search & discovery

Plutonium result supports theory of shape isomers

Over the past few years evidence has grown for the existence of a double-humped fission barrier in many different nuclei. These nuclei when caught between the two humps would then exist in isomeric states with lifetimes that were very long considering their excitation. The phenomenon goes by the name of "shape isomerism." Now a Munich group has reported (at the European Conference on Nuclear Physics in Aix en Provence, at the end of June) that they have found a rotational band associated with the second minimum in the fission barrier, thus providing strong support for the idea of shape isomerism. The group consists of Hans J. Specht and J. Weber of the University of Munich and E. Konecny and D. Heunemann of the Munich Technical University.

In the old fission picture, when you plotted potential energy as a function of deformation, if the nucleus behaved like a harmonic oscillator the more you deformed it the bigger the restoring forces would be, and the potential would be parabolic. The minimum would not be at zero deformation because the nucleus is prolate to begin with; rather the minimum would be off to the side. When the nucleus fissioned particles would run up the side of the barrier, and spill over the top.

Several years ago G. N. Flerov, S. M. Polikanov and their collaborators at Dubna found that instead of the nucleus fissioning with a lifetime of 10^{-17} to 10^{-18} seconds, some nuclei had spontaneously fissioning isomers with lifetimes measured in nanoseconds. Subsequently Neil Lark and his collaborators at Copenhagen found these isomers way down in the periodic table.

A second piece of experimental information came from studies at Saclay in France and Geel in Belgium. When the energy dependence of the cross section for fission was measured the experimenters found a spectrum with both a fine and an intermediate structure.

The combination of these two kinds of information led many theorists, including Walter Greiner (Frankfurt), Vilen Strutinski (Kurchatov Insti-

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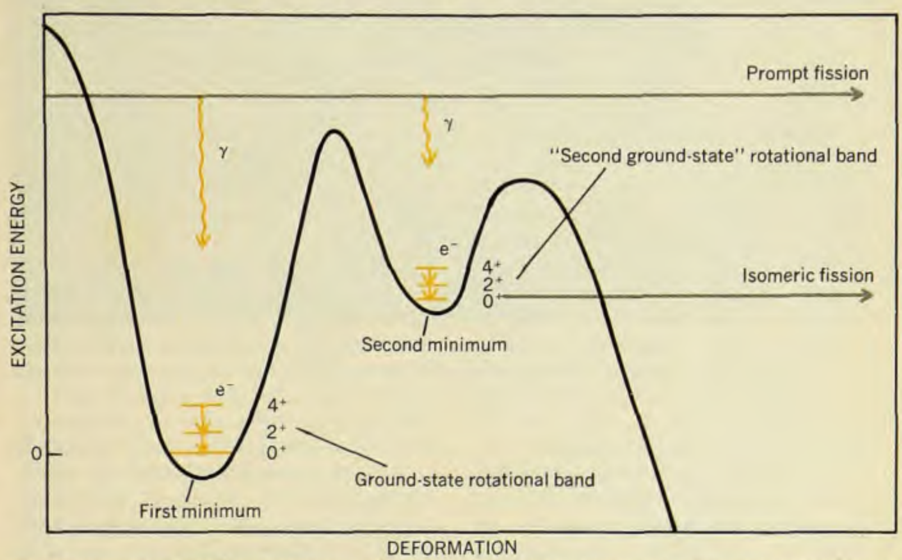

Double-humped fission barrier. Munich group has observed delayed coincidence between conversion electrons and fission fragments. They find that the deformation observed for the fission isomer minimum is much bigger than that of the ground state.

Neoclassicism challenges QED

Some physicists are questioning the necessity of quantum electrodynamics in quantum optics and perhaps elsewhere. A lively discussion on possible alternatives developed during the Third Rochester Conference on Coherence and Quantum Optics at the end of June. The most widely discussed alternative was the neoclassical theory of Edwin Jaynes and his collaborators (Washington University in St. Louis). This theory regards the Maxwell equations as describing the radiation field while the Schrödinger equation is applied to the atoms. The charge and current sources of the Maxwell field are taken to be given by the corresponding probability densities of wave mechanics. Jaynes contends that these nonlinear equations describe physical phenomena better than has been appreciated in earlier times.

Marlan Scully and Murray Sargent (University of Arizona) have pointed out (PHYSICS TODAY, March 1972, page 38) that if one takes the neoclassical theory literally such fundamental aspects of quantum mechanics as the uncertainty principle are no longer preserved even for matter. It is therefore clear that this neoclassical theory (if taken as completely correct) would involve a rethinking of all aspects of quantum mechanics. However, in view of the successes of semiclassical theory in many quantum-optical contexts, Jaynes has embarked on a program to ascertain the limits of validity of the semi- or neoclassical theory. As Jaynes put it in the last Rochester Conference (1966), "Physics goes forward on the shoulders of doubters, not believers, and I doubt that quantum electrodynamics is necessary."

This position continues to attract attention and in fact was challenged (at that time) by Peter Franken (University of Michigan) with what is now a celebrated $50 bet. The terms of the bet were that Jaynes calculate either the Lamb shift or the anomalous electron moment by the neoclassical theory within a ten-year period. Neither claims a victory as yet, and Willis Lamb (Yale University) still holds the purse.

One difference between the neoclassical theory and a fully quantum theory of the atom field interaction is that in neoclassical theory a purely excited state would not radiate at all because the required off-diagonal elements of the atomic density matrix are zero. However, Jaynes told us that no experimenter has ever put an atom in exactly a pure excited state, and if he did it would take only an infinitesimal perturbation to produce conventional spontaneous emission; this is analogous to the state of an inverted pendulum. Thus isolated atoms excited to something near but not quite the fully excited state would exhibit a decay of a spontaneous-emission variety.

The quantum theory of radiation on the other hand predicts a simple exponential decay that some say is brought about by vacuum fluctuations. This was investigated experimentally by Hyatt Gibbs of Bell Labs (*Phys. Rev. Lett.* 29, 459, 1972). He reported observations of incoherent resonance fluorescence from a rubidium atomic beam coherently excited by a 6-nanosec (FWHM) optical pulse. The fluorescence was a maximum for an input pulse area of π and 3π and a minimum for areas of 0, 2π and 4π; this result, Gibbs noted, is in excellent agreement with the quantized field theory of radiation in the Weisskopf–Wigner approximation.

To this, Jaynes told us that the criterion of a 2π pulse was that the fluorescence reach a minimum; thus the correctness of one theory was already assumed in the process of interpreting the data. Gibbs, on the other hand, claims that the input pulse area was calibrated by self-induced transparency —a phenomenon that can be explained by a semiclassical theory.

According to neoclassical theory an atom's radiation is proportional to the square of its dipole moment, which vanishes for an atom in the pure excited state. Even for an equal admixture of ground and excited states the difference between the predicted fluorescences in the two theories is large, Gibbs says. Jaynes disagrees. According to Gibbs, computer simulations of the experiment including actual pulse shape, beam absorption width and radiative damping are in good agreement with quantum electrodynamics but in poor agreement with neoclassical theory, even for all possible values of the "dynamic shift" that occurs in the neoclassical theory. According to Jaynes an analysis of the experiment suggests that one never got far enough from the ground state for differences to show up.

John F. Clauser (Berkeley) pointed out that neoclassical theory is unable to explain previous observations of the polarization correlation of photons emitted successively in a $J = 0 \rightarrow J = 1 \rightarrow J = 0$ atomic cascade. Quantum electrodynamics predicts no coincidences with the analyzing polarizers crossed. Previous semiclassical theories would have predicted a nonvanishing of the coincidence rate with analyzers crossed.

In his lecture Lamb pointed out that in the 1947 experiments on the electromagnetic level shift, Retherford and he separated a beam of hydrogen atoms by a molecular-beam technique such that the atoms in the 1s ground state went on one side of a divider while atoms in the 2s metastable excited state were deflected by recoil to the other side of the barrier. The atoms in the 2s state were then transferred by incident microwaves to the 2p state and were then observed to decay radiatively to the 1s ground state. Lamb points out that, since the excited atoms were rather carefully separated from the ground-state ones, the atoms that pass from the 2s state to the 2p state under the influence of the microwaves would have a wave function that contains only (appreciable) probability amplitudes for being in the 2s or 2p state. Hence there would be no significant matrix element of the transition current corresponding to the transition between the 2p and 1s ground state. Therefore neoclassical theory would seem to imply greatly diminished decay of the 2p state; this is in direct contrast to experimental evidence, Lamb said.

Jaynes points out that the statement that the 2s and 1s atoms were separated is not an experimental fact but an inference based on the assumed correctness of conventional theory. In reply, Lamb told us that this remark indicates that not only does Jaynes disbelieve quantum electrodynamics but he also does not believe in the conventional interpretation of quantum mechanics either.

At the meeting Jaynes and Franken agreed it was premature to decide who had won their bet.

X-ray laser formed from a gelatine–$CuSO_4$ sandwich?

A group at the University of Utah believes they have made a hard x-ray laser. The strikingly simple experiment was reported by John G. Kepros in a post-deadline paper at the Third Rochester Conference on Coherence and Quantum Optics at the end of June. Subsequently Edward M. Eyring, F. William Cagle Jr and Kepros published a paper in the *Proceedings of the National Academy of Sciences* (**69**,1744, 1972).

The report has met with considerable skepticism but also much interest. Many workers have been trying to produce an x-ray laser. It could be used, for example, to make an x-ray microscope, either scanning-spot or holographic, which could have a 1.5-Å resolution, allowing one to observe the electronic structure of matter, particularly the structure of biochemical molecules. Many other applications are envisioned, such as producing coherent excitation of nuclear states and for heating and diagnostics in plasma physics.

The Utah group takes some ordinary Knox gelatine, mixed according to manufacturer's directions in a 10^{-3} molar copper-sulfate solution, and puts the gelatine between two microscope cover glasses. Then they pump the gelatine sandwich with a neodymium-glass laser that produces 30–40 joules in 20 nanosec. They focus the light to a rectangle (1.0 cm × 0.1 mm) on the sandwich. To detect the x rays the experimenters use x-ray film wrapped in four layers of black paper and four layers of aluminum foil. They found spots between 0.1 and 0.2 mm in diameter; the spot size did not alter when they changed the distance between film and sandwich from 30 to 110 cm, thus suggesting that the x rays are collimated.

No precise wavelength determination has been made, but Kepros says he believes they are seeing copper K radiation around 1.5 Å (8 keV); in particular he feels they are probably seeing the $K\alpha_1$ line. The group has done absorption measurements with various metals, finding that the radiation is absorbed and attenuated the appropriate amount by iron and nickel and not attenuated significantly by the aluminum. Also the fact that the radiation passes through about 110 cm of air indicates that the energy is greater than about 5 keV.

The Utah group would like to do a powder diffraction experiment but the alignment problems are enormous, because every time they fire the laser the gel sandwich is shattered. The lab is strewn with pieces of cover glass.

X-ray laser? Light from neodymium-glass laser passes through condensing lens and cylindrical lens (next to hands of John Kepros). Light then strikes copper gel sandwich. At right and rear are x-ray cameras; at left and above are ionization chambers.