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INVESTIGATION OF THE $V^{51}(C^{12}, 2n)Cu^{61}$ *REACTION*

A. S. KARAMYAN* and A. A. PLEVE

Joint Institute for Nuclear Research

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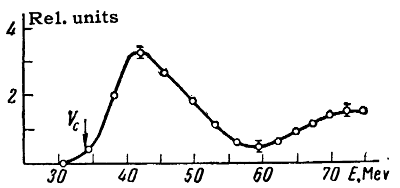
In a study of the reaction $V^{51}(C^{12}, 2n)Cu^{61}$ it was discovered that previously published results may be inaccurate, owing to the presence of Mn^{56} among the reaction products. This isotope emits radiation similar to that of Cu^{61}. The quantitative side of the problem requires further, more detailed investigation.

THE reaction $V^{51}(C^{12}, 2n)Cu^{61}$ was investigated previously, using the stacked foil method. The copper was chemically separated from the samples. The excitation curve for this reaction has a characteristic evaporation maximum at small energies. As the energy of the C^{12} ions increases, however, the cross section does not fall off to zero but remains roughly constant at 10 mb in the energy range of 55 to 75 Mev. This was somewhat unexpected for a heavy-ion reaction, since such an excitation curve shape is typical of direct knock-on processes. These are observed in reactions involving fast light particles whose energy is substantially greater than the binding energy of the nucleon in the nucleus. In the experiments described, the energy of the heavy ions did not exceed 6.3 Mev/nucleon. Therefore another investigation of the products of the $V^{51} + C^{12}$ reaction has been undertaken. The isotope Cu^{61}, which is obtained when two neutrons are emitted from the compound system, was studied first. As in reference 1, the method of stacked foils was employed. The induced activity was measured in an end-window beta counter. The reaction products were identified by their half-lives and by the end-point energies of the beta spectra. These latter were measured by absorption.

*Deceased.



The figure presents the yield curve of the product with $T_{1/2} \sim 3$ hours, formerly ascribed completely to Cu^{61} (V_C is the Coulomb barrier of the reaction). It is seen that the curve rises to a certain extent at large energies. In this connection, a careful analysis was made of the experimental data. It was found that the half-lives and energies of beta particles on the right and left portions of the yield curve were somewhat different. This difference, although small, is distinctly apparent. It is probable that we are dealing with two different products here.

The respective periods and energies are presented in the table, where the letter X designates the product responsible for the rise of the yield curve at $E^* \sim 60$ Mev (E^* is the excitation energy of the compound nucleus).

Thus, at large energies, it is apparently impossible to attribute the yield of the product with $T_{1/2} \sim 3$ hours entirely to the reaction $V^{51}(C^{12}, 2n)Cu^{61}$. If this reaction continues to take place, its yield is

Product	Half-life, hours: Data of present work	Half-life, hours: Literature data[2]	Particle energy, Mev: Data of present work	Particle energy, Mev: Literature data[2]
Cu^{61}	3.3±0.05	3.33	1.2±0.2	1.22
X	2.8±0.05		2.0±0.4 (60%) 0.5±0.2 (40%)	

masked by another activity with a larger yield and similar characteristics. According to reference 2, only Mn^{56} among the possible products of the $V^{51} + C^{12}$ reaction has similar characteristics: $T_{1/2} = 2.6$ hours, $E_\beta = 2.8$, 1.0 and 0.6 Mev. It can be formed when an alpha particle, a neutron, and two protons are emitted from the compound system. The energy threshold for this reaction is approximately 55 Mev, which is not in disagreement with estimates made from the excitation curve in the figure (computations of the threshold energy value were based on Cameron's data (private communication) on nuclear masses with different assumptions as to the mechanism of the reaction). But in such an event, the source of error in the chemical separation[1] remains obscure.

Dorofeev and others[3] tried to detect neutrons produced in reactions involving heavy ions. The authors made use of secondary reactions caused by neutrons in threshold detectors, in particular the reaction $C^{12}(n, 2n)C^{11}$, where $Q = -18.5$ Mev. If the excitation energy is on the order of 70 Mev and only two neutrons are emitted as a result of the reaction $V^{51} + C^{12}$, they can have an energy of 20 Mev or even more. With a cross section of ~ 10 mb for the reaction $V^{51}(C^{12}, 2n)Cu^{61}$, it can be expected that neutrons with $E \geq 18.5$ Mev will induce a marked activity in the carbon. Measurements have shown[3] that this activity is considerably smaller than anticipated.

Reactions involving heavy ions, which at large excitation energies lead to emission of two neutrons, require further and more detailed investigation. It can only be said that the cross section for such a reaction on vanadium is known to be less than 10 mb.

It was reported earlier[4] that the cross section for the reaction $Nb^{93}(C^{12}, 2n)Ag^{103}$ is also constant in the energy inverval 55 — 70 Mev and is approximately 10 mb. This result is obviously also in need of verification.

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[2] Strominger, Hollander, and Seaborg, Revs. Modern Phys. **30**, 585 (1958).

[3] Karamyan, Dorofeev, and Klochkov, JETP **40**, 1004 (1961), Soviet Phys. JETP **13**, 705 (1961).

[4] A. S. Karamyan and A. A. Pleve, JETP **37**, 654 (1959), Soviet Phys. JETP **10**, 467 (1960).

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