search & discovery

Attempts to explain and observe TCNQ behavior at 60 K

Considerable theoretical and experimental activity has been inspired by the report by a Penn group that they had observed superconducting fluctuations in an organic solid above 60 K. John Bardeen has published a possible explanation for the effect involving a coupling between electrons and a lattice wave. Bernd Matthias has criticized the quality of the experiment and attributes the observations to dirt and ferroelectricity. A group at Johns Hopkins University has done microwave conductivity experiments on one of the organic solids studied by the Penn group and does not find unusually high conductivity. And experimenters at Brown Boveri, who studied a different one-dimensional compound, believe that the Penn group might be observing spurious conductivities.

The Penn group had reported (PHYSICS TODAY, May, page 17) finding a conductivity 500 times the room-temperature value in an organic charge-transfer salt based on tetracyanoquinodimethan (TCNQ). The high conductivity value had been found in a particular (TCNQ) salt called (TTF)(TCNQ), but only in three crystals out of 70. Then the experimenters put an asymmetry into the (TTF) molecule, making it into (ATTF)(TCNQ); with this material, they could not make an absolute determination of the conductivity, but they did report finding that their results with (ATTF)(TCNQ) were reproducible.

As an explanation for their observation, the Penn group suggested[1] they were observing a so-called Peierls instability; in this phenomenon, as the system approaches T_c, the critical temperature, and is about to go semiconducting, it undergoes a doubling of the unit cell in which the molecules pairwise distort. They attributed the high conductivity observed just above T_c to a paraconductivity (or fluctuation superconductivity) arising from a BCS-type pairing of the electrons associated with the Peierls instability.

Bardeen (University of Illinois) has pointed out[2] that the Penn results could correspond to a type of one-dimensional superconductivity considered by Herbert Fröhlich in 1954, prior to BCS theory. Fröhlich assumed that the combined electron-phonon gas was drifting with the same total momentum. Working out the consequences of the momentum being constant in time, he found that a Peierls instability occurred that drifts down through the crystal through a Peierls distortion. Electrons are trapped between atoms

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Element 104 identified by characteristic x rays

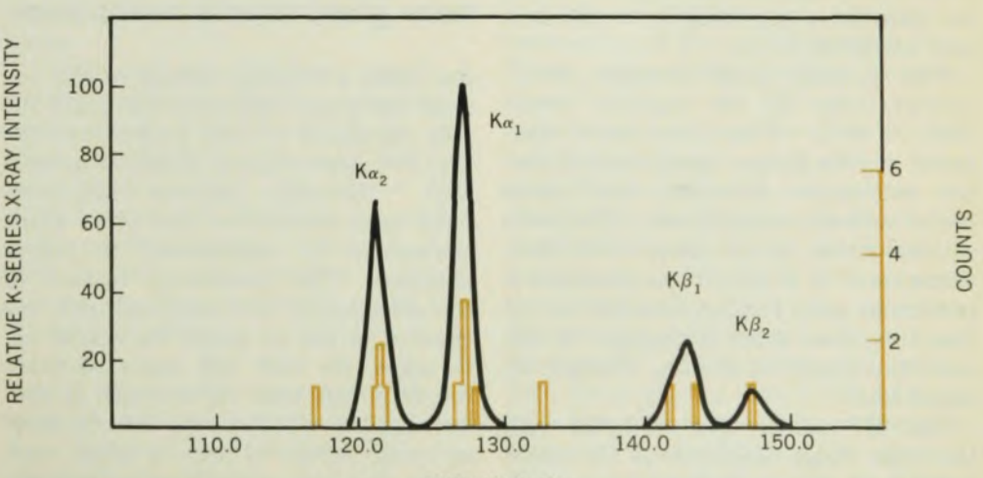
A research team at the Oak Ridge National Laboratory has recently announced that they have conclusively identified the 257 isotope of element 104. This new work shows promise of shedding light on the controversy between Albert Ghiorso and Georgi N. Flerov, the leaders respectively of the groups at Lawrence Berkeley Laboratory and the Joint Institute for Nuclear Research, Dubna. The isotope $_{104}X^{257}$ decays by alpha emission to $_{102}No^{253}$ with a half-life of 4.3 seconds. The Oak Ridge group observed the K-series x rays from nobelium in coincidence with the alpha particles from $_{104}X^{257}$; the observation of x-ray spectra has never been reported previously by the Berkeley or Dubna workers, according to Curtis E. Bemis Jr, spokesman for the group.

The other members of the Oak Ridge group are: Robert J. Silva, David C. Hensley, O. Lewin Keller Jr, James R. Tarrant, Lee D. Hunt, Peter F. Dittner, Richard L. Hahn and Charles D. Goodman.

Flerov first reported the discovery of element 104 in 1964 when his group produced the 260 isotope with the reaction $_{94}Pu^{242}$ (Ne^{22}, 4n)$_{104}X^{260}$. The experimenters assigned its atomic number, Z, via the properties of the excitation function and the reaction mechanism. They found it to be fission active and to have a half-life of approximately one-tenth of a second. In 1966, after Ivo Zvara performed comparative chemical studies of the isotope, Flerov proposed the name Kurchatovium, Ku (after Igor Vasilievich Kurchatov), for the new element.

In 1969, Ghiorso and his group reported the production of the 257, 259, and 261 alpha-active isotopes of element 104 via the reactions:

$$_{98}Cf^{249}(C^{12}, 4n)_{104}X^{257}$$
$$_{98}Cf^{249}(C^{13}, 3n)_{104}X^{258}$$
$$_{98}Cf^{249}(O^{18}, 5n)_{104}X^{261}$$



Identification of element 104. The theoretical K-series x-ray spectrum of nobelium (Z = 102) is plotted in black. The histogram (color) gives the experimental x-ray spectrum counted in coincidence with alpha particles emitted in the range 8.5–9.1 MeV. The agreement between theory and experiment identifies $_{102}No^{253}$ as the daughter of alpha-active $_{104}X^{257}$ that is produced in the reaction $_{98}Cf^{249}(C^{12},4n)\ _{104}X^{257}$.

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 products 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 $_{104}X^{257}$ 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 $_{104}X^{257}$ 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 $_{104}X^{257}$.

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, $_{104}X^{260}$. They plan to try to produce it with the ORIC machine in the reaction $_{98}Cf^{248}$ (N^{15}, 4n) $_{105}X^{260}$ followed by the possible branching decay of $_{105}X^{260}$ via electron capture. The decay can leave the K shell of $_{104}X^{260}$ 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 $_{104}X^{260}$. —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-