# The Transmutation of Scandium by Th C′ Alpha-Particles

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(Received July 11, 1938)

The emission of protons from scandium under bombardment by Th C′ alpha-particles has been observed according to the reaction $Sc^{45}+He^4 \rightarrow Ti^{48}+H^1$. Three groups of protons are found corresponding to nuclear energy changes −0.3, −1.4 and −2.6 Mev. With Dempster's value for the mass of $Ti^{48}$ the mass of $Sc^{45}$ is deduced to be 44.9599.

## INTRODUCTION

WHEN bombarded by Th C′ alpha-particles a target of scandium oxide was found to emit a rather small yield of protons. As scandium has only one stable isotope these must correspond to the reaction

$$Sc^{45}+He^4 \rightarrow Ti^{48}+H^1,$$

in which a stable isotope of titanium is formed. The protons are found to be emitted in several groups and there is some interest in the analysis of these groups into their appropriate $Q$ values since relatively little information is available regarding the excited states of nuclei as heavy as the resulting $Ti^{48}$. Measurement of the maximum energy of the protons enables the mass of $Sc^{45}$ to be deduced from Dempster's recent value for the mass of $Ti^{48}$.

## EXPERIMENTAL ARRANGEMENT AND RESULTS

The experimental arrangement and procedure was precisely as described in previous papers.[1] The targets used were layers of $Sc_2O_3$ either squeezed onto a fiber backing or, for layers transparent to protons, painted onto a gold foil from an alcoholic suspension. All experiments were carried out with "thick" layers, although the fact that only the more energetic alpha-particles are effective in causing transmutation reduces the overlapping of groups considerably. The protons were detected by means of a proportional counter and amplifier and were observed by the so-called "right angle" and "forward" methods; absorption curves were plotted in each case in the usual way. Sources varied between 0.5 and 1.0 mC.

The results are shown in Fig. 1 which gives two graphs of yield *versus* absorption. The lower curve was obtained by the forward method with a rather high bias on the thyratron recorder (this is rendered necessary by the unsteadiness of the background due to gamma-radiation) so that protons of residual range exceeding fifteen centimeters are not counted. It can be seen that three groups are present of ranges 49, 66 and 87 cm. Considerable time was spent in establishing the reality of the low point at 66 cm, which is the only evidence for this group, and a total of five hundred particles per point were counted in twenty all-night runs taken at ten values of absorption. All experiments of this kind are open to statistical uncertainty but it is felt to be reasonably sure that this group is real. The yield is roughly one-third of the background count at 66 cm absorption. The upper curve was taken by the right angle method and shows the presence

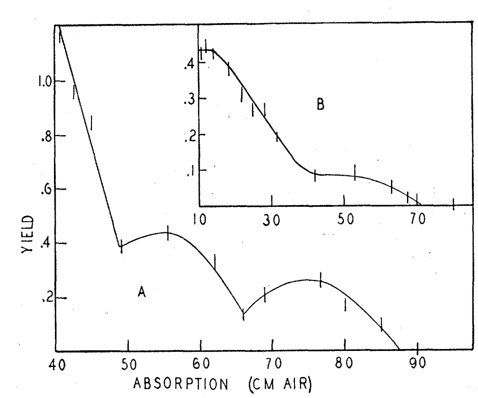


FIG. 1. Absorption curves for protons emitted, $A$ in forward and $B$ in right angle directions. Three groups are present, one of which is not resolved in graph $B$ because of the small yield. Consistent $Q$ values for the shortest and longest range groups are obtained from the two graphs.

[1] C. J. Brasefield and E. Pollard, Phys. Rev. **50**, 296 (1936); E. Pollard and C. J. Brasefield, Phys. Rev. **50**, 890 (1936); W. L. Davidson, Jr. and E. Pollard, Phys. Rev. **54**, 408 (1938).

TABLE I. *Values of Q for the three groups.*

| | Right Angle | | Forward | | Average |
|---|---|---|---|---|---|
| Group | Range cm | "Q" Mev | Range cm | "Q" Mev | "Q" Mev |
| 1 | 40 | −2.7 | 49 | −2.5 | −2.6 |
| 2 | not resolved | | 66 | −1.4 | −1.4 |
| 3 | 71 | −0.5 | 87 | −0.2 | −0.3 |

of two groups of ranges 40 cm and 71 cm. The third group found in the other curve should occur at 58 cm. The yield in this region is so small that it is not possible to resolve groups and no attempt was made to do so. There appears to be a flattening of the graph for absorption less than 15 cm.

## Discussion

The values for the nuclear energy change [$Q$ values] derived from the above data are given in Table I. It will be seen that there is reasonable agreement between the values found by the two methods of observation for groups 1 and 3. As the yield of protons is low, the error should be taken as $\pm 0.3$ Mev, which corresponds to an uncertainty in range of roughly 5 cm.

TABLE II.[2] *Average spacing of levels for various elements arranged according to their excess of neutrons over protons.*

| Excess of Neutrons Over Protons | Element | Average Spacing of Levels Mev |
|---|---|---|
| 1 | $Al^{27}$ | 0.90 |
| | $P^{31}$ | 0.80 |
| | $Cl^{35}$ | 0.70 |
| 2 | $Ne^{22}$ | 1.54 |
| | $Na^{24}$ | 3.20 |
| | $Mg^{26}$ | 1.67 |
| | $Al^{28}$ | 1.10 |
| | $Si^{30}$ | 1.56 |
| | $S^{34}$ | 1.42 |
| | $A^{38}$ | 2.00 |
| | $Ca^{42}$ | 1.35 |
| 4 | $Ti^{48}$ | 1.15 |
| 5 | $V^{51}$ | 2.37 |

[2] These values are collected from the following papers: O. Haxel, Physik. Zeits. **36**, 804 (1935); A. N. May and R. Vaidyanathan, Proc. Roy. Soc. **A155**, 519 (1936); E. McMillan and E. O. Lawrence, Phys. Rev. **47**, 343 (1935); E. O. Lawrence, Phys. Rev. **47**, 17 (1935) and papers in reference 1.

The various $Q$ values correspond to excited states of the product nucleus $Ti^{48}$. There is as yet no known simple method of classifying nuclei to exhibit regularities of properties; however the excess of neutrons over protons is often referred to in theoretical calculations. In Table II is collected the average spacing of all the known levels of nuclei from $Ne^{22}$ to $V^{51}$, grouped according to this manner. It can be seen that there is no significant trend in level spacing as the neutron excess increases beyond two.

The drop in proton yield for absorptions less than 15 cm is consistent with the fact that the potential barrier to emergent protons will greatly diminish the chance of escape of a proton which has sufficient energy to do so, but yet has to penetrate the barrier. Calculations show that a proton of 15 cm range has a 20 percent chance of traversing the barrier while one of 10 cm range has only one-fourth the chance. This would thus indicate that the lifetime of the composite $V^{49}$ nucleus is very short, of the order of $10^{-22}$ sec.

From Dempster's[3] value for the mass of $Ti^{48}$ we have

$$Sc^{45} + He^4 \rightarrow Ti^{48} + H^1 [+Q]$$
$$Sc^{45} + 4.0039 = 47.9561 + 1.0081 - 0.0004,$$

which gives the value 44.9599 for the isotopic weight of $Sc^{45}$.

The author wishes to thank Mr. W. L. Davidson, Jr. for helping him to complete the observations in spite of the competition of constructing a cyclotron, and Professor A. F. Kovarik for his interest in the work.

[3] A. J. Dempster, Phys. Rev. **53**, 64 (1938).