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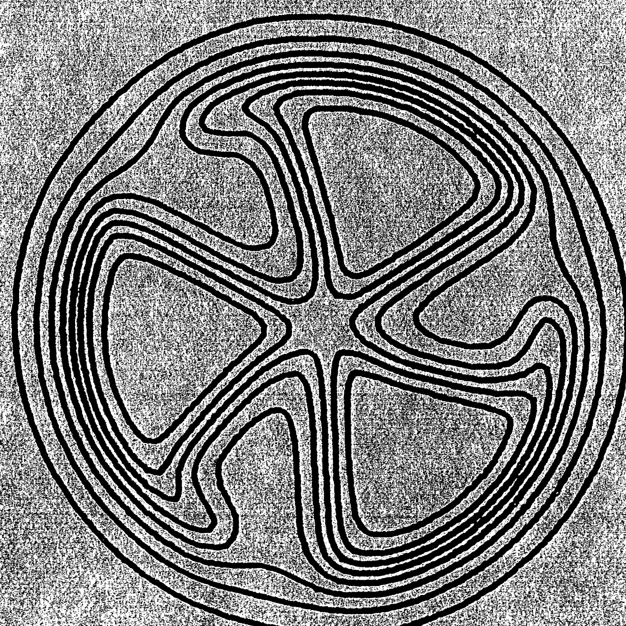

MSUCL — 59

JUNE 1972

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ABSTRACT

Nuclear wave functions from recent shell-model calculations are used to evaluate the log (ft) values relevant to the neutrino absorption cross-section of ^{37}Cl.

*Research supported in part by the U.S. National Science Foundation.

In order to understand better the causes and/or consequences of the unexpectly low yield of the solar neutrino experiment,[1] we have re-examined some of the assumptions which underlie the calculation of the neutrino absorption cross-section of ^{37}Cl. As has been pointed out,[2,3] there is very little uncertainty in the calculated absorption cross-section for low energy neutrinos (E_ν<2.22 MeV) in the $\nu + {}^{37}Cl \rightarrow {}^{37}Ar + e$ reaction since this calculation depends only upon the measured electron capture rate of ^{37}Ar and other known quantities. However, there are unmeasured quantities which enter into the calculation of absorption cross-sections for neutrinos with energies greater than 2.22 MeV.

These uncertainties result from the lack of experimental β-decay log(ft) values for the transitions which connect the ^{37}Cl ground state with some excited states of ^{37}Ar. Under the standard assumption that isospin is a good quantum number, the measurement of the delayed proton spectrum from the β-decay of ^{37}Ca provides log(ft) values for transitions to the excited states of ^{37}Ar above 3 MeV,[4] relative to the superallowed transition to the J=3/2,T=3/2 state at 4.993 MeV in ^{37}Ar. (This latter state is the isobaric analogue of the ^{37}Cl ground state.) Transitions to excited states below 3 MeV and to the 4.993 MeV isobaric analog state are not easily accessible to experimental measure and estimates for their contribution to the neutrino capture cross-section must be based on nuclear structure calculations.

When the neutrino experiment was first proposed, Bahcall made simple shell model estimates of these log(ft) values.[2] In this note we report values for these transitions based on the most complete nuclear wave functions presently available.[5] (We use the results of Hamiltonian 11.0h+ASPE.) The low-lying spectrum of ^{37}Ar is now well known, and the transitions of interest are to the $1/2^+$ state at 1409 keV, the $5/2^+$ at 2797 keV and the $3/2^+$ T=3/2 state at 4993 keV. The calculated log(ft) values for these transitions are shown in Table I and Fig. 1. These numbers were obtained as part of a general study of β-decay in this region of the nuclear chart.[6] We have calculated all the β-decays for which experimental data exist in the mass ranges A-17-23 and 34-39 and the overall percentage rms deviation between calculated and experimental log(ft) values in these nuclei was 5%.

We show in Fig. 1 the calculated and experimental energies and log(ft) values for the states of $^{37}Ar(^{37}K)$. By examining this figure, one sees that there is good agreement between the calculation and experiment for the states below 3.5 MeV. Above 3.5 MeV, there are more transitions observed than are predicted by the calculation, and the observed transitions are slightly weaker than the model predicts. Both these results are not unexpected since for states above about 3 MeV, shell model configurations with 2 particles in the $f_{7/2}$ shell become important. Such configurations are not included in our model and would provide a mechanism which would split the beta-decay strength among more states than predicted by our model. Hence, one might expect to observe more beta-decays with larger log(ft) values (on-the-average) than the model predicts.

By examining Table I, one sees that there is good agreement between the present calculation and the experimental log(ft) to the ground state ($\log(ft)_{cal} = 5.14$, $\log(ft)_{exp} = 5.06$). There is also reasonable agreement between the present calculation and Bahcall's estimates for the transitions to the $5/2^+$ state and to the $3/2^+$, T=3/2 state. However, there is substantial disagreement for the transition to the $1/2^+$ state at 1409 keV. The present calculation indicates that the transition is much weaker (larger log(ft)) than estimated by Bahcall. Since the cross-section for neutrino absorption is inversely proportional to (ft), the change of log(ft) from 4.48 to 5.44 implies a decrease of one order of magnitude in cross-section for absorption to this $1/2^+$ state. The use of this larger log(ft) in the calculation of Ref. 2 and 3 yield an averaged cross-section for absorption of neutrinos from ^8B decay of $\langle\sigma(^8B)\rangle = 1.15\times10^{-43}$ cm^2, which is 15% lower than the previous value. Calculations with the alternate "12.5p+^{17}O" Hamiltonian of Ref. 5 yield a result $\langle\sigma(^8B)\rangle$ which is 20% lower than Bahcall's result.

We should also point out that our calculations indicate that there are no strong transitions which have not been included in the calculated neutrino absorption cross-section. Hence the present result for $\langle\sigma\rangle$ is unlikely to be a large underestimate.

It is a pleasure to acknowledge several helpful discussions with Sam M. Austin.

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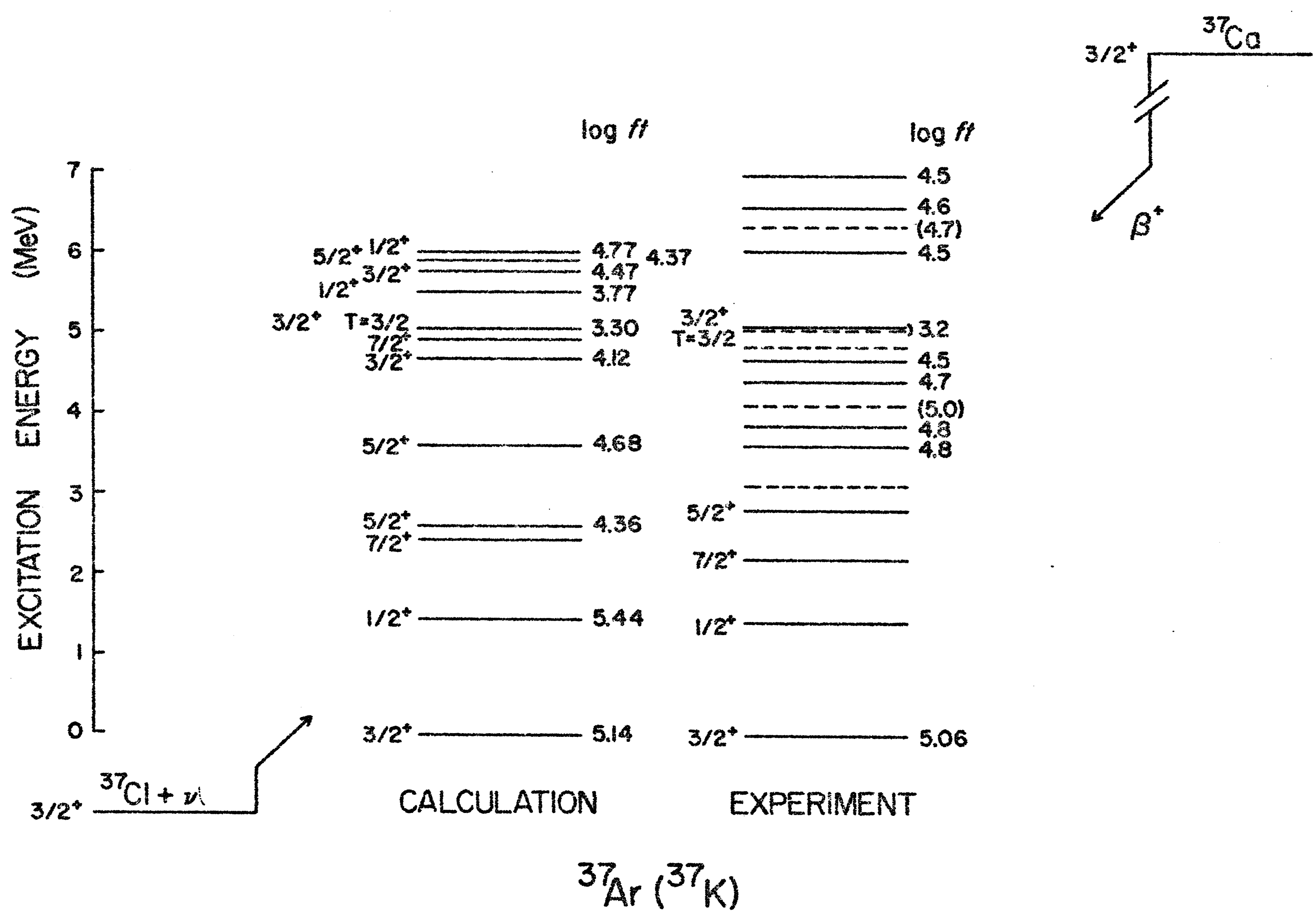
TABLE I: The calculated log(ft) values for transitions which connect the ground state of ^{37}Cl with excited states in ^{37}Ar; these log(ft) values are needed to predict the solar neutrino absorption cross-section.

			log(ft)	
J_f	T_f	E_x(keV)	Bahcall	Present Calculation
3/2	1/2	0	(5.06)[a]	5.14
1/2	1/2	1409	4.48	5.44
5/2	1/2	2797	4.34	4.36
3/2	3/2	4993	3.28	3.30

[a]This is an experimental number, based on the EC of ^{37}Ar.

FIGURE CAPTION

Figure 1 -- The calculated and experimental spectra and log(ft) values for ^{37}Ar(^{37}K). The experimental spectrum includes the known positive parity states in ^{37}Ar below 3 MeV of excitation and the states populated in the beta-decay of ^{37}Ca for the states above 3 MeV. Note that by mirror symmetry, the spectra of ^{37}Ar and ^{37}K should be identical and the beta-decay log(ft) values connecting ^{37}Ca and ^{37}K should equal the log(ft) values connecting ^{37}Cl and ^{37}Ar. The experimental log(ft) values are from Ref. 4. There is no calculated log(ft) to the $7/2^+$ state since it is not an allowed decay.


EXCITATION ENERGY (MeV)
0
1
2
3
4
5
6
7
log ft
log ft
3/2+
37Cl + ν
37Ca
3/2+
β+
5/2+ 1/2+
3/2+
1/2+
3/2+ T=3/2
7/2+
3/2+
5/2+
5/2+
7/2+
1/2+
3/2+
4.77 4.37
4.47
3.77
3.30
4.12
4.68
4.36
5.44
5.14
3/2+
T=3/2
5/2+
7/2+
1/2+
3/2+
4.5
4.6
(4.7)
4.5
3.2
4.5
4.7
(5.0)
4.8
4.8
5.06
CALCULATION
EXPERIMENT
37Ar (37K)