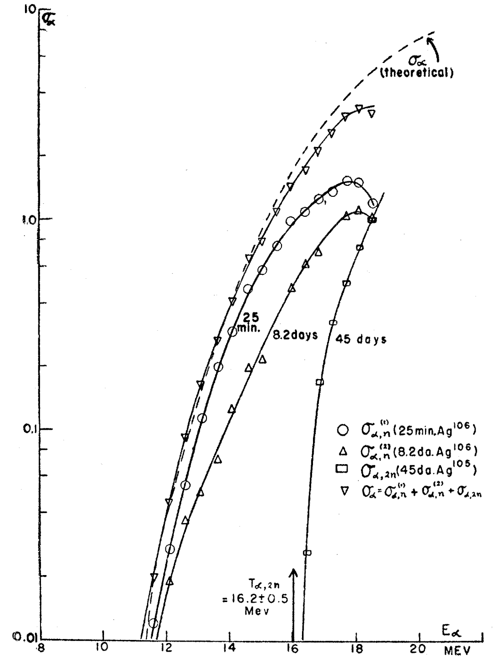

FIG. 2. Relative probabilities of the $Ag^{109}(\alpha, 2n)In^{111}$ and $Rh^{103}(\alpha, 2n)Ag^{105}$ reactions.

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.

---

[*] Assisted by the Office of Naval Research under Contract N6ori-222 Task Order I.

[1] D. J. Tendam and H. L. Bradt, Phys. Rev. **72**, 527 (1947).

[2] V. F. Weisskopf and D. H. Ewing, Phys. Rev. **57**, 472 (1940).

[3] Unpublished thesis (1941).

[4] T. Enns, Phys. Rev. **56**, 872 (1939).

[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]

D. J. TENDAM AND H. L. BRADT
Purdue University, Lafayette, Indiana

October 23, 1947

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

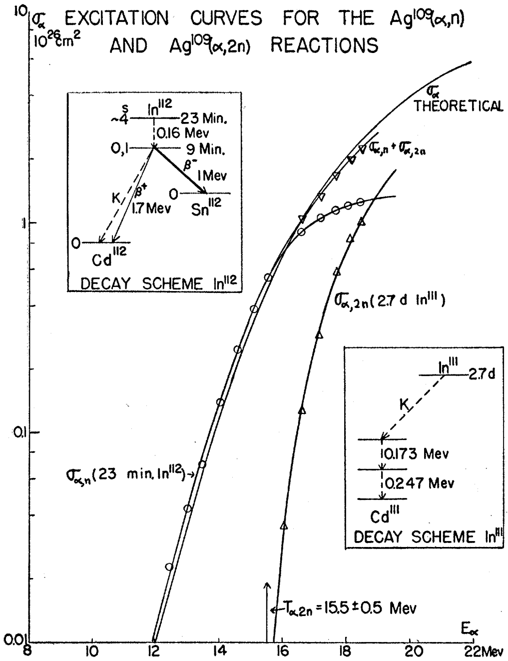

FIG. 1. Excitation curves for the $Ag^{109}(\alpha, n)$ and $Ag^{109}(\alpha, 2n)$ reactions.

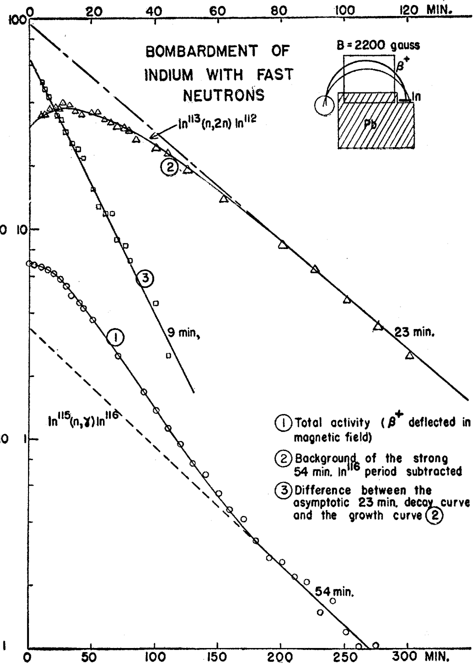

FIG. 2. Bombardment of indium with fast neutrons.

its excitation curve is almost identical with that of the 66-min. In^{110}, produced by the $Ag^{107}(\alpha, n)In^{110}$ reaction, the 23-min. period must be assigned to mass number 112 as the product of the $Ag^{109}(\alpha, n)In^{112}$ reaction. Further proof of this assignment is the fact that the 23-min. isotope decays chiefly by negative electron emission to a Sn isotope; the stable Sn isotope of lowest mass number is Sn^{112}.

It is seen from its excitation curve (Fig. 1) that the 2.7-day period is the product of an $(\alpha, 2n)$ reaction with a threshold of 15.5±0.5 Mev and must be assigned to In^{111}. Lawson and Cork[2] produced a weak 2.7-day activity with fast $(Li+d)$ neutrons and assigned this period of In^{112} as the product of an $(n, 2n)$ reaction. From our result we must conclude that this activity was the product of the $In^{113}(n, 3n)$ reaction. The 2.7-day In^{111} decays by electron capture to an excited state of Cd^{111}, which goes into the ground state by successive emission of two gamma-quanta.[2, 3]

The 23-min. period of In^{112} is followed by negative and positive electrons, both In and Cd x-rays, and the conversion electrons of a highly converted 0.16-Mev γ-radiation. While the Cd K-radiation accompanies the K-capture of In^{112}, the emission of In K-radiation can only be due to internal K-conversion of the 0.16-Mev γ-ray. This converted γ-ray hence is emitted in the transition between two isomeric states of In^{112}. Since both the conversion electrons and the In K-x-rays follow the 23-min. period from the beginning, this period is the half-life of the upper, metastable level of In^{112}. The decay curve for the negative and positive electrons follows the 23-min. period only after a certain time; this curve, first recognized by R. N. Smith,[4] as such, is a growth curve, showing that a 9-min. activity grows from the 23-min. activity.[5] Figure 2 shows the decay curve of the positrons from a sample produced by the $In^{113}(n, 2n)In^{112}$ reaction with $(Li+10 \text{ Mev } D_1^2)$ neutrons.

The deviation of the growth curve from the asymptotic 23-min. period during the time immediately following bombardment depends on the relative probabilities of excitation of the isomeric states by the nuclear reaction involved. It is largest for samples produced by (γ, n)[6] and $(n, 2n)$ reactions, smaller for those from the $Ag^{109}(\alpha, n)$ reaction, and not noticeable for those from the $Cd^{111}(d, n)In^{112}$ reaction.

The In^{112} isomeric transition belongs in the $l=4$ group. Both the β^- and the β^+ transitions from the ground state to the even, even-nuclei Sn^{112} and Cd^{112} are allowed; the spin quantum number of the lower level is hence 0 or 1.

---

[*] Assisted by the Office of Naval Research, Contract N6ori-222 Task Order I.

[1] D. J. Tendam and H. L. Bradt, Phys. Rev. **72**, 527 (1947).

[2] J. L. Lawson and J. M. Cork, Phys. Rev. **57**, 982 (1940).

[3] H. L. Bradt, P. C. Gugelot, O. Huber, H. Medicus, P. Preiswerk, and P. Scherrer, Helv. Phys. Acta **19**, 77 (1945).

[4] R. N. Smith, Phys. Rev. **61**, 389 (1942).

[5] Analysis of the growth curve into exponentials led Smith to assume periods of 16.5±2 min. and 17.5±2 min. for the In^{112} isomers in order to obtain the best fit. The growth curve can be reproduced, over a considerable interval, in this way; the decay curve for the conversion electrons and x-rays, however, shows that the half-life of the upper level is 23 min.

[6] We are indebted to Dr. John McElhinney for irradiating an In foil with the x-rays of the 20-Mev betatron of the University of Illinois and measuring its activity.

Phase Change in Barium Titanate Crystals Induced by Infra-Red Radiation Absorption

NORMAN J. FIELD AND A. P. DEBRETTEVILLE, JR., *Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey*

AND

H. D. WILLIAMS, *Harshaw Chemical Company, Cleveland, Ohio*

October 22, 1947

BARIUM titanate is a ferro-electric material[1–3] or dielectric with a non-linear constant. The microcrystalline material has been reported to have a phase transition[4] from the tetragonal form ($a=3.986$ kX, $c=4.026$ kX for 20°C to the cubic form ($a=4.004$ for 200°C) at 120°C[5] by the x-ray heating camera. A discontinuity in the electrical properties of the material has also been noted at this temperature.[1–3]

These characteristics have now been confirmed by direct microscopic observation of synthetic crystals in polarized light.

Plate-like macrocrystals of barium titanate, grown by the method of Matthias,[6] are optically anisotropic when examined between crossed Nichols with moderate illumination by a tungsten lamp source. Increase in intensity of illumination causes a striking change in the crystal to the isotropic phase. This change is readily observed as the interference colors and patterns give way to a homogeneously grey color which does not vary with rotation of the crystal in the polarized light. The transformation is rapid and reversible, originating at the point of most concentrated illumination, and rapidly spreading towards the periphery of the crystal.