samples from around the world. Those samples all include U as impurities, not major components, so to get enough U to measure the isotopic ratio with sufficient precision, the researchers needed tens to hundreds of milligrams of material from each location—orders of magnitude more than is necessary for a routine dating measurement.

For most of their samples, they found a $^{238}U/^{235}U$ range of 137.818 ± 0.045, about 0.5 parts per thousand less than the commonly used value. But they also found a few outliers far outside that range, including a sample from the Fish Canyon Tuff in southwest Colorado (shown in the figure), for which they measured an anomaly of almost 5 ppt, the largest found to date. But a second Fish Canyon sample, of a different mineral, showed a $^{238}U/^{235}U$ ratio in the normal range. Previous U anomalies were all found in materials formed at low temperature, such as sedimentary rocks and fossil corals. Their U ratios could be affected by U fractionation in chemical processes in water. But the Fish Canyon Tuff formed volcanically, from cooling magma, in which no such chemistry was at work. The mechanism of high-temperature U fractionation has yet to be understood.

A 0.5-ppt change in the $^{238}U/^{235}U$ ratio means that ages calculated through Pb–Pb dating need to be revised by almost a million years. A 5-ppt anomaly would mean a change of several million years. (The Fish Canyon Tuff itself is only 28.5 million years old, so its age was not calculated by Pb–Pb dating and therefore doesn't need to be revised.) That's a small relative error in an age of a billion years or more, but it can potentially make a qualitative difference, especially in questions of which of two events happened first.

Samarium

There's virtually no ^{146}Sm left in the solar system. No natural process creates it in any measurable amount, and all of the primordial ^{146}Sm has long ago decayed into stable neodymium-142. So the usefulness of ^{146}Sm dating (measuring the amount of radiogenic ^{142}Nd relative to other Nd isotopes) is limited to materials and events from the first few hundred million years after the solar system began to condense into solid objects.

The accepted ^{146}Sm half-life of 103 million years is based on two measurements: one from 1966 by a group at Argonne National Laboratory and one from 1987 by a group at the University of Göttingen.[4] But other, earlier measurements had found the half-life to be much shorter (albeit with large uncertainty), which inspired Paul, Nakanishi, and colleagues to revisit the question. They used three nuclear reactions to create some ^{146}Sm in a sample of ^{147}Sm. Alpha decays from ^{146}Sm and from ^{147}Sm are distinguishable by their alpha-particle energies, so the researchers could count the number of decays from each isotope over a period of several months. Then they measured the Sm isotopic ratio in the sample. From that information and the known half-life of ^{147}Sm, they found the ^{146}Sm half-life to be just 68 ± 7 million years.

The 1966 Argonne measurement used a similar technique; that group's measurement of the sample composition could have been marred by isobaric contributions—specifically, ^{146}Nd masquerading as ^{146}Sm. Paul, Nakanishi, and colleagues avoided that problem by analyzing their samples with accelerator mass spectrometry, which distinguishes atoms not only by their mass but also by their atomic number. But the 1987 Göttingen measurement used a different technique entirely, one that wasn't prone to isobaric interference. Paul has no explanation for the discrepancy between their measurement and the Göttingen one, and he suspects it will take an independent new measurement to settle the issue.

If the new, shorter half-life turns out to be correct, it means that every event dated with ^{146}Sm happened much earlier during the solar system's formation than previously thought. That would have important implications for the timeline of the differentiation of Earth's mantle, the solidification of the Moon's magma ocean, and the accretion of Mars.

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DNA-based sensors know what the nose knows

The sensors can "smell" the difference between similar molecules.

Can a machine mimic the human—or better yet, the canine—sense of smell? To do so, it would have to not only determine whether a chemical vapor is present in small amounts but also figure out, at least partially, what chemical it is.

Carbon nanotubes and other nanomaterials do a good job on the first front. Their small size means that the presence of just a few gas molecules is enough to measurably change their electrical properties. But to discriminate among many different molecules, an "electronic nose" must contain an array of sensors, each with different response characteristics.

In 2005 A. T. Charlie Johnson (University of Pennsylvania), Alan Gelperin (Monell Chemical Senses Center in Philadelphia), and their colleagues began to investigate whether a nanotube

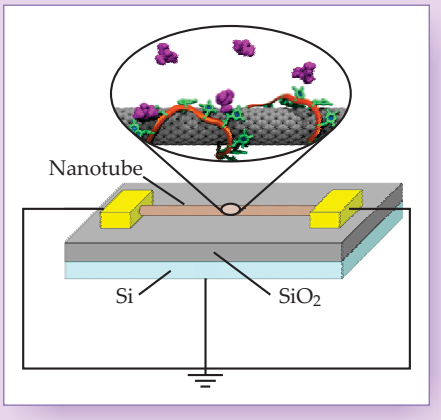

Figure 1. A chemical sensor based on a carbon nanotube (tan) decorated with a piece of single-stranded DNA (red and green). The presence of odorant molecules (purple) is detected by a change in the nanotube's conductivity. (Adapted from ref. 2.)

sensor decorated with single-stranded DNA, as shown in figure 1, might provide the needed specificity to serve as an array element.[1] They found that sensors made with different DNA strands did indeed show different responses, as measured by the nanotube's conductivity, to the same odorant chemicals. The sensors responded to the odorants within seconds, recovered their equilibrium conductivity when the odorant was removed, and maintained a reproducible response for dozens of cycles.

Now, the same researchers have turned their attention to the problem of telling the difference between very similar molecules. They've found that with suitably chosen DNA sequences, they can create sensors that discriminate between organic molecules that differ by a single carbon atom, and even between molecules that are enantiomers, or mirror images, of each other.[2] Human noses can do that, but not many electronic sensors can.

Figure 2 shows one pair of enantiomers the researchers looked at, (+)-limonene and (−)-limonene. To us, one smells like lemon–orange; the other smells like sour orange and turpentine. In DNA–nanotube sensors made with one particular DNA sequence, conductivity through the nanotube increased—by up to 40%—in the presence of (+)-limonene and decreased just as much in the presence of (−)-limonene. The same sensor could also distinguish, though less strongly, between the two enantiomers of carvone, one of which smells like spearmint and the other like caraway.

The researchers tested their sensors in the lab under carefully controlled conditions, with just one odorant in a stream of argon gas. But to be useful components of an electronic nose, sensors would have to operate in air under a range of atmospheric conditions—humidity, for example—and in the presence of background odors.

It's still not understood exactly how the DNA–nanotube sensors work. "But that's the case for essentially all chemical detection schemes based on nanostructure transistors," says Johnson. "It would be terrific if we could develop that understanding in the coming years, ideally to the point where we could model the responses quantitatively."

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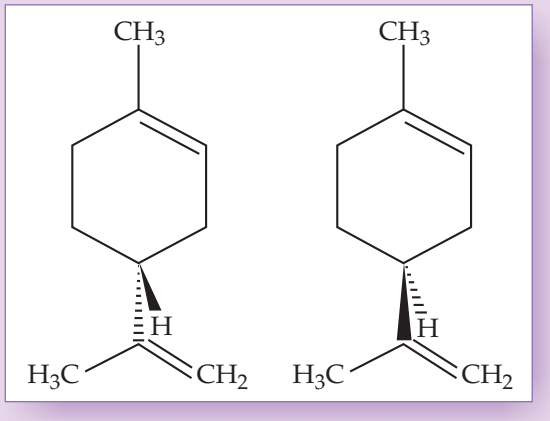

Figure 2. The two enantiomers, or mirror-image molecules, of limonene. Solid and dashed triangles represent chemical bonds that extend above and below the plane of the page, respectively. The human olfactory system can distinguish the two molecules; so can a nanotube sensor decorated with a suitably chosen strand of DNA.

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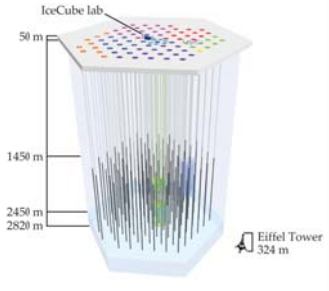
physics update

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

IceCube fails to see neutrinos from gamma-ray bursts. Cosmic-ray protons and nuclei with ultrahigh energies exceeding 10^{18} eV originate in powerful extragalactic accelerators; gamma-ray bursts (GRBs) are a well-studied possibility. From April 2008 to May 2010, even as the IceCube neutrino observatory was being constructed near the South Pole (see the article by Francis Halzen and Spencer Klein, PHYSICS TODAY, May 2008, page 29), it was already looking for the neutrinos that would be produced by the interactions of ultra-high-energy protons with the intense photon field of a GRB. If GRBs were the source of all ultra-high-energy cosmic rays, the detector would have registered at least some neutrinos coming from the bursts—exactly how many is model dependent, but the most popular model gives 8.4. However, the IceCube team has announced it saw none. Evidently, they concluded, either GRBs are not the exclusive source of ultra-high-energy gamma rays, or some basic GRB physics has eluded our understanding. IceCube, shown in the figure and now fully functional, contains 86 strings of photodetectors embedded deep in Antarctic ice. The detectors observe the Cherenkov radiation produced by energetic muons created by neutrino–ice interactions. Armed with a catalog of GRBs that exploded during their data runs—which used 40 and 59 strings of photodetectors—the IceCube team searched in vain for suitable muon tracks that coincided with a GRB and that pointed back to the burst. In addition to its continued search for GRB neutrinos, IceCube is looking for neutrinos from another class of impressive cosmic accelerator, active galactic nuclei. (R. Abbasi et al., IceCube collaboration, *Nature* **484**, 351, 2012.) —SKB



Entangled two-spin qubits. Individual spin states in quantum dots were one of the systems first proposed for implementing qubits for quantum computation. Among their advantages are their potential for scalability and for miniaturization. But they are hard to control, and they can also quickly decohere and lose the information stored in their quantum states. In contrast, qubits built from pairs of spins in two adjacent quantum dots are much more easily controllable and more isolated from their environment. That isolation, though, makes it difficult for researchers to couple them—a critical step in any computation process. Now, Amir Yacoby and