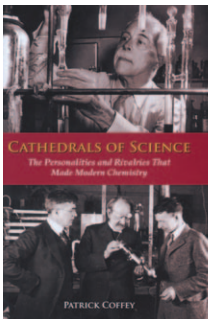
The scientific content of *Cathedrals of Science* deals with a great deal of modern physical chemistry, which will be familiar to any undergraduate student of chemistry. However, less familiar will be the way in which consensus emerged over so many concepts that are now taken for granted. This study draws together several strands in the history of physical chemistry, from the last quarter of the 19th century up to the middle of the 20th century: With splendid attention to detail, it covers the development of the first and second laws of thermodynamics, arising from studies of the steam engine, the third law (the Nernst heat theorem; Nernst established Lewis's integration constant), the theory of electrolytes, surface phenomena, electronic theory, the origin of color, photochemistry, and the role of physical organic chemistry.

Throughout, Coffey takes a biographical approach, with an eclectic cast of characters, thirteen men and one woman, in Europe and the United States. As he documents their careers, the focus is on rivalries, antagonisms, and personalities, as well as friendships, that brought about the merging of physics and chemistry to create a subdiscipline that transformed the other branches of chemistry and the biological sciences. In this, Coffey succeeds brilliantly.

The story opens, appropriately as it turns out, in Sweden, with the 1884 doctoral graduation of Svante Arrhenius, whose two supervisors literally turned their backs on him, but whose work on electrolytic dissociation was to become one of the foundations of physical chemistry, as was soon recognized by Wilhelm Ostwald. At that time organic chemistry, particularly as it was practiced in Germany, was the dominant force in chemistry, and the pioneers in physical chemistry found the going difficult. However, moves towards industrial diversification in Germany stimulated an interest in the behavior and reactions of gases, particularly in relation to their use in electric lamps and to the fixation of atmospheric nitrogen. In 1897, Walther Nernst succeeded with his cerium oxide lamp (a rival to Edison's light-bulb), and in 1909 Fritz Haber demonstrated his high-pressure ammonia process, which was developed by Carl Bosch of BASF. Irving Langmuir, supervised by Nernst, studied the dissociation of gases on hot filaments, and after 1909 at the General Electric laboratory he improved the incandescent light-bulb and developed a theory of gas adsorption and heterogeneous catalysis.

While monetary wealth was important to a few of the protagonists, such as Nernst and Haber, the principal driving forces were invariably reputation and gaining credit among peers. However, the way in which credit was apportioned, particularly through the ultimate accolade, the Nobel Prize, was not always straightforward, as seen here in the accounts of blocking tactics, some of which continued over several years, and of instances where there was a distinct lack of transparency. The discussion of the roles of the Swedish physical chemists Arrhenius and Theodor Svedberg and of the electrochemist Wilhelm Palmaer, as referees for the Nobel chemistry committee, is particularly illuminating, involving personal and scientific disputes, and alliances that were sometimes reversed. Lewis, who was opposed by Arrhenius, is the main example. Moreover, Coffey suggests that Lewis's somewhat withdrawn and sometimes resentful personality often went against him, while his dislike of Nernst (Lewis had studied under both Ostwald and Nernst) was also a major factor in denying Lewis the Nobel Prize. No less critical was the fact that, shortly after succeeding with his concept of ionic strength in 1921, Lewis lost interest in thermodynamics and chemical bonding, and thus also lost out on applying the new quantum mechanics to the resolution of chemical problems. However, he later returned to physical chemistry, with his work on the electron pair (the importance of which he had recognized during the years 1913–1916), and on "odd molecules" (free radicals). Some of Lewis's outstanding contributions, including the explanation for phosphorescence, were appreciated only after his death. He also had to deal with apparent plagiarism. Haber and Nernst, despite strong anti-German feeling after World War I, were Nobel laureates, in 1918 and 1920 respectively (Arrhenius had opposed Nernst's nomination for a decade and a half). Haber worked like a maniac, ruined his family life, and often took refuge in sanatoria.

The many facets of the chemical bond, particularly the contributions of Linus Pauling—who, revising the work of Lewis, introduced ideas about electronegativity and ionic and covalent character and adopted the hydrogen bond—are discussed in the context of research into protein structure. Proteins represented a major change for Pauling, and the interest was stimulated by the availability of funding from the Rockefeller Foundation, whose Warren Weaver in 1936 coined the term "molecular biology". The Rockefeller Foundation also funded the work of the English mathematician Dorothy Wrinch on protein structure and her cyclol theory, but she made the mistake of entering an unfamiliar field, and, despite support from Langmuir and Harold Urey, and even from Niels Bohr, paid dearly for that, incurring the wrath of Pauling. Coffey gives several examples of physical chemists who confronted similar problems, such as the



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attempt by Arrhenius to apply the law of mass action to immunochemistry, in opposition to the concepts of Paul Ehrlich (who was supported by Nernst).

Coffey's own historical research is mainly concerned with Lewis and Langmuir, and he shows how Langmuir received credit for much of Lewis's chemical bonding theory. This was partly a result of the presentational skills and outgoing personality of Langmuir, which also helped gain him the Nobel Prize in 1932 for his work in surface chemistry. Langmuir (who introduced the terms "covalent bond" and "octet theory") was the second American to be so honored, and the first from an industrial laboratory. Coffey also discusses the circumstances of Lewis's death, in 1946, in a laboratory filled with hydrogen cyanide fumes, and concludes, based on Lewis's lifestyle, that it was not suicide.

Side issues, some with dramatic impacts, include the conduct of gas warfare (mainly through the efforts of Fritz Haber), the influence of anti-Semitism, the rise of the Nazis—which led to Germany's loss of many leading chemists—and the involvement of Glenn Seaborg and Harold Urey in the Manhattan Project. For these and the various protagonists, Coffey has drawn on reliable secondary sources, as well as personal interviews. In a few cases the lack of available scholarly biographies meant that Coffey had to rely on the more hagiographic accounts and reminiscences, although with reservations.

In conclusion, this is a highly readable account, bringing alive both the fascinating personalities and their science.

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