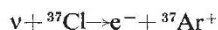


matters arising

Polymerisation and the solar neutrino problem

JACOBS¹ has questioned the efficiency of the helium flushing method for extracting Ar⁺ ions produced in the reaction

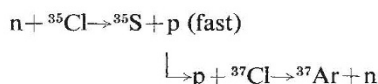


He suggests that Ar⁺ ions could induce polymerisation in the liquid C₂Cl₄ and get trapped before they are neutralised by capturing electrons, and consequently all the Ar⁺ ions produced in the above reaction are not detected.

Tetrachloroethylene is an unsaturated molecule which undergoes polymerisation, when irradiated by MeV γ rays, at the rate of $\sim 2.1 \times 10^{-10}$ mol ml⁻¹ s⁻¹ (based on the dose rate of 1.5×10 eV ml⁻¹ s⁻¹ and the polymer yield in the radiation experiments)². It is known that halogenated ethylenes undergo predominantly free-radical polymerisation, the cationic initiation of the chain is less likely because of the presence of electronegative groups in C₂Cl₄ leaving an electropositive carbon atom at the polymerisation site. Even if Ar⁺ can initiate polymerisation, the rate will be much smaller than that quoted above for γ rays. On the other hand, since the electron affinity of Ar⁺ is high, the Ar⁺ radical produced by the solar neutrino can be neutralised at a very fast rate. The electron transfer between the neutral radical and the positively charged ion is diffusion controlled with the rate constant 10^9 – 10^{10} l mol⁻¹ s⁻¹, while the rate constants of generalised polymerisation³ are of the order of 1–30 l mol⁻¹ s⁻¹. It is clear there will be negligible trapping of Ar⁺ ions through polymerisation in the tank.

The foregoing arguments receive indirect but unambiguous support from two experiments: (1) Barabanov *et al.*⁴ have measured the relative efficiency of removing a small number of ³⁷Ar atoms by helium purging in liquid C₂Cl₄ and in solid C₆Cl₆ by irradiating both the substances with fast neutrons from a PuBe source. They find that for the same number of fast neutrons, the same number of ³⁷Ar atoms is produced. Considering the different physical and chemical properties of C₂Cl₄ and C₆Cl₆, the probability of identical rate of trapping is surely negligible. (2) In the helium-purging efficiency experiment of Davis⁵, liquid C₂Cl₄ was irradiated with neutrons from an RaBe source to get an apparent ³⁷Ar production rate per incident neutron of 7.5×10^{-7} . If chemical trapping is im-

portant, the true production rate should be at least an order of magnitude higher than the observed one. The cross sections for the nuclear reactions



are sufficiently well known to render a theoretical calculation of the true production rate of ³⁷Ar possible; we find it to be $\sim 4 \times 10^{-7}$, in reasonable agreement with Davis' measurements.

We may add to these the very careful analyses by Wolfendale *et al.*⁶ and by Cassidy⁷ of the cosmic ray-induced background in Davis' experiment. These analyses lead to values for the photo-nuclear cross section which are in substantial accord with other cosmic ray and accelerator measurements. If the normalisation of the background at the depth of 25 m.w.e. (metres water equivalent) is wrong as implied by Jacobs, this would hardly have been the case. The conclusion thus seems inescapable, that chemical trapping of any kind—polymerisation or other chemical process—is of negligible significance in Davis' experiment.

B. BANERJEE
S. M. CHITRE
P. P. DIVAKARAN
K. S. V. SANTHANAM

Tata Institute of Fundamental Research,
Bombay 400005, India

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JACOBS REPLIES—In a brief communication¹ I explored the logic of the possibility that the solar neutrino problem might be caused by the chemistry of the solar neutrino experiment. I concluded that this chemical hypothesis was viable only if ³⁷Ar⁺ became 'chemically trapped' in Davis' system; five mechanisms for trapping the argon in C₂Cl₄ were suggested.

Banerjee *et al.*² criticise one of my trapping mechanisms—induced polymerisation in the liquid tetrachloroethylene—and imply by heuristic arguments that Davis' neutron-irradiation test³ and the cosmic-ray background test^{4,5} completely rule out the possibility of any significant

'chemical trapping'. I suggest that the conclusions of Banerjee *et al.* are comfortably plausible, but they are by no means logically inescapable.

Induced polymerisation of C₂Cl₄ is the least tenable of my suggested trapping mechanisms; the large atomic radius of chlorine will hinder the formation of any long chain polymer¹. It is much more probable that the argon is 'chemically trapped' in a small bound molecule or ion-molecule. One could just as easily interpret the results of Barabanov *et al.*⁴ as positive support for the formation of ArCl_n, with $n = 2, 4$ or 6 .

Order-of-magnitude arguments are unsafe in this controversy. The uncertainties intrinsic to present-day solar models can easily render acceptable a theoretical solar neutrino rate as low as 4 SNU (ref. 7), whereas Davis' latest two runs (36 and 37) indicate an experimental rate of ~ 4 SNU—with a 1σ upper limit of ~ 1.5 SNU for the average of runs 21–37 (ref. 7; estimated by eye from their Fig. 2). Thus, 'chemical trapping' need not hide 9 of every 10 argon atoms produced by solar neutrinos, but could well conceal only 60% of the argon on average.

Therefore, order-of-magnitude (or even crude qualitative) agreement between theory and experiment in some of the crucial tests^{3–5} is not sufficient to eliminate the chemical hypothesis—only precise quantitative matching can do that. Finally, I conclude again that my chemical solution to the solar neutrino problem remains a viable alternative.

Leander McCormick Observatory,
PO Box 3818, University Station,
Charlottesville, Virginia 22903

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Sub-microscopy porosity and superfluid ⁴He

VAN Brakel and Heertjes¹ have reported on transfer phenomena in porous media, using the capillary rise of a wetting liquid. I would like to add to this by mentioning a phenomenon apparently similar to capillarity, although funda-