PROTONS EJECTED FROM NICKEL BY 17·5 MeV BREMSSTRAHLUNG*

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It has been shown that the energy and angular distribution of photoprotons from middle-weight nuclei (Z about 30) can be almost entirely accounted for by the statistical theory of nuclear reactions (Byerly and Stephens 1951 ; Toms and Stephens 1954). The evidence indicates that the direct photoeffect contributes only a small amount to the emitted photoproton spectrum. However, the statistical theory does not explain, among other things, why the photoproton yield at 23 MeV from copper and nickel should be about three times that from cobalt (Mann and Halpern 1951).

An investigation of the photoprotons from nickel at energies below the peak of the (γ,p) giant resonance has been made. A nickel foil of thickness 0·0007 in. was irradiated with 17·5 MeV bremsstrahlung, and the charged particles emitted were detected in two Ilford C2 emulsions (100 μ thick). The target-plate geometry was similar to that of Diven and Almy (1950).

Table 1

Q-values of photon and neutron reactions in nickel

$^{58}Ni(\gamma,p)^{57}Co$	—7·8±0·4 MeV
$^{58}Ni(\gamma,\alpha)^{54}Fe$	—6·3±0·4 MeV
$^{58}Ni(\gamma,d)^{56}Co$	—17·3±0·3 MeV
$^{60}Ni(\gamma,p)^{59}Co$	—9·5±0·4 MeV
$^{60}Ni(\gamma,\alpha)^{56}Fe$	—6·2±0·3 MeV
$^{60}Ni(\gamma,d)^{58}Co$	—17·6±0·3 MeV
$^{58}Ni(n,p)^{58}Co$	0·6±0·3 MeV
$^{58}Ni(n,\alpha)^{55}Fe$	3·0±0·3 MeV
$^{60}Ni(n,p)^{60}Co$	—2·0±0·3 MeV
$^{60}Ni(n,\alpha)^{57}Fe$	1·4±0·3 MeV

The Q-values of the photon-induced reactions in nickel leading to charged particle emission are given in Table 1. Also shown are the Q-values for the neutron-induced reactions which could lead to background tracks. All these Q-values are calculated from masses given by Wapstra (1955). It is estimated that the (n,p) and (n,α) reactions in the nickel isotopes contribute less than 5 per cent. of the total tracks observed. The chief sources of neutrons are the lead collimator and the platinum target in the synchrotron. Both are sources of photoneutrons of which about 90 per cent. have energy less than 2 MeV. Combined with this is the fact that the Coulomb barrier inhibiting proton

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emission from nickel is about 7 MeV, and this would certainly inhibit all (n,p) and (n,α) reactions except those with very positive Q-values. The number of background tracks due to $n-p$ scattering in the emulsion was shown to be quite negligible by means of a scanning programme previously described (Spicer 1955).

The proton energy distribution is shown in Figure 1. The proton energies were calculated by adding the energy at the emulsion surface and the energy lost in half the effective foil thickness. Only those tracks in the angular region 50–130° were used in the plotting of the energy distribution.

The angular distribution is plotted in Figure 2, for all the protons, and for the energy groups 2–4 and 4–8 MeV.

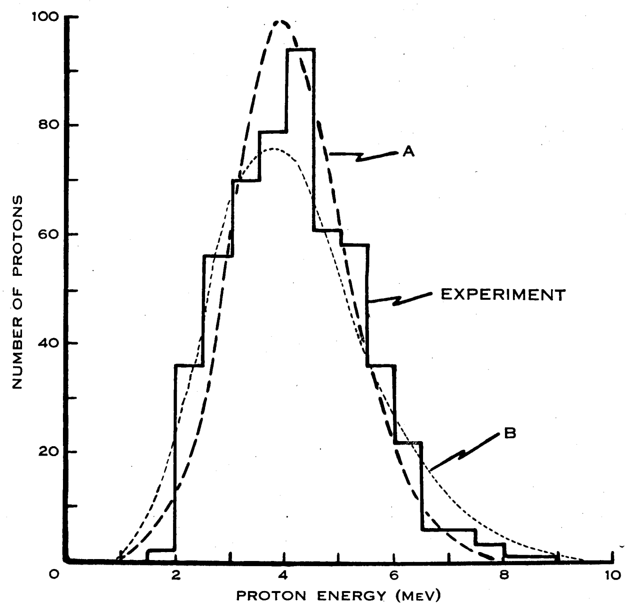

Fig. 1.—Energy distribution of photoprotons ejected from nickel by 17·5 MeV bremsstrahlung.

Discussion

A calculation of the yield of photoprotons gave 7×10^4 protons per mole-roentgen which is in good agreement with the value inferred from the yield curve given by Mann and Halpern (1951). Our figure of 2×10^3 α-particles per mole-r is in good agreement with that found by Haslam, Smith, and Taylor (1951) for the $^{65}Cu(\gamma,\alpha)^{61}Co$ reaction at 17·5 MeV.

The energy distribution of photoprotons expected from an evaporation model is shown by the alternative curves on Figure 1. These curves are normalized to represent the same number of total tracks as appear in the experimental distribution. Curve A was calculated using a Coulomb barrier height of 6·9 MeV and a residual level density which varied with excitation energy as $\exp(6E^{\frac{1}{2}})$. This level density corresponds to a mean nuclear temperature of

0·9 MeV for the residual cobalt nucleus. This is in fair agreement with the data of Graves and Rosen (1953) from inelastic neutron scattering, and of Gugelot (1951) from neutron spectra from nuclear reactions of 18 MeV protons.

An equally good fit to the data can be made using a Coulomb barrier of 5·6 MeV, and assuming a level density form of exp $(1 \cdot 04E)$. This is shown in curve B of Figure 1. The level density form assumed corresponds to the same nuclear temperature as the first one.

It seems, then, that if one accepts the hypothesis of Livesey (1955), that the nuclear temperature remains constant up to excitations of 10 MeV or so, then one must also use a Coulomb barrier which is smaller than the classical

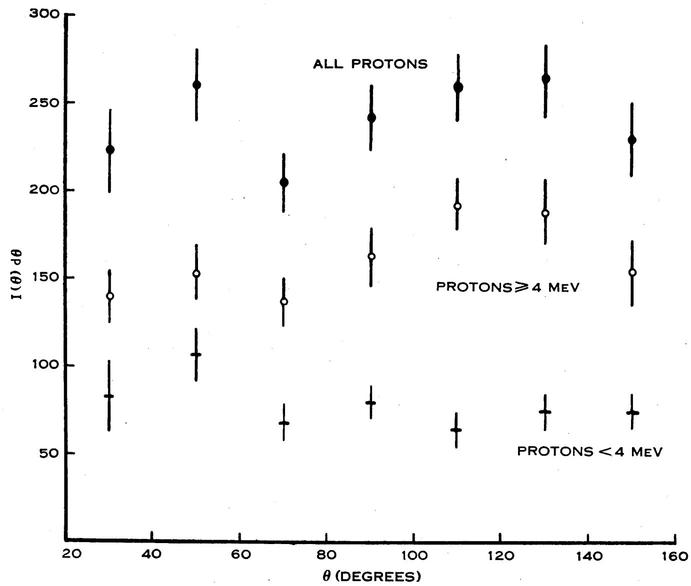

Fig. 2.—Angular distribution of photoprotons from nickel.

barrier height (in this case 7 MeV). This possibility is covered in the hypothesis of an unsharp nuclear surface (Scott 1954). The Coulomb barrier height of 5·6 MeV which was used here is not as low as the figure recommended by Scott, which is 4·7 MeV.

While the angular distributions are not inconsistent with isotropy, it is reasonable to suggest the existence of peaks at 50 and 120°. This suggestion may also be made concerning the angular distributions of protons ejected from nickel by 21 MeV bremsstrahlung (Lejkin, Osokina, and Ratner 1956). Similar peaks were obtained by Toms and Stephens (1955) for tantalum photoprotons. If this similarity could be definitely established one would have to explain why the energy distribution of the nickel photoprotons can be accounted for on statistical theory, while Toms and Stephens state that the mechanism of the direct photoeffect must be invoked to account for the energy distribution of the tantalum photoprotons. It should be noted that the present theory of the direct photoeffect will not give two peaks in the angular distribution at 50 and 120°.

On the basis of the present study and that of Lejkin, Osokina, and Ratner (1956), it is concluded that, though statistical theory can account for the energy distribution of all or most of the photoprotons emitted from nickel, the angular distribution shows evidence of peaks. These peaks are not easily explained on either statistical theory or direct photoeffect theory.

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THE MEAN THICKNESS OF NIGHT-TIME E_s CLOUDS AT BRISBANE*

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It has been stated that the sporadic E region of the ionosphere at Brisbane is very thin, with a maximum thickness of the order of a few hundred metres (McNicol and Gipps 1951). The measurements reported below indicate that at Brisbane E_{sc} clouds (patches of enhanced ionization in the sporadic E region which maintain an almost constant height) at night are, on the average, almost certainly less than 1 km thick.

The thickness of E_{sc} clouds was obtained from measurements of:

(*a*) the equivalent paths of echoes from the under-surfaces of these clouds, and also from the F region; and

(*b*) simultaneously observed equivalent paths of echoes which had experienced one internal reflection between the F region and the top surface of the E_{sc} cloud before returning to the ground (so-called "M reflections").

The assumption is made that both the E region cloud being measured and the base of the F region are horizontal, at the times when the M echoes which were used for measurement appeared.

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