Neutrino Detection using Lead Perchlorate

P. J. Doe, S. R. Elliott, C. Paul, R. G. H. Robertson[a]

[a]University of Washington, Seattle, Washington 98195, USA

We discuss the possibility of using lead perchlorate as a neutrino detector. The primary neutrino interactions are given along with some relevant properties of the material.

1. Introduction

Due to its large cross section and relative cheapness, a number of groups have expressed interest in using Pb as a target for neutrino interactions to study supernovae[1,2] or oscillations[3]. As a result there have been several cross section calculations done recently[1,4,5]. The interesting neutrino interactions on Pb consist of:

$$\begin{array}{lcll} \nu_e +^{208} Pb & \Rightarrow & ^{208}Bi^* + e^- & (CC) \\ & & \Downarrow & \\ & & ^{207}Bi + x\gamma + yn & \end{array}$$

$$\begin{array}{lcll} \nu_x +^{208} Pb & \Rightarrow & ^{208}Pb^* + \nu_x^{'} & (NC) \\ & & \Downarrow & \\ & & ^{207}Pb + x\gamma + yn & \end{array}$$

The number of neutrons emitted (0, 1, or 2) depends on the neutrino energy and whether the interaction is via the charged current (CC) or neutral current (NC). The nuclear physics of this system is described in Ref. [4].

A lead-based neutrino detector must have an appreciable density of Pb atoms and the capability of detecting the electrons, gammas and neutrons produced in the reaction. Lead Perchlorate ($Pb(ClO_4)_2$) has a very high solubility in water (500 g $Pb(ClO_4)_2$ /100 g H_2O [6]) and the saturated solution appears transparent to the eye. The cost for an 80% solution is approximately \$10,000/tonne in quantities of 100 tonne [8]. This raises the possibility that a cost effective, Pb based, liquid Čerenkov detector can be constructed. The presence of ^{35}Cl provides a nucleus with a high cross-section for neutron capture with the subsequent emission of capture γ rays totaling 8.4 MeV.

Table 1
Some properties of an 80% $Pb(ClO_4)_2$ solution.

^{208}Pb number density	1.7 x 10^{21}cm^{-3}
^{208}Pb(ν_e, e^-) at 30 MeV	34.22 x 10^{-40}cm^{-3}
^{35}Cl n capture cross-section	44.0b
Density	2.7 gm cm^{-3}
Refractive index	1.50

Using Pb as a target would make a powerful supernova detector [1,4]. The average energies of neutrinos emitted by a supernova are expected to follow a heirarchy: $E_{\nu_e} < E_{\bar{\nu}_e} < E_{\nu_{\mu,\tau}}$ The observation of high energy ν_e would be an indication of μ, τ oscillations.

The large cross section and delayed coincidence ν_e signature of Pb could provide a high statistics oscillation experiment at a beam stop [7] where a short duration beam spill such as at ISIS allows the temparal separation of any mono energetic ν_e which result from ν_μ oscillation. The hydrogen content of $Pb(ClO_4)_2$ solution also makes the detector sensitive to $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations. Finaly, measuring the cross section for neutrino interactions in Pb is also of importance to supernova modelers[4] investigating the explosion mechanism and transmutation of nuclei.

2. Physical Properties

Some relevant properties of $Pb(ClO_4)_2$ are given in Table 1. To build a large Čerenkov detector viewed by photo-multiplier tubes from the periphery, the attenuation of the light must be minimal. Data on the refractive index, spec-

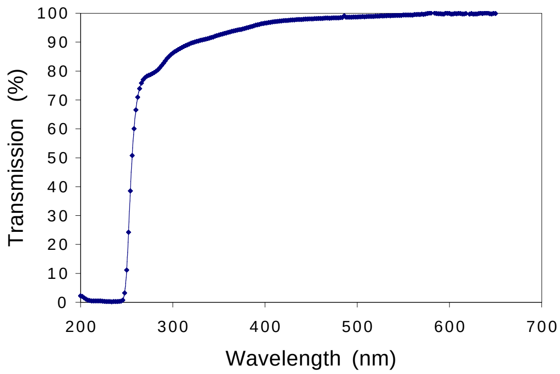

Figure 1. Spectral transmission though a 1 cm cell of 80% solution of $Pb(ClO_4)_2$ referenced to deionized water

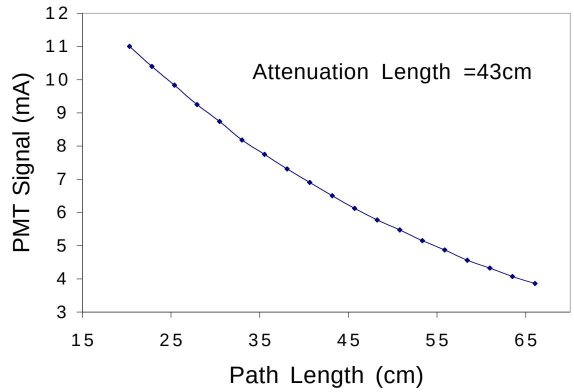

Figure 2. Attenuation length of 430 nm light in 80% $Pb(ClO_4)_2$.

tral transmission and attenuation length of various $Pb(ClO_4)_2$ solutions were obtained using an 80% solution from a commercial source [8]. No attempt to filter suspended particulates or purify the solution was made. The strength of the solution was reduced using deionized water with an attenuation length of greater than 20 meters. The spectral trasmission, referenced with respect to a deionized water sample is given in Figure 2. There are no obvious absorption regions seen in the $Pb(ClO_4)_2$ sample between 300 and 600 nm, the sensitive region of most PMT's. Figure 3 shows the attenuation of light at 430 nm in an 80% solution. These data were obtained by passing a monochromatic, collimated beam of light through a column of liquid and measuring the transmittance using a PMT. The length of the column could be varied from 0 $\rightarrow$100 cm length

3. Discussion

The lack of absorption lines in the transmission spectrum of $Pb(ClO_4)_2$ is encouraging. However, the current attenuation length of 43 cm in an 80% solution is too small to realize a conventional Čerenkov neutrino detector. Further more, diluting the solution with high purity water resulted in significant reduction of the attenuation length while the transmission spectra were uneffected. This suggests that the loss of light is due to scattering, perhaps due to the formation of Pb salts or polymeric molecules such as $Pb_4(OH)_4$, possibly as a result of reaction with dissolved O^2 and CO^2. The science of building massive, low background water Čerenkov detectors is well understood. To demonstrate the feasibility of a $Pb(ClO_4)_2$ Čerenkov detector, it remains to investigate the chemistry pertinant to light transmission in the solution.

REFERENCES

1. C. K. Hargrove, *et al.*, Astroparticle Physics **5**, 183 (1996).
2. D. B. Cline *et al.*, Phys. Rev. **D50**, 720 (1994); P. F. Smith, Astroparticle Physics **8**, 27 (1997).
3. C. K. Hargrove, private communication.
4. G. M. Fuller, W. C. Haxton, and G. C. McLaughlin, Phys. Rev. D**59**, 085005 (1999).
5. E. Kolbe, K. Langanke, and G. Martínez-Pinedo, Phys. Rev. C**60**, 052801 (1999).
6. Handbook of Chemistry and Physics, 65^{th} edition, CRC Press, Inc.
7. B. Armbruster, *et al.*, Phys. Rev. **C57**, 3414 (1998).

8. GFS Chemicals, P.O. Box 245, Powell, OH 43065.