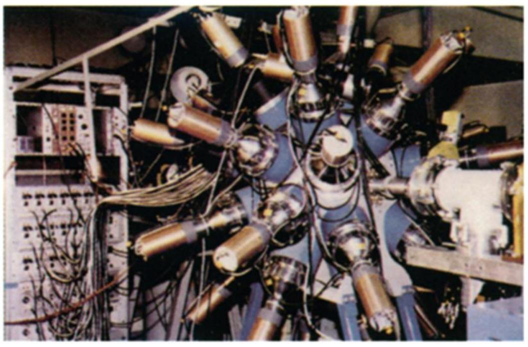
Taking temperatures of nuclear transitions


Jon Wikne/U. Oslo

This instrument, called CACTUS, detects helium particles and gamma rays emerging from excited nuclei that undergo low-energy transitions.

Most earthly matter dwells in a sleepy neighborhood that has been largely neglected by nuclear physics. It's the burg populated by unexcited nuclei that appear to be rich in orderliness but poor in energy.

In recent years, Norwegian physicists have devised a technique to probe the structure of nuclei inhabiting such low-energy landscapes. In an upcoming PHYSICAL REVIEW LETTERS, Elin Melby and her colleagues at the University of Oslo will report extending the technique to allow them for the first time to infer the temperature of such nuclei as they go through some intriguing transformations.

The researchers deduce temperature from the way the neutrons and protons, together called nucleons, rearrange themselves when energy is added to the nucleus. Knowing these temperatures will make it possible to better identify the stages that nuclei pass through as they crumble from an orderly arrangement of nucleons into a disorderly high-energy gas, says Magne Guttormsen, who led the research team.

Until an unexcited nucleus gains about 2 million electron volts (MeV) of energy, theories predict, its nucleons should orbit in well-defined pairs of identical particles. Each nucleon pair shares one internal energy level. In line with these predictions, the data gathered by the Norwegian team indicate that the pairs start to break up as the overall nuclear energy increases to more than 2 MeV.

"We are just now trying to find out the critical temperature," Guttormsen says.

A succession of jumps in the number of energy levels that the nucleons can occupy also indicates that the pairs split apart one at a time, not in a rout, he adds.

So far, the scientists have determined an average temperature of one type of nucleus as the first few nucleon pairs break up: roughly 6 billion kelvins, or 375 times as hot as the center of the sun. "It's actually a quite cold system," says Guttormsen, compared with extremely excited nuclei at much higher temperatures in accelerator experiments (SN: 4/15/95, p. 228).

Exciting low-energy nuclei to study them without destroying their internal structure has proven challenging. The Norwegians have explored the transitions by bombarding the heavy nuclei of the rare earth elements dysprosium, erbium, and ytterbium with light, relatively low-energy helium-3 ions. The ions steal neutrons from the target, changing themselves into helium-4, and leave behind nuclei excited just enough to give off gamma rays that lay bare their inner workings.

By learning more about such transitions, researchers may deepen understanding not only of nuclear structure but also of superconductivity and the behavior of tiny objects composed of only a few atoms, comments Teng L. Khoo of Argonne (Ill.) National Laboratory.

Most striking, Khoo finds, is the Norway team's evidence of steps. Compared with transitions of electron pairs in superconducting metals, which suddenly fall apart at certain temperatures, the rare earth transitions are "smeared," he says.

Although previous calculations have shown that pair disintegrations take place progressively, "we've never been able to trace how that happens," Khoo says. "This paper is the first good glimpse of this stepwise smearing of this transition."

Steven Koonin of the California Institute of Technology in Pasadena says that he and his colleagues are planning further calculations in the same low-energy range to see if they also can find a step pattern in the transition. "It's difficult to get down to such low energies with good resolution for us. With more computers and computer time, we're going to try that," he says. —*P. Weiss*

Warmth switches on a polymer's tackiness

Bandages gummy enough to stay put often seem a bit too sticky when the time comes to pull them off. Now, researchers in Paris have created a glue that could take the "Ouch!" out of removing an adhesive strip. In a new study, they show that a polymer can switch from sticky to not-sticky with just a slight temperature change.

The team, a joint research group of the National Center for Scientific Research and the chemical company Elf Atochem, created the new adhesive by combining two types of polymer molecules. Both have long carbon backbones with side groups poking out like the legs on a centipede. The side groups of one molecule contain hydrogen atoms while the other's contain mostly fluorine atoms. Because fluorinated polymers repel both oil and water, they provide the nonstick coating for cookware and the waterproofing for shoes and clothing.

At room temperature, about 25°C, the two molecules organize themselves in neat, alternating layers to form a hard material. Raising the temperature to 35°C melts the polymer, which can be considered a liquid crystal.

At the transition point, when the molecules lose their crystalline arrangement, the material turns from hard to sticky, says study coauthor Ludwik Leibler. He and his colleagues Guillaume de Crevoisier, Pascale Fabre, and Jean-Marc Corpart report their findings in the Aug. 20 SCIENCE.

"The change is very dramatic," Leibler says. The polymer switches to its sticky state as the temperature increases by just 2°C. Conventional adhesives, by contrast, lose their tackiness only if they are cooled to about –40°C.

Because the transition happens close to body temperature, "I think this has high potential for bandage-type applications," says Richard P. Wool of the University of Delaware in Newark. With an adhesive derived from this polymer, "you could just cool [bandages] down and they'd pop off," he predicts.

Bandages made with this material would also be easy to reposition: Simply warming them up would renew the stickiness of the adhesive.

Leibler suggests that the polymer could also work as a coating on the grips of golf clubs or tennis rackets. The heat from an athlete's hand would improve his or her grasp, but dust and grime would fail to stick when the equipment is not in use.

The researchers can control the temperature at which the transition occurs by either altering the ratio of polymers in the adhesive or controlling the composition and length of the side chains, says Leibler.

"That's a very nice aspect of this technology," says Wool. "If it's truly switchable, this is a very interesting material."

The polymer's ability to wet a surface explains in part how it turns tacky. At the transition point, the material is no longer solid and flows into the crevices of a rough surface, making better contact. Improved contact with the surface in turn improves adhesion.

Changes on a molecular level also contribute to the stickiness. At room temperature, "the fluorine groups will fend off the surface, and you get very low stick," says Wool. When the material heats up, however, the molecules become disordered, and "the backbone can start to play a role in making contact with the surface," he says.

The polymer could serve as "a model system to understand the nature of adhesion," Leibler suggests. He and his group are now studying how changes in the chemical composition of the polymer components affect stickiness. —*C. Wu*