The small intensity at energies close to the first resonance must be due partly at least to the large barrier effect on the proton. The large yield of γ-rays at high energies indicates successful competition with dissociation into $O^{16}+He^4$. It suggests the origin of these γ-rays as due to $(O^{16})^* \rightarrow O^{16}+h\nu$. The apparently diffuse structure of the levels at the highest energies may be caused partly by the increased width due to dissociation into $(O^{16})^*+He^4$ as well as the broadening due to proton escape.

In conclusion it must be emphasized that the above considerations are speculative.

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The Transmutation of Titanium by Th C′ Alpha-Particles

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Protons have been observed from the bombardment of titanium by Th C′ alpha-particles. They are probably due to the reaction $Ti^{48}+He^4 \rightarrow V^{51}+H^1$. Three groups of protons are found corresponding to nuclear energy change $[Q]$ values of $+1.10$, 0.00 and -3.63 Mev. The separation of the last two groups is abnormally great. Combined with Dempster's value for the mass of Ti^{48}, the results lead to a mass of 50.9598 for V^{51}.

INTRODUCTION

TITANIUM, under bombardment by high energy alpha-particles, has been found to give a considerable yield of protons. The magnitude of the yield seems to require that the following reaction is responsible:

$$Ti^{48}+He^4 \rightarrow V^{51}+H^1+[Q]$$

where $[Q]$ represents the nuclear energy change which takes place in the process.

We have investigated the transmutation protons arising from this reaction. Two different geometrical arrangements were used; first, an arrangement whereby the protons ejected at 90° to the incident alpha-particle are detected; and second, one in which the emergent proton and incident alpha-particle are in the same direction. Absorption curves have been obtained for both arrangements. Any definite "steps" in such a curve may be interpreted as representing energy levels in the residual nucleus, and by finding the nuclear energy change [Q value] corresponding to each group of protons, the spacing of these energy levels can be found. The recent publication by Dempster of a value for the mass of Ti^{48}, combined with the Q value corresponding to the limiting energy of the protons, should enable us to use this reaction to calculate the mass of V^{51}. The reaction is of additional interest since vanadium has an excess of five neutrons over protons in its nucleus. No other element studied has such a high excess of neutrons and hence any anomalies found might be considered significant.

APPARATUS

The apparatus used has been described in earlier papers.[1, 2] A few minor additions have been made, which tend to make the apparatus more nearly automatic in operation. In its present state, an all night run, involving ten changes of absorption foils, may be carried through with no attention required after it is started. The proportional counter was filled with argon at one atmosphere of pressure and operated

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[1] C. J. Brasefield and E. Pollard, Phys. Rev. **50**, 296 (1936).

[2] E. Pollard and C. J. Brasefield, Phys. Rev. **50**, 890 (1936).

at a case potential of 2600 volts. This arrangement proved entirely satisfactory throughout the whole experiment, which involved a total counting time of more than 400 hours.

Figure 1 gives the details of the two arrangements. A $\frac{1}{8}$-inch layer of titanium metal filings cemented to a copper backing served as a target for the so-called "right angle" scheme. For "forward" observation it was necessary that the layer be thin enough to allow the protons to get through to the counter. It proved inconvenient to obtain a layer of the metal sufficiently thin for our purpose. Hence a layer was prepared by brushing an alcoholic suspension of TiO_2 onto a thin gold foil, and an attempt made to obtain a uniform layer of the oxide over the whole bombardment surface.

The solid angle subtended between source and counter is normally greater in the "forward" method. However, because of the reduced effective area of the "forward" layer since oxygen is present, the yield from both arrangements was very nearly the same. The "forward" method is not open to use at ranges of less than 40 cm on account of the masking effect due to natural protons from the source in this region. Hence the "right angle" method is superior to the "forward" arrangement for the complete analysis of an element.

EXPERIMENTAL PROCEDURE AND RESULTS

A straightforward procedure was employed. Protons ejected from the target under bombardment by alpha-particles from a Th C′ source were detected by the counter after passing through various thicknesses of aluminum foil. The strength of the sources used varied from day to day but averaged around half a millicurie. This necessitated long runs at each absorption point in order to obtain data of reasonable statistical weight. Our counter background was never greater than 12 counts per hour, and the actual background was subtracted in every case from the total yield. Between 200 and 1000 particles were counted at each point on the "right angle" curve. The "forward" curve represents a somewhat smaller number of counts.

Figures 2 and 3 depict the absorption curves obtained. The number of protons ejected per minute per millicurie is plotted as ordinate against the range R of the protons in centimeters air equivalent.

From Fig. 2 it is evident that there are three proton groups present, corresponding to ranges of 26 cm, 73 cm, and 98 cm. These two latter groups are verified in Fig. 3, which shows ranges of 92 cm and 112 cm. Q values for each group are tabulated in Table I. It is clear that the values for corresponding groups from both arrangements agree to within the experimental error.

It is seen that the energy levels are for the most part widely separated. This is contrary to the trend one would expect in elements of increasing atomic weight. Perhaps the high neutron excess in vanadium may be the underlying cause of this phenomenon.

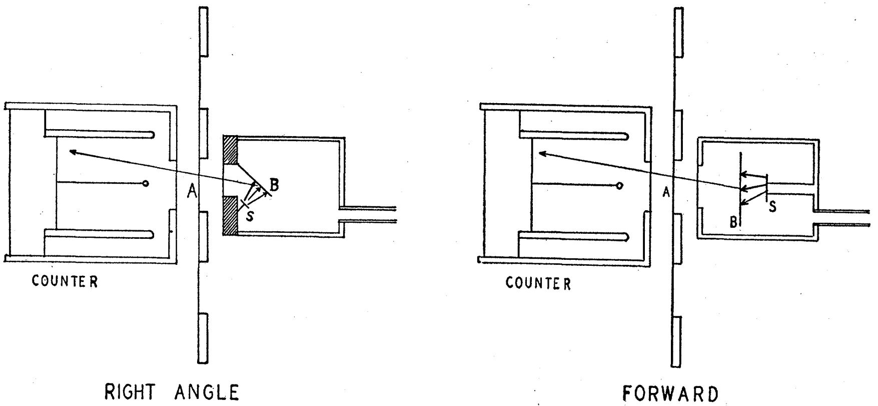

FIG. 1. Schematic arrangement of source (S), target (B), and screens (A) in "right angle" and "forward" methods of bombardment and detection.

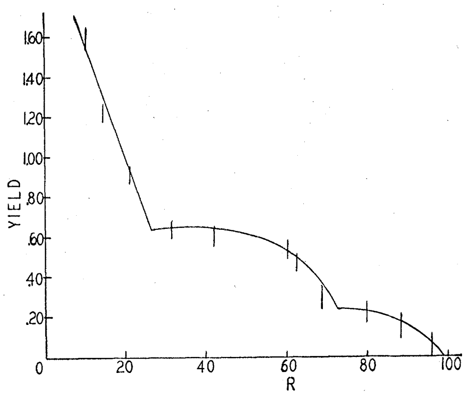

FIG. 2. Absorption curve for the protons ejected in the "right angle" direction. Three groups of protons of ranges 26, 73 and 98 cm are present.

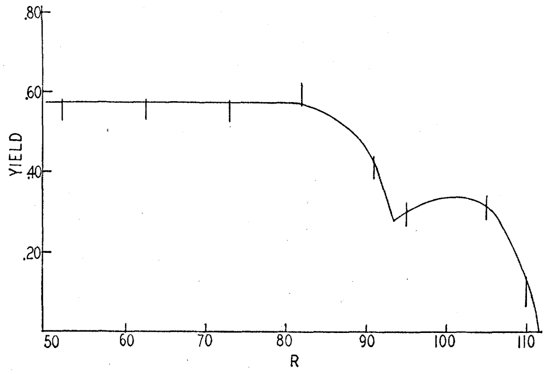

FIG. 3. Absorption curve for the protons ejected in the same direction as the incident alpha-particles. Two groups are present, of range 92 and 112 cm, whose "Q" values agree with those of the two most penetrating groups of Fig. 2.

Expressing the energy change for the longest range proton group in terms of mass units and adopting Dempster's recent value for the mass of Ti^{48} [3] we have:

$$Ti^{48}+He^{4}\rightarrow V^{51}+H^{1}+[Q],$$
$$47.9651+4.0039=V^{51}+1.0081+0.0011$$

and we derive the value 50.9598 for the mass of the stable vanadium nucleus.

TABLE I. *Value of Q in the* Ti^{48}–He^{4} *reaction for the various groups of ejected protons.*

Right Angle			Forward		Average
Group	Range cm	"Q" Mev	Range cm	"Q" Mev	"Q" Mev
1	26	−3.63			−3.63
2	73	−0.19	92	+0.19 Mev	0.00
3	98	+1.20	112	+1.00 Mev	+1.10

We wish to thank Professor A. F. Kovarik for his interest in this work.

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