Platt and later Roothaan into the physics department to help build the spectroscopic laboratories back up again. For nearly 20 years the three of us worked fruitfully side by side with our various students and co-workers on our very different molecular interests. Mulliken always found bright young men and support money, first from the ONR and then from other granting agencies, and he made this group, in what came to be called the laboratory of molecular spectra and structure, the largest one of its kind in the world. The succession of brilliant quantum chemists who spent months or years in the group includes Bigeleisen, Cade, Clementi, Gouterman, Huo, Klevens, Kasha, Kolos, J. S. Ham, N. S. Ham, Huzinaga, Lichten, Longuet-Higgins, Matsen, McConnell, Moccia, Nagakura, Orgel, Parr, Person, Price, Ransil, Ruedenberg, Scherr, Shull, Tanaka, Tsubomura, Wahl, Wilkinson, and many others. The red-bound technical reports containing all our reprints were sent out twice a year to a mailing list of hundreds, and today they fill some 2 feet of shelf space.

Since the war, Mulliken's most important papers have undoubtedly been those of the 1950's on the "charge-transfer" interpretation of the binding and spectra of "molecular complexes," the relatively weak associations of two molecules that often give rise to intense spectra. He showed quantum-mechanically how the partial transfer of an electron between the two molecules might explain the observations, as well as many other observations on weak intermolecular forces.

His Fulbright year at Oxford and his year as science attaché in London in 1955 did not diminish his flow of work. More recently, many honors have been coming to him. They include a 1964 Festschrift volume of reminiscences and contributions entitled "Molecular Orbitals in Chemistry, Physics, and Biology," five major awards from the American Chemical Society, and honorary doctorates from Columbia University and the University of Stockholm. And he has been made at last a member of the department of chemistry of the University of Chicago, although he now spends the winter months as professor of chemical physics at Florida State University in Tallahassee.

In his manner, Mulliken has always been calm, courteous, and tolerant. He does not get angry, never swears, never jokes, and never quits, but goes on steadily and good-humoredly to the next item in the mountain of work that seems to be always before him. His lectures are full of intricate details and often run long past the hour. When he is willing to spare the time for it, he is full of interesting anecdotes and is a good host who mixes a good Manhattan; and on his very rare walks in the park he reveals himself to be an amateur botanist who knows the names of more plants and grasses than many professionals. He dresses conservatively and always wears a hat outdoors, but he is indifferent to clothes, and when his office was cold in the Chicago winters he would simply put his overcoat back on and go on working steadily all day. He is a chain-smoker, and the most vivid image of him that most of his colleagues have is the vision of him pinching the last half-inch of his cigarette with his fingertips and continuing to make fine pencil notes on the margin of a manuscript or reprint while listening to a lecture or taking part in a conversation.

Chemists and colleagues everywhere will be glad that this new recognition has now been given to Robert Mulliken and to the molecular-orbital interpretations on which he has worked so diligently and so long.

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1966 Nobel Laureate in Physics: Alfred Kastler

On 3 November, the Swedish Royal Academy of Science announced that the 1966 Nobel prize in physics had been awarded to Alfred Kastler for his work on the energy levels of atoms. Professor Kastler and his co-workers at the Ecole Normale Superscience in Paris have, since 1950, developed many new techniques for studying the fine and hyperfine structure of atoms. These new methods have led to many refinements in atomic spectroscopy and to a better understanding of atomic energy levels and the perturbation of atomic energy levels by their environment.

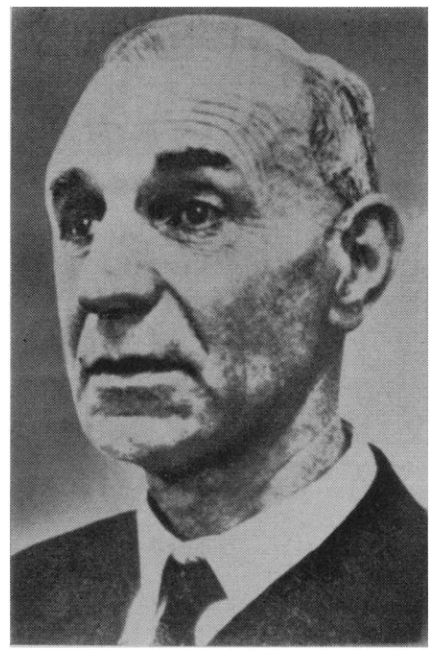
Shortly before World War II a group at Columbia University under the leadership of I. I. Rabi learned how to use radio-frequency fields to make precise measurements of the energy levels of atoms in their ground state. In general an atom in its ground or lowest energy state has several magnetic substates, and when the atom is placed in a magnetic field these states differ slightly in energy and each state has a characteristic effective magnetic moment. The Columbia group used deflection magnets and slits to prepare an atomic beam such that all of the atoms were in a few magnetic substates and such that only atoms in certain substates could make a complete journey through the apparatus from the source to the detector. They then applied a radio-frequency field of the proper frequency to cause the atoms to make transitions from one magnetic substate to another. When these transitions took place the number of atoms transmitted through the apparatus changed. Thus these workers were able to use the number of transmitted atoms to determine when the radio-frequency field was of the proper frequency to cause the atoms to make transitions from one state to another. From the frequency they could calculate the energy separation of the energy levels. Thus a new method for studying the energy levels of atoms in these ground states was discovered. This method became known as the atomic beam, magnetic resonance technique. For this discovery and other atomic beam work Rabi was awarded the Nobel prize in 1944.

While working on radar development and other government research projects during World War II, physicists developed new techniques for dealing with radio-frequency fields and for detect-

ing small amounts of radio-frequency power. Using these improved methods, Purcell, Pound, and Torrey at Harvard and Block, Packard, and Hansen at Stanford were able to detect the energy absorbed when protons in a solid or liquid sample placed in a magnetic field make transitions from one energy level to another. This magnetic resonance technique gave a new method for measuring nuclear magnetic moments and for studying the structure of solids. For this development Block and Purcell shared the 1952 Nobel prize in physics.

At the time of these developments other physicists were seeking to find new and more precise methods for studying the energy levels of atoms in their excited states. At that time all of the measurements of the fine and hyperfine structure of excited atomic energy levels came from atomic spectroscopy. One used a spectroscope to observe the light emitted by excited atoms and then made precise measurements of the wavelength of the emitted lines. With this technique it was discovered that each atomic level that gives rise to one optical line has, in general, many sublevels, and that when examined closely each optical line consists of many closely spaced lines with almost the same frequency.

There are two phenomena which make it difficult to study this structure —the Doppler effect and the energy uncertainty due to the lifetime of the atom in its excited state. Since the atoms are in motion, the wavelength and the frequency of the emitted light depend upon the velocity of the emitting atom and the direction of emission of the light quanta. The Doppler shift produces a fractional change in the frequency of the emitted light, and the spectral lines broaden out and obscure the fine and hyperfine structure. The energy uncertainty due to the lifetime of the excited state is a fundamental limit due to the uncertainty principle and is, in general, less than the uncertainty due to the Doppler effect. Since the Doppler shift gives rise to a fractional change in the frequency which depends on the velocity, if one could directly observe the radio-frequency waves emitted or absorbed when an atom in an excited state makes a transition from one fine-structure sublevel to another fine-structure sublevel, one could obtain precise measurements of the fine structure. Instead of trying to measure small increments



Alfred Kastler

in a large frequency, one could directly measure the difference frequency of interest. Since the lifetime of most excited levels is short, it is difficult to use atomic beam techniques; since at any one time there are only a few excited atoms, it is difficult to detect the absorption or emission of radio-frequency waves, and one cannot use magnetic resonance techniques. Kastler and one of his associates, Jean Brossil, were the first to realize how one could overcome these difficulties, and were among the most persevering in the development and refinement of the new technique.

Kastler reasoned that one should be able to use the light emitted by an atom in an excited state to detect the radio-frequency transitions in the excited state. If one illuminates a group of atoms with a beam of light of the proper wavelength, the atoms will absorb some of the light quanta and make transitions from the ground or lowest energy state to one of the optical excited states. The atoms will remain in the excited state a short time and then make a transition back to the ground state. The average time that the atoms spend in the excited state is called the lifetime of the state.

Let us now assume that we set up apparatus with which we can measure the polarization and the angular distribution of the photons emitted when the atoms return to the ground state. When a beam of light is used to excite a group of atoms, not all of the sublevels of the excited state are equally populated and, in general, the emitted radiation will not be isotropic and the radiation emitted in any particular direction will be partially polarized. If a radio-frequency field is now applied so as to cause transitions from one of the populated levels of the excited state to an unpopulated level, the angular distribution of the radiation will change—thus one can use the emitted light to detect the radio-frequency transitions in the created state and one has a new precise tool for studying the structure of excited atomic levels. This was Kastler's basic discovery, and it is for the development of this technique that he has been honored.

Kastler also realized that one could use optical techniques to move atoms in their ground state from one magnetic sublevel to another. This technique operates as follows. Let us assume that we have an atom with two magnetic sublevels such that, when one shines circularly polarized light on the atoms, atoms in one sublevel absorb light and make transitions to the excited state and atoms in the other sublevel do not absorb light and do not make transitions to the excited state. It can be shown that the rules for optical transitions are such that, when the atoms in the excited state radiate and fall back into the ground state, they will make transitions into both of the two magnetic sublevels of the ground state. Thus one can use light to pump atoms from the absorbing level to the non-absorbing level. This is called optical pumping, and this technique can be used to polarize atoms. It has been used as a spectroscopic technique, to make masers, to polarize other atoms by collisions with optically pumped atoms, and to make polarized targets for nuclear physics experiments.

In the years that followed these early experiments the techniques were extended and developed in various directions. It was soon realized that an electron beam as well as a light beam could be used to excite the higher atomic levels. This made it possible to study levels which could not be easily excited with a beam of light. It was also discovered that one could use the emitted light to determine when certain atomic energy levels were made to cross and have the same energy. This technique became known as level crossing, and it has yielded a great deal of new in-

formation concerning hyperfine structure and the lifetimes of atomic states. Optical resonance techniques have been used to develop frequency standards, to measure nuclear spins and magnetic moments, to make precision magnetometers, to study diffusion, to measure disorientation and spin-exchange cross sections, to set a limit on the electric dipole moment of the electron, and to make precision measurements of fine and hyperfine structure intervals. Throughout all this development Kastler's laboratory has played a major role and been an inspiration to other physicists.

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Oceanography: Interior Department Bids for a Major Role

The U.S. Department of the Interior, which has been responsible for the conservation and development of natural resources since its establishment in 1849, began to get an uneasy feeling a few months ago that it was losing its hold, such as it was, on the relatively undeveloped but potentially important field of marine resources. The department's officials found that, while marine science and technology were receiving more and more attention from Congress and the Administration, few people thought of Interior as a major focal point of activity in these fields.

In recent weeks Interior has been trying to establish for itself a new image by setting up a department-wide program of marine resource development. The urgency with which this effort has been launched becomes understandable when one recalls that, twice since January, Interior has seen evidence that, from the standpoint of public "visibility," its work in oceanography might just as well have been performed entirely under water.

Interior wanted to be given responsibility for administering the new sea-grant college program, which Congress authorized shortly before adjournment. But the National Science Foundation was chosen as the administering agency, despite the fact that, in the past, NSF generally had not supported applied research and had never participated in extension service activities.

Applied research and practical demonstrations of marine technology will figure importantly in sea-grant activities. Even so, the Interagency Committee on Oceanography, impressed by NSF's extensive dealings with the academic community through its fellowship programs and basic research grants, said the Foundation was the best agency to administer the program. NSF wanted the assignment, provided the Foundation would not have to become involved in the development of marine hardware.

Testifying before a Senate subcommittee, Thomas F. Bates, science advisor to the Secretary of the Interior, had insisted that major responsibility for programs aimed at developing ocean resources properly belonged to Interior. NSF's role, he said, should be that of supporting basic research and education in oceanography. His plea was given little heed. Had Interior's involvement in oceanography been more conspicuous, the sponsors of the sea-grant program perhaps would have responded differently. Indeed, they might have concluded, without prompting, that the sea-grant legislation should foster between Interior and the sea-grant colleges a relationship similar to that which has long existed between the Department of Agriculture and the land-grant institutions.

Interior, already behind in the capital's continuing game of bureaucratic rivalry because of the loss of the sea-grant program to NSF, was soon to lose more points. The report of the President's Science Advisory Committee's panel on oceanography was made public (*Science*, 22 July), and among its recommendations was one for the creation of a new environmental sciences agency which would administer most non-Navy governmental activities in oceanography.

The agency would consist largely of the Commerce Department's Environmental Science Services Administration (ESSA), Interior's Geological Survey, and the oceanographic programs of Interior's Bureau of Commercial Fisheries and Bureau of Mines. The reorganization recommended would place in a single agency all federal civilian programs related to description, prediction, and modification of the environment (ocean, atmosphere, and solid earth) and to management and development of marine resources.

The panel did not say whether the new agency should be independent or part of Commerce or Interior. But, for Interior, the government's natural-resources department, the panel's statement that "no natural advocate" for oceanography now exists within the federal establishment was painful. Moreover, Interior found nothing consoling in the fact that the panel's proposal for a federal reorganization closely resembles what certain people suspect, with some reason, to be the ultimate goal that J. Herbert Hollomon, assistant secretary of commerce for science and technology, has in mind for ESSA. ESSA was established in 1965 through a reorganization plan which had the principal effect of placing the Weather Bureau and the Coast and Geodetic Survey under the same administrative roof. Four research institutes, for oceanography and other environmental sciences, have been set up within ESSA.

Even before the PSAC report appeared, the heat was on Interior, ESSA, the Navy, and other agencies to strengthen their programs in oceanography. In June Congress passed a bill providing for the establishment of two temporary advisory bodies (*Science*, 10 June), the Cabinet-level Council on Marine Resources and Engineering Development, headed by Vice President Humphrey, and the Commission on Marine Science, Engineering, and Resources. The commission, still not appointed as this was written, will consist of people from government, industry, the academic community, and the oceanographic institutions. Its report to the President will include a recommendation on the government's organizational structure for its oceanographic activities.

Since the commission will be the