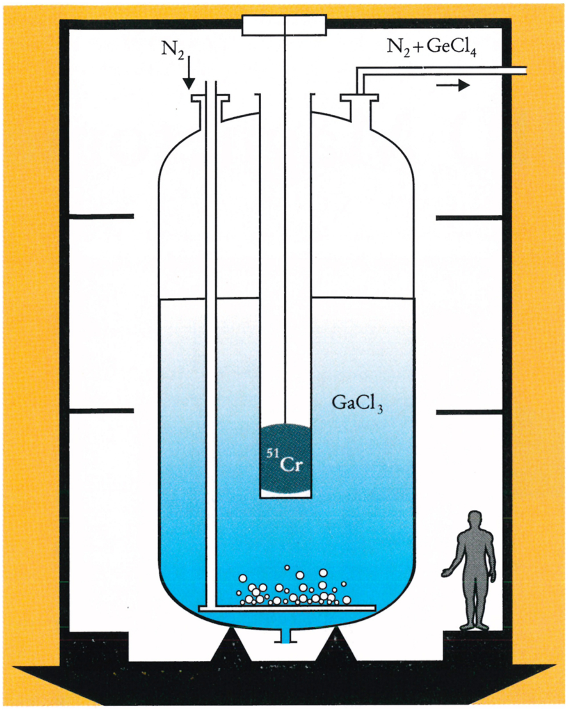
CHROMIUM surrogate Sun spews 10^{17} neutrinos per second into the surrounding gallium chloride solution in the Gallex solar neutrino detector. Nitrogen is bubbled through the solution at intervals to carry off the handful of germanium atoms engendered by neutrinos hitting gallium nuclei.



signal predicted for chlorine detectors.

The great virtue of the gallium detectors is that their threshold (233 keV) is low enough to see much of the pp neutrino spectrum. And indeed, the 60% of the predicted solar neutrino signal that the gallium detectors report seeing is just about what they would see if all the other processes in the solar core were shut down *except* the principal fusion reaction $p + p \rightarrow {}^2H + e^+ + \nu_e$. The neutrino flux from the pp reaction is predicted within 1 or 2% by the solar models. Unlike the ^7Be and ^8B neutrino fluxes, it's hard to tinker with.

Now that the chromium experiment has lifted the shadow of exaggerated skepticism from the gallium experiments, it's tempting to make the simple assumption that the solar-cycle byways leading to beryllium and boron production are somehow cut off. But that way lies a paradox: All the boron in the solar cycle comes from beryllium absorbing a proton. Kamiokande sees fully half the predicted boron signal, and unless the gallium *and* chlorine results are severely wrong, there's room in the data for only a small fraction of the predicted beryllium-decay neutrinos. But there's no way you can produce so much boron in the core of the Sun from so little beryllium. That's why astrophysicists are beginning to call the solar neutrino problem "the missing-beryllium paradox."[3]

Right now the Mikheyev–Smirnov–Wolfenstein hypothesis of resonant neutrino oscillation in the outer reaches of the Sun offers the most convincing way out of the paradox. That theory, now in circulation for almost a decade, leaves the standard solar model intact except to point out that neutrino oscillation *in vacuo* could be greatly amplified by resonant interaction between solar matter and neutrinos on their way out. Because the probability of resonant oscillation is strongly energy dependent in the MSW theory, different kinds of detectors can see different shortfalls.

The new Los Alamos neutrino-oscillation data suggests a ν_μ mass that's attractive to cosmologists worrying about dark matter.[2] But it's much too large for the MSW fits to the solar neutrino data. And the Los Alamos $\nu_\mu - \nu_e$ mixing angle is much too small to account for a significant disappearance of solar neutrinos. So if the Los Alamos result survives, solar electron neutrinos would appear to be metamorphosing into something other than mu neutrinos.

The next generation of solar neutrino detectors should do much to unravel this tangled web. Unlike the radiochemical detectors, the new Čerenkov and scintillator systems will be sensitive to all three neutrino flavors. And they will have enough energy resolution to tell us what parts of the solar-neutrino spectrum are most severely depleted.

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References

1. P. Anselmann *et al.* (Gallex collaboration), Phys. Lett. B **342**, 440 (1995).
2. J. Primack *et al.*, Phys. Rev. Lett. **74**, 2160 (1995).
3. J. Bahcall, Phys. Lett. B **338**, 276 (1994).

Horseradish can clean industrial wastewater

Horseradish is so potent that it clears clogged sinuses, tickles tastebuds when dabbed on gefilte fish or roast beef . . . and now, it can clean up industrial wastewater. Jean-Marc Bollag, codirector of Penn State's Center for Bioremediation and Detoxification, and Jerzy Dec, a research associate there, report[1] that minced horseradish root can clean wastewater containing phenols a lot more cheaply than other chemical and physical treatments.

Fifteen years ago Alexander M. Klibanov at MIT and his collaborators had pointed out that the enzyme horseradish peroxidase, when added to wastewater with hydrogen peroxide, causes pollutants such as phenols, anilines and other aromatic compounds to form insoluble polymers that can then be filtered off. Phenols are found in wastewater from steel and iron manufacturing, ore mining, paper bleaching, coal conversion, and manufacture of dyes, resins, plastics, pesticides, textiles and detergents.

Bollag and Dec used wastewater from the production of the herbicide 2,4-D. They minced ordinary horseradish root to maximize the enzyme's contact with the water, and found that the minced root cleaned up phenol as well as purified horseradish peroxidase does. Better results occurred as the root was chopped finer; mashed worked best. The horseradish remained effective for as many as 30 treatments.

The Penn State horseradish treatment takes 30 minutes, compared to the weeks or even months required by microbial degradation, according to Bollag and Dec. They say the major reason that enzymatic treatment hasn't been applied on an industrial scale is the huge size of polluted environments needing bioremediation and the cost of treating them. Bollag told us minced horseradish costs half as much as standard chemical methods.

Although minced horseradish works best, minced white radish and minced potato also remove phenols. So if you're all out of horseradish, try potato latkes.

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Reference

1. J. Dec, J.-M. Bollag, Biotechnol. and Bioeng. 44, 1132 (1994).