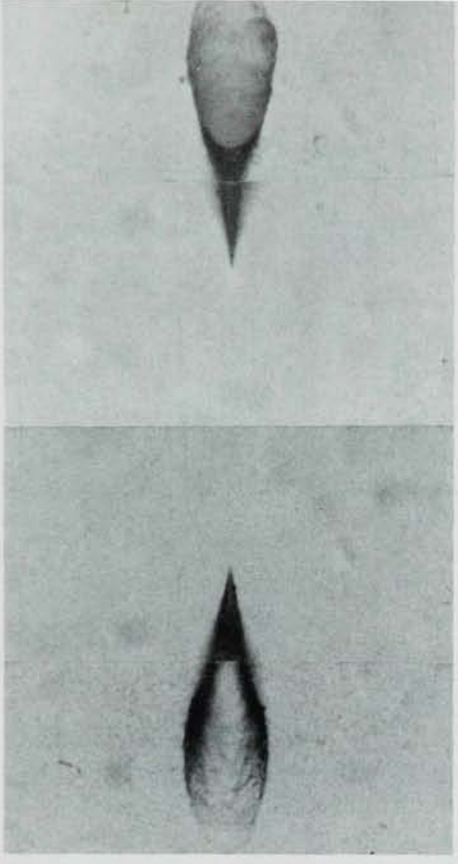


SUPERHEAVY COSMIC-RAY trajectory is recorded in 1/4-mm-thick sheet of Lexan plastic that was etched in sodium-hydroxide solution, which attacks plastic more rapidly along path of heavily ionizing particle than elsewhere. This side view shows nucleus entering at base of one cone and leaving at other (*Phys. Rev. Letters* 21, 630, 1968). The four photos were taken by varying the focus of microscope.

for neutron-rich fission products coming from ${}_{110}X^{294}$.

P. H. Fowler of the University of Bristol and his collaborators have been scanning the skies at high altitudes with a detector consisting of iron sheets sandwiched between nuclear emulsions. They have reported evidence for elements up to uranium in cosmis rays (*Proc. Roy. Soc.* **A301**, 39, 1967) and more recently for one particle they believe may be heavier than uranium.

Using huge detector arrays of interleaved plastic track detectors and nuclear emulsions, groups at General Electric (Robert L. Fleischer, P. Buford Price and Glenn E. Nichols) and Washington University (George Blanford, Michael W. Friedlander, Joseph Klarmann, Robert M. Walker, John Wefel and William Wells) have found several nuclei about as heavy as those found by the Bristol team and have established that the nuclei were recorded at ceiling altitude (37 km) and were truly relativistic. Following three recent balloon flights with Fowler's group they have located the tracks of about 40 relativistic superheavy nuclei that they traced through the plastics and emulsions. All three groups are proceeding with the rigorous identification of these nuclei, some of which may be heavier than uranium. —GBL

Mind Your k's and q's to Simplify Solid-State Theory

Many solid-state theorists are enthused about a new quantum-mechanical representation recently developed by Joshua Zak of the Technion, Haifa (while at the Bitter National Magnet Laboratory, MIT). Zak's "*kq* representation" can be used to reproduce in an almost trivial way the many earlier and often complicated derivations of electron behavior in a periodic potential.

Although the uncertainty principle prevents treating particle coördinate x and momentum p together, in some situations precise information about either the coördinate or the momentum is irrelevant, Zak explains. In a solid where the potential is periodic, all the unit cells are identical; so all you need specify is the position of a particle within any such cell. He uses the well-known solid-state concept of quasi-momentum (reduced wave vector) defined so that exp $(-i\mathbf{k}\cdot\mathbf{t})$ is the eigenvalue of the operation of translation by the lattice vector $\mathbf{t}$ in ordinary space; p can equal k, $k + 2\pi/a$, $k + 2(2\pi/a)$, etc. Similarly he specifies the position by a quasi-coördinate q, which ranges only over the volume of a unit cell and is defined so that exp $(i\mathbf{K}\cdot\mathbf{q})$ is the eigenvalue of the operation of translation by the reciprocal lattice vector $\mathbf{K}$ in momentum space. k and q can be measured together, and they form the kq representation. Zak emphasizes that the uncertainty principle is not violated by the representation, since one only uses partial information about the coördinates.

Zak has applied his kq representation to the motion of electrons in solids in external fields. The derivation of the acceleration theorem for a Bloch electron in an electric field, $\hbar k = -eE$ usually involves quite complicated expansions and integrations, Zak notes. But with his representation k is an independent variable in Schrödinger's equation, and the theorem follows at once from the simple quantum-mechanical rule that the time variation of k is given by the commutator of the Hamiltonian with k.

For a Bloch electron in a magnetic field, the main result of the effective Hamiltonian follows at once from Schrödinger's equation in the kq representation.

Zak is presently at Northwestern University.

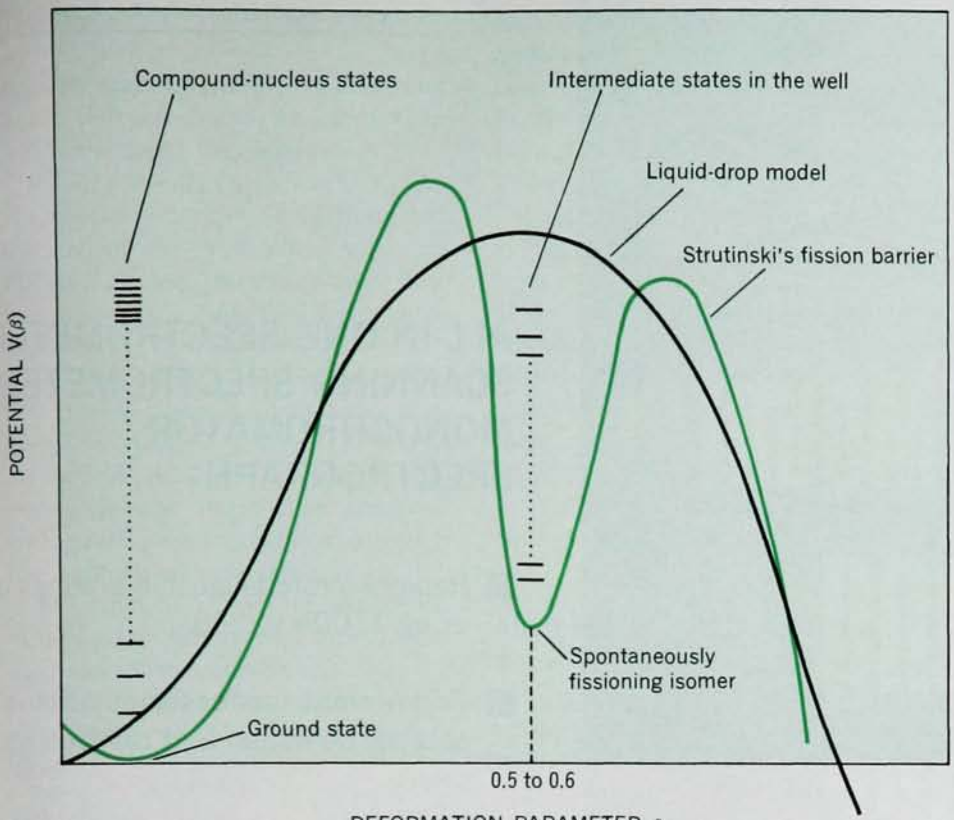
New Insight Is Offered into the Fission Process

The existence of a double-humped fission barrier appears to be the explanation for the behavior of a wide range of heavy and superheavy nuclei.

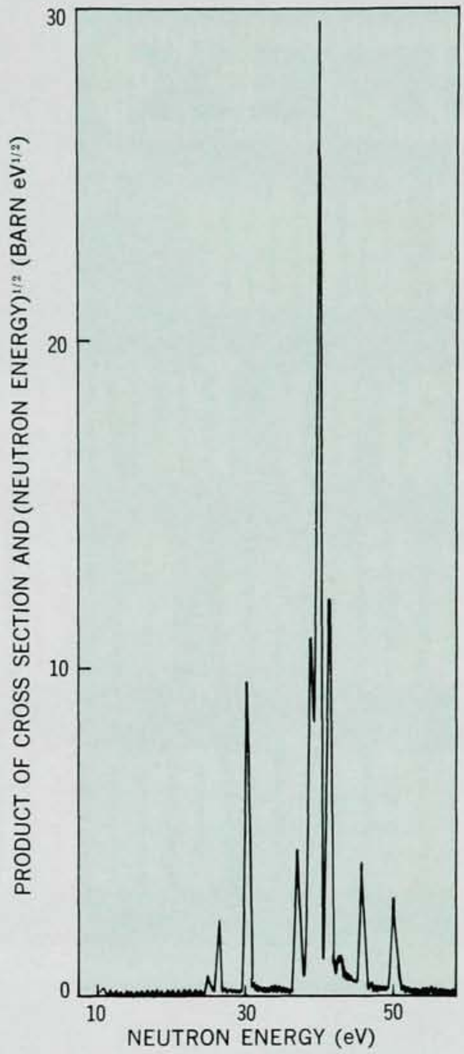
This type of fission behavior was predicted by V. Strutinski[1] of the Kurchatov Institute (on leave at the Niels Bohr Institute), who calculated shell-energy corrections to the liquid-drop model as a function of deformation. These corrections modify the single-humped fission barier obtained previously with the uncorrected liquid-drop model to produce two humps (or more) separated by a well (figure 1). This well appears for rather large deformations ($\beta = 0.5$ to 0.6, where high values for β mean great deformation). The well allows formation of intermediate quasi-stationary states of the compound nucleus at these deformations.

The ground state, corresponding to the bottom of the second well, can explain the existence of spontaneously fissioning isomers, first observed by S. M. Polikanov and G. N. Flerov (Joint Institute for Nuclear Studies, Dubna) about seven years ago.

Saclay studies.[2] The excited states in the well can be responsible for certain structure effects found in some fission cross sections. The most spectacular of these effects is the intermediate structure in the cross section for subthreshold fission induced by resonance neutrons. Such structure was first observed and reported in 1966 by André Michaudon, Jacques Blons, A. Fubini and D. Paya at Saclay, in the fission cross section of Np^{237}; the 45-MeV electron linac served as a pulsed neutron source. Since at that time such intermediate structure was



DOUBLE-HUMPED FISSION BARRIER predicted by Strutinski (colored curve) and single-humped fission barrier given by liquid-drop model (black curve). Well between two humps allows formation of intermediate states of compound nucleus. —FIG. 1



FISSION CROSS SECTION of neptunium-237 (multiplied by square root of neutron energy) vs. neutron energy. Gross structure appears at 40 eV, 118 eV (not shown), etc., and it corresponds to intermediate states in the well. —FIG. 2

very peculiar and never reported before, and since no interpretation was available, the group made two other measurements in the first half of 1967.

They found that the compound-nucleus neutron resonances in the total cross section of Np^{237} are distributed relatively uniformly as a function of neutron energy. The average level spacing of these slow-neutron resonances is 0.6 eV. In contrast, the resonances in the fission cross section are grouped around some discrete energies, where they appear clustered in big peaks or gross structures.

In a plot of fission cross section as a function of neutron energy, gross structure shows up at 40 eV, 118 eV, etc.; there are 38 of these up to 2 keV; average level spacing is about 53 eV. (Figure 2 shows the lower end of the plot.) This spacing is roughly 100 times larger than that of individual resonances. Between these big peaks the fission cross section is almost too small to be measured.

In the first major peak at 40 eV, resolution is sufficiently high to resolve individual resonances in the group. At higher energies attainable resolution is too low.

This type of intermediate structure shows clearly, Michaudon explains, that the coupling of the compound-nucleus states (observed as individual resonances in the total cross section) to the fission exit channels is more intense at some discrete energies: 40 eV, 118 eV, etc. It is now believed that the intermediate quasi-stationary states, situated in the second well, are responsible for the enhancement of coupling to fission exit channels at these energies.

Other laboratories (Geel in Belgium and Harwell) later found intermediate structure in nuclei such as Pu^{240}.

Spontaneous-fission isomers. The phenomenon found at Saclay is closely related to the existence of spontaneously fissioning isomers, as both are supposed to be direct consequences of the double-humped fission barrier. Thus, for example, the intermediate structure in the fission cross section of Np^{237} implies the existence of the fission isomer Np^{238*}.

Until 1967 the only known spontaneously fissioning isomers were in odd-odd isotopes (and possibly in Cf^{246}). Why they should exist at all was unclear. During the past year at least ten new spontaneous-fission isomers have been found.

Neil L. Lark of Raymond College worked with Sven Bjørnholm and Geirr Sletten at the Niels Bohr Institute to discover[3] the new spontaneous-fission isomers. Their method was to bombard available isotopes of thorium, uranium, neptunium and plutonium with protons and deuterons that had energies up to 13 MeV. Most nuclear reactions led to prompt fission, as expected. But about one reaction in a million gave a product that fissioned only after a measurable delay. The half-lives, inferred from the distance that the products traveled before fissioning, ranged from 10^{-6} to 10^{-8} sec.

To the five spontaneous-fission isomers already known (Am^{238}, Am^{240}, Am^{242}, Am^{244}, Cf^{246}) the team added the following: U^{236}, Pu^{240}, Pu^{241}, Pu^{242}, Pu^{243}, Am^{239}, Am^{241} and three more observed but not identified. One

of these may be Np^{238}. In fact they found delayed fission in more than half the isotopes they studied.

Robert Vandenbosch and K. L. Wolf of the University of Washington[4] reported at the November American Physical Society meeting that they found spontaneous-fission isomers in Pu^{236}, Pu^{237}, Pu^{239} and Pu^{240}.

The phenomenon may be related to the double-humped potentials suggested by Allan Bromley, J. A. Kuehner and E. Almqvist[5] to explain the quasi-molecular states they observed in the inverse-fission situation (in which two carbon nuclei interact).

Now that this type of isomerism turns out to be so widespread, the suggestion that it can be explained by a double-humped fission barrier looks increasingly good to many nuclear physicists.

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Interstellar Isotopic Abundance Of Carbon Agrees with Earth's

The C^{12}/C^{13} ratio in the interstellar medium has been measured by Victor J. Bortolot of Columbia University and Patrick Thaddeus of the Goddard Institute for Space Studies (and reported in the January issue of *Astrophys. J. Letters*). They find the ratio to be 82 with an upper limit of 137 and a lower limit of 67; the ratio on earth is 89.

Because the observed interstellar value agrees with the terrestrial one, Thaddeus explains, we can conclude that carbon-rich stars contribute very little to the interstellar medium. (In these rather cool stars, which burn carbon in the CNO bi-cycle, the C^{12}/C^{13} ratio is known to be approximately 4). Furthermore, the agreement suggests that the composition of the interstellar medium has been extremely stable for as long as the earth has been around.

Bortolot and Thaddeus took 25 high-quality spectra at the Lick 120-inch (3-meter) telescope and integrated the data to improve signal-to-noise ratio. They found, in addition to the strong 423.2-nanometer line from $(C^{12}H)^+$, a weak line shifted the amount expected for $(C^{13}H)^+$.

Until recently isotopic abundance in the interstellar medium had not been measured. Sander Weinreb (now at the National Radio Astronomy Observatory) showed a few years ago that the H^1/D^2 ratio must be greater than 10^4. In their observations of hydroxyl radicals, Alan Barrett and Alan Rogers found that the O^{16}/O^{18} ratio is roughly the same as the terrestrial value, 490.

Short-Period Pulsar Slows By 38 Nanoseconds Per Day

A pulsar found last fall near the Crab Nebula, already remarkable for its short 0.033-sec period, appears to be slowing down. The observation gives new support to the neutron-star explanation for the rapidly pulsing radio sources.

D. W. Richards reported from Cornell's radio observatory in Puerto Rico that the period of pulsar NP 0532 had lengthened by 1.26 microseconds from 20 Oct. to 22 Nov.

Thomas Gold of Cornell suggested last May that a plasma cloud spun by a rotating neutron star at its core could approach the velocity of light at its edges. Relativistic effects could account for the emissions, and rotation would account for the period. Because a neutron star is small enough to rotate once per millisecond, he suggested looking for pulsars with periods shorter than those known last May. Because friction should slow the rotation of the neutron star and its plasma cloud, he suggested looking for a pulsar that was slowing down. NP 0532 meets both conditions.

Interstellar Medium Shows It Contains Ammonia, Too

Ammonia molecules have been observed in the interstellar medium by Charles H. Townes, David M. Rank, Albert C. Cheung, William J. Welch and Douglas Thornton of the University of California, Berkeley (*Phys. Rev. Letters* **21**, 1701, 1968). The 1.25-cm emission probably comes from a dense cloud of 3-minute angular diameter in which strong OH absorption had previously been reported, according to the Berkeley group.

The observers used the new 20-foot millimeter-wavelength radio telescope at Berkeley's Hat Creek Station.

Infrared Background Radiation Found Higher than Expected

Rocket-flight measurements of the far-infrared night-sky background radiation have yielded results 30 times higher than predictions based on the 3-K cosmic background radiation found at microwave frequencies. The observed flux corresponds to a black-body temperature of 8.3 K.

Kandiah Shivanandan of the Naval Research Laboratory and James R. Houck and Martin O. Harwit of Cornell reported results in the spectral range 0.4–1.3 mm (*Phys. Rev. Letters* **21**, 1460, 1968). Further rocket measurements are under way.

IN BRIEF

The highest known superconducting transition temperature is now 20.7 K—for a multiphase system of niobium, aluminum and germanium. The experiment was done by Bernd T. Matthias, of Bell Telephone Laboratories and the University of California, San Diego (La Jolla), E. Corenzwit and G. W. Hull Jr of Bell, G. Arrhenius, R. Fitzgerald and H. L. Luo of La Jolla, and W. H. Zachariasen of the University of Chicago.

Pioneer IX, launched 8 Nov., is measuring solar plasma, individual particles and the magnetic field propagated by the sun. Nearly two years after launch the satellite will pass behind the sun (as seen from earth), allowing analysis of how the solar corona affects the satellite's radio signals.

Solar radio waves, particularly those caused by storms, will be studied by a University of Massachusetts team directed by G. Richard Huguenin. Observations will be made at the Harvard Radio Astronomy Station at Fort Davis, Texas.

Mexico's first nuclear reactor, a TRIGA Mark III, went critical 8 Nov. at the Nuclear Energy Commission center near Mexico City.

The Low-Intensity Testing Reactor at Oak Ridge National Laboratory was shut down 10 Oct. after nearly 20 years of service. Officials said technical obsolescence, not old age, led to the decision. □