Putting quantum theory to a nuclear test

Quantum mechanics, the preeminent theory of matter and its interaction with radiation, has a remarkable track record, allowing scientists to predict accurately such properties as the energy levels of a hydrogen atom. Indeed, the theory agrees so well with experiment that it's difficult to imagine alternatives to the present formulation of quantum mechanics. And that has made it hard for scientists to think of experiments to effectively test the theory's completeness. However, the recent development of techniques that allow atomic measurements of unprecedented precision, combined with a novel generalization of quantum mechanics, now makes it possible to set stringent limits on conceivable corrections to standard quantum mechanics.

To provide a plausible framework for testing quantum mechanics, physicist Steven Weinberg of the University of Texas at Austin reworked ordinary quantum mechanics to include an extra, small "nonlinear" term in the equations expressing the theory. His generalized theory predicts that the frequency of radiation used to drive any atomic system from one energy level to another would depend on the amplitude of the radiation, an effect normally ruled out.

Weinberg's original proposal, published in the Jan. 30 PHYSICAL REVIEW LETTERS, prompted four experiments. Three concentrate on nuclear interactions, where the effect seems likely to be largest. The fourth focuses on hydrogen-atom energy transitions.

John J. Bollinger and his colleagues at the National Institute of Standards and Technology in Boulder, Colo., reported their findings first. Bollinger's team studied the behavior of the nuclei of beryllium ions held for long periods of time in a magnetic trap.

An atomic nucleus, which can be pictured as a tiny magnet, has a characteristic spin. When that spinning nucleus is tipped relative to an external magnetic field, the nucleus precesses at a particular frequency. The effect of a nonlinear correction to quantum mechanics would be to make the precession frequency depend on the angle between the spin axis and magnetic field direction.

To detect such a small effect, Bollinger and his colleagues cooled 5,000 to 10,000 beryllium ions in a magnetic trap to temperatures of less than 1 kelvin. They then measured the precession frequency for different tipping angles, looking for deviations as small as 5 microhertz in a 303-megahertz signal.

"We didn't see any effect," says David J. Wineland, a member of the Boulder team. The result, reported in the Sept. 4 PHYSICAL REVIEW LETTERS, sets a limit of 4×10^{-27} on the fraction of the binding energy per proton and neutron in a beryllium nucleus that could be due to nonlinear corrections to quantum mechanics.

The main limitation in this experiment was the stability of the cesium-beam clock used as a reference for measuring frequencies. A better reference clock, now being developed, could allow the researchers to improve their measurements by an order of magnitude.

Such a high degree of precision is already in sight for E. Norval Fortson and his colleagues at the University of Washington in Seattle. Like the Boulder group, Fortson's team observes the precession of atomic nuclei, but they're looking at mercury atoms at a much lower frequency (1 hertz). "We should get results about a factor of 40 or 50 better than the Boulder group," Fortson says.

Two groups at Harvard University have taken different approaches. Timothy E. Chupp and his team are probing the nuclei of neon atoms, whereas Isaac Silvera and graduate student Ronald L. Walsworth are looking at the interaction between the electron and proton in a hydrogen atom.

Walsworth extended Weinberg's theory to include systems in which the spin can change during an interaction. When applied to a hydrogen maser, which produces microwave radiation of a specific frequency, a nonlinear correction to quantum mechanics would mean the maser's output frequency depends on the number of excited hydrogen atoms pouring into the cavity where the device amplifies the radiation.

Although Walsworth's results put less stringent limits on theory than those set by experiments involving atomic nuclei, they do provide a test of Weinberg's ideas in a different context. "In one sense, nuclear tests are a lot better," Walsworth says. "But it's probably good to be able to test the theory for systems other than just nuclei [with a certain spin]."

"The whole point of my paper was not to say that the sky is falling and quantum mechanics is on its way out," Weinberg says. "The point was to stimulate experimental tests of quantum mechanics, and now they've been done, and the accuracy is really remarkable. I never realized that you could do so well."

Weinberg adds, "I think it's good to think hard about these things because you might come to a conclusion that there simply is no substitute for quantum mechanics, in which case that would be a good thing to know. Or you might come to the conclusion there is a substitute for quantum mechanics, and that then might be considered seriously as a candidate theory." *— I. Peterson*

Fish oil lowers even normal blood pressure

Researchers showed last April that among mildly hypertensive men, diets high in fish oils can lower blood pressure — a major risk factor for heart attack and stroke. Now, another team reports that such diets can similarly lower blood pressure in healthy, nonhypertensive men and women. The new findings also point to a possible mechanism behind the effect: increased excretion of sodium and body fluids by the kidneys.

Study director Constance Kies of the University of Nebraska at Lincoln described her group's results this week at the American Chemical Society's fall national meeting in Miami Beach. For 28 days, the researchers placed five men and five women on a diet supplemented with approximately 1 gram of polyunsaturated fat per day. Each participant received capsules of either safflower oil (rich in omega-6 fatty acids) or fish oil (rich in omega-3 fatty acids). Kies says the fish oil dose resembled the amount consumed in a single daily serving of salmon, lake trout or tuna. After two weeks, diners switched to the other supplement.

Though the two participants with the lowest starting blood pressure showed no change during the test, all others experienced a drop in both diastolic and systolic blood pressure — but only when receiving the fish oil supplement. The reductions proved small but statistically significant, generally about 2 to 3 millimeters of mercury, Kies says. However, notes Garret A. Fitzgerald of Vanderbilt University in Nashville, who coauthored the earlier study involving hypertensive men, larger reductions would not be expected with the doses Kies used — less than one-tenth those yielding discernible blood pressure changes in his study.

"Fish oils appear to operate much like a low-sodium diet," Kies says. By increasing urine output, they reduce the volume of fluids pressing against the inside of blood vessel walls, she explains. People on fish oil in her study increased their urine output by roughly 10 percent. And unlike most diuretics, fish oil did not increase the excretion of potassium, important in regulating blood pressure.

Kies suspects the changes may trace to the regulation of kidney function by eicosanoids — a class of "biological activators" that can speed or slow many body activities. Eicosanoids derived from the omega-6 fatty acids in safflower oil are perhaps 1,000 times more active than those derived from fish oil's omega-3 fatty acids, Kies says. The less responsive eicosanoids from fish oil, she suggests, might "tie up reaction sites" in the sodium management system, slowing or tempering chemical processes that could otherwise lead to more fluid retention and higher blood pressure. *— J. Raloff*