Isotope Separation and Solar Neutrino Experiments

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Isotopic enrichment of target chemical elements in NSE is discussed as means for increasing validity of experimental results.

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In spite of great recent theoretical efforts (see [1] and references therein), the problem of solar neutrinos is still with us: the gap between experimental values and theoretical estimations of solar neutrino fluxes on the Earth is too large as compared with the declared uncertainties of both theory and experiment [2].

I am not going here to argue with existing (often really brilliant) theoretical attempts to find way out in the situation but rather I would like to speculate somewhat about one (even looking fantastic at present) possibility of the drastical improvement at the experimental side of the problem. The point is the isotope composition of target elements in Solar Neutrino Experiments (NSE) and problem of improvement of this composition.

Table 1 presents some data on isotope composition of the chemical elements suggested by various authors as target in NSE's (see comprehensive Compendium [3] and references therein). In each row, first given is active isotope taking part in neutrino detection reaction, with the relative cosmic abundance of this isotope, taking (absolute) cosmic abundance of $^{12}$C equal to $10^{16}$ (all data on composition are taken from [4]); second shown is passive isotope with its abundance; $x$ is relative abundance of active isotope.

From Table 1 one sees that the "best" is $^{127}$I (with 100% relative abundance of active isotope) and the "worst" is $^{37}$Cl with only 24.2% of useful isotopes in natural mixture of Cl. (Curiously enough, Chlorine is characterized in otherwise excellent review [5] as particularly convenient target element having such a good relative abundance."

And there is some irony that namely Chlorine is used in the first (and may be best) NSE. In huge tank containing 610 tons of perchloretylene (dry-cleaning fluid) (or tetrachloroethylene $C_2Cl_4$ [127-18-4] by "official" chemical classification) only one-fourth of the whole detector works hard and honestly while three-fourth is only presented but not involved!

If one would have (in ideal) 100% pure $^{37}$Cl and 100% pure $^{35}$Cl in the form of $C_2Cl_4$ both in quality, say, 146 tons, then it will be crucial in solving experimentally the Problem of Solar Neutrinos (at least in this radiochemical experiment).

The classical astronomical observation method star—background—star (or on—off—on) will allow to increase enormously the validity of experiment results.

The great disadvantage of most (if not all) SNE’s is lacking possibility of switching off the source to measure the background. The availability of active and dull targets with otherwise identical characteristics allows - as it is well known - to measure the fluxes which may be even much smaller than background! By the way, the volume of target matter may be in this case much smaller than in current SNE’s.

That is O.K., but what may be done in reality (not in ideal)? - quite rightly may ask reader. That is real question and we forward it to specialists in isotope separation [6,7]. What we may do now and here is only to mention that relative mass difference $\delta M/M$, which defines largely the elementary separation factor $q_0$ of the all separation methods [6,7], in our case is much larger that for "sadly famous" $UF_3$. Just as example: for gaseous diffusion $(q_0 - 1) \propto (\delta M/M)^{1/2}$.

And if one will start to deal with this problem one important thing is that - as we guess - there is no need to build special plants or installations, as such things are quite in common in many countries. Certainly the isotopic-dependant characteristics of $Cl_2$ or $C_2Cl_4$ (the latter being even the subject of the whole recent book [8]) relevant to isotope separation (see e.g. [9]) may be serve as goal of an international collaboration.

"Today isotope separation is done on an industrial scale only for production of $^{235}$U and heavy water" [6].

May be in near future the situation will be drastically changed and industrial scale isotope separation will serve to solve the pure scientific problem - is it so that thermo-nuclear reactions proceed not only in bombs but also in debris of the Sun giving the flux of $10^{41}$ neutrinos per second per cm squared of Earth surface?

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[1] Bahcall J.N., Basu S. and Pinsonneault M.P, astro-ph/9805135; see also hep-ph/9807525, hep-ph/9807216 and astro-ph/9805133.

[2] I should note that along with a number of more or less "concordant" SSM's (see references in BP98), there is also the somewhat "dissident" SSM DS98: A. Dar, G. Shaviv, astro-ph/9808098. In this SSM, situation with reconciling experimental results and predictions is not so tense. However I am not in position to judge "who is right, who - not".

[3] Bahcall J.N. Solar neutrinos, Addison-Wesley N.Y. 1994.

[4] Lang K.R. Astrophysical formulae, Springer N.Y. 1980.

[5] Bahcall J.N. Neutrino astrophysics, CUP N.Y. 1989.

[6] Villani S. Isotope Separation. Am. Nucl. Soc. N.Y. 1972.

[7] Radiochemical Separation Methods. Eds. Braun T. and Bujdoso Elsevier Amsterdam 1975.

[8] Tetrachlorethylene. GDCh (Wiss Verlagages) Stuttgart 1996.

[9] Isotope Effects in Chemical Reactions. Eds: Collins C.J. and Bowman N.S. VNR N.Y. 1970.

### TABLE I. Some isotopic data on proposed targets in SNE's

| Element   | Isotope | Acting | Passive | Cosmic | Rel. | \( \delta M/M \) |
|-----------|---------|--------|---------|--------|------|------------------|
| Lithium   | Li      | 7Li    | 6Li     | 45.8   | 3.67 | 0.926           |
| Chlorine  | Cl      | 37Cl   | 35Cl    | 1390   | 4310 | 0.242           |
| Gallium   | Ga      | 71Ga   | 69Ga    | 19.2   | 29.0 | 0.398           |
| Bromium   | Br      | 81Br   | 79Br    | 6.68   | 6.82 | 0.495           |
| Rubidium  | Rb      | 87Rb   | 85Rb    | 1.72   | 4.16 | 0.293           |
| Indium    | In      | 115In  | 113In   | .181   | .098 | 0.958           |
| Iodium    | I       | 127I   |         | 1.09   |      | 1.0             |