Title

MAGNETIC FIELD DEPENDENCE OF Am2^3 O.-V-ANGUIAR CORRELATIONS

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I. INTRODUCTION

Strong perturbations have been shown to occur in α-γ angular correlations of Am^{243} and Cm^{243} when the α decay recoils are allowed to enter a vacuum or a mylar enviornment.(1) These perturbations were attributed to a magnetic interaction involving the orbital electron shell excited in the α decay process and the magnetic moment of the nucleus. When a magnetic field was applied parallel to the path of the α particles, the correlation appeared to be restored in part, but the results were not conclusive.

Perturbations interpreted as a magnetic interaction have also been observed in Hg^{197m} electron-gamma angular correlations. By applying a magnetic field parallel to the α particle path essentially all of the perturbation assigned to the internal magnetic interaction was removed.(2) In the present experiments the anisotropy of the Am^{243} α-γ angular correlation (with recoils traveling into vacuum or into Ag) was investigated as a function of an applied magnetic field.

II. APPARATUS

A diagram of the apparatus is shown in Fig. 1. The electromagnet consisted of two coils of 5700 turns of #22 Cu wire, each wound on hollow iron cores. Fields up to 12 kilogauss were obtained, homogeneous to ~ 10% over the area of the sample. Six openings at 90° or 180° from each other were available for the detectors, source and vacuum pump-out.

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The α detector was a 6-mm diameter Au-Si surface barrier counter kindly provided by Dr. R. Latimer of the Lawrence Radiation Laboratory. This detector was placed inside one of the hollow iron cores and subtended an angle of 1% of 4π at the source. The α pulses from the detector were amplified, biased, and fed to a single channel pulse height analyzer. This analyzer could select α groups of any desired energy. Its output was then used to gate a multichannel pulse height analyzer. The resolution of the α detector was 25 keV, full width at half maximum.

The γ detector was a 3" diameter by 3" thick NaI crystal commerically mounted (Harshaw) on a 6393 Dumont photomultiplier tube. A solid angle of ~ 2% of 4π was subtended at the source. The γ detector could be moved to either the 90° or 180° position relative to the α detector and gave reproducible results to better than 1% precision. The output of the γ detector, after amplification, was fed into the signal input of the multichannel analyzer.

III. SAMPLE PREPARATION

The source material was vaporized from a white hot tungsten filament onto a cold Ag foil, 0.0001" in thickness. The radioactive material, which was invisible, was distributed over an area 0.6 cm in diameter and had an average thickness of 1.4 ugm/cm^2 of Am^{243}. The source composition by α activity was 36% Am^{243}, 16% Am^{241}, and 48% Cm^{244}. The α particles in most of the experiments passed through the 0.0001" Ag foil before reaching the α detector in order to allow the α daughters to recoil into the vacuum system. The Ag foil smeared the α spectrum to such an extent it was not possible to resolve α_{75} and α_{118} of Am^{243} (α_x refers to the α group populating a state X keV above the ground state of the daughter nucleus and γ_x refers to the gamma ray with an energy of X keV).

IV. UNPERTURBED ANGULAR CORRELATION

A partial decay scheme of Am^{243} is shown in Fig. 2. The α-γ correlation of interest is that between the most intense α group and the 75 keV gamma ray. The theoretical unperturbed correlation depends on the relative amounts of L = 0 and L = 2 angular momentum waves in the main α transition. From the reduced intensities(3) of the α transitions to the rotational band based on the 75 keV state and the Bohr, Freemen and Mottelson theory,(4) the ratio of L = 2 to L = 0 transitions calculated in the usual way is 0.22.(1) This corresponds to an anisotropy of 46.5% if the two waves are nearly in phase. Chasman and Rasmussen(5) have considered the effect of quadrupole coupling in U^{233} α decay and have deduced that the L = 2 admixture in the main α transition ought to be increased by 43%. If we apply this correction to the Am^{243} angular momentum ratios, the theoretical anisotropy becomes 50.5%. The anisotropies for the α_{75} - γ_{75} correlation will be reduced somewhat by the α_{118} - γ_{75} triple correlation, which has a theoretical unperturbed anisotropy of ~ 0.06 if we assume a pure L = 2 α wave. The resulting theoretical unperturbed anisotropies for the combined $(\alpha_{75} + \alpha_{118})$ - γ_{75} correlation are shown in Fig. 3.

V. RESULTS

The experimental anisotropies for the combined $(\alpha_{75} + \alpha_{118})$ - γ_{75} angular correlation, with recoils going into vacuum are shown in Fig. 3 as a function of an applied magnetic field. The values have been corrected for the finite size of the source and detectors. With no applied magnetic field our anisotropy is consistent with the hard core value for a static interaction, G_2 ~ 0.20 for the combined correlation. It is also, however, reasonably close to the previous value,(1) which was definitely below the hard core value (Fig. 4). (Our experiment differed principally from the previous one in that our source was about an order of magnitude thicker.

As seen in Fig. 3 the anisotropies become more pronounced with increasing magnetic field parallel to the α path. This is the type of behavior expected for a hyperfine structure interaction.[6] Thus our results confirm the earlier diagnosis[1] as to the cause of the perturbations observed in vacuum.

Our results are presently not adequate to determine the validity of the corrections of Chasman and Rasmussen. In Fig. 4 we have assumed these corrections to be valid and have plotted the attenuation factor, G_2, as a function of the applied magnetic field. With the exception of the point at 0 field the remaining points, which have relatively large standard deviations, appear to exhibit an exponential dependence on the magnetic field. The shape of this curve could be analyzed theoretically from the equations of Goertzel.[6]

With the recoils going into the Ag backing material the anisotropy for the $\alpha_{75} - \gamma_{75}$ angular correlations with no applied magnetic field is -0.30 ± 0.02, in good agreement with the earlier[1] value of 0.28. Our value corresponds to G_2 (with the Chasman and Rasmussen correction) of 0.54 ± 0.05. With an applied magnetic field of 1.1 kilogauss, the anisotropy is 0.29 ± 0.03 corresponding to a G_2 of 0.52 ± 0.05. Thus the attenuation is not reduced by the application of a magnetic field; hence, the observed perturbations, with recoils going into Ag, are caused by field gradients external to the recoiling atom.

VI. ACKNOWLEDGMENTS

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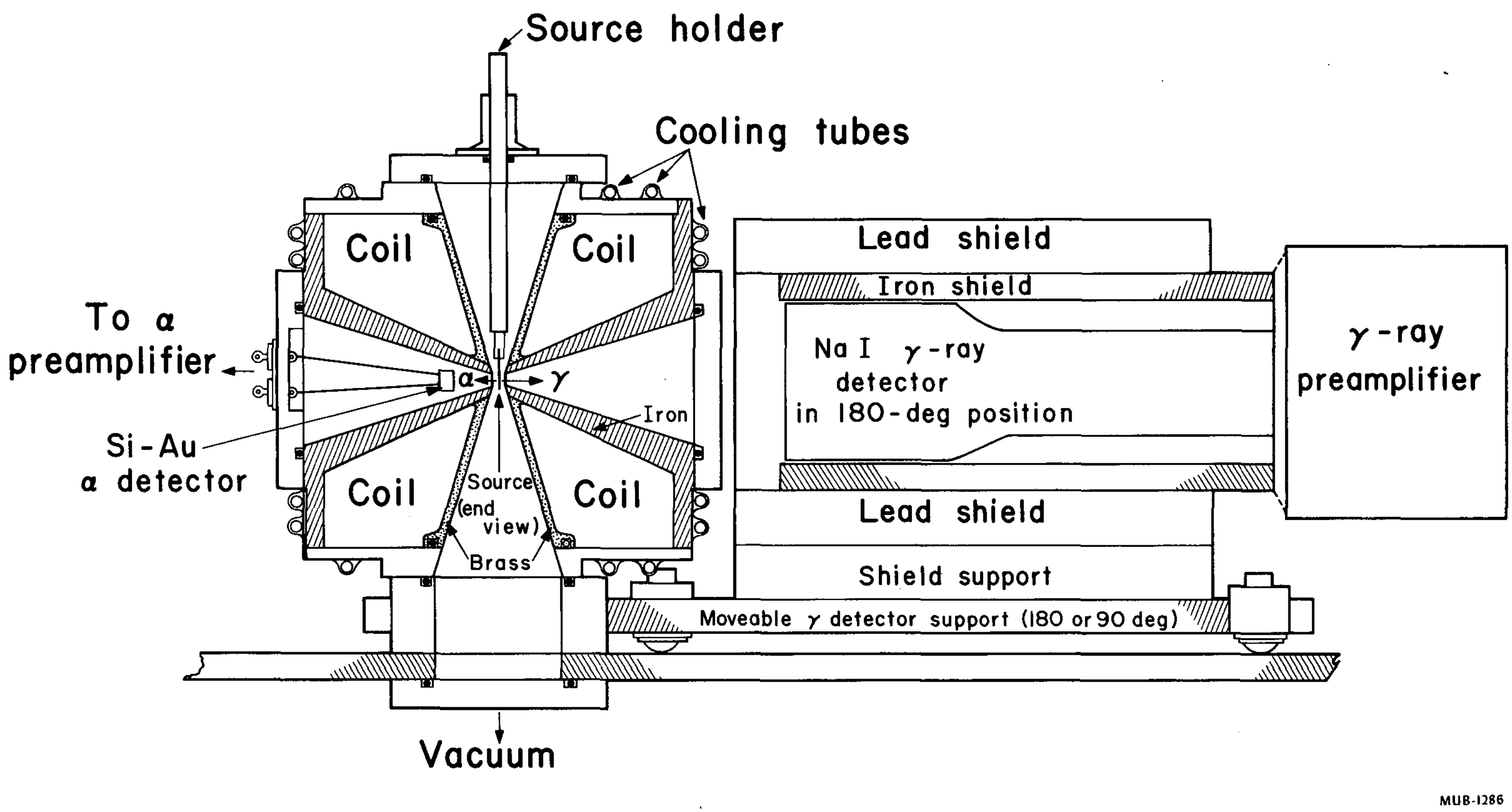

Fig. 1. Diagram of the angular correlation magnet.

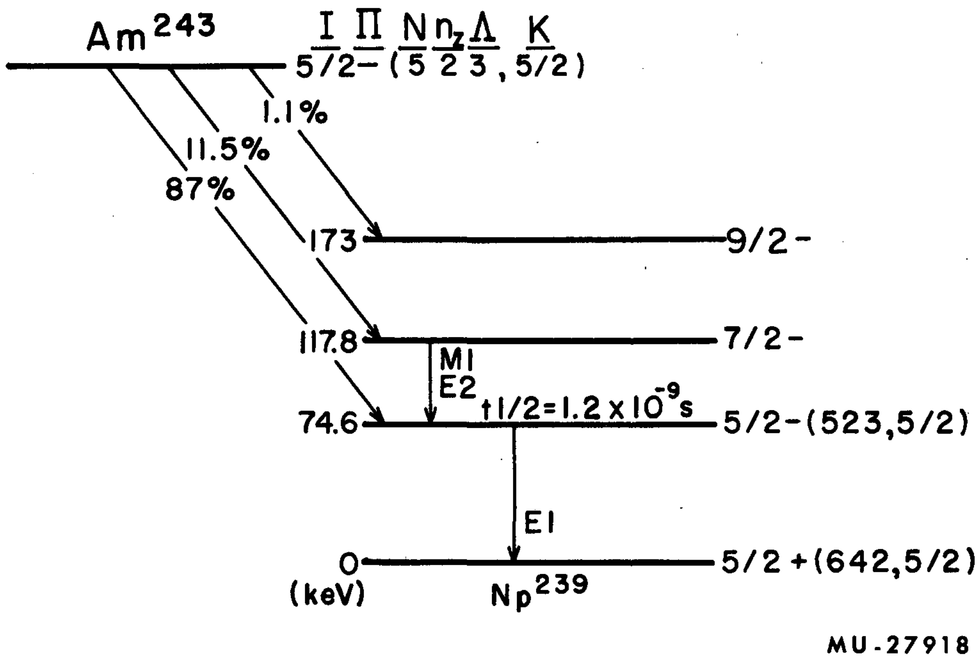

Fig. 2. Partial decay scheme of Am^{243}. This figure was taken from reference 1.

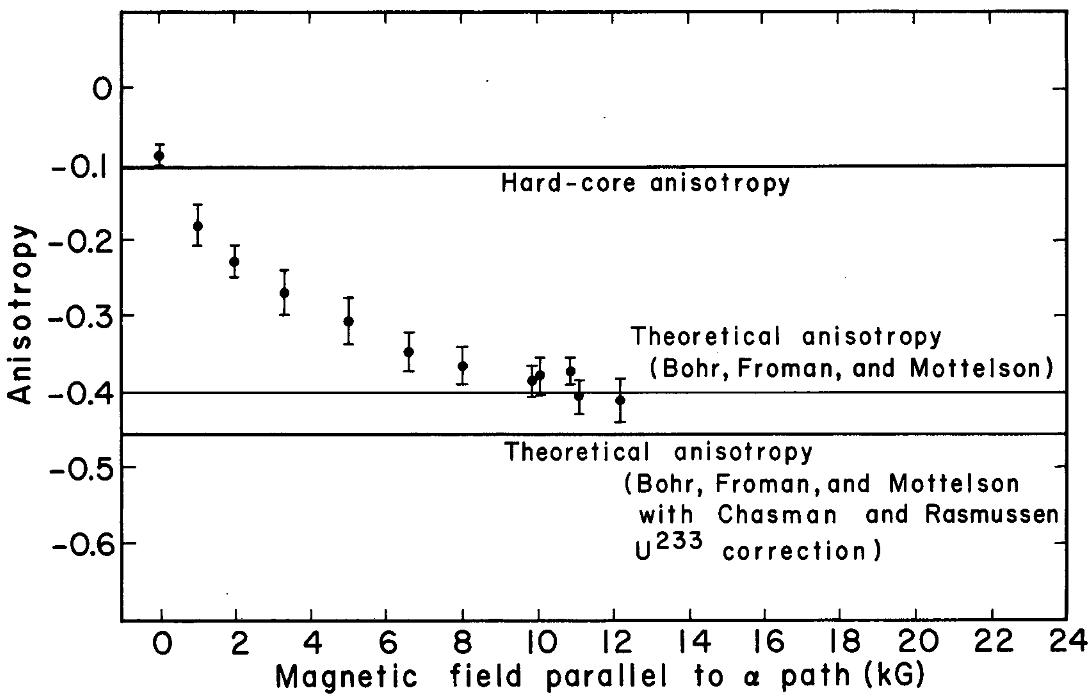

Fig. 3. Am^{243} $(\alpha_{75} + \alpha_{118})$ - γ_{75} angular correlation as a function of an applied magnetic field. The recoiling nuclei are in a vacuum environment.

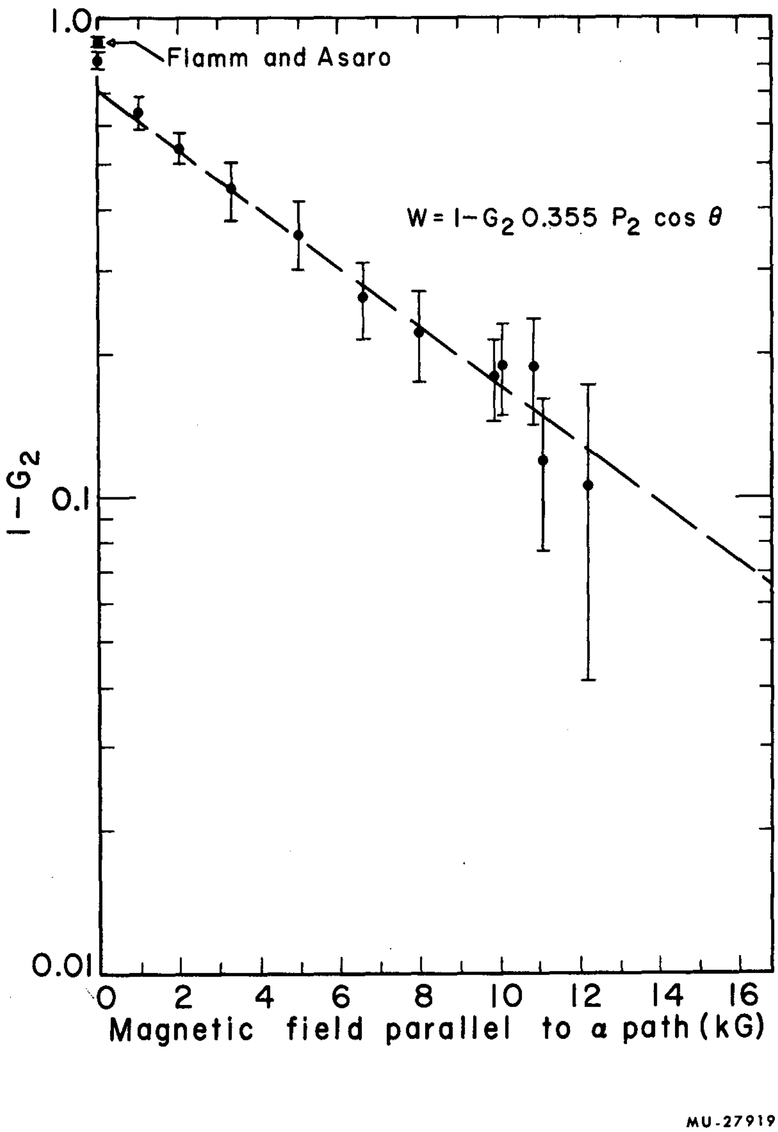

Fig. 4. The attenuation factor, G_2, for the Am^{243} $(\alpha_{75} + \alpha_{118}) - \gamma_{75}$ correlation in a vacuum environment as a function of an applied magnetic field. The theoretical anisotropy was calculated with the correction of Chasman and Rasmussen. The dashed line, which is the best representation of the data from 1 → 12 kilogauss can be expressed by the equation $1 - G_2 = 0.7 \times 10^{-0.6H}$.