SCIENTIST'S NOTEBOOK

The Quest for COLD!

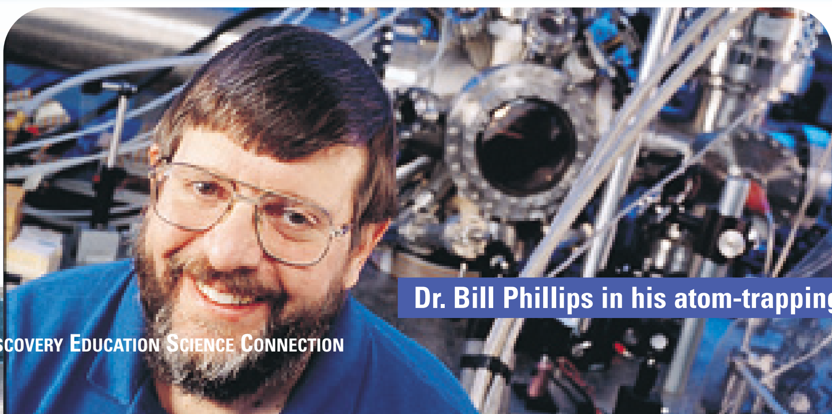
Zero degrees Celsius is cold, 0ºF is colder, but 0 kelvin—which is equal to -273ºC—is the coldest of all. As temperatures decrease, atoms and molecules move more slowly. At 0 K—known as absolute zero—they do not move at all. Zero motion has not yet been achieved in a lab. Physicists try to produce and maintain extremely low temperatures to examine what happens to matter. They're studying superconductivity and superfluidity, conditions at extreme temperatures. Among other developments, this work has led to more accurate and precise timekeeping, faster computers, and safer and more accurate medical technology.

How Cold Is Cold?

For more than 20 years, physicist Bill Phillips has been on a quest to reach absolute zero. At the laboratories of the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, he and his colleagues have simulated the coldest temperatures in the universe—temperatures that are only millionths of a degree above absolute zero. The lowest natural temperature—found only in interstellar space—is almost three degrees warmer.

In his laboratory, Phillips uses lasers, or focused beams of light, to slow down gas atoms. Then he "traps" the slowed atoms in electromagnetic fields. A vacuum chamber keeps out other atoms. At room temperature, atoms are difficult to study because they move too quickly. But atoms that have been cooled and trapped are easier to study in detail, even though they remain trapped for only about a minute. Phillips compares the process of slowing, cooling, and trapping atoms to spraying a stream of water at rapidly volleyed tennis balls.

One of the goals of his experiments with super-cold atoms is to improve the accuracy of the official U.S. atomic clock, located in his lab. The atomic clock is the most accurate clock in the world. (Check it out at the Web site www.time.gov.) The uses of this clock are many and varied: maintaining high-speed communications systems, calculating bank transfers, regulating power grids, and synchronizing NASA's interplanetary travel.



Dr. Bill Phillips in his atom-trapping lab

Keepin' His Cool

Minutes, seconds, millionths of degrees . . . Phillips's research requires incredible precision. Times, temperatures, electromagnetic fields, and other conditions must be measured and remeasured with extreme accuracy. Lasers and other equipment must be calibrated, or adjusted, to exact specifications. Because noise can affect the experiments, he must keep the laboratory dark and quiet.

Phillips received the Nobel Prize in physics in 1997 for his work. "Winning the prize has been an enormous honor," says Phillips. "It is thrilling to have your work recognized—and to have made the discoveries in the first place."

What's So Super About Superconductivity?

Research into absolute zero has major implications for technology today. It is already changing our world. Besides the atomic clock, another practical use for absolute zero is superconductivity, the ability of

Peering into a vacuum chamber, a scientist spies a yellow dot—supercooled sodium atoms.

A patient undergoes an MRI test.

some materials to lose their electrical resistance at very low temperatures. This means that electrical currents do not lose some of their energy to heat loss. Superconductors are an important part of electro-magnets because they can carry the very high electrical currents necessary to produce large magnetic fields without melting. Electromagnets are a key component of Magnetic Resonance Imaging, or MRI. An MRI machine uses radio waves to create a three-dimensional picture of the inside of the human body, a kind of super-detailed X-ray. Doctors use the MRI test to examine soft human cartilage, membranes, and brain tissue. Before the MRI was introduced in the late 1980s, doctors often had to perform invasive exploratory surgery to make a diagnosis, which was far more dangerous and time-consuming. The MRI is now the safest and fastest way to determine the source of many physical ailments.

Scientists and engineers are also hard at work on perfecting the Mag-Lev train (short for a superconducting magnetically levitated train). The Mag-Lev train in Japan runs on a test track made of superconducting magnets. These high-strength electromagnets lift and propel the train along—no more than a few centimeters above a monorail guideway. So the train actually rises, or levitates! One advantage of the Mag-Lev is the lack of wheel-and-rail frictional forces that might someday allow high-speed travel with low environmental impact and minimum maintenance.

Mag-Lev train

The work that Phillips and others have done in the search for absolute zero (and the creation of a heat-free environment and materials) has had a significant impact on many aspects of daily life and points to new avenues for further research and technological developments. "The quest for absolute zero has been a fantastic experience," Phillips says. "This isn't something that I did all by myself. It's something that we—a team of scientists from all over the world—accomplished, and the story is still unfolding in labs around the world."

Activity

ELECTRIC ENERGY **One way to see how heat affects electrical energy is to test an electric circuit at different temperatures. A teacher or parent must help you with this.**

Materials:

2 small flashlights, each with new batteries.

1. **Assemble the flashlights and turn them on. Record the time.**
2. **Place one flashlight on a table or desk at room temperature.**
3. **Place the other flashlight in the refrigerator or freezer.**
4. **Record the time it takes for the flashlight at room temperature to dim and eventually lose its power.**

What happens to the flashlight in the refrigerator? What effect does heat have on electric current? What do you think would happen at absolute zero?

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