SCIENCE NEWS of the week

First Nuclear Waste Dump Finally Ready

After three years of delays, the Department of Energy last week declared itself ready to open the nation's first permanent repository for nuclear waste. The opening of this controversial facility, located deep beneath the desert near Carlsbad, N.M., will inaugurate a new phase in the nuclear history of the United States.

But before DOE could actually transport the first waste shipments from Idaho to the storage facility, New Mexico's attorney general moved this week to file suit in federal court to temporarily block the facility's opening.

The repository, called the Waste Isolation Pilot Plant (WIPP), consists of 56 rooms, each as long as a football field, carved out of a salt formation 653 meters underground. If it passes the federal approval process, it will serve as a permanent disposal site for waste contaminated by plutonium and other radioactive nuclides during the production of nuclear weapons. WIPP's opening represents a milestone in the nation's efforts to deal with the tons of nuclear wastes that have accumulated over the decades.

DOE originally planned to open WIPP in October 1988 to begin a testing phase, during which the repository would receive limited numbers of waste canisters. But the department had not completed the facility by that time, and numerous technical problems delayed the project.

By initiating a suit against DOE, New Mexico officials hope to stall the waste shipments long enough to resolve certain issues, Governor Bruce King announced last week.

The battle between New Mexico and the Energy Department centers largely on the amount of waste WIPP will store during its six-year testing phase, when DOE researchers will attempt to prove that the facility can meet federal regulations governing long-term disposal of nuclear material.

Last year, DOE announced it would place 4,250 drums of waste – 0.5 percent of the repository's capacity – into WIPP's underground chambers during the testing period. Department officials said they wanted to study gas generated by the waste in order to address concerns that gas pressure will build rapidly in the WIPP rooms. This past summer, however, DOE declared its intention to load the facility with up to 1 percent of its capacity, saying the testing process might require more flexibility.

The State of New Mexico and some members of its congressional delegation contend the limit should remain 0.5 percent. "The Department of Energy has never justified the need for doubling the amount of transuranic waste for the experimental program," says Sen. Jeff Bingaman (D-N.M.).

"We are not satisfied that all the waste used in the tests will be retrieved and disposed of elsewhere in the event WIPP does not prove to be a suitable long-term disposal site," Governor King said last week.

The Environmental Evaluation Group (EEG), an Albuquerque-based organization charged by DOE with overseeing the WIPP project, has long maintained that the department should not put any more waste than necessary into WIPP during the experimental phase, because the tests might indicate a need to process the waste before permanent storage. Workers would then have to remove waste already placed in WIPP – a potentially dangerous procedure.

"EEG supports a maximum of 0.5 percent for experiments in the mine that DOE has identified they need. That's all that they have identified they need," says EEG Director Robert H. Neill.

This percentage debate "doesn't appear to be an issue that would be irreconcilable when you look at all the issues involved," he adds.

Charles Fairhurst, who chairs the National Academy of Sciences' committee on WIPP, says he personally believes 1 percent represents a reasonable limit for the experimental phase. "It is always a good idea to have some flexibility in a testing program," he told SCIENCE NEWS.

– R. Monastersky

Exploring trihydrogen auroras, by Jove!

Using an infrared telescope, two research teams have independently produced the most detailed images ever of auroras in Jupiter's atmosphere. These radiant regions – shaped like a pair of croissants over vast sections of Jupiter's north and south polar areas – vary in brightness on time scales as short as an hour.

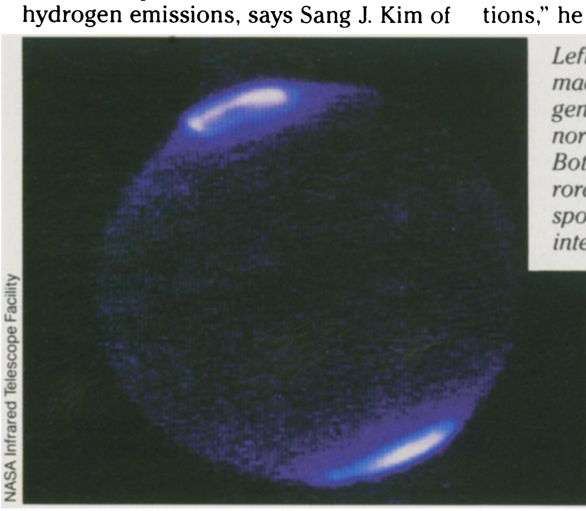
The infrared glow stems primarily from ions of trihydrogen – a simple molecule that many astronomers believe may trigger complex chemical reactions in interstellar gas clouds. For more than a decade, scientists searched in vain for trihydrogen ions far beyond our solar system, in remote, gaseous regions of the Milky Way. Then, in 1989, the elusive molecule turned up close to home, in infrared emissions from the hydrogen-rich atmosphere of Jupiter.

That discovery prompted researchers to obtain the new infrared images, which show the spatial distribution of the trihydrogen emissions, says Sang J. Kim of the University of Maryland in College Park. He and his colleagues conducted one of the two imaging studies undertaken early this year with NASA's Infrared Telescope Facility in Hawaii.

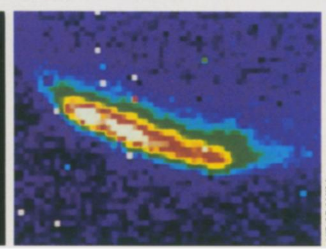
Jovian auroral storms, like those on Earth, develop when electrically charged particles crash into the magnetic field surrounding the planet and then spiral inward toward the north and south magnetic poles. When these particles hit the upper atmosphere, they excite atoms and molecules there, causing them to glow.

The ions that strike Earth's atmosphere come from the sun. But Jupiter lies five times farther from the sun, and astronomers have speculated that most of the particles bombarding its atmosphere come instead from ions spewed out by volcanoes on Io, one of Jupiter's moons.

The infrared studies call that scenario into question, says Kim. "Everything [in the new findings] is against common sense, everything is against our predictions," he asserts. For example, he says,



NASA Infrared Telescope Facility



Kim et al.

Left: False-color infrared image, made in January, depicts trihydrogen auroras located near Jupiter's north and south magnetic poles. Bottom: Close-up of southern aurora, imaged in March, depicts hotspot (white zone denotes highest intensity).

researchers have calculated that ions from the doughnut-shaped plasma cloud surrounding Io should intercept particular regions above Jupiter's north and south magnetic poles, triggering auroras within those regions. The infrared images of trihydrogen, however, only partly coincide with the apparent locations of the ion phenomenon.

Trihydrogen hotspots – regions of high-intensity emissions in the northern and southern auroras – pose another puzzle, he notes. Previous observations of ultraviolet and far-infrared Jovian auroras indicate they typically have a single, nearly stationery hotspot. But Kim's group found that the southern trihydrogen aurora contains two hotspots that vary rapidly in brightness and appear to rotate at a speed of several kilometers per second relative to the face of Jupiter. These hotspots may thus bask in sunlight at all times, which suggests the sun may modulate their activity, says Kim. The single northern hotspot moves more slowly and occasionally migrates out of Earth's view, he says.

In March, while Kim and his colleagues obtained images with NASA's infrared telescope, they simultaneously recorded the intensity of trihydrogen spectra at several wavelengths using the nearby Canada-France-Hawaii Telescope. A second team, led by Richard Baron of the University of Hawaii in Honolulu, had used the infrared telescope to image auroras in January and February. Both groups report their work in the Oct. 10 NATURE.

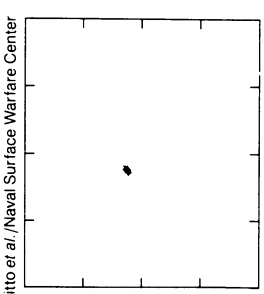
In a commentary accompanying those reports, Alexander Dalgarno of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., notes that the Jupiter findings provide new evidence that trihydrogen ions exist outside Earth-based laboratories. He and others have devised a theory to explain how the ions might form beyond the solar system: Cosmic rays ionize molecular hydrogen on interstellar dust grains; the ions then combine with neutral hydrogen molecules to create trihydrogen ions, which in turn trigger the formation of nearly 100 types of complex interstellar molecules.

Dalgarno says he and his colleagues have now tentatively identified trihydrogen ions in infrared emissions from supernova 1987A – a finding that would represent the first such discovery beyond our solar system. *– R. Cowen*

Achieving control of chaos at high speeds

Steering a car around a corner generally requires more than a steady hand. Most drivers must periodically adjust their estimates of how far to turn the steering wheel before they safely emerge from a curve. Few manage to keep the steering wheel's orientation fixed throughout the entire maneuver.

Nudging a chaotic system so that its erratic behavior settles into a regularly repeating pattern requires a similar approach (SN: 1/26/91, p.60). Troy Shinbrot, a physics graduate student at the University of Maryland in College Park, and his collaborators have now demonstrated just such a technique for rapidly directing a chaotic system to a particular type of periodic motion. Taking advantage of a chaotic system's extreme sensitivity to initial conditions, they use a series of tiny, judiciously chosen and carefully applied perturbations to maneuver its behavior into the type of periodic motion desired.



Ditto *et al.*/Naval Surface Warfare Center

Attractor depicting the chaotic movements of a magnetoelastic ribbon. Adjustments to an applied magnetic field confine the ribbon to a periodic motion.

Shinbrot and his colleagues worked with a metal strip – resembling stiff tinsel – made from a specially prepared iron alloy that changes its stiffness in accordance with the strength of an applied magnetic field. Periodically changing that field causes an upright ribbon to alternately bend and straighten as the ribbon softens and stiffens.

For certain strengths and frequencies of the applied magnetic field, the strip arbitrarily and abruptly shifts from one position to another. Researchers can "map" these chaotic motions on a diagram showing how the strip's position changes with each cycle of the alternating magnetic field (see illustration). Such a map, or "attractor," shows an array of scattered points. An equivalent diagram representing a motion that precisely repeats itself every cycle would display a single point.

By periodically adjusting the magnetic field in just the right way, researchers can keep the ribbon from moving chaotically. It settles into a repeating motion that corresponds to a particular point on the attractor. But to get it to that point, where control of the chaotic motion becomes possible, researchers normally have to wait until the chaotic system's motion, as depicted by its attractor, happens to land near the desired point.

Shinbrot and his colleagues show that a succession of small, carefully selected changes in the magnetic field can bring a chaotically oscillating ribbon from some initial position to the desired behavior in far less time than required by waiting for the system itself to come around to this type of motion.

These experimental results, presented by Shinbrot at last week's Experimental Chaos Conference in Arlington, Va., demonstrate that earlier theoretical work by the Maryland group has validity for real physical systems. For instance, computer simulations showed that one particular chaotic system, left on its own, would require 6,000 steps to reach its target, whereas the use of small perturbations would cut the number of steps to 12.

"Our work can be interpreted as a means of controlling or limiting the troubles that chaos causes," Shinbrot says. "I prefer the view that our work opens up new possibilities for designing chaos into systems." This might provide new insights into how biological organisms switch so easily from one state to another, he adds. *– I. Peterson*

Shakeup over sacred blood

Thixotropy – the property that lets toothpaste ooze when squeezed out of its tube and yet not drip off the toothbrush – may explain a centuries-old miracle.

Blood, once congealed, tends to stay that way. But when religious leaders handle a vial believed to contain the blood of St. Januarius, the dark brown substance begins to flow. Periodic demonstrations of this effect have drawn crowds to Naples since 1389, notes Luigi Garlaschelli, an organic chemist at the University of Pavia in Italy.

In the Oct. 10 NATURE, Garlaschelli and two other Italian researchers propose that medieval alchemists could have created a thixotropic substance that looked like blood by mixing water and salt with a mineral called molysite. Thixotropic materials exist as gels until a mechanical stress – such as picking up or tilting their containers – makes them flow.

To explore this possibility, Garlaschelli searched through the scientific literature and discovered that about 70 years ago, researchers demonstrated thixotropy in an iron hydroxide alloy. He reproduced their work by mixing a ferric chloride compound with calcium carbonate in water, then separating out the iron hydroxide that formed. By adding salt to a solution of this alloy, he created a dark brown gel. "It looks exactly like the samples in Naples," he told SCIENCE NEWS.

All of these materials were available five centuries ago, including ferric chloride, found near Mt. Vesuvius in the form of molysite, he says. While noting that the Catholic Church forbids opening the sacred vials and analyzing their contents, Garlaschelli and his colleagues write: "Our replication of the phenomenon seems to render this sacrifice unnecessary." □