XeO_2 (though its crystal structure has not yet been resolved).[6]

Dewaele's new experiment offers a different formation route. It directly exposes Xe to oxygen, the most abundant element in Earth's lower mantle, at pressures and temperatures within the range of what's experienced there. Even so, the experiment doesn't solve the missing Xe problem. For one thing, Xe is so scarce that the element seems unlikely to accumulate in sufficient quantities to be accommodated into deep mineral phases. For another, the O atoms in those deep phases are themselves bound as interstitial components of the minerals, not the free O_2 molecules present in the new experiments.

Alternatively, Xe may not form part of a mineral phase at all. Like most other atoms, Xe can be retained at grain boundaries or other defect sites in mantle silicates and oxides. But why the atoms did not then outgas to the atmosphere over geologic time is its own mystery.

Theory to the rescue

The new work is also driven by pure curiosity. The synthesis and identification of new compounds are at the heart of chemistry. Although at first glance the reaction of two gases could hardly be simpler, its interpretation wasn't. The x-ray beamlines at ESRF are among the most intense in the world, but the diffraction peaks Dewaele and her team observed didn't yield enough detail for them to reconstruct the number and position of O atoms in the newly produced materials. With its number of electrons less than one-seventh that of Xe, O scatters too few incident photons.

Dewaele also examined absorption spectra of the material to convince herself of the presence of Xe–O bonds and the absence of any bonds between Xe and the carbon in the diamond anvils or the metal in the cell's gasket.

What's more, the structures of high-pressure phases can defy chemical intuition. One might suspect that when squeezed tightly together, elements should favor close-packed configurations. After all, atomic Xe sluggishly transforms from one close-packed variant (face-centered cubic) into another (hexagonal-close packed) before it eventually becomes metallic above 130 GPa. But work from the past two decades has proven that supposition wrong.[1] The problem of energy-efficient packing is even more complicated if the spheres are unequal in size.

To resolve the structure and stoichiometry of the new oxides, Dewaele asked Cambridge University's Richard Needs to predict, using first-principles methods, the most stable, low-energy lattice configurations that should exist under a range of pressures. Reassuringly, the diffraction-peak positions Needs and colleagues Nicholas Worth and Chris Pickard calculated from two of the candidate structures matched the positions visible in the experimental patterns.

To achieve that match, the theorists had to consider Xe's d-shell electrons as part of the valence shell. The compression essentially opens that otherwise closed core shell thanks to the spatial overlap of the $4d$ orbitals with the higher-energy $5s$ and $5p$ ones. Xe atoms adopt different oxidation states—the number of Xe electrons associated with bonding—in the same compound (see the figure). Although such mixed valency is common in high-pressure chemistry, it is rare in the noble gases.

More practically, the theoretical treatment of the $4d$ orbitals produced a more accurate and lower prediction for the pressure at which the new oxides would be stable. As a result, Xe and O_2 are more reactive under pressure than theorists had previously realized.

Mark Wilson

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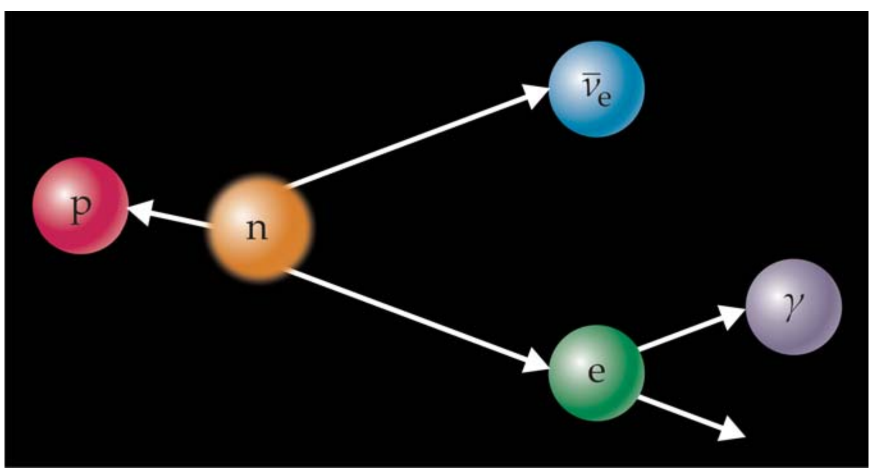
The colors of radiative beta decay

The energy distribution of photons produced in a rare neutron-decay mode has now been measured.

The neutron, though an essential component of most stable nuclei, is itself unstable: After a mean lifetime of about 15 minutes, a free neutron decays into a proton, an electron, and an electron antineutrino. Because the process depends on only a handful of parameters, it's an ideal testing ground for understanding the fundamental physics of the weak interaction.



WHEN A DECAYING NEUTRON produces a photon—in addition to the usual proton, electron, and electron antineutrino—the photon is usually associated with the creation of the electron. The energy distribution of those photons can be predicted by quantum electrodynamics; that prediction has now been experimentally confirmed.

The sudden creation of a high-speed electron in the decay can be thought of as the rapid acceleration of an electron initially at rest—a process that's accompanied by radiation, as shown in the figure. Through that so-called electron inner bremsstrahlung, theory predicts that nearly all neutron decays produce low-energy photons. But every so often, an inner bremsstrahlung photon should carry a significant and detectable fraction of the 782 keV released in the decay.

Fifteen years ago, researchers at NIST in Gaithersburg, Maryland, heard about an experiment in preparation at the Institut Laue–Langevin (ILL) in Grenoble, France, to try to measure radiative neutron decay. They realized that their own superconducting magnet, previously used in measurements of the neutron's lifetime, was ideally suited for them to make their own attempt, which entailed monitoring a neutron beam for the characteristic signature of radiative decay: a proton, electron, and photon all produced at the same time.

The challenge was to distinguish the radiative-decay photons from an overwhelming background of photons from other sources, such as the external bremsstrahlung that's produced when protons and electrons decelerate in a particle detector. In their RDK experiment (not an abbreviation but a play on the words "radiative decay"), the NIST team and its collaborators used a magnetic field to direct the charged particles away from the path of the neutron beam. As a result, the decay protons and electrons could be efficiently detected without the external bremsstrahlung ever reaching the photon detector.

The ILL experiment measured only an upper bound on the prevalence of radiative decay.[1] Then, in 2006, the RDK collaboration, led by Jeffrey Nico, found that out of every 1000 neutron decays, 3.1 ± 0.3 produced a photon with energy between 15 keV and 340 keV, the range over which their detectors were sensitive.[2]

Now Nico and his colleagues have re-

PHYSICS UPDATE

These items, with supplementary material, first appeared at www.physicstoday.org.

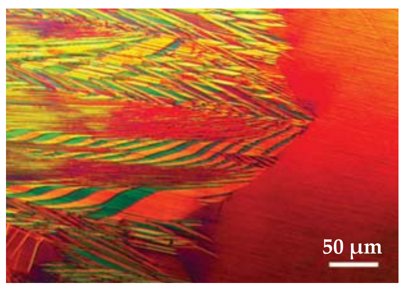
TWO KINDS OF DWARF PLANETS

Between 30 AU and 50 AU from the Sun lies a disk of ancient icy objects known as the Kuiper belt. Most of the objects are just a few tens of kilometers across; they never coalesced with other objects to form planets. But there are exceptions. Astronomers estimate there are a few hundred dwarf planets in the Kuiper belt. Thanks to ground-based observations using adaptive optics and the visit to Pluto last year by *New Horizons*, the properties of five of the Kuiper belt dwarfs—Eris, Haumea, Orcus, Pluto, and Quaoar—are becoming clearer. In particular, Amy Barr of the Planetary Science Institute in Tucson, Arizona, and Meg Schwamb of Academia Sinica in Taipei, Taiwan, have reexamined each planet's density and the mass ratio of each to its principal moon. Barr and Schwamb found that the planets fall into two groups. Pluto (shown here) and Orcus each have mean densities below 2 g/cm^3 and a large moon. Eris, Haumea, and Quaoar each have mean densities above 2 g/cm^3 and a small moon. Given that the dwarf planets formed initially by accreting building blocks made from the same mix of ice and rock, Barr and Schwamb propose that the distinction between the two groups arose from the nature of the collisions that created the planet–moon systems. Pluto and Orcus captured their respective moons in relatively gentle collisions that preserved the bodies' compositions and sizes. The other systems were created in collisions that were so violent that the planets lost some of their ice and the moons were formed anew from collision ejecta. (A. C. Barr, M. E. Schwamb, *Mon. Not. R. Astron. Soc.* **460**, 1542, 2016.) —CD

NASA/JHUAPL/SWRI

THIS PHASE-TRANSFORMING METAL NEVER GETS OLD

Three years ago, Richard James and his coworkers at the University of Minnesota discovered a metallic film—an alloy of zinc, gold, and copper—that seemed to flout the rules of materials science. When chilled to about −40 °C, it collapsed from a high-symmetry crystalline phase, austenite, to a low-symmetry one, martensite. The phase change reversed itself just as abruptly when the film was reheated. (The microscope image shows martensite, left, advancing into austenite, right, as the alloy is cooled.)



Such phase transformations normally take a mechanical toll; typical metals show wear and tear after just a few cycles across the phase transition. But the Minnesota group's alloy, $Zn_{45}Au_{30}Cu_{25}$, remained pristine through tens of thousands of cycles. Aided by one of the world's brightest x-ray sources, James and collaborator Sherry Chen (Hong Kong University of Science and Technology) now think they've figured out why.

Diffraction experiments that Chen performed at Lawrence Berkeley National Laboratory's Advanced Light Source show that the alloy's austenite and martensite lattices, despite having vastly different symmetries, can arrange themselves to match up almost perfectly at shared edges. As a result, austenite can grow within martensite, and vice versa, without introducing strain at the interfaces. And it's interfacial strain that causes ordinary metals to crack and form dislocations during phase transformations. If $Zn_{45}Au_{30}Cu_{25}$'s lattice attributes can be replicated in other alloys—and James and his coworkers suspect they can—they could potentially guide the design of efficient multiferroic switches, microelectromechanical actuators, sensors, and other devices. (X. Chen et al., *App. Phys. Lett.* **108**, 211902, 2016.) —AGS

ANCIENT METEORITE IS IN A CLASS OF ITS OWN

More than four-fifths of the asteroids recovered on Earth as meteorites are ordinary chondrites—iron-poor rocks that contain small leased the results of their follow-up RDK II experiment: They've cut their uncertainty in half, extended their energy limits down to 0.4 keV and up to the full 782 keV, and made the first precision measurements of the shape of the radiative decay spectrum.[3]

The aim of the original RDK was to test whether radiative decay could be seen at all, so the researchers could disregard many experimental subtleties. For example, the response of the scintillators in the photon detectors isn't precisely proportional to the incoming photon energy, and the charged particles produced in the decay are sometimes deflected away from the particle detector. Because RDK II no longer had the luxury of ignoring those effects, much of the intervening decade was taken up with auxiliary studies of the detectors' energy response and detailed Monte Carlo simulations (spearheaded by team member Matthew Bales, now a postdoc at the Technical University of Munich) of every aspect of the experiment.

The spectrum the researchers ultimately derived was fully consistent with theoretical predictions. Indeed, it would have been astonishing if it hadn't been. Electron inner bremsstrahlung is governed by quantum electrodynamics (QED), a well-understood theory that's been thoroughly tested, though never before in this particular way.

But QED treats the proton and neutron as point particles rather than as composite particles made up of quarks. Chiral perturbation theory predicts that the nucleons' internal structure and nonzero size should alter the radiative decay spectrum by about 1%. If RDK's accuracy can be increased by a further factor of five, the experiment should be sensitive to those effects.

Johanna Miller

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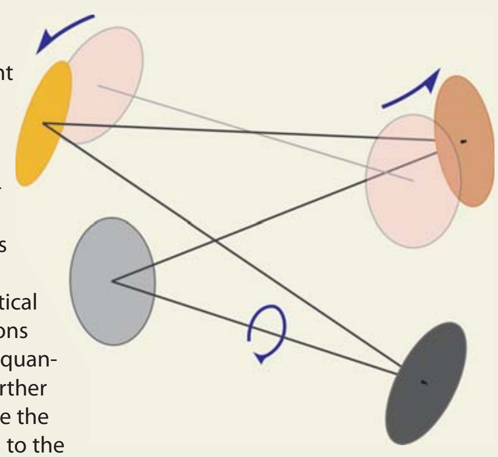
round grains, or chondrules. Over the past two decades, Birger Schmitz at Lund University in Sweden and his colleagues have assembled evidence that a subset of ordinary chondrites, known as L chondrites, are pieces of a single large asteroid that was shattered in a collision about 470 million years ago.

Now Schmitz and his team have conducted a detailed analysis of a peculiar meteorite that has the age of an L chondrite but not the composition. Österplana 065 (pictured here) was discovered in 2011 at the Thorsberg quarry in southern Sweden, where workers for a company that produces limestone floors have uncovered more than 100 L chondrites in ancient sediment. Compared with the L chondrites, Öst 65 contains far less oxygen-17 than it should based on its concentration of chromium-54; the ratio of the two isotopes is used to classify meteorites. The quirky space rock also lacks certain minerals and the chondrule texture that distinguish chondrites.

The researchers argue that the discovery of this one anomalous specimen out of the more than 52 000 meteorites classified worldwide has major implications. Schmitz and his colleagues propose that Öst 65 is the first evidence of an extinct meteorite, which no longer falls to Earth yet is representative of the kinds of rocks that exist elsewhere in the solar system. The researchers go further and suggest, based on the meteorite's age, that Öst 65 is a fragment of the object that slammed into the parent body of the L chondrites. (B. Schmitz et al., *Nat. Comm.* **7**, 11851, 2016.) —AG

PHOTONIC QUANTUM HALL EFFECT



Because photons, unlike electrons, have no charge, they don't couple to applied magnetic fields. Yet it's possible to make them behave as if they do—the key is to manipulate the photons' quantum mechanical phase. (See the Quick Study by Mohammed Hafezi and Jake Taylor, Physics Today, May 2014, page 68.) One way to do that is to use an orderly arrangement of discrete optical resonators to synthesize an artificial magnetic field. Now Jonathan Simon and colleagues at the University of Chicago have demonstrated a new, lattice-free approach. The researchers exploit a powerful analogy: Quantum mechanically, photons bouncing back and forth between curved mirrors exhibit the same transverse behavior as massive particles in a two-dimensional harmonic oscillator. Routing the light using four mirrors instead of just two, the team made its path nonplanar. That caused photons to pick up an additional phase proportional to their angular momentum, just as if they were charged particles in a magnetic field. Through careful tuning of the resonator's 78 mm optical path, the researchers induced photons from a 780 nm laser into an integer quantum Hall state. The Chicago team further engineered their resonator to induce the photons to behave as if constrained to the surface of a cone, and provided the first experimental validation of a 1992 theory describing the response of quantum Hall particle density to spatial curvature. The researchers expect the approach to allow further exploration of the interplay between geometry and topology and to lead to the creation of photonic fractional quantum Hall fluids. (N. Schine et al., *Nature* **534**, 671, 2016.) —RJF