A Fascinating Biography Of an Important Molecule

Heavy Water and the Wartime Race for Nuclear Energy

Per F. Dahl
IOP, Philadelphia, 1999. 399 pp. $60.00 hc ISBN 0-7503-0633-5

Reviewed by David C. Cassidy

When Ernest Rutherford hypothesized the existence of a neutral nuclear constituent in 1920, he suggested that it might lead to the discovery of heavier isotopes of hydrogen. Twelve years later, just as James Chadwick in Cambridge, England, announced the discovery of the neutron, Harold Urey and his colleagues at Berkeley announced almost simultaneously the discovery of deuterium, the first isotope to be separated from an element in pure form. Deuterium atoms, bound to oxygen, form deuterium oxide—better known as heavy water—which constitutes about one part per 4500 of natural water. Soon after the outbreak of war in Europe in 1939, the rare heavy water proved to be the optimal substance for the necessary slowing of fission-produced neutrons in a reactor using natural uranium.

Per Dahl, a former staff scientist at the Lawrence Berkeley Laboratory, who has written previously on the histories of the electron and superconductivity, provides a fascinating, broadly readable, technically accurate account of deuterium oxide—essentially the biography of a molecule—from its prediction and discovery to its production and uses in the race to unleash nuclear energy during World War II. Reminiscent of the passage of an exquisite Stradivarius from setting to setting in the recent film *The Red Violin*, Dahl traces his molecule from Berkeley and Cambridge to wartime fission researchers in Italy, France, England, Canada, the US, Germany, and, briefly, the Soviet Union and Japan. But a good deal of the story centers on Norway, which, well into the war, possessed the world's only heavy-water production plant. It is a story that, analogous to the film, contains a mixed cast of fascinating characters and events. And, similar to the violin painted in blood, the story of heavy water carried a sinister side. In addition to its central role in the acquisition of nuclear weapons, an estimated 120 people—commandos, guards, and civilians—died in its cause during the war.

For their part, the Americans chose ultra-pure graphite over heavy water as the neutron moderator for their main wartime reactors, principally because they lacked at first the production capacity for heavy water. But they did eventually produce heavy water on a massive scale and did construct heavy-water reactors as a backup. The Germans took the opposite approach: Deciding against graphite and the building of their own production facilities, they chose instead to rely on shipments of heavy water from the forced enhancement of production at the plant in Norway, then under German occupation. This left the German effort dependent on a foreign source that was vulnerable to sabotage and aerial bombardment, both of which occurred.

The reasons for this fateful decision, and for the ultimate failure of the German effort, are not quite clear from Dahl's account. German researcher Walther Bothe had measured a prohibitively high absorption cross section for neutrons in graphite, which was later attributed to the presence of impurities. But it is not evident why better tests for impurities were not made or why purer graphite was not obtained, even though Paul Harteck had argued to the authorities for both. Without elaboration, Dahl makes the novel assertion that, in any event, cross-section experiments were less important than "the economics of high-purity graphite on an industrial scale . . . [which] effectively eliminated carbon as a moderator in a German reactor."

Although the Germans were ahead of the Allies in fission research at the beginning of the war, they eventually fell far behind. The reasons for the failure of the German project to achieve even a chain reaction are well researched, if still hotly debated. Although he consulted a host of archival sources, Dahl's tendency to rely only on two secondary sources and one published postwar interview of the chief German scientist, Werner Heisenberg, leads at times to vagueness. For instance, Dahl remarks only in passing that, beginning in June 1942, German researchers displayed a sense of complacency and lack of urgency about fission research. This has been discussed at length in the literature as a symptom of underlying attitudes among the research leaders, especially Heisenberg, that hindered the German effort.

Nevertheless, Per Dahl has written an outstanding, fascinating account of the discovery and applications of heavy water in the wartime race for nuclear energy, one that specialists and the general public alike will find intriguing.

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Dynamic Earth: Plates, Plumes and Mantle Convection

Geoffrey F. Davies
Cambridge U. P., Cambridge, N.Y., 1999. 458 pp. $90.00 hc ($39.95 pb) ISBN 0-521-59067-1 hc (0-521-59933-4 pb)

Geophysicists divide Earth's surface into 10 (more or less) nearly rigid tectonic plates, which move with respect to each other at rates of a few centimeters a year. Plates move apart at midoceanic ridges. Trenches and island arcs occur at subduction zones, where plates converge. Horizontal motion without convergence or divergence occurs at transform faults, such as the San Andreas Fault in California. This hypothesis provides a unifying framework for solid-Earth science to the point that allusions to it appear even in TV ads.

The underlying dynamics of plate tectonics is not as well known, however, and, in *Dynamic Earth*, Geoffrey Davies fills this void with an excel-