TABLE II. Relative total cross section in c.m. system.

| Group | $E_d$(Mev) =0.75 | 1.00 | 1.20 | 1.45 |
|---|---|---|---|---|
| $P_0$ | 1.00 | 1.00 | 1.00 | 1.00 |
| $P_1$ | 2.90 | 2.71 | 3.40 | 4.71 |
| $P_3+P_4$ | 2.03 | 2.21 | 2.40 | 3.32 |

TABLE III. Coefficients in the expansion,

$$1+\sum_{i=1}^{4} a_i(E_d)P_i(\theta).$$

| $E_d$ (Mev) | $a_1$ | $a_2$ | $a_3$ | $a_4$ |
|---|---|---|---|---|
| 0.75 | $+0.35\pm0.05$ | $+0.45\pm0.06$ | $+0.13\pm0.07$ | $-0.06\pm0.08$ |
| 1.00 | $+0.38\pm0.03$ | $+0.31\pm0.04$ | $-0.06\pm0.05$ | $-0.12\pm0.05$ |
| 1.20 | $+0.56\pm0.03$ | $+0.19\pm0.04$ | $-0.06\pm0.05$ | $-0.06\pm0.06$ |
| 1.45 | $+0.22\pm0.04$ | $+0.07\pm0.05$ | $-0.04\pm0.05$ | $-0.01\pm0.06$ |

mum becomes more flat at 1.45 Mev. At this low bombarding energy, we could not find the obvious effect of the stripping process as did Bromley *et al.* The angular distribution of $P_0$ was expanded into series of Legendre polynomials up to $P_4(\theta)$. The coefficients are given in Table III. The group $P_1$ shows a large peak at about 60° (c.m.) and it seems to be caused by the stripping process of *d*-neutrons, in agreement with the result of Bromley *et al.* The agreement of experimental points with the theoretical curve becomes better as the bombarding energy increases. Unexpectedly, this process contributes to the main part of the total intensity at these low bombarding energies. The distribution of the group $P_3+P_4$ is composed of two patterns, namely the forward peak and backward maximum. The former does not change its shape with deuteron energy, in contrast with the latter, and may be interpreted as the stripping peak of *s*-neutrons, the latter is considered as due to the compound-nucleus formation process. If this is true, then either the third or the fourth excited state would be $0^+$ or $1^+$.

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# Beta Decay of $Ne^{23}$

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The disintegration of $Ne^{23}$ was formerly considered to contribute to the few examples of superallowed transitions in negative beta decay. We have reinvestigated this decay, using scintillation techniques for measuring beta and gamma rays. No gamma ray of ~3 Mev is found; however, a gamma ray of 440±5 kev occurs in 36±4% of the beta decays. For both transitions, to the ground state as well as to the 440-kev level of $Na^{23}$, $\log ft \approx 5.2$. Upper limits for the intensity of higher energy gamma rays show that $\log ft \gtrsim 5.0$ for possible transitions to other levels in $Na^{23}$.

In the $\beta$ decay of 40-sec $Ne^{23}$, a branching with exceptionally high transition probability ($\log ft = 3.8$) to an ~3-Mev excited state in $Na^{23}$ has been reported,[1] based on the observed shape of the beta spectrum and an absorption curve of the gamma radiation. In view of the scarcity of superallowed transitions in negative beta decay, it seemed desirable to verify the presence of the high-energy $\gamma$ ray by scintillation measurements, which should, at the same time, give information about the possibility of beta decay to the 440-kev state in $Na^{23}$. This level is known from inelastic scattering of protons[2] and alpha particles[3] on sodium.

The $Ne^{23}$ activity has been produced in sodium targets by $(n,p)$ reaction, using Li$(d,n)$ neutrons from our 600-kev accelerator. The scintillation techniques used for the investigation of $\beta$ and $\gamma$ rays and their coincidences were the same as described previously.[4] A logarithmic energy deflection circuit has been added which facilitates the detection of weak high-energy components in $\gamma$-ray scintillation spectra.[5]

$\gamma$ *Spectrum.*—The pulse amplitude distribution reproduced in Fig. 1 shows a mixture of the different activities produced in thick targets (~5 g Na, enclosed in iron capsules). Similar photographs taken at different times after irradiation indicate that the three photopeaks appearing at 440±5, 860±10, 1630±15 kev are due to $Ne^{23}$, $Mn^{56}$, and $F^{20}$ respectively. During these exposures, pulses were also counted in eight amplitude channels indicated below the spectrum in Fig. 1. In order to separate the expected high-energy

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[1] H. Brown and V. Perez-Mendez, Phys. Rev. **78**, 812 (1950); V. Perez-Mendez and H. Brown, Phys. Rev. **78**, 812 (1950).

[2] Stelson, Preston, and Goodman, Phys. Rev. **86**, 629 (1952); Donahue, Jones, McEllistrem, and Richards, Phys. Rev. **89**, 824 (1953).

[3] G. M. Temmer and N. P. Heydenburg, Phys. Rev. **93**, 351 (1954); **96**, 426 (1954).

[4] D. Maeder and P. Staehelin, Helv. Phys. Acta **28**, 193 (1955).

[5] D. Maeder, Rev. Sci. Instr. **26**, 805 (1955).

component belonging to $Ne^{23}$ from the contributions of other activities, decay curves in the counting channels were followed for two hours after irradiations of different duration (10 sec, 1 min, and 10 min). The analysis given in Fig. 2 for the channels 2 and 8 is based on the known half-lives of $F^{20}$(11 sec), $Ne^{23}$(40.5 sec), and $Mn^{56}$(2.6 h). A slight indication of a possible 40-sec component is left in channel 8 after subtraction of the extrapolated $F^{20}$ and $Mn^{56}$ counting rates, and effects of the same order are observed in channels 4 to 7. However, no 40-sec contribution was found in the region $\geqslant 1780$ kev, which should contain $\sim 50\%$ of the total counting rate produced by a 3-Mev $\gamma$ ray. Therefore, if a hard $\gamma$ ray is emitted in an appreciable fraction of the $Ne^{23}$ disintegrations, its energy must be $\lesssim 1.7$ Mev. The subtraction procedure mentioned above places upper limits for the intensities of possible $\sim$1.7- and $\sim$3-Mev $\gamma$ rays at 10% and 1% of the number of 440-kev quanta.

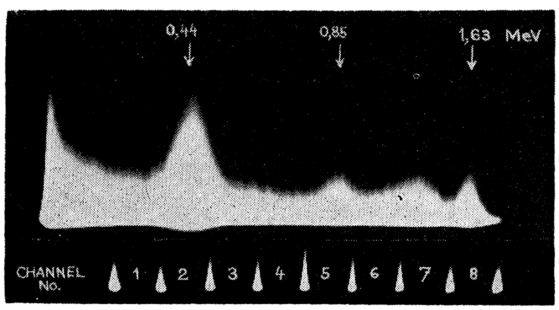



FIG. 1. NaI$\gamma$-scintillation spectrum (logarithmic in energy, linear in intensity), integrated from 10 seconds to 10 minutes after neutron irradiations of a sodium target in an iron container. Photopeaks from $Ne^{23} \rightarrow Na^{23}$ (440 kev), $Mn^{56} \rightarrow Fe^{56}$ (850 kev), and $F^{20} \rightarrow Ne^{20}$ (1630 kev) are visible. Below the spectrum the limits of the eight counting channels have been marked with artificial pulses, regulated automatically to the proper pulse height for each pair of adjacent channels.

*$\beta$ Spectrum.*—Na targets 0.5 mm thick, covered with cellophane foil, yielded satisfactory counting rates in the $\beta$-ray counter. Decay analysis permitted to separate the $Ne^{23}$ spectrum from that of $F^{20}$ and to use the latter for energy calibration (5.41 Mev). We thus obtain an end point of $3.9 \pm 0.3$ Mev for the $Ne^{23}$ $\beta$ rays, in reasonable agreement with previous results.[1]

*Branching ratio.*—The $[\beta\gamma(0.3 \div 0.55 \text{ Mev})/\beta]$ coincidence rate, measured between 90 and 150 sec after

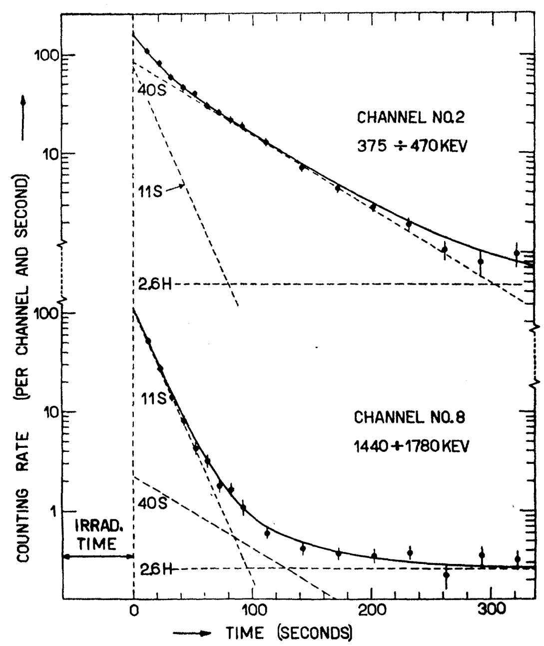
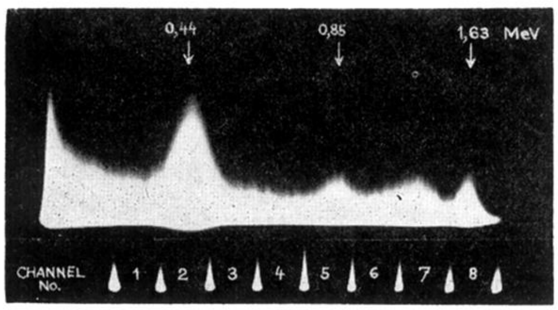



FIG. 2. Decay of the $\gamma$ activity produced by a 1-min irradiation (average of 2 runs), as measured in the counting channels 2 and 8. These two channels contain the photopeaks of 440 and 1630 kev respectively.

1-min irradiations, was compared with the coincidence rate produced by a $Au^{198}$ source. Since the $\gamma$-counter sensitivity is nearly the same at 440 and 412 kev and the contributions of higher energy $\gamma$ rays are very small in both cases, the evaluation is straightforward. $(36 \pm 4)\%$ of the $\beta$ rays from $Ne^{23}$ are thus shown to be in coincidence with 440-kev quanta, and for both $\beta$ transitions (to the ground state as well as to the 440-kev level) $\log ft \approx 5.2$. Using the upper limits given above for the relative intensity of higher energy $\gamma$ rays, we conclude that $\log ft \geqslant 5.0$ for any possible transitions to other levels in $Na^{23}$.[6]

A detailed report will be published in *Anales de la real sociedad española de fisica y quimica* (*Madrid*).

[6] When our experiments had been completed, an abstract on the same subject came to our attention: J. R. Penning and F. H. Schmidt, Bull. Am. Phys. Soc. **30**, No. 5, 8 (1955). Absence of the $F^{20}$ contamination from their sources permitted these authors to identify a $\gamma$ ray of 1647 kev in the $Ne^{23}$ activity. Their results are essentially in agreement with ours.

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