Hollow excitement energizes atomic physics

Researchers have discovered that a close encounter between a highly charged, slowly moving ion and a metal surface often yields a neutral atom flush with excess energy – an intriguing product they describe as a "hollow" atom. In this unusual, ephemeral atomic state, nearly every electron present occupies one of the atom's outer shells, leaving the inner shells empty.

"That's a very exotic atomic state, which no one has ever been able to study before," says Fred W. Meyer of the Oak Ridge (Tenn.) National Laboratory. "Right now, we're investigating the details of how a hollow atom is formed, how fast it's formed and how fast it decays. Our emphasis is on trying to understand the fundamental physics to find out what's going on."

The discovery of this remarkable atomic state hinged on the development several years ago of a new type of ion source capable of stripping atoms of nearly all their electrons without imparting extremely high speeds to the resulting ions. "That development initiated a whole research program in which people started looking at collisions between low-energy, multicharged ions and metal surfaces," Meyer says. For anyone with access to such an ion source, "it's a very active field of research."

These investigations revealed that a highly charged ion – in many cases, little more than a bare nucleus – traveling toward a metal surface can extract and capture a large number of electrons from its target in an extraordinarily short time. Indeed, enough electrons make the jump to neutralize the bombarding ion before it crashes into the metal surface.

Measurements of the characteristic X-rays emitted by electrons shifting from high-energy, outer shells to low-energy, inner shells allow researchers to track the process. Recent studies of this radiation, conducted at a laboratory in Grenoble, France, suggest that argon ions can capture 16 or 17 electrons from a silver surface in just a few femtoseconds. At Oak Ridge, a more direct measurement of neutralization times based on observations of highly charged nitrogen ions striking a gold surface gives similar values.

"We know from the [X-ray] energy spectrum that the ion must have been neutralized," Meyer says. "From the speed of the ion and the distance at which these things start to happen, we can infer that a multicharged ion captures a bunch of electrons extremely quickly."

But that leaves a disturbing puzzle. Conventional theoretical models predict that after electrons pass from the metal to highly excited states of the projectile ion, they trickle down to lower energy levels in a cascade of small steps, each step taking an appreciable amount of time. The observations, however, indicate that the whole neutralization process occurs several orders of magnitude faster than this complex mechanism would suggest.

The effort to reconcile theory and observation raises some fundamental questions about atomic physics, Meyer says. For example, to what extent is the structure and decay scheme of excited ions or atoms perturbed by their closeness to a surface? Perhaps the incoming ion and the metal surface combine to form a hybrid structure inadequately described by any present atomic model. Another possibility is that strong interactions among electrons during the capture process may propel some of them directly into low-lying states.

Resolving the mystery will require more detailed experimental and theoretical investigations, Meyer says. Eventually, such studies may also lead to a better understanding of how the leakage of ions from magnetically confined plasmas affects the walls of devices built to contain nuclear fusion. *– I. Peterson*

New superconductor clue

High-temperature superconductors continue to tantalize researchers and attract funding. Yet despite mountains of experimental data and mind-years of theory, no one understands how these layered compounds work. A new computer study, focusing on the ordering of oxygen atoms in specific layers of yttrium-barium-copper-oxide (YBaCuO) superconductors, may supply a clue.

The molecular formula for YBaCuO superconductors includes six to seven oxygen atoms. The total amount of those atoms and their arrangement around copper atoms somehow determines the material's transition temperature – the point at which it conducts electricity without resistance.

A team led by Henning Friis Poulsen at the Risø National Laboratory in Roskilde, Denmark, now reports computer calculations that seem to provide a quantitative picture of the link between oxygen and transition temperature.

The proportion of two copper-oxygen arrangements, which the Danish researchers correlate with two observed transition temperatures in the YBaCuO materials, shifts with changes in the amount of oxygen in the compounds. For compounds hosting both arrangements, possibly segregated into molecular neighborhoods too small to observe with conventional techniques, the transition temperature is a "weighted average of the two types of ordered oxygen domains," the researchers write in the Feb. 14 NATURE. The weights derive directly from the population of oxygen atoms in each kind of neighborhood.

In an accompanying commentary, James D. Jorgensen of Argonne (Ill.) National Laboratory notes that the team's calculations show "remarkable agreement" with experiments and provide "an important insight into the microscopic mechanisms that influence superconductivity in this material." □

EPA targets 17 toxics

The EPA made an unprecedented pledge last fall: to systematically target low-cost strategies for solving the nation's worst unresolved pollution problems (SN: 11/3/90, p.283). Last week, the agency fired off one of the first salvos in that campaign. Letters to the largest industrial polluters requested voluntary cuts in U.S. emissions of the 17 chemicals identified by EPA as posing the greatest threats to human health.

Participating firms must agree to cut by one-third all industrial releases or transfers (to landfills, for instance) of these toxic chemicals by next year, and to limit releases of these substances to no more than half of 1988 levels within another three years. In his letter to some 600 chief executive officers, EPA Administrator William K. Reilly promised to assist their firms in identifying cost-effective ways to limit pollution. He noted that a pilot program involving nine of the nation's largest toxic polluters resulted in a voluntary commitment to collectively reduce their emissions 83 percent by 1993.

Under Clean Air Act amendments passed last fall (SN: 11/3/90, p.277), EPA will designate technologies companies must use to limit pollution from 189 toxic substances, including those on the new priority list. Only companies willing to enter federally enforceable agreements to cut these emissions by at least 90 percent will qualify for waivers of up to six years from the new Clean Air Act rules. However, Reilly notes, some firms may find the new, voluntary program a cost-effective way to avoid the need for future controls.

Focusing on toxicity and exposure potential, EPA has designated the following chemicals as toxic enemies No. 1 through 17: benzene; cadmium and its compounds; carbon tetrachloride; chloroform; chromium and its compounds; cyanides; dichloromethane; lead and its compounds; mercury and its compounds; methyl ethyl ketone; methyl isobutyl ketone; nickel and its compounds; tetrachloroethylene; toluene; 1,1,1-trichloroethane; trichloroethylene; and xylene(s). □

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