The solar neutrino mystery deepens

". . . We must persevere. I feel that [the late George] Gamow knows the answer by now and is chuckling while we sweat."

by Dietrick E. Thomsen

Deep in a mine near Lead, S.D., is a tank of dry-cleaning fluid that has engendered something of a panic among solar physicists.

The tank is an experiment to detect neutrinos coming from the sun. It is based on the expectation that a neutrino colliding with a chlorine nucleus in the tank will convert chlorine 37 to argon 37. It is operated by Raymond Davis and colleagues from Brookhaven National Laboratory. The experiment has been recording far fewer solar neutrinos than theory expects. Solar physicists have had a year and a half to try to explain the absence of the predicted neutrinos (SN: 9/25/71, p. 210), but they have not found a satisfactory answer.

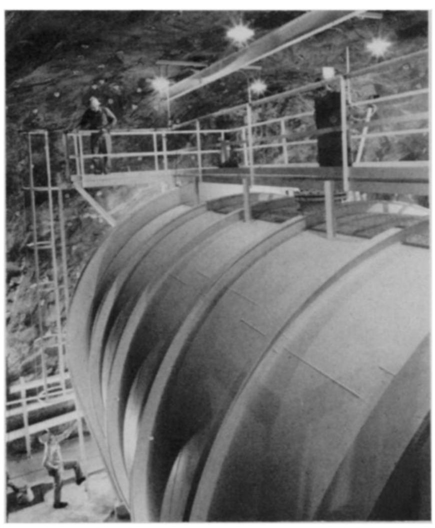
Various alterations of theory have been suggested to account for the discrepancy. A talk at the recent American Physical Society meeting in New York by Peter D. Parker of Yale University and two recent papers in Nature Physical Science tend to negate the suggestions.

Solar neutrinos are expected to come out of the nuclear-burning reactions by which the sun fuses lightweight elements into heavier ones. According to Parker, most of the solar neutrinos that the Lead experiment ought to detect would come from the positron decay of boron 8, in which boron 8 becomes beryllium 8, yielding a positron and a neutrino.

First Parker considers whether the boron 8 might be prevented from forming in the sun in the expected quantity. The theoretically preferred way to make boron 8 is a reaction in which beryllium 7 captures a proton. If there are other ways of burning beryllium 7 that do not yield boron 8, less boron 8 should be produced. There are some possibilities. But Parker says none of the three possible alternate reactions can compete with the one that produces boron 8. Thus, the boron 8 should be made in the expected amount.

Another possibility is that there may be a way to do away with the boron 8 that is more likely than the positron decay. There are quite a number of reactions that could, Parker says, but their rates are all wrong. Their lifetimes, which measure the speed at which they happen, are on the order of 10^{10} or 10^{20} years, infinitely slow compared with the positron decay and therefore "no competition."

One can go further back in the chain



Brookhaven National Laboratory

The neutrino detecting tank at Lead.

of nuclear processes and postulate a resonance, an energetically favorable possibility of a reaction, of helium 3 plus helium 3 to make beryllium 6, which would greatly diminish the importance of the reaction helium 3 plus helium 4 that yields beryllium 7. The Nature paper of Parker and colleagues D. J. Pisano, M. E. Cobern and G. H. Marks is concerned with an experimental search for the resonance. They report that they did not find it.

A further suggestion is that the calculated cross section (likelihood of reaction) for the transformation of chlorine 37 plus neutrino into argon 37 may be in error. But Parker points out that this process has a mirror image in the decay of calcium 37 to potassium 37, and study of the mirror image, which should have the same probability as the original, lends confidence to calculations of the chlorine-to-argon reaction. Says Parker: "It is not unreasonable to have confidence in the neutrino-capture cross section."

Others suppose that there is vertical mixing of matter in the sun, thus burying the neutrino-producing material and cutting down the external flux of neutrinos (SN: 1/27/73, p. 61). To Parker this appears "terribly ad hoc. When it is coupled with basic uncertainties, a credibility gap results." In the other paper in Nature, R. K. Ulrich and R. T. Rood of the California Institute of Technology theorize that even when the proposed conditions for mixing appear (overstability of the material against oscillations caused by gravity) mixing is unlikely to occur.

In summation, there is, as Parker puts it, "no sense of the problem's being solved." He says the Lead experiment shows the importance of doing an experiment when everybody else knows the answer. What is needed is a second experiment and Davis is trying to provide it. He is designing a detector that will use lithium 7 in a process whereby lithium 7 captures a neutrino to become beryllium 7, which becomes lithium 7 again by capturing one of its electrons into the nucleus. This will be less dependent on neutrinos from boron 8, and will be able to pick up more from proton-deuteron reactions.

"The puzzle persists," says Parker, "but we must persevere. I feel that [the late George] Gamow knows the answer by now and is chuckling while we sweat." □