

The Berkeley workers assigned the atomic number 104 to these isotopes on the basis of genetic-linkage experiments and also reported a comparative chemical study of the element and further claimed that they were unable to produce the isotope 260. They disputed the Russian work and proposed that the new element be named Rutherfordium, Rf.

Matters are complicated because the Berkeley and Dubna groups have been doing parallel but not identical work on producing and identifying elements with Z greater than 101. They have often contested the priority of each other's claims. With regard to element 105, Ghiorso has suggested the name Hahnium (Ha) while Flerov proposed the name Nielsbohrium (Ns). The nomenclature committee of the International Union of Pure and Applied Chemistry, which has jurisdiction over these proposals, will meet in Germany this month.

In 1913 Henry G. J. Moseley first used x rays to identify and order elements in parts of the periodic table when he established that Z is proportional to the square root of the frequency of each particular line in the characteristic x-ray spectra of the elements. In the 1940's, his methods were used again at Oak Ridge to verify the atomic numbers of the manmade elements technetium ($Z = 43$) and promethium ($Z = 61$).

Moseley's law cannot, however, be reliably extrapolated beyond $Z = 95$, Bemis told us; but the Oak Ridge group was able to use the work of Tom Carlson and his collaborators, also of Oak Ridge, who calculated the K-series x-ray energies of the heavy elements up to $Z = 126$ using a computer code based on relativistic Hartree-Fock-Slater wavefunctions. These calculations have been experimentally checked and agree to within 30 eV up to $Z = 101$ and as one researcher put it, "peg the x-ray energies to within a gnat's eyelash."

The K-shell x-ray energies for Z greater than 100 are typically about 100–150 keV. They have been measured at Oak Ridge, using state-of-the-art solid-state detectors, and agree with Carlson's calculations. The basis of their claim for an unequivocal identification of Z is that if one considers a particular x-ray line such as the $K\alpha_1$ or $K\alpha_2$ line, then when Z changes by one unit, the energy of the line changes by about 3 keV.

The 257 isotope was produced with the Oak Ridge Isochronous Cyclotron (ORIC) in the same reaction used at Berkeley. The target consisted of 220 micrograms of isotopically pure Cf^{249} that had been electrodeposited on a 2.5 mg/cm² beryllium foil with a surface area of 0.36 cm². The reaction prod-

ucts recoiling out of the target were thermalized in a small chamber filled with helium. The gas was continually pumped through a small orifice and jetted onto a small aluminum disk (with area 1.5 cm²) that collected the $^{104}\text{X}^{257}$ nuclei. After a collecting time of about 10 seconds, the disk, called a "rabbit," was pneumatically transferred ten meters along a track to a counting station outside the target room.

Some 30 000 ten-second counting cycles were performed during which approximately 3 000 atoms of $^{104}\text{X}^{257}$ were produced. The alpha particles arising from their decay are expected to lie in the energy range between 8.5 and 9.1 MeV. Only x rays emitted in coincidence with the alpha particles in this energy channel were counted in the experiment. Most of these x rays formed the $K\alpha_1$ and $K\alpha_2$ lines. The measured values of these two predominant lines in the x-ray spectrum were (121.9 ± 0.3) and (127.2 ± 0.3) keV respectively. The Oak Ridge workers conclude that the agreement between theory and experiment provides a positive identification of nobelium-253 as the daughter of the alpha-active $^{104}\text{X}^{257}$.

We asked Bemis about the future plans of his group and he said that now that they have completed work on the "Berkeley isotope" they are going to tackle the "Dubna" isotope, $^{104}\text{X}^{260}$. They plan to try to produce it with the ORIC machine in the reaction $^{98}\text{Cf}^{248}(\text{N}^{15}, 4n)^{105}\text{X}^{260}$ followed by the possible branching decay of $^{105}\text{X}^{260}$ via electron capture. The decay can leave the K shell of $^{104}\text{X}^{260}$ with a vacancy, and then one can look for the spontaneous x-ray emission spectra characteristic of atomic number 104 in coincidence with fission events in the expected decay mode of $^{104}\text{X}^{260}$. —RJC

New giant resonances found near giant dipole resonance

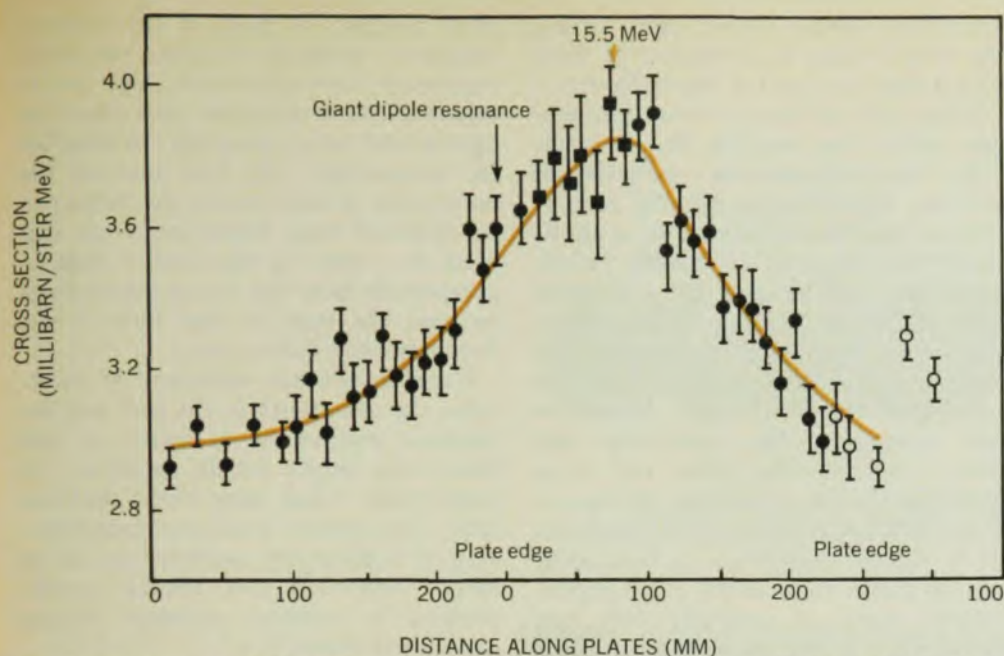
For years a familiar feature of the nuclear spectrum has been the giant dipole resonance (GDR) located at $(70-80)/A^{1/3}$ MeV with a width of several MeV. Recently nuclear physicists have been excited to find other giant resonances at neighboring or higher energies. The interesting feature of the discovery of this new multipole excitation is not so much its actual occurrence, for that was expected theoretically, but that its strength is concentrated in a sufficiently narrow energy range for it to form a giant resonance that can be detected experimentally. The most prominent of these new resonances appears to be an isoscalar quadrupole resonance located just a few MeV below the giant dipole and having a comparable width.

These giant resonances are highly collective modes of excitation in which a large number of nucleons move together as a fluid rather than as individual particles. An energy-weighted sum rule relates the strengths of these excitations to the single-particle transition rates. A giant resonance could be defined as excitations within a limited energy range that exhaust a large fraction of the sum rule. The new resonances seem to obey these criteria, but their strengths are not well known.

Theorist G. Ray Satchler (Oak Ridge National Laboratory) told us that the new giant resonances offer both new puzzles and new insights. One challenge is to explain why the strengths are so concentrated: The shell model gives a general understanding, but the complete calculations are difficult to perform. Another interesting aspect is the influence of these collective modes on transitions between low-lying states. In this connection, the giant resonances relate to the need for effective charges for valence nucleons in shell-model calculations of electric moments and transition rates. The strength and energy of the new quadrupole resonance is consistent with the effective quadrupole charge. It is hoped, then, that the excitation of low-lying states and the effective charges of higher multipoles will provide information about other giant resonances.

Evidence for the new giant resonances comes from several different types of scattering data. Monty B. Lewis and Fred E. Bertrand of Oak Ridge have noted that broad peaks observed in inelastic proton scattering data were consistently about 2 MeV below the energy that is now well established for the giant dipole from photonuclear experiments: They proposed that this peak was not the dipole after all but a new giant resonance (see figure). Almost simultaneously, two groups—R. Pitthan, Th. Walcher and their colleagues at the Technische Hochschule in Darmstadt, Germany and Y. Torizuka and others at Tohoku University, Sendai, Japan—investigated inelastic electron scattering at high excitation energies. Their data also gave evidence for a new giant resonance just below the giant dipole resonance. Since then the new giant resonance has also been identified in data from the scattering of alpha particles and helium-3 nuclei. This work was done by Lewis and by A. Moalem, Walter Benenson and Gerard M. Crawley of Michigan State University.

Much of the experimental data is consistent with a classification of this resonance as either a monopole or a quadrupole, although the strength of its excitation by alphas and helium-3 strongly favor the latter. One way of identifying the multipolarity is by ex-



New giant resonance (colored arrow) appears in inelastic proton scattering spectra at an energy 2–3 MeV below giant dipole resonance. (Note that energy decreases from left to right. Calibration factor is 34 keV/mm.) Spectrum shown is for natural copper at a proton energy of 66 MeV and a laboratory angle of 20 deg. Curve is adapted from M. B. Lewis, F. E. Bertrand, D. J. Horan, *Phys. Rev.* **C8**, 398 (1973).

amination of the scattering of polarized protons from nuclei. The results of such an experiment, reported in August at the International Conference on Nuclear Physics in Munich by D. C. Kocher and his collaborators at Oak Ridge, supports the quadrupole assignment. The identification of this giant resonance as isoscalar results because it can be excited by an alpha particle with a strength comparable to helium-3. In some models alphas could also excite an isovector oscillation but the amplitude would be weak.

Experimentalists are going on now to investigate other giant resonances at higher energies. They also hope to obtain more information about the strength of the new quadrupole resonance. Its measurement is difficult because it rests on a large background. So far the strengths measured in inelastic electron scattering do not altogether agree with those measured in proton scattering. Another new experimental thrust is the investigation of possible structure of these resonances. Inelastic electron scattering on lead, investigated by Torizuka and his colleagues, revealed that the quadrupole resonance was composed of five peaks. Such structure has not yet been seen in other nuclei but it does present a new puzzle to explain. —Barbara G. Levi

TCNQ behavior

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that are drawn closer together and are pushed away from the region where the atoms are further apart. When the atoms along the chain are paired, the ones that are nearer capture a little

more electron concentration. If that pairing pattern, in which atoms one and two are together, three and four are together, and so on, is moved so that now two and three are together, four and five are together and so on, then the electrons simply move right along with that lattice distortion wave. The effect is similar in a rough sense to the traveling-wave tube problem, in which electrons are trapped by an electromagnetic field and move along down the tube in bunches. In the Fröhlich-Bardeen picture, the lattice distortion field traps the electrons and then the whole thing slides down as a collective state.

The electrons move along with the lattice distortion and carry current. There is an energy gap in the moving reference frame so that just as in ordinary superconductors the gap is not destroyed and the electrons move along.

Explaining the Bardeen paper, J. Robert Schrieffer (Penn) compared it to the quark model, in which one considers quarks; from these one gets current algebra, then one throws the quarks away and continues to believe in the current algebra. Similarly, Bardeen considers the Fröhlich model to explain the moving Peierls waves and trapping of electrons in them to get the conductivity. But now he says we should throw away the mechanism because it does not actually work below T_c . Instead, he supposes that just above T_c one can have traveling waves carrying current, but that they are unstable. Thus they can account for paraconductivity although not for true superconductivity.

Subsequent theoretical work by

Bruce Patton and Lou Sham (University of California at La Jolla) and by David Allender and James Bray (University of Illinois) has shown that the magnitude of the increase in conductivity just above T_c is much less than that reported by the Penn group. The La Jolla theorists have also found that the Peierls instability tends to depress BCS-type superconductivity.

Recently Patrick Lee, Maurice Rice and Philip Anderson (Bell Labs) have emphasized³ that these fluctuations can exist over a wide temperature interval in one-dimensional systems. They interpret the transition at 60 K as a locking of the Peierls wave into a three-dimensional structure and show that the fluctuations may extend up to room temperature. The Bell group feels that the high dielectric constant observed by Soviet workers is characteristic of a Peierls transition.

Matthias (University of California at La Jolla) is convinced that all the (TCNQ) compounds are ferroelectrics. Peter Kapitsa and his colleagues had studied the dc and microwave conductivities of two (TCNQ) compounds. At Matthias's suggestion they also measured the dielectric constant, which they then reported in *JETP Letters* three years ago. L. I. Buravov and his collaborators said⁴ that the compounds were more likely to become ferroelectrics than superconductors. The dielectric constants were between 350 and 800, a fantastically large value, Matthias asserts. He says it is well known that all ferroelectrics are conducting when they are impure and that all the (TCNQ)'s do contain impurities. "These conductivities are, however, not as high as Heeger's three crystals show. These values are due to the four-probe technique in nearly perfect (where perfect implies almost no cracks) crystals, which creates an inhomogeneous current distribution." He says, "In my opinion, superconductivity in the (TCNQ) compounds is as erroneous as all the previous results concerning very high transition temperatures."

Commenting on Matthias's criticism, Alan Heeger of the Penn group said that he feels the evidence is very strong that they have a one-dimensional metallic state that is not impurity-dominated. "The basic system above the phase transition is that of a one-dimensional metal, not a dirty semiconductor." Furthermore, he believes that although the dielectric constants are large, this is naturally explained in terms of a one-dimensional semiconducting ground state with a small band gap. The Penn group is now looking at microwave conductivities and is continuing to do dc conductivity measurements, putting its emphasis on (TTF)(TCNQ).