

Re NaCl tubes and other options?

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1) According to the white book with 2.5 t of NaCl in 99.85% D2O 83% of the neutrino neutrons are captured in Cl or D and about 60% of these give gamma rays above 6 MeV. Peter Skensved can tell us the probability of detecting these photons once they are produced. Jerry Wilhelmy has mentioned in passing that his calculations don't agree with CRNLs but they are close enough. (He says that 87% of neutrons are captured in Cl with 100% D2O)

2) According to Jerry 3He tubes which are on a 75 cm lattice, 2 cm inradius and with 3 atm of 3He capture 49% of the neutrino neutrons. Of course all these neutrons give detected signals.

3) If these same tubes were filled with NaCl, density 2.2 g/cm³ (a very optimistic concentration) then the probability of capturing a neutron is 77% of the 3He probability. This number is from a comparison of the atom density and neutron cross sections for 3He and Cl and does not take into account the fact that in the case of the NaCl as compared to 3He there are more neutrons passing through a tube and later captured in another tube. This has got to be a second order effect. Still over 40% of the neutrons should be captured in Cl. This tube option has nearly twice the salt of the dissolved salt option i.e. 4.5 tonnes if I use the equation in the LANL 3He report on volume in the tubes assuming a 75 cm lattice and 2 cm diameter. So for nearly twice the NaCl and radioactivity we get 1/2 the signal. This does not appear to be an attractive option at this point. Putting the NaCl into the tubes in a solution would make the tubes larger in diameter.

LANL has calculated this tube option for a more realistic NaCl concentration in the tubes and come to the same conclusion i.e. that not more than 40% of the neutrons can be captured in NaCl tubes. There appears to be an inconsistency between their Monte Carlo and my back of the envelope in that for 5 times more NaCl I get more or less the same capture probability. Nevertheless our conclusion is the same- NaCl tubes are unattractive.

4) If 2.5 t of NaCl is a no-no then we have to return to an examination of the 4.6 kg Gd option. It has the same neutron capture probability of 83%. The energy of the gamma rays are about 75% of the NaCl option according to the white book which says the average # of PMTs hit is 33 and 25 for NaCl and Gd. But as we show below this white book estimate appears to be in error. Bonvin has mentioned to David and I the alternative of using Cd. The Gd/Cd neutron cross section ratio is 20 so we need 92 kg of Cd but the Q value is higher and there is quite a bit more gamma ray intensity above 6 MeV. To be quantitative about the hardness of the spectra I get that one gets a greater than 5 Mev gamma ray about 15% of the time with Gd and about 30% of the time with Cd. If Gd deserves a second look and 92 kg is ok then we should also get quantitative about Cd.

delta E	Gd intensity	Cd intensity
0-1 MeV	0.7	1.9 gammas per neutron capture
1-2	1.3	0.9
2-3	1.0	0.9
3-4	0.5	0.5
4-5	0.2	0.3
5-6	0.1	0.2
6-7	0.03	0.05
7-8	0.002	0.02
8-9	-	0.01

But the water purity people say that Cd is too toxic and they would not be able to remove it from the D2O at the end of the experiment.

Sm has a higher cross section than Cd, the highest multiplicity of all the elements but the spectrum looks softer than Gd. Still we might look at it also. ??

Both Gd and Cd could also be put in tubes or acrylic rods if we had to go the tube route and that would seem to be a possibility whereas the amount of NaCl required seems to rule out the tube option for it.

5) Peter Skensved has calculated the SNO detector response from dissolved Gd. To do this he has to assume a decay scheme. This is possible for Cl since the bulk of the transitions are known but only 20% of the Gd transitions are known so we "created" the transitions. This is an idealized decay scheme and is definitely more favorable for SNO than reality.

We assume

E(gammas) in cascade	Probability
7.5 + 0.5	0.002
6.5 + 1.5	0.03
5.5 + 2.5	0.1
4.5 + 3.5	0.2
3.5 + 2.5 + 2	0.3
2 x 2.5 + 2 x 1.5	0.3
4 x 1.5 + 2 x 1	0.2

This decay scheme has a total decay probability of 1.13 (1.0 is correct) and the intensity per capture as compared to reality is

delta E	Intensity/capture	
	fake scheme	reality
0-1	0.4	0.7
1-2	1.4	1.3
2-3	1.2	1.0
3-4	0.5	0.5
4-5	0.2	0.2
5-6	0.1	0.1
6-7	0.03	0.03
7-8	0.002	0.002

The response of the SNO detector is available in graphical form. The peak of the response is below 4 MeV as compared to above 6 MeV for Cl and the ratio of detected events above 5 MeV is about 1:3. Not an attractive alternative.

Conclusion: We want dissolved NaCl if at all possible. If not possible we should make certain dissolved Cd is out before considering Gd or just D2O. Acrylic rods containing Cd might be better than dissolved Gd and should be calculated.