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JAMES FRANCK
1882—1964

A Biographical Memoir by

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Biographical Memoir

James Franck.

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August 26, 1882–May 21, 1964

BY STUART A. RICE AND JOSHUA JORTNER

Most scientists earn recognition from the quality of their contributions to the development of our understanding of nature, some earn recognition because of the public stances they take, at personal peril, on moral issues, and some earn recognition by the positions they take on important issues at the intersection of science and politics. Only a very few earn recognition for all three reasons. James Franck was one such scientist. He made early very important contributions to the experimental basis for the quantum mechanical description of atoms and molecules, for which he was awarded the Nobel Prize in Physics in 1925, and to the understanding of the physical processes underlying photochemical processes and reactions. He was elected to membership in the National Academy of Sciences in 1944.

Franck was one of the first, and one of the very few, to openly demonstrate against the racial laws introduced by the Nazi regime in Germany, and in 1933 he resigned from the University of Göttingen as a personal protest against the Nazi regime. As the principal author of a June 1945 report that attempted to convince the United States to provide a public demonstration of the first nuclear bomb before deploying it against Japan, he played a major role in the unsuccessful effort to abort an international race for supremacy in nuclear

armaments, and he played an important background role in the successful effort to achieve civilian control of nuclear power in the United States.

James Franck was born on August 26, 1882, in Hamburg, Germany, the son of a Jewish banker. His mother, Rebecka (née Nachum-Drucker), came from a family of rabbis, while his father, Jacob Franck, was deeply religious. David Nachmansohn used to say that James, in contrast with his father, was not orthodox but very liberal. At a later age James Franck himself would state that science was his god and nature his religion. Still, he was very proud of his Jewish cultural heritage.

The early education of James Franck, as was the style of those times, was strong in classics. He studied at the Wilhelm Gymnasium in Hamburg, and as he was fond of relating, he was anything but a brilliant scholar, and only just managed to pass the high-school final examinations, which enabled him to enroll at a university. His father sent him to the University of Heidelberg to study law and economics, to prepare him to eventually join the family firm. However, it was James's desire to study science, despite his father's wishes, and for two semesters he studied chemistry and geology in Heidelberg. It was there that he met Max Born. The two became lifelong friends and, as Born wrote, neither the professors nor the romantic atmosphere of the town were the most important things in his life, rather it was his friendship with Franck. Born and other friends supported James Franck in his efforts to persuade his father to agree to change the course of his studies toward science. Then, in 1902 he moved to Berlin to study physics, where his principal tutors were Emil Warburg and Paul Drude.

Franck's student Werner Kroebel noted that Franck began the scientific work for his thesis by converting on his own initiative a seemingly unimportant subject proposed to him

by his professor into highly significant research on ion mobilities. Under the supervision of Warburg, Franck obtained his doctorate degree in 1906, for research on the mobilities of ions in gaseous discharges. Such research themes were very popular at the time, since they were meant to clarify the atomic structure of matter. After a short stay in Frankfurt-am-Main, Franck returned to Berlin as an assistant in Heinrich Rubens's laboratory. There he began his exploration of the electronic structure of atoms and molecules and the elementary processes associated with collisions between atoms. He invoked his previous studies of ion mobility, as well as spectroscopic investigations with R. W. Wood, on the connection between the quantum hypothesis and fluorescence quenching of iodine by foreign gases, to explore electron affinities of atoms and molecules. Together with his younger colleague and friend Gustav Hertz he carried out seminal studies of elastic collisions between electrons and inert gas atoms. Franck and Hertz laid the foundation for the development of what we now call electron impact spectroscopy (i.e., the study of inelastic collisions between electrons and atoms and/or molecules).

In 1911 James Franck obtained the *Venia legendi* for physics to lecture at the University of Berlin. When the First World War broke out in 1914, he volunteered to join the army as a private. He was wounded, decorated with the Iron Cross 1st Class, and returned as a lieutenant. In spite of his Jewish origin he became an officer, a sign of his courage and the quality of his military activities. He was then assigned to a research group led by Fritz Haber, Pioneer Regiment 35-36, which was involved in chemical warfare. As Franck reported, he became Haber's confidential assistant at the front; it was his job to inform Haber of the various battle actions and how they had developed (Stolzenberg, 2004).

In 1917 Haber suggested to Franck that he join his Kaiser Wilhelm Institute of Physical Chemistry and Electrochemistry in Berlin. In 1918 Franck took over as head of the physics department in Haber's institute. Here he and Gustav Hertz continued the seminal experiments they had begun in 1912-1913 on electron impact spectroscopy. Lise Meitner recalled James Franck's lecture in Berlin—"On the Excitation of the Mercury Resonance Line by Electron Impact"—in which he reported his joint work with Gustav Hertz, which provided the first experimental evidence for the quantization of atomic energy levels. After that lecture, Einstein said to Meitner: "It's so lovely, it makes you cry!"

In the period between 1900 (when Planck accounted for the spectrum of black body radiation with the postulate of quantization of energy) and 1913 (when Bohr introduced his model of the hydrogen atom) essentially nothing was known of the internal structure of atoms and molecules. The Franck-Hertz experiment was initiated before the publication of the Bohr model but reported six months after the model was published, and provided the first direct experimental evidence for the existence of discrete internal states of an atom (Figure 1). This experiment showed that in collisions of an electron with an atom, if the energy is less than a threshold value, (1) the collision is elastic, (2) excitation of an internal state of an atom occurs at a precisely defined threshold energy, (3) successive excitations likewise require discrete amounts of energy and appear at distinct thresholds, and (4) these inelastic collisions lead to emission of light with frequency v and change in the collision energy ΔE that satisfy the Planck relation $\Delta E = hv$. Our understanding of the world was transformed by the results of this experiment; it is arguably one of the most important foundations of the experimental verification of the quantum nature of matter. The significance of this work was recognized by the award to

James Franck and Gustav Hertz of the 1925 Nobel Prize in Physics "for their discovery of the laws governing the impact of an electron on an atom."

In 1920 James Franck moved to Göttingen to serve as professor of experimental physics and director of Physical Institute II. Initially the laboratory was completely bare of equipment, and James Franck bought apparatus from his private resources; it quickly became one of the most important world centers of research in atomic and molecular physics. All reports of the character of Franck's laboratory emphasize how different it was from almost all other laboratories in German universities by virtue of the warmth and informality of the student-professor interactions, the mutual respect between all laboratory members, and the open and spirited discussions of scientific problems.

Franck became a leading scientific and personal figure in Göttingen, and was extremely well liked and respected by the entire university community. In 1925 when he was awarded the Nobel Prize, the students formed a torchlight procession as a celebration in his honor. James Franck was extremely popular as a teacher, selecting the very best applicants to his institute from Germany and other countries. Among his students were Blackett, Hanle, Herzberg, von Hippel, Rabinowitch, and Sponer. His institute also attracted outstanding scientists to Göttingen as visiting professors, some of whom were K. T. Compton, E. U. Condon, J. E. Mayer, and G. Scheibe.

Franck's tenure in Göttingen coincided with the tenure of Max Born as professor of theoretical physics, and during that time the University of Göttingen became one of the world's leading centers for the study of quantum physics. There was a remarkably strong interaction between quantum theory and experiment. Louis de Broglie told the story that when Born read his Ph.D. thesis, he discussed it with his students

and with James Franck. Ellaser, one of Born's students, proposed studying the interference of de Broglie waves by means of diffraction of free electrons. Franck immediately responded: "It would be nice, but not necessary, since the experiments of Davisson and Germer sufficiently prove the existence of the effect," thus establishing the experimental basis for wave-particle duality in quantum mechanics.

Franck was also involved in the training of graduate students in theoretical physics and was present at the Ph.D. examination of Robert Oppenheimer on the Born-Oppenheimer separation of electronic and nuclear motion. Oppenheimer was quoted to have said: "I got out of there just in time. He was beginning to ask questions."

The years in Göttingen were one of the most creative periods of Franck's life. From 1920 until 1933 Franck and his collaborators produced seminal studies of collisions of electrons with atoms, collisions between electronically excited and nonexcited atoms and molecules, formation and dissociation of molecules, and a variety of novel phenomena now characterized as aspects of molecular photochemistry. Investigations of fluorescence quenching in excited atom-molecule collisions elucidated nonradiative energy transfer processes, establishing the role of energy resonance effects. The occurrence of sensitized fluorescence in vapors was observed and interpreted by Franck and Cario, and studies of photo dissociation of hydrogen molecules by collisions with excited mercury atoms provided the first evidence for sensitized photochemical reactions. The studies of the mechanisms of photo-induced chemical reactions of diatomic molecules led to the formulation of the Franck-Condon principle. The difference in the excited-state dynamics of nonfluorescent diatomic ionic molecules with a continuous absorption spectrum (e.g., alkali halides) and fluorescent molecules such as Na_2 and AgBr with a band absorption

spectrum was explained in terms of the relative positions of the potential energy curves for the ground and excited electronic states. In a remarkable paper James Franck (1926b) established the vertical nature of the electronic-vibrational excitations of diatomic molecules (Figure 2). His discussion of the coupling between electronic transitions and vibrational motion led him to the discovery of the Franck principle for excited-state dynamics (dissociation or fluorescence) driven by instantaneous excitation to higher electronic-vibrational states. Edward Condon extended this insight in his Ph.D. dissertation and in a *Physical Review* article (Condon, 1926) in which he provided the quantum mechanical formulation for the intensities of vibrational transitions between two electronic states. In his thesis Condon stated that "my work is merely an extension of leading thoughts on a subject studied by Professor J. Franck."

The Franck-Condon principle constitutes a discovery of very great and general importance. An early important quantitative application of this theory to excited-state energetics of diatomic molecules was Franck's determination of molecular binding energies from the convergence of the molecular band system in optical absorption. Since the 1920s the Franck-Condon principle has been the cornerstone of molecular spectroscopy. A major contribution to the description of the intensity distribution over the vibrational components of molecular transitions in polyatomic molecules was provided in the masterful books of Gerhard Herzberg (1950, 1966). Later, very widely used applications of the Franck-Condon principle to radiative transitions in pure and doped solids were pioneered by J. Frenkel in 1931, A. Pekar in 1951, K. Huang and A. Rhys in 1950, M. Lax in 1952, A. S. Davydov in 1953, M. Born and K. Huang in 1954, K. K. Rebane in 1963, and M. H. L. Pryce in 1964, among others. Extension of the Franck-Condon principle to interpretation of electron-phonon

coupling spectroscopy in condensed phases was reviewed by Karl Rebane (1970). This work developed the concepts of multiphonon transitions, Stokes shifts, the vibronic structure of exciton states, and zero phonon lines, which constitute the optical analogue of the Mössbauer transition. All these developments rest on the physical and conceptual framework established by James Franck.

In 1949 Franck, inspired by experimental studies from the 1940s of ionic excitation-reduction processes in polar solvents, advanced a major conceptual extension of the Franck-Condon principle. In this work he laid the basis for theoretical interpretation of oxidation-reduction processes between ions in solution, asserting that the Franck-Condon principle was applicable to thermal electron transfer in the condensed phase. In a remarkable abstract presented at the 1949 meeting of the American Chemical Society in San Francisco, Franck pointed out that electron transfer rates are determined by horizontal Franck-Condon factors, in analogy with radiative processes where the transition probabilities are determined by the vertical Franck-Condon factors. The central role of horizontal Franck-Condon factors in determining electron transfer rates was addressed by Willard Libby in 1952, while the work of Rudolph Marcus in 1956 pioneered the quantitative description of horizontal Franck-Condon factors in solution electron transfer, thereby providing the first theoretical description of chemical reactions in the condensed phase. James Franck, Willard Libby, and Rudolph Marcus established that the Franck-Condon vibrational overlap constraints for nonradiative electron transfer processes are analogous to radiative optical emission in the limit of zero frequency. These ideas were elaborated by Kubo and Toyozawa (1955) for condensed phase nonradiative relaxation, and intramolecular radiationless transitions (as reviewed by Jortner et al. [1969]). The influence of these seminal ideas

is far reaching, particularly in the realm of photochemistry of complex systems in chemistry and biology. The articulation of the Franck-Condon principle in 1926 and its extension in 1949 continue to be the mainstay for interpreting the spectroscopy of, and nonradiative dynamics in, isolated molecules, condensed phases, and biological systems.

In 1928 another branch emerged from the mainstream of Franck's research, the application of the ideas developed in the investigation of atomic and molecular electron affinities in the gas phase to solution spectroscopy. In collaboration with G. Scheibe in 1928 and with Fritz Haber in 1931, the absorption spectra of alkali halides in aqueous solutions were interpreted as electron affinity spectra of the halide ions, originating from charge transfer from the anion to the solvent. Franck was the first to realize how considerably different the anion solution spectra are from the corresponding atomic anion spectra. The theoretical description of solution charge transfer spectra was provided in 1949 by Robert Platzman and James Franck at the University of Chicago. They based their findings on Landau's large polaron model and the Franck-Condon principle for the optical excitation. Other important work in this field was subsequently conducted with E. Rabinowitch: addressing radical reactions in the condensed phase and advancing the cage effect concept in the interpretation of atom recombination in solution photochemistry. These early 1928 studies triggered Franck's interest in biological photosynthetic processes.

Franck's remarkable scientific activities in Göttingen were terminated by the rise of the National Socialist (Nazi) party to power in Germany. After the federal election in Germany in 1932 the Nazi party held 37 percent of the seats in the Reichstag, and on January 30, 1933, Adolf Hitler was appointed chancellor of Germany. Although Hitler initially headed a coalition government, he quickly eliminated his

government partners and began the process of passing discriminatory legislation. On April 17, 1933, James Franck became the first German academic to resign in protest of the laws excluding Germans of Jewish descent from government office. Franck's war record exempted him from the racial exclusion laws, but he chose to risk his career and personal safety by resigning his position so as not to be forced to dismiss his Jewish colleagues and students. In his letter of resignation Franck wrote to the minister of education that his action was an inner necessity to him because of the attitude of the German government toward the Jews. In a letter to the rector of the university he stressed that it was intolerable that German Jews should be treated as aliens and enemies of the state. He published his statement of resignation and protest in the national press. As stated by Eugene Rabinowitch: "He was willing to act where others drifted silently." Franck did not intend to leave Germany immediately, hoping to be able to conduct useful work outside the university and help fight the Nazi regime. But the conditions of the Jews deteriorated rapidly, and no external work or resistance was possible.

In the fall of 1933 Franck left Germany. From 1933 to 1938 Franck was successively a visitor at Johns Hopkins University (1933-1934), a visitor at the Bohr Institute in Copenhagen (1934-1935), and then professor of physics at Johns Hopkins University (1935-1938). In 1938 he became a professor of physical chemistry at the University of Chicago, where he remained until retirement as professor emeritus in 1947 while retaining a continued association as head of the Photosynthesis Research Group until 1956 and as a member of the Institute for Radiobiology and Biophysics until his death in 1964.

Franck's research agenda at the University of Chicago focused on photosynthesis. At a time when the attention of most investigators concentrated on the sequence of chemical

reactions that transform CO_2 and H_2O into carbohydrates, Franck was concerned with the primary step that converts light into molecular excitation that initiates the reaction sequence. Franck's experimental photosynthetic research dealt mainly with fluorescence, flashing excitation, and afterglow (delayed fluorescence) effects in chlorophyll and its assemblies. Concurrently he focused on the construction of an overall theory of photosynthesis consistent with the experimental information available at that time.

Franck's approach toward theories of photochemical processes in complex biological systems was summarized in a 1941 article with K. F. Herzfeld, where he stated that "a theory by its own nature can contain only a partial truth." His theoretical work addressed the central issues of electronic energy transfer, the functions of independent types of photosynthetic units, and the mechanism of the primary photosynthetic process. In the context of electronic energy transfer to the photosynthetic reaction center, Franck and Teller (1938) considered exciton transfer in a one-dimensional linear array of chlorophyll molecules, reaching the conclusion that this mechanism was too slow to bring the excitation energy to the reaction center. An extension of the excitonic model to two and three dimensions by Bay and Pearlstein (1963) and by Wilse Robinson (1967) demonstrated that electronic energy transfer in higher dimensions is fast enough to induce the primary process within the reaction center. The central question raised by Franck regarding the mechanism of electronic energy transfer, from the antenna to the reaction center in the photosynthetic apparatus, is still under active exploration, using the theoretical concepts and experimental techniques of femtosecond spectroscopy (Scholes and Fleming, 2006).

Regarding the function of the plant photosynthetic apparatus, Franck tried to elucidate the mechanism of the

partitioning of the reactivity between photoreactions I and II. Franck and Rosenberg (1964) proposed mechanisms for sequential one-photon excitation of the two reaction centers. At the time when this proposal was made, the isolation and determination of the structures of photosynthetic reaction centers I and II had not yet been achieved, precluding the delineation of the mechanism for balancing the reactivities of the two reaction centers.

Concerning the mechanism of the primary photosynthetic processes, Franck attempted to determine the minimal number of photochemical and thermal reactions required for the occurrence of the full photosynthetic cycle and to specify the relevant time scales for the occurrence of these processes (1941). The input information was based on measurements of the overall kinetics and yields of oxygen production, the consumption of carbon dioxide, and the chlorophyll fluorescence as a function of light intensity. As pointed out by Jerome Rosenberg (2004) this scheme attempted to provide an oversimplified description of the primary reactions in terms of a complex sequence of processes.

Regarding mechanistic issues, it should be noted that in the 1940s and 1950s Franck considered the primary oxidation of chlorophyll in the photosynthetic reaction center only in terms of the transfer of a hydrogen atom, without invoking electron transfer. Modern work on the structure and picosecond-femtosecond dynamics of the primary processes in the photosynthetic reaction centers of bacteria (Deisenhofer et al., 1985; Allen et al., 1988; Holzapfel et al., 1990) and of plant photosystems I and II (Witt et al., 2001) has demonstrated the prevalence of electron transfer between the prosthetic groups, thus establishing the dominance of charge separation dynamics for the primary processes in photosynthesis.

In an attempt to provide an overview of the work of James Franck on photosynthesis, David Nachmansohn wrote:

"Having lived in the world of atoms and molecules, Franck had probably underestimated the infinitely greater complexity of biological systems." It is admirable that Franck's approach to biological photosynthesis, which drives life on Earth, was based on pioneering applications of the strictly logical deductive methods of molecular and chemical physics to biological problems, which prior to his work were treated in an empirical way. It is also remarkable that in the 1940s James Franck addressed some of the most important questions that underlie the basic processes of energy acquisition by energy transfer, as well as energy storage and disposal driving the primary processes in the photosynthetic reactions centers. Contemporary studies of structure-dynamics-function relations for the primary processes in photosynthesis (Jortner and Bixon, 1996) rest to a large extent on the conceptual framework and central questions envisioned by James Franck 70 years ago.

James Franck's evolution from dedicated scientist uninterested in politics into a moral leader was driven by his sense of social responsibility. He saw clearly that responding to the discriminatory Nazi regime legislation of 1933 was a fundamental issue, to be based on principle, and he eschewed available compromise and personal expedience. This sense of social responsibility was accompanied by a strong personal charity. From 1933 on, he assisted German scientists and other professionals expelled by the Nazi regime to find employment wherever available. After World War II ended, understanding the devastation wrought by the war and looking beyond the excesses of the Nazi regime, he responded to many appeals from Germany for food, clothing, and money.

An important spur to the initiation of the Manhattan Project that led to the development of the first nuclear bomb was the fear that if this weapon were first developed by Germany it would determine the outcome of World War II.

James Franck shared this fear, and he joined the Manhattan Project on December 1, 1942, as director of the Chemistry Division of the Metallurgical Laboratory at the University of Chicago, one day before the first demonstration of a self-sustained nuclear chain reaction by the group led by Enrico Fermi. As early as mid-1943 concern about military control of the Manhattan Project began to be expressed in meetings of the Metallurgical Laboratory scientists. Franck participated in these meetings and articulated his concern about lack of foresight with respect to the use of a nuclear bomb and the potential danger of government control of science as he had experienced in Germany.

In 1944 he served on the Jeffries committee, which solicited opinions from group leaders in the Manhattan Project for a report that was submitted to General Groves, the military commander of the Manhattan Project, on the future of nuclear energy. In early 1945 Franck appealed personally to Henry Wallace, the secretary of commerce, characterizing his and his colleagues' views as follows: "They cannot help but worry about the fact that mankind has learned to unleash atomic power without being ethically and politically prepared to use it wisely."

At the request of the director of the Metallurgical Laboratory he chaired a committee consisting of himself, D. J. Hughes, J. J. Nickson, E. Rabinowitch, G. T. Seaborg, J. C. Stearns, and L. Szilard to consider the political and social implications of the use of nuclear bombs. Their report, addressed to Secretary of War Henry Stimson, argued that the destructive power of a nuclear bomb be demonstrated before representatives of the United Nations before a decision was made to use it in an attack on Japan. The Franck committee hoped that this demonstration would be sufficient to induce Japan to surrender, making it unnecessary to use a nuclear bomb in an attack. The report asked the United

States to regard the decision to use a nuclear bomb to be a fateful political issue, not a military tactic, and it argued that its use would initiate an international competition to acquire nuclear weapons and prejudice the possibility of reaching an international agreement on the future control of such weapons. The Franck committee report was completed on June 11, 1945, and was taken by K. T. Compton to Los Alamos; when he arrived there, he passed copies to Enrico Fermi, Ernest Orlando Lawrence, and Robert Oppenheimer. On June 16 these three scientists concluded that "we cannot propose a technical demonstration likely to bring an end to the war, and we see no acceptable alternative to direct military use" (Lanouette and Szilard, 1994). With this advice from the panel of leading scientists, Stimson confidentially rejected the Franck committee's recommendations on June 21. President Truman never saw the Franck report. The attempt to stop the use of the bomb had been shattered.

That the Franck report did not succeed in changing the determination to use nuclear bombs to end the war with Japan disappointed Franck, but it did not deter him; he continued his political involvement, and played an important role in the struggle to achieve civilian control of the development of nuclear energy.

James Franck was a great scientist who changed our perception of the world, and he was a symbol and pioneer for a new generation of scientists who recognized their great responsibility toward mankind. His friend Peter Pringsheim (1952) admired Franck's "obsession with science," and this predominant quality was described by Lise Meitner (1964) in her obituary statement.

> Franck enjoyed talking about his problems, not so much to explain them to others as to satisfy his own mind. Once a problem had aroused his interest he was completely captivated, indeed obsessed by it. Common sense and straight logic were his main tools, together with simple apparatus. His research

followed an almost straight line, from his early studies of ion mobilities to his last work on photosynthesis; it was always the energy exchange between atoms or molecules that fascinated him.

Shortly after his death in 1964, the University of Chicago renamed one of its interdisciplinary research institutes the James Franck Institute, with research focus on chemical physics and solid-state physics. This renaming, initiated by one of us (S. A. R.), paid tribute both to Franck's scientific contributions and to his stature as a spokesperson for the responsibility of science for the public good, but it was intended to honor the university by continuing association with the name and persona of a great human being.

Franck's scientific talent was coupled to a great and admirable personality (Nachmansohn, 1979). The second predominant quality in his character, beyond his science, was "his inexhaustible kindness, his generosity, his lovability" (Pringsheim, 1952), as described by Lise Meitner's obituary statement (1964): "Franck was equally interested in people. His kindness and generosity, not only to his friends and family but to everybody who needed help, were known to all who knew him. He was the most lovable of men because he loved people; kindness shone from his eyes."

James Franck's high ethical standards, his integrity, and his warmth were greatly respected and admired by his friends, colleagues, and collaborators. It is an everlasting credit to James Franck that he, one of the world's outstanding scientists, took the initiative in 1945 to try to prevent the catastrophe caused by the production of nuclear weapons. His vision and actions evoke deep respect and admiration, not only in the scientific community, but in all people. The Franck report (Jungk, 1958) is a monumental document in the history of mankind; it manifests the great social responsibility of scientists and their deep obligation and commitment

to carefully weigh the possible dangerous consequences of scientific research.

James Franck's personal life is sketched in David Nachmansohn's book (1979) and in the records of the Nobel lectures (http://nobelprize.org/nobel_prizes/physics/laureates/1925/franck-bio.html). In 1911 he married Ingrid Josephson of Goteborg, Sweden, whom he met in Berlin, where she had come to study music; they were deeply devoted to each other. Ingrid died in 1942 in Chicago at age 59. Four years later Franck married Henrietha Sponer, then professor of physics at Duke University, whom he had known for many years. Franck had two daughters, Dagmar and Elizabeth. Dagmar married Arthur von Hippel, who became professor of physics at the Massachusetts Institute of Technology, and Elizabeth married Hermann Lisco, who became professor of anatomy at Harvard University.

Franck was always proud of his Jewish heritage. David Nachmansohn recollected that he was not a Zionist. But in 1934 when the Jewish chemist and leader Chaim Weizmann asked Franck whether he would be willing to continue his work in Israel (at that time Palestine), he strongly expressed great interest. Regretfully, many of Weizmann's plans for building science in Israel at that time were unfeasible, because of lack of funds and infrastructure. The Israeli science community, recognizing his contributions, paid tribute to James Franck. In 1954 he was awarded an honorary doctorate by the Technion–Israel Institute of Technology. In 1988 the Binational German-Israeli James Franck research program on laser-matter interaction was initiated by Raphael Levine, Edward Schlag, and one of us (J. J.) and established in five Israeli universities: the Hebrew University of Jerusalem, Tel Aviv University, the Technion–Israel Institute of Technology, Ben Gurion University, and Weizmann Institute of Science.

Franck's admirable personal character was manifested again after the end of World War II, when he was able to look beyond the horrors of the Nazi regime and renew his personal, cultural and scientific relations with Germany. Only a few years after the end of World War II, he consented to being honored by German academic and research institutions. In 1951 he was the recipient of the Max Planck Medal of the German Physical Society, and in 1957 he was awarded an honorary doctorate (*Dr. rer. nat.*) by the University of Heidelberg. He remained attached to the city of Göttingen, receiving its honorary citizenship in 1953. At the same time, Born and some other old friends of Franck were awarded, together with him, honorary Doctor's degrees. It was an odd turn of fate that he died during a visit to Göttingen on May 21, 1964, at the age of 81.

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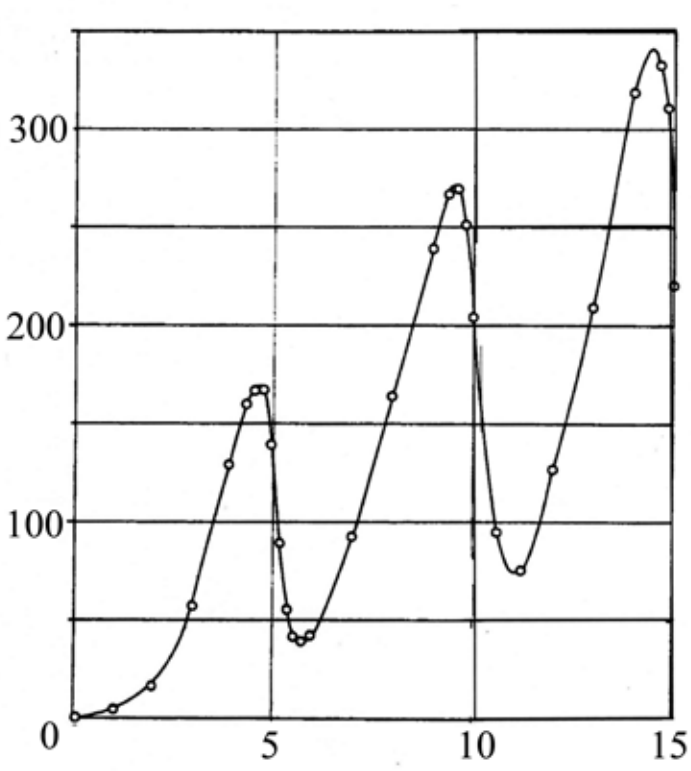

FIGURE 1

The Franck-Hertz experiment demonstrating the quantization of atomic energy levels, in accord with Niels Bohr's model of the atom. The data show the accelerating voltage (in volts) on the horizontal axis, versus the anode current (in arbitrary units) on the vertical axis, in the electron impact excitation of mercury atoms.

SOURCE: Data adopted from Franck (1926a).

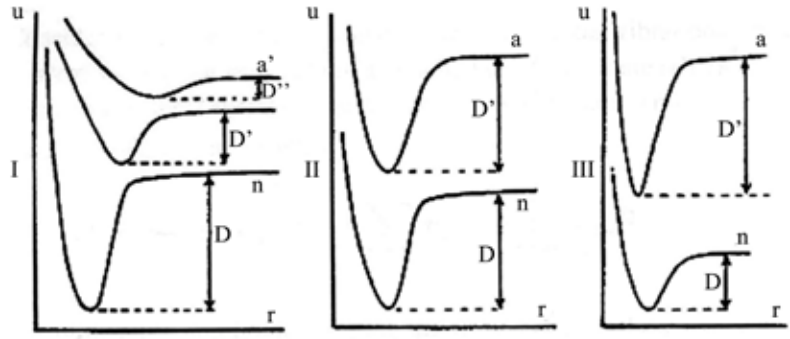

FIGURE 2

The first presentation of the Franck-Condon principle, portraying three diagrams of potential energy curves of diatomic molecules. This figure was adopted from Franck (1926b, p. 536), where he wrote: "Diagram I shows a great weakening of the binding on a transition from the normal state *n* to the excited states *a* and *a*′. Here we have D > D′ and D′ > D′′. At the same time the equilibrium position of the nuclei moves with the excitation to greater values of *r*. If we go from the equilibrium position (the minimum of potential energy) of the *n* **curve vertically** upwards to the a curves in Diagram I. the particles will have a potential energy greater than D′ and will fly apart. In this case we have a very great change in the oscillation energy on excitation by light. Diagram II shows no change in the binding on a vertical transition from the normal state n to the excited state a, when D = D′ and the equilibrium position of the nuclei is invariant with the excitation. Diagram III shows a bound-bound vertical transition from the normal state n to the excited state *a*, when D < D′ and the equilibrium position of the nuclei moves with the excitation to lower values of *r*. Going from the equilibrium position of the *n* state to the *a* curve, the particles will have a potential energy lower than D′, resulting in a vibrationally excited *a* state."