Elastic scattering of electrons by solar neutrinos and weak interaction theories

1971 J. Phys. A: Gen. Phys. 4 L109

(http://iopscience.iop.org/0022-3689/4/6/026)

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Elastic scattering of electrons by solar neutrinos and weak interaction theories

Abstract. The counting rate of recoil electrons for the elastic scattering of electrons by solar neutrinos, considering that the CNO cycle is responsible for nuclear energy generation in the sun, is calculated according to the photon–neutrino weak coupling theory as well as the current–current coupling theory. It is suggested that this result can be used to decide which type of weak interaction exists in nature.

Recently from the energy balance between the nuclear energy generation and the neutrino emission according to the photon–neutrino weak coupling theory it was shown by Ray Chaudhuri (1971) that the sun derives its nuclear energy from the CNO cycle. So the neutrinos from the pp cycle energy generation (Bahcall 1967)

$$\begin{array}{lll}
{}^{1}\mathrm{H}+{}^{1}\mathrm{H}+\mathrm{e}^{-} \rightarrow {}^{2}\mathrm{H}+\mathrm{e}^{+}+\nu_{\mathrm{e}} & (E_{\nu,\mathrm{max}} = 0{\cdot}420\ \mathrm{MeV}) & \\
{}^{2}\mathrm{H}+{}^{1}\mathrm{H} \rightarrow {}^{3}\mathrm{He}+\gamma & {}^{3}\mathrm{He}+{}^{3}\mathrm{He} \rightarrow {}^{4}\mathrm{He}+2{}^{1}\mathrm{H} & \\
{}^{3}\mathrm{He}+{}^{4}\mathrm{He} \rightarrow {}^{7}\mathrm{He}+\gamma & \mathrm{e}^{-}+{}^{7}\mathrm{He} \rightarrow {}^{7}\mathrm{Li}+\nu_{\mathrm{e}} & (E_{\nu,\mathrm{max}} = 0{\cdot}861\ \mathrm{MeV}) \\
\qquad\rightarrow {}^{7*}\mathrm{Li}+\nu_{\mathrm{e}} & (E_{\nu,\mathrm{max}} = 3{\cdot}383\ \mathrm{MeV}) & \\
{}^{7}\mathrm{Li}+{}^{1}\mathrm{H} \rightarrow 2{}^{4}\mathrm{He} & {}^{3}\mathrm{He}+{}^{4}\mathrm{He} \rightarrow {}^{7}\mathrm{He}+\gamma & {}^{7}\mathrm{He}+{}^{1}\mathrm{H} \rightarrow {}^{8}\mathrm{H}+\gamma \\
{}^{8}\mathrm{H} \rightarrow {}^{8*}\mathrm{He}+\mathrm{e}^{+}+\nu_{\mathrm{e}} & (E_{\nu,\mathrm{max}} = 14{\cdot}06\ \mathrm{MeV}) &
\end{array}$$

should not be taken to be responsible for the observed counting rate for the solar neutrino experiment of Reines and Kropp (1964). Therefore only neutrinos from CNO cycle energy generation (Bahcall 1967)

$$\begin{array}{lll}
{}^{12}\mathrm{C}+{}^{1}\mathrm{H} \rightarrow {}^{13}\mathrm{N}+\gamma & {}^{13}\mathrm{N} \rightarrow {}^{13}\mathrm{C}+\mathrm{e}^{+}+\nu_{\mathrm{e}} & (E_{\nu,\mathrm{max}} = 1{\cdot}20\ \mathrm{MeV}) \\
{}^{13}\mathrm{C}+{}^{1}\mathrm{H} \rightarrow {}^{14}\mathrm{N}+\gamma & {}^{14}\mathrm{N}+{}^{1}\mathrm{H} \rightarrow {}^{15}\mathrm{O}+\gamma & \\
{}^{15}\mathrm{O} \rightarrow {}^{15}\mathrm{N}+\mathrm{e}^{+}+\nu_{\mathrm{e}} & & (E_{\nu,\mathrm{max}} = 1{\cdot}74\ \mathrm{MeV}) \\
{}^{15}\mathrm{N}+{}^{1}\mathrm{H} \rightarrow {}^{12}\mathrm{C}+{}^{4}\mathrm{He} & &
\end{array}$$

are mainly responsible for the observed counting rate of the solar neutrino experiment of Davis *et al.* (1968) and the solar neutrino experiment of Reines and Kropp (1964) should be adjusted along this line. Assuming a certain lepton–hadron relation proposed by Bandyopadhyay (1964) (the configuration for the neutron and proton was taken as $\mathrm{n} = \mu^{-}\mathrm{B}^{+}$ and $\mathrm{p} = \nu_{\mu}\mathrm{B}^{+}$, where B is the baryonic matter) and the dynamical origin of charge (Bandyopadhyay 1970), Bandyopadhyay (1971, submitted for publication) has calculated the cross section for the absorption of neutrinos by ^{37}Cl and has predicted

$$\Sigma\phi\sigma = 0{\cdot}9\times 10^{-36}\ \mathrm{s}^{-1} \text{ per } ^{37}\mathrm{Cl} \text{ atom for the CNO cycle}$$

and

$$\Sigma\phi\sigma = 0{\cdot}2\times 10^{-36}\ \mathrm{s}^{-1} \text{ per } ^{37}\mathrm{Cl} \text{ atom for the pp cycle.}$$

So the theoretically predicted $\Sigma\phi\sigma$ according to this model of weak interactions is well within the experimental upper limit (Davis *et al.* 1968).

Reines and Kropp (1964) have attempted to detect solar neutrinos produced from (^{8}H decay) pp cycle nuclear energy generation using knock-on electrons in ν–e scattering (ν_e (solar) + $e^- \rightarrow \nu_e + e^-$). This experiment is important in distinguishing the different weak interaction theories and to judge which weak interaction theory exists in nature. The advantage of using this reaction for the observation of solar neutrinos is that it permits the measurement of neutrino energy and the direction in principle. In the experiment of Reines and Kropp, the secondary electron is projected forward with a cone of ± 10 ° with respect to the primary neutrinos. This experiment consisted of looking for unaccompanied counts in a 200 litre liquid scintillator detector (5×10^{28} target electrons) which was surrounded by a large Cerenkov anticoincidence detector and located 2000 ft underground (to avoid background effects) in a salt mine. They have observed 3 counts in 4500 h of recoil electrons in the energy range (8 to 14 MeV), unaccompanied by pulses in the anticoincidence guard, which is 20 times the predicted counting rate from $(e\nu_e)(e\nu_e)$ coupling theory (Bahcall 1967). It can be shown that according to the photon–neutrino weak coupling theory the predicted counting rate is about 10^4 times less than the observed counting rate. So it seems that Reines and Kropp probably observed background effects. It is pointed out above that the CNO cycle is responsible for the nuclear energy generation in the sun, thus neutrinos from the CNO cycle cannot produce a recoil electron energy greater than 2·24 MeV. So the solar neutrino experiment of Reines and Kropp should be modified to observe counts from solar neutrinos in the energy range 1 to 2·24 MeV of the recoil electron. Although this type of interaction (ie scattering electrons by low energy neutrinos in the energy range 1·20 to 1·74 MeV) is not very feasible, it should be possible to observe solar neutrinos from the counting rate if a suitable scintillator with the same number of target electrons as Reines and Kropp is used.

Assuming the events of recoil electrons in the energy range 1 to 2·24 MeV produced by the elastic scattering of neutrinos from 150 (maximum neutrino energy as predicted from CNO cycle energy generation in the sun) decays, we have calculated the cross section for this scattering and the predicted counting rate both from $(e\nu_e)(e\nu_e)$ coupling theory and the photon–neutrino coupling theory by taking the same number of target electrons (ie $N = 5\times 10^{28}$) as used in the Reines and Kropp experiment. The results are displayed in table 1.

It is observed that if the experiment of Reines and Kropp is modified as suggested then according to $(e\nu_e)(e\nu_e)$ coupling and the photon–neutrino coupling theory the maximum counting rate 135 and 3 in 100 day respectively should be observed in the recoil electron energy range 1 to 2·24 MeV. From this experiment and the following three experiments it should be possible to decide which type of weak interactions exists in nature. (i) Solar neutrino experiment of Davis *et al.* (1968). (ii) Elastic scattering of electrons by fission antineutrinos (Reines and Gurr 1970, Bandyopadhyay and Ray Chaudhuri 1971). (iii) The interaction ^{37}Cl (ν_e, e^-) ^{37}Ar from neutrinos

Table 1. Elastic scattering of ^{15}O neutrinos

Energy of recoil electron (E in MeV)	$\sigma(E)$ (cm^2)		Calculated rate $R_1 \times 10^2$ day^{-1}	
	current–current coupling theory	photon–neutrino coupling theory	current–current coupling theory	photon–neutrino coupling theory
1·0	9×10^{-45}	$2{\cdot}06 \times 10^{-46}$	135	3·1
1·25	$8{\cdot}33 \times 10^{-45}$	$1{\cdot}05 \times 10^{-46}$	125	1·6
1·5	$6{\cdot}75 \times 10^{-45}$	$6{\cdot}60 \times 10^{-47}$	101	1·0
1·74	$5{\cdot}32 \times 10^{-45}$	$4{\cdot}82 \times 10^{-47}$	80	0·7
2·24	$1{\cdot}81 \times 10^{-45}$	$3{\cdot}13 \times 10^{-47}$	27	0·5

$R_1 = \sigma_e(E)Nf$, $N = 5 \times 10^{28}$ target electrons, f = predicted neutrino flux from CNO cycle $= \phi_\nu\,(^{13}\mathrm{N}) = \phi_\nu\,(^{15}\mathrm{O}) = 3{\cdot}5 \times 10^{10}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

generated by mesons in the laboratory as proposed by Davis (1971, private communication).

We conclude that the experiment as suggested in this paper and the final conclusion from the solar neutrino experiment of Davis *et al.* (1968) not only determines the nature of weak interactions but also gives us a clue in determining whether our present sun burns in the pp or CNO cycle.

I should like to thank P. Bandyopadhyay for helpful discussions.

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31st August 1971

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Explosive instability in a collisionless shock

Abstract. It is pointed out that, in the configuration of a perpendicular collisionless shock, a resonant interaction is possible between a negative energy Bernstein mode and two positive energy ion acoustic modes. An estimate is made of the growth rate of the resulting explosive instability.

Recently, a number of authors have investigated the drift cyclotron instability, which occurs when electrons drift relative to ions in a direction perpendicular to