quadrupole interaction and that defined by Eq. (2) is

$$[eQ(\partial^2 V/\partial z^2)]_{G,\,S,\,S} = \frac{2I+3}{4I} eQ(\partial^2 V/\partial z^2). \qquad (6)$$

Thus, the published values of the "quadrupole coupling" of iodine ($I=5/2$) in CH_3I[2] and ICN[3] should be multiplied by the factor $4I/2I+3=5/4$, giving values of $eQ(\partial^2 V/\partial z^2)$ of -1900 mc/sec. and -2588 mc/sec., respectively.

The factor $4I/2I+3$ for chlorine and bromine ($I=3/2$) turns out to be equal to 1. Thus, the "quadrupole couplings" given by the above authors for these nuclei in BrCN,[3] CH_3Cl, and CH_3Br[4] are identical with those which would have been obtained by the use of Eq. (2).

Although Townes, Holden, Bardeen, and Merritt[1] have not published the formula which they used to determine "quadrupole couplings", their definition of $eQ(\partial^2 V/\partial z^2)$ appears to be identical with ours.

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Alpha-2 Neutrons Nuclear Reactions

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DURING a series of investigations with 15-Mev alpha-particles, we also started a systematic search for the $(\alpha, 2n)$ reaction to test the predictions of the statistical theory[1] of nuclei. The following elements have been investigated:

V, Co, Cu, Ga, As, Rb, Y, Rh, Ag, In, and I.

We found the following reactions:

$Ga^{69}(\alpha, n)As^{72}(26^h)$, $Ga^{71}(\alpha, n)As^{74}(16^d)$,
$Rb^{87}(\alpha, n)Y^{90}(60^h)$, $I^{127}(\alpha, n)Cs^{130}$(30 min.).

In no case was there any indication of an $(\alpha, 2n)$ reaction.

At the end of 1942~18-Mev alpha-particles became available, and preliminary experiments were carried out with cobalt and rhodium. In bombarding cobalt, both the Cu^{62} activity of 10 min., as well as the Cu^{61} activity of 3.4 hr. were found, indicating the existence of both (α, n) and $(\alpha, 2n)$ reactions. Bombarding rhodium, the 8.2-day activity of Ag^{106} resulting from the (α, n) reaction and, in addition, a ~40-day activity were found, indicating the existence of the $(\alpha, 2n)$ reaction. We assign this period to the Ag^{105} isotope.[2]

The investigation was interrupted because of the authors' assignments to war research activities and was continued only recently.

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The Relative Yields of (α, n) and $(\alpha, 2n)$ Reactions for Ag and Rh with 15–20-Mev Alpha-Particles*, 1

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THE statistical theory of nuclear reactions, as developed by Weisskopf and Ewing,[2] predicts a Maxwell-like distribution for the energy spectrum of the neutrons evaporated from a heavy, highly excited compound nucleus formed by α-particle bombardment. If the energy of the emitted neutron is sufficiently small so as to leave the residual nucleus in an excited state above the dissociation energy, the emission of a second neutron will be by far the most probable event.

From the energy distribution of the neutrons given by the statistical theory, the cross section for the $(\alpha, 2n)$ reaction is calculated to be

$$\sigma_{\alpha,\,2n} = \sigma_\alpha[1-(1+\Delta E/kT)e^{-\Delta E/kT}], \qquad (1)$$

where $\Delta E = E_\alpha - T_{\alpha,\,2n}$ is the excess of the α-particle energy over the threshold $T_{\alpha,\,2n}$ of the $(\alpha, 2n)$ reaction, T is the temperature of the residual nucleus for an excitation energy

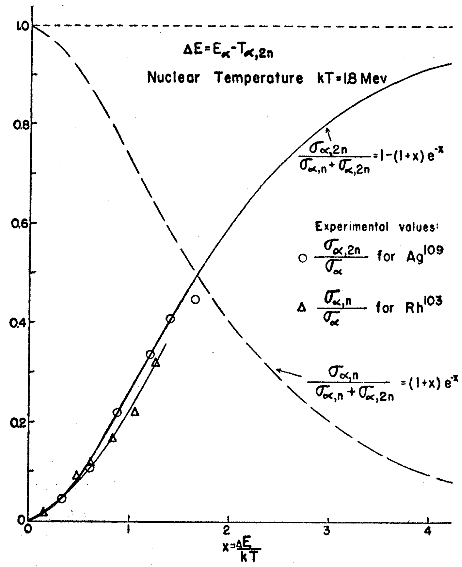

FIG. 1. Excitation curves for the (α, n) and $(\alpha, 2n)$ reactions with Rh.

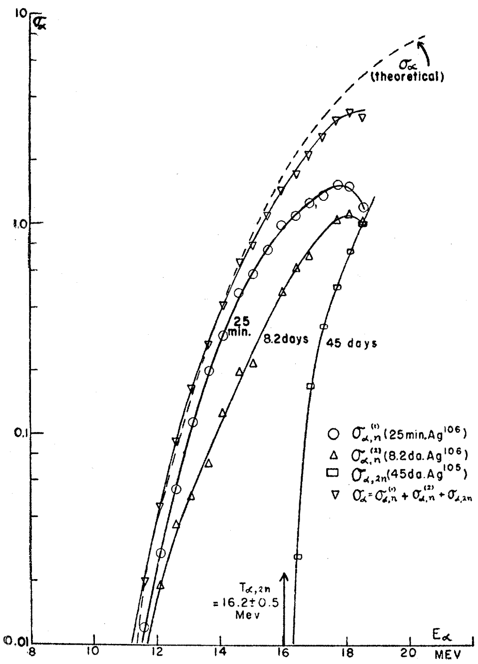

FIG. 2. Relative probabilities of the $Ag^{109}(\alpha, 2n)In^{111}$ and $Rh^{103}(\alpha, 2n)Ag^{105}$ reactions.

equal to the upper limit of the neutron spectrum, and $\sigma_\alpha \approx \sigma_{\alpha, n}+\sigma_{\alpha, 2n}$ is the cross section for the formation of the compound nucleus. In order to test the validity of (1), we have, in continuation of experiments started in 1940 by K. Lark-Horovitz in collaboration with J. R. Risser and R. N. Smith,[3] measured excitation curves for the radioactive products of the (α, n) and $(\alpha, 2n)$ reactions, induced by bombardment of stacked Ag and Rh foils with α-particles from the Purdue Cyclotron.

The $Rh^{103}(\alpha, n)Ag^{106}$ reaction leads to the well-known isotope Ag^{106} either in its ground state or in its isomeric metastable state, which decays by β^+ emission with a half-life of 25 minutes, or by K-capture with a half-life of 8.2 days, respectively. The $Rh^{103}(\alpha, 2n)$ reaction leads to the silver isotope Ag^{105}, to which heretofore a period of 45 days has been assigned only tentatively.[4] Bombardment of Rh with α-particles produced these three activities of 25 min., 8.2 days, and 45 days, and the excitation curves for them are reproduced in Fig. 1. It is clear that the 45-day period is the product of the $Rh^{103}(\alpha, 2n)Ag^{105}$ reaction, the threshold being 16.2 ± 0.5 Mev; hence this period must be assigned definitely to the mass number 105.

The ratio of the cross sections for the excitation of the two isomeric states of Ag^{106} was determined by comparing the saturation gamma-activities of the 25-min. (annihilation radiation) and the 8.2-day (nuclear cascade γ-rays[4]) periods. Then the ratio of the $(\alpha, 2n)$ to the (α, n) cross section was determined by comparing the saturation x-ray intensities of the 45-day Ag^{105} and the 8.2-day Ag^{106}. The rapid rise of the $(\alpha, 2n)$ cross section above 16 Mev at the expense of the (α, n) cross section is clearly seen from Fig. 1. The analogous excitation curves for the $Ag^{109}(\alpha, n)In^{112}$ and $Ag^{109}(\alpha, 2n)In^{111}$ reactions are shown in Fig. 1 of the letter following. For Rh^{103} as for Ag^{109} the sum of the (α, n) and $(\alpha, 2n)$ cross sections in Fig. 1 follows rather closely the theoretical curve for σ_α, given by the figures in Weisskopf's lecture in the Los Alamos (24) report,[5] for both the $Rh^{103}(\alpha, 2n)Ag^{105}$ and the $Ag^{109}(\alpha, 2n)In^{111}$ reactions.

Figure 2 shows the experimental values for $\sigma_{\alpha, 2n}/(\sigma_{\alpha, n}+\sigma_{\alpha, 2n})$ plotted against $x=\Delta E/kT$. As is seen, good agreement with formula (1) can be obtained by assuming for the nuclear temperature the reasonable value $kT=1.8$ Mev.

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5 $R=1.3\cdot 10^{-13}A^{\frac{1}{3}}$ cm has been assumed. In order to obtain an experimental value for the effective nuclear radius, a determination of the absolute cross sections will be made.

The Radioactive Indium Isotopes of Mass Numbers 111 and 112*,1

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THE irradiation of silver with 15–20-Mev alpha-particles produces the following four periods, all of which have been chemically identified as belonging to indium isotopes: 23 min., 66 min. 6.5 hr., and 2.7 days. Since

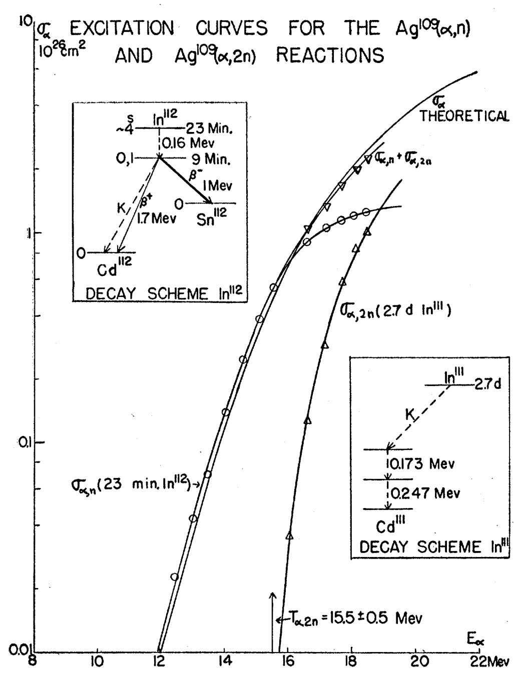

FIG. 1. Excitation curves for the $Ag^{109}(\alpha, n)$ and $Ag^{109}(\alpha, 2n)$ reactions.