Photodeuteron/Photoproton Yield from Sulfur

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An investigation of the relative deuteron/proton yield from sulfur, produced by irradiation with the Iowa State College 65-Mev synchrotron, was made by employing a 12-inch, helium-filled, magnetic cloud chamber as the means of detection. The average curvature and the range of each acceptable track were measured and were used to find an experimental mass histogram that provided a clear indication of proton and deuteron groups. Analysis of the mass histogram produced a ratio of deuterons to protons of 0.19±0.04. It is estimated that the corresponding ratio for an infinitesimally thick target is 0.15±0.04.

INTRODUCTION

THE ratio of deuterons to protons ejected from nuclei excited by high-energy x-rays has been studied with several elements. Data reported so far in the literature[1–5] are summarized in Table I.

The present work to be described employed the cloud-chamber technique of Smith and Laslett[3] to determine the ratio of deuterons to protons from a thick sulfur target.

METHOD

A sulfur plate of thickness equivalent to the range of a 15-Mev proton was placed in a helium-filled, 12-inch, magnetic cloud chamber and was exposed to the collimated x-ray spectrum produced by 65-Mev electrons in the Iowa State College synchrotron. Approximately 6600 stereoscopic photographs were taken at 30-second intervals as the synchrotron was pulsed in coincidence with the cloud chamber.

The film was reprojected through the optical system of the stereoscopic camera, and 185 tracks were selected which (a) originated in the target, (b) had a minimum range of seven centimeters, (c) contained no point scattering, and (d) ended in the chamber at least one centimeter from the wall.

The stopping power of the chamber atmosphere relative to an air atmosphere was obtained by measuring the range of the 5.30-Mev alpha particles emitted from a polonium source placed in the cloud chamber. The range of each x-ray-induced track was measured and corrected to its air equivalent range by means of the measured stopping power of the cloud-chamber atmosphere. The curvature and azimuth of each track, in a pulsed magnetic field of 4000 gauss, were measured and the curvature was corrected[6] to that of a track in a plane normal to the magnetic field.

The magnetic field encompassing the cloud chamber was measured with a proton resonance device. The field was found to be uniform to less than 0.5 percent over the entire volume occupied by the chamber.

TABLE I. Reported photodeuteron/photoproton yields.

Element	Ratio	Maximum x-ray energy Mev	Reference
Beryllium	0.21[a]	310	1
Copper	0.14[a]	310	1
Copper	0.31[b]	24	2
Copper	0.76[c]	65	3
Cerium	0.05[b]	24	4
Cobalt	0.02[b]	24	5
Carbon	0.12[a]	310	1
Lead	0.24[a]	310	1
Sulfur	0.15[d]	65	present work

[a] Two-crystal telescope at 90°. Both particles have 40-Mev average energy.
[b] Obtained with nuclear emulsion. Particles were identified by grain counting.
[c] Magnetic cloud chamber. Particles in equal range and solid angle intervals. Measured protons were 1.1 to 1.8 Mev. Deuterons were in energy interval 1.2 to 2.3 Mev.
[d] Conditions identical to (c). Ratio computed for thin target based on thick target observations.

RESULTS

The range and magnetic curvature of each track were used[7] to determine its mass. A mass histogram was plotted (Fig. 1) which exhibits two well-defined peaks at the mass value of a proton and a deuteron. The experimental ratio of deuterons to protons from a thick sulfur target is 0.19±0.04.

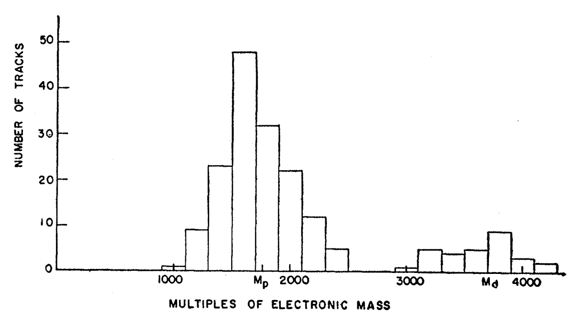

FIG. 1. Observed mass distribution of particles from sulfur. Ratio of No. of deuterons to No. of protons = 0.19±0.04.

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To correct this ratio for target thickness, it was assumed that the target consisted of 63 thin lamina. An energy distribution for singly charged particles emitted from a compound sulfur nucleus[8] was attributed to each layer. Using range-energy relations[9] for sulfur, the energy distributions for protons and for deuterons that leave the thick target from each layer were determined. The contributions from all of the layers were combined to give composite energy distributions for the protons and the deuterons that emerge from the thick target.

The cloud chamber physically limited the solid angle available for particles of different ranges and therefore different energies. The range-energy relation for the cloud-chamber vapor was different for protons than for deuterons and gave a different energy range available to be measured for each type of particle. Corrections for these two effects were applied to the theoretical energy distributions of particles from the thick target. The ratio of the number of protons to the number of deuterons in the two respective energy intervals is the correction that was applied to the experimental ratio. The corrected ratio of deuterons to protons from a thin sulfur target when irradiated by 65-Mev bremsstrahlung is 0.15 ± 0.04.

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Elastic Scattering of Protons by F^{19}†

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The differential cross section for the elastic scattering of protons by F^{19} has been measured for proton energies from 550 to 1800 kev at center-of-mass angles of 90, 125.3, and 159.8 degrees and for proton energies from 1300 to 1500 kev at 53.2, 60, 70, 80, 100, 110, and 136 degrees. Marked scattering anomalies were observed for proton energies near 669 (1^+), 843 (0^+), 873 (2^-), 935 (1^+), 1346 (2^-), 1372 (2^-), 1422 (1^+), and 1700 kev. The indicated spin and parity assignments for the corresponding levels in Ne^{20} are required by the results of this experiment or are consistent with them. Observations of the elastic scattering have also been made in the regions of 340 and 480 kev at 159.8 degrees, and no anomaly was observed in either case. The ambiguity in the choice of Γ_p/Γ has been resolved for several of the Ne^{20} levels. An approximate method of correcting the observed cross sections for the effects of finite energy resolution has been developed, and the relative stopping cross section for protons in lithium fluoride has been measured for proton energies from 400 to 1600 kev.

I. INTRODUCTION

THE study of the elastic scattering of protons by F^{19} was undertaken in connection with the recent investigations[1] at this laboratory of the low excited states in F^{19}. The spin and parity assignments for these states as determined from the $F^{19}(p,p'\gamma)$ reaction depend upon the assignments for the Ne^{20} states involved as resonances in the reaction, and the study of $F^{19}(p,p)$ was made to assist in the determination of the Ne^{20} assignments.

In addition to the information regarding spin and parity, the study of the elastic scattering yields useful information in many cases concerning the partial widths of the levels in the compound nucleus. Measurements of the reaction cross sections, $F^{19}(p,p')$ and $F^{19}(p,\alpha)$ and the total width, Γ, permit the determination of the sum and product of the proton width, Γ_p, and the reaction width, $\Gamma_\alpha+\Gamma_{p'}$. The solution of these relations yields two sets of values for Γ_p and $\Gamma_\alpha+\Gamma_{p'}$, and the size of the elastic scattering anomaly at the resonance may usually be used to resolve this ambiguity. A large anomaly generally indicates $\Gamma_p>\Gamma_\alpha+\Gamma_{p'}$ and a small anomaly, $\Gamma_p<\Gamma_\alpha+\Gamma_{p'}$.

The present article describes the experimental procedure and results, and the analysis and interpretation of these data will be discussed in the following paper.[2] Preliminary results of this experiment have been presented to the American Physical Society, and similar measurements and results have recently been reported by Dearnaley.[3]

In the course of this work, it was found desirable to

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