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GAMMA-RAY PRODUCTION CROSS SECTIONS FOR ALPHA-PARTICLE INDUCED REACTIONS ON ^{19}F AND ^{23}Na

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DISCLAIMER

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Abstract Production cross sections have been measured for γ-ray lines excited in α-particle bombardments of a NaF target for beam energies from 4.5 to 26 MeV.

INTRODUCTION

The understanding of spectra obtained from γ-ray astronomical observatories requires knowledge of γ-ray production cross sections for a large number of proton and α-particle induced reactions. In addition, proton and α-particle induced γ-ray emission can serve as useful tools for quantitative elemental analysis if the requisite cross sections are known. As part of a study of the nucleosynthesis of ^{26}Al via the ^{23}Na (α,n) reaction[1], we measured γ-ray yields from α-particle interactions with a NaF target. In the present work, production cross sections have been determined for the γ-ray lines most strongly excited in these bombardments.

EXPERIMENTAL METHOD

Gamma-ray production cross sections were measured for beam energies of 4.5 to 26 MeV. A 50 cm^3 Ge(Li) detector was used to observe γ rays produced in α-particle bombardments of a target that consisted of 730 μg/cm^2 of NaF evaporated onto a 27 μg/cm^2 carbon foil. The NaF thickness was determined from the energy loss in the target of α particles from a ^{241}Am source.

The detector was positioned 23.2 cm from the target center and was oriented at 90 degrees with respect to the beam direction for most of the data collection. Angular distributions were measured at 5, 10, 16, and 19 MeV to correct the 90 degree measurements for anisotropy in γ-ray emission.

Spectra of γ rays from 0.07 to 3.8 MeV were accumulated in either 4096 or 8192 channels. Detector energy and efficiency calibrations were performed in the experimental geometry by placing calibrated γ-ray sources at the target position. Alpha-particle beams were provided by the University of Washington tandem accelerator. Dead time corrections were determined by sending signals from a pulser into the Ge(Li) preamp and into a scaler. The energy resolution of the system was approximately 2.9 keV (FWHM) for the 1332 keV ^{60}Co line.

RESULTS

Figure 1 illustrates the γ-ray spectrum observed during the bombardment of the NaF target with 12.0 MeV α particles.

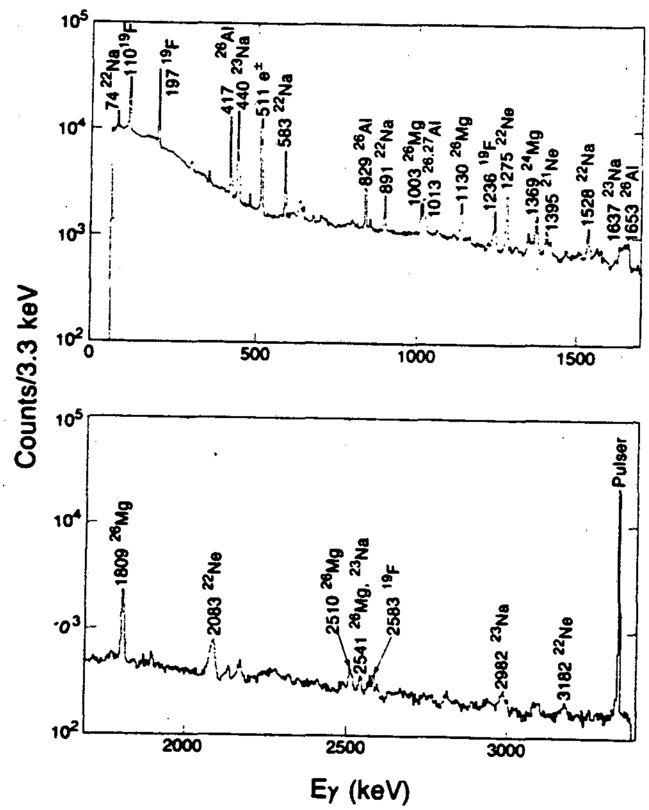


FIGURE 1 γ-ray spectrum observed at 90 degrees from 12 MeV α-particle interactions with NaF.

Twelve of the strongest lines were selected for analysis. The 110- and 197-keV lines are the 1-0 (i.e., first excited to ground state) and 2-0 transitions in ^{19}F produced by inelastic α scattering. The 583-, 891- and 1528-keV γ rays are the 1-0, 3-0, and 4-0 transitions in ^{22}Na produced by the $^{19}F(\alpha,n)$ reaction. The 1275-keV line is the 1-0 decay in ^{22}Ne from the $^{19}F(\alpha,p)$ reaction. The 440-keV feature is the 1-0 decay in ^{23}Na resulting from inelastic α scattering. The 417- and 830-keV 2-0 and 3-1 transitions in ^{26}Al are produced by the $^{23}Na(\alpha,n)$ reaction. The 1809-keV line is the 1-0 transition in ^{26}Mg resulting from the $^{23}Na(\alpha,p)$ reaction. The 1130-keV line includes contributions from the 2-1 transition in ^{26}Mg and from the single escape peaks of the multiplet of γ rays near 1640 keV.

Peak areas for these lines were extracted from the data. Interpolations and extrapolations based on the angular distribution measurements were used to convert the observed 90-degree yields into the total production cross sections illustrated in Figure 2. Representative error bars are shown for a few points on each excitation function.

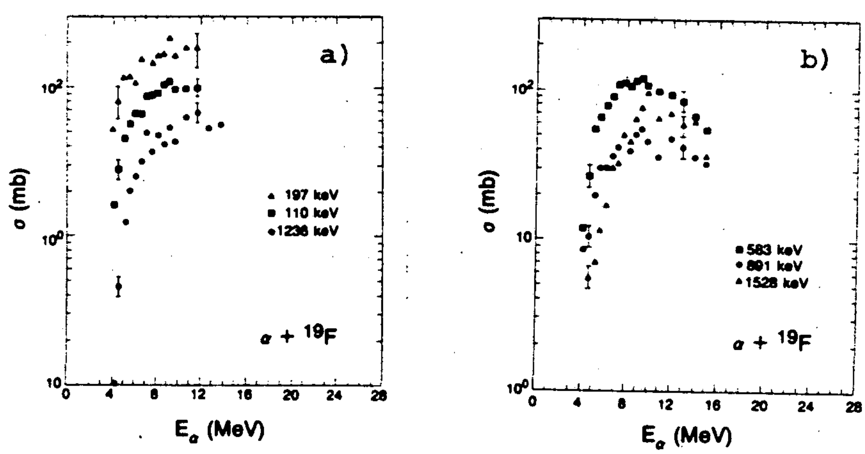
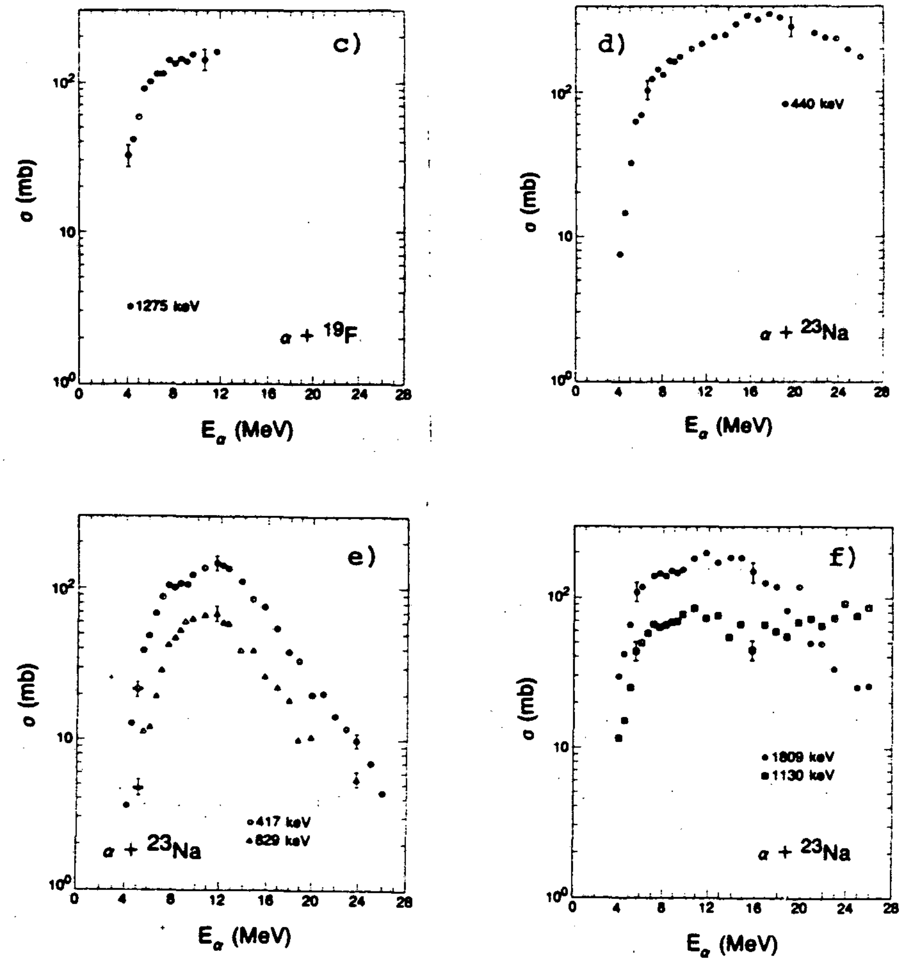


FIGURE 2 γ-ray production cross sections for α + ^{19}F (a-c) and α + ^{23}Na (d-f) reactions.

For relatively high bombarding energies ($\geq$ 12 - 15 MeV) ^{19}F, ^{22}Ne, and ^{22}Na can be produced by α-induced reactions on ^{23}Na. Thus, the cross sections for γ rays from these nuclei are reported only for those energies where they can be uniquely attributed to reactions on ^{19}F.

While the solar-system abundances of F and Na are fairly low, it is possible that in some astronomical environments their abundances may be enhanced. Thus, the potential usefulness of the present results will have to await further γ-ray observations from space.



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