two gamma-ray photopeaks from Y^{90m} were identified by energy and decay measurements. Seventy-nine hour Zr^{89} was identified by gamma-ray energy and decay measurements. It was produced by $Zr^{90}(n,2n)Zr^{89}$. The Y^{90m} was produced by $Zr^{90}(n,p)Y^{90m}$ and is the activity observed by the workers in reference 4.

DISCUSSION AND CONCLUSIONS

The original assignment[1] of the 3.1-hr activity to Y^{90m} has been confirmed through cross bombardment. The two gamma rays are in coincidence and of nearly equal intensity.

No beta particles or electrons with 3.1-hr half-life were observed. This indicates the 3.1-hr activity is an isomeric transition in Y^{90}. The data reported herein are inconclusive as to whether the 3.1-hr isomer feeds the 64-hr Y^{90}. If it should, the 203-kev level would lie above the 2^- beta-emitting level in Y^{90} and presumably would have the level assignment 3^- as determined by Bartholomew *et al.*[9] The 203-kev γ transition would thus be M1; the predicted K conversion coefficient as calculated using the tables of Sliv and Band[11] is ~ 0.02 which is in agreement with the observation reported above regarding no observed negatrons. Haskin and Vandenbosch[5] report that the growth of Y^{90} from Y^{90m} was observed. They propose a decay scheme in which the 683-kev level is given a 7^+ assignment. Thus, the 483-kev gamma-transition would be M4; the predicted K conversion coefficient is ~ 0.06. The calculated lifetime τ_γ, where

$$\tau_\gamma = T_{\frac{1}{2}}(1+\alpha_{\text{total}})/\ln 2 \qquad (2)$$

(and α_{total} is small), is in agreement with the predicted value as discussed by Goldhaber and Sunyar.[12] τ_γ calculated from Eq. (2) is 1.6×10^4 sec; the theoretical value computed from normalized lifetime energy relations for M4 transitions with spin correction is $\tau_\gamma = 1.1\times 10^4$.[11]

An adventitious result of these later experiments has been the measurement of a number of 14-Mev neutron cross sections in this region of the periodic table. These data, which include cross sections for production of both Y^{90} and Y^{90m}, will be presented in a subsequent paper.

Note. Cline *et al.*,[13] by neutron irradiation of Y^{89} have confirmed the experiments reported in part A above. On the basis of gamma-gamma directional correlation and internal conversion measurements, these workers propose spin and parity assignments for levels in Y^{90m} which are in agreement with those suggested by Haskin and Vandenbosch.[5]

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10-Mev Proton Reaction Cross Sections Compared with Surface and Volume Absorption Optical Models of the Nucleus*

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(p,n) cross sections were measured at 9.85 Mev for self-supporting thin targets of Al, Ti, Fe, Co, Ni, Cu^{63}, Cu^{65}, Rh, Ag, Sn, Ta, and Au. ($p,2n$) contributions were calculated using the statistical model of the nucleus for Rh, Ta, Ag, and Au. Charged-particle emission was assumed negligible in Ta and Au because of small Coulomb penetrabilities. Approximate proton reaction cross sections were obtained by adding (p,n) and ($p,2n$) cross sections to (p,p') and (p,α) cross sections previously reported by Meyer and Hintz. These results were compared with volume absorption and surface absorption optical-model calculations of proton reaction cross sections. The parameters for both model calculations were obtained prior to this work by fitting proton elastic scattering and polarization data. The results incidate a surface-absorption potential rather than a volume-absorption potential.

IN order to obtain approximate reaction cross sections for the nuclei, Al, Ti, Fe, Co, Ni, Cu^{63}, Cu^{65}, Rh, Ag, Sn, Ta, and Au, (p,n) cross sections were measured at 9.85 Mev and added to (p,p') and (p,α) cross sections previously measured.[1] The Rh, Ta, Ag, and Au reaction cross sections were corrected for ($p,2n$) contributions

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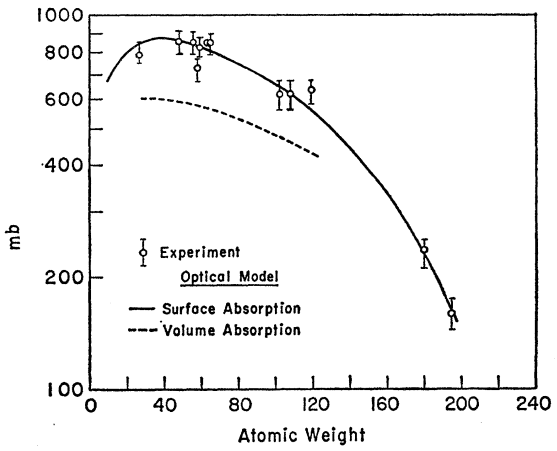

FIG. 1. Proton reaction cross section at 10 Mev.

using the statistical model of the nucleus.[2] Charged-particle emission was assumed to be negligible in the latter two heavy elements because of the large Coulomb barrier.

The results were compared with predictions of the optical model of the nucleus for the volume absorption Woods-Saxon[3] well and the surface absorption well of Bjorklund and Fernbach.[4] Reaction cross sections had been predicted previous to our measurements on the basis of both models,[5,6] using parameters obtained from fitting elastic scattering and polarization data at 10 Mev. It has been previously pointed out that reaction cross-section measurements obtained for several nuclei[1,7] are larger than those predicted by the optical model with a uniform nuclear volume absorption. Results were previously obtained by us for the copper isotopes which agree within experimental error with surface absorption optical model calculations.[8]

Our present results extended to other nuclei are plotted against atomic weight in Fig. 1 where they are compared with surface absorption reaction cross sections previously calculated by Bjorklund and Fernbach[6] using parameters that fit elastic scattering and polarization measurements obtained by others. The parameters are the following:

$$r_0=1.25 \text{ f}, \quad b=1.2 \text{ f}, \quad V=(44+Z/A^{\frac{1}{3}}) \text{ Mev},$$
$$a=0.65 \text{ f}, \quad W=11 \text{ Mev}.$$

The spin-orbit potential is 20 times the Thomas term. Also plotted are reaction cross sections obtained using the volume absorption model for a nuclear radius of 1.2 f.[5] Our results are much higher than those predicted by the volume absorption calculations, and show much better agreement with the surface absorption calculations.

Better agreement with the volume absorption model for copper could be obtained using a nuclear radius parameter of 1.33 f and would agree almost as well with elastic scattering and polarization data[5] due to the ambiguity between V and r_0 parameters. However, in the case of argon and tin this large a nuclear radius gives poor agreement with elastic scattering and polarization data.[5]

Reaction cross-section measurements may be a crucial test of which model is correct, since the higher orbital partial waves localized at the nuclear surface are weighted by the $(2l+1)$ factor in the reaction cross-section calculation. Thus one expects to get a larger reaction cross section from a surface absorption optical model calculation.[9] It has also been pointed out that an even larger value may be obtained by assuming a radius for the imaginary well larger than that of the real well.[1] It is felt that the precision of the present experimental results does not warrant investigation of the validity of this point. However, it appears that the present results do constitute strong support in favor of surface absorption over volume absorption for the optical model of the nucleus.

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