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High Energy Gamma Rays from the $^{27}Al(\alpha,p\gamma)$ Reaction

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We have directly measured the high energy gamma production from alpha capture on Al targets with Berkeley's 88-Inch Cyclotron. In earlier collaboration meetings, some concern was expressed regarding the viability of Al as a construction material for SNO due to the possibility of large fluxes of background γ rays with energies greater than 5 MeV.

We measured the in-beam gamma ray production from a thick (0.020 inch) Al target. We used two Ge detectors situated at 30.5 and 109.9 degrees wrt to the beam. The absolute detection efficiency was determined using a calibrated ^{238}Pu-^{13}C Source and standard low energy gamma ray sources. These efficiencies were checked against γ rays yields for other reactions at these energies, specifically the $^{12}C(\alpha,\gamma)$ yield from the careful work of Dyer and Bodansky. In extrapolating the efficiency upwards from the highest γ rays source energy, we assumed that $\varepsilon_\gamma \; \alpha \; 1/E_\gamma$

The detectors were placed in close geometry, approximately 3 inches from the target position at the specified angles. The use of these two angles permits the determination of the absolute cross section for transitions with multipolarity less than or equal to 2 (zeros of the appropriate Legendre Polynomials).

We ran at two energies, 8.80 and 7.70 MeV, chosen to match the maximum alpha energy from the Th and U chains. The gain in the detectors was set to observe upto 10 MeV in γ ray energy. We observed many of the γ rays noted in the literature for the $^{27}Al(\alpha,p\gamma)$ reaction (see Table I and II).

To relate these production rates to the yield of γ rays above 6 MeV in Al due to natural radioactivity we make the following assumptions:

[U] = [Th] = 1 ppm (so each 1000 kg of Al contains 1 g each U, Th)

$N_U\lambda_U = 1.08 \times 10^9$/day

$N_{Th}\lambda_{Th} = 3.53 \times 10^8$/day

and that only the highest energy α for each chain is significant for γ ray production. So from Table I and II we see:

$$
\begin{aligned}
N_{\gamma \geq 6\ MeV} &= (3.53 \times 10^{8}/day)(1.68\times10^{-7}) + (1.08 \times 10^{9}/day)(6.54\times10^{-8}) \\
&= 59.3 + 70.6\ /day \\
&= 130/day\ per\ 1000\ kg\ Al
\end{aligned}
$$

Assuming only 1/2 go towards the D_2O and getting the attenuation factor from the Red Book (2.5 m of water $\Rightarrow 8 \times 10^{-4}$) we conclude that:

number of γ rays $\geq$6 MeV reaching the D_2O is 0.052/day/1000 kg Al

Table I

8.80 MeV α + ^{27}Al

E_γ (keV)	Y_γ (per α)
4809	3.9×10^{-7}
5890	2.3×10^{-8}
6530	3.7×10^{-8}
6745	8.1×10^{-8}
6914	2.0×10^{-8}
7265	7.5×10^{-9}
7635	6.5×10^{-9}

$$\sum_{5890}^{7635} Y_\gamma = 1.75 \times 10^{-7} \text{ per } \alpha$$

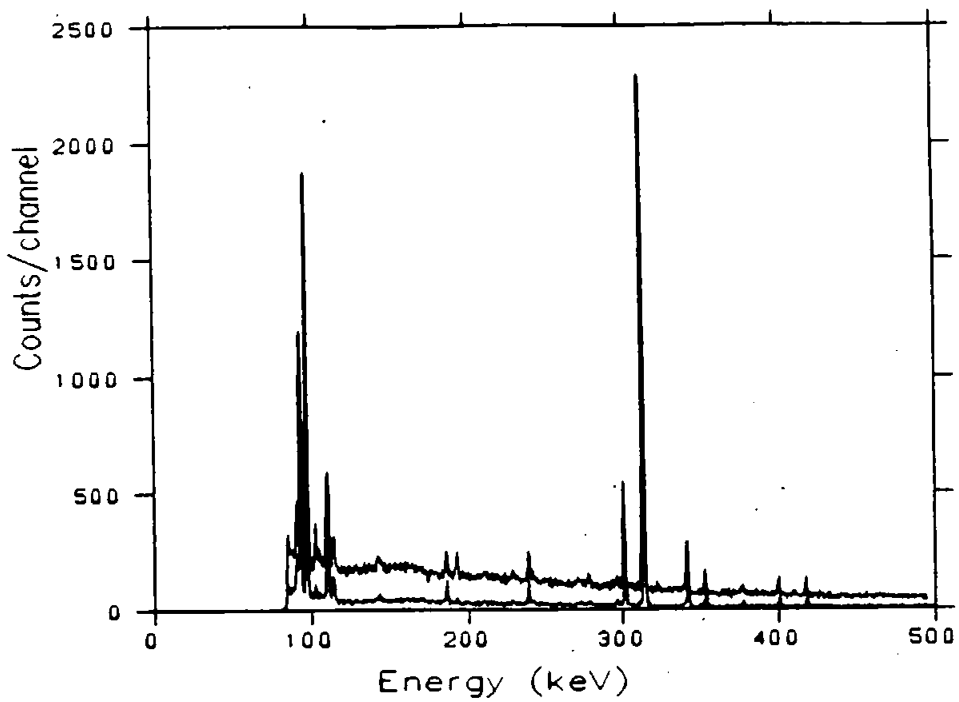

Figure 2: γ-Ray spectrum of chemically separated acrylic sample. Compton suppression was used to obtain the lower curve.

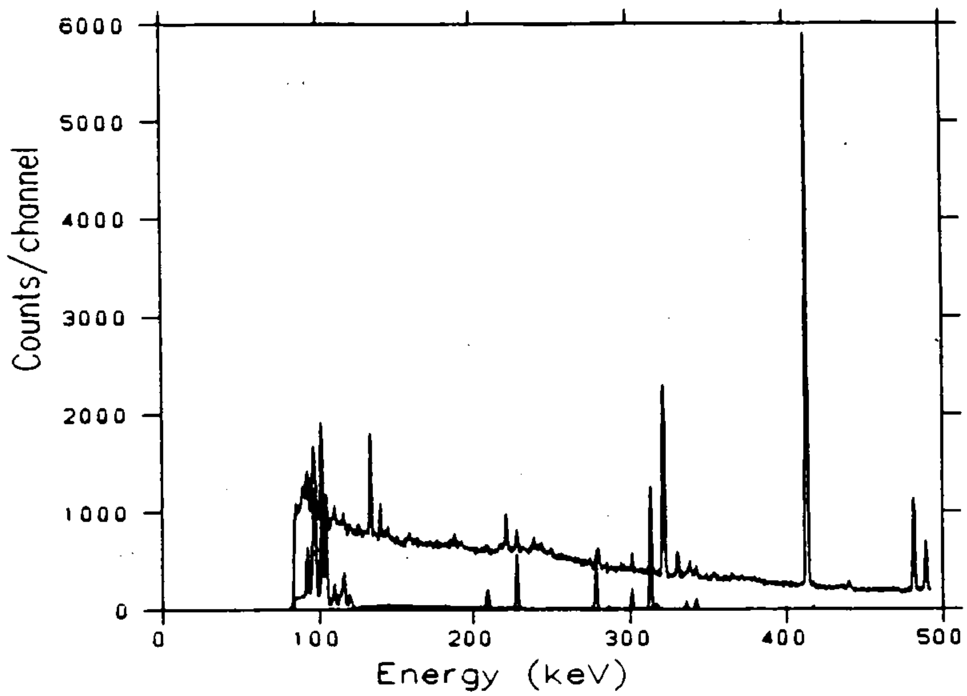

Figure 3: Compton suppressed spectrum of acrylic. (Same as middle curve in figure 1.) The lower curve is the calibration source which contained known amounts of thorium and uranium.