15/IV-70

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E7 - 4949

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NEW ISOTOPES ^{21}N, ^{23}O, ^{24}O AND ^{25}F, PRODUCED IN NUCLEAR REACTIONS WITH HEAVY IONS

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NEW ISOTOPES ^{21}N, ^{23}O, ^{24}O AND ^{25}F, PRODUCED IN NUCLEAR REACTIONS WITH HEAVY IONS

Submitted to Phys. Lett.

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It has been shown in refs.[1,2] that nuclear reactions with heavy ions represent an effective way of producing new neutron-rich isotopes of light elements.

The present work is a successive stage of the experimental study of particle-stability for the extremely neutron-rich isotopes of nitrogen, oxygen and fluorine.

The experiment was performed with the 310-cm heavy-ion cyclotron at Dubna. A metallic ^{232}Th target of 11 mg/cm^2 thickness was bombarded with 174 MeV ^{22}Ne ions. The reaction products emitted from the target at 40° with respect to the incident beam passed the magnetic spectrometer and were detected in a counter telescope placed in the focal plane of the spectrometer. The telescope consisted of two semiconductor detectors: a 46.6 μm thick ΔE detector (16 mm in diameter) and a 0.6 mm thick $E-\Delta E$ detector. The pulses from both detectors, after amplification, were sent to a two-dimensional, 64 x 64 channel pulse-height analyser.

For a fixed magnetic rigidity BR the two-dimensional $(\Delta E, E-\Delta E)$ pulse-height spectra represent a set of well separable maxima. Each maximum corresponds to a different reaction product with definite mass number A, atomic number Z and ion charge Z_i.

The experimental technique is described in detail in ref./3/.

Fig. 1 shows the yields of oxygen heavy isotopes as a function of BR. Similar curves were obtained for isotopes of nitrogen and fluorine. The energy spectra displayed on the right hand side of Fig. 1 show that the exchange-type $(-2p, +xn)$ reactions producing heavy oxygen isotopes proceed with the average value of excitation energy $E^*_{av} = Q_{g.g} - Q_{av}$ equal to about 12 MeV, independently of the number of transferred neutrons. This fact was used for estimation of the BR value at which reactions producing new ^{23}O and ^{24}O isotopes should proceed with maximum yields. The masses of ^{23}O and ^{24}O isotopes necessary for calculation of the $Q_{g.g}$ values (e.g. for reactions leading to the ground states of both reaction products) were taken from paper of Garvey and Kelson/4/. The estimate has shown that the maximum yield of ^{23}O and ^{24}O isotopes passing through the magnetic spectrometer with charge $Z_1 = 7$ should be expected at BR = 10.4 kGs·m. As we have already reported /2/, the detection of the heaviest isotopes of the given element with charge $Z_1 = Z - 1$ allow for a sufficient decrease of the background caused by other reaction products, in contrast to the case when the ions with charge $Z_1 = Z$ are detected.

The yields of C, N, O, F and Ne isotopes obtained at BR = 10.4 kGs·m are shown in Fig. 2. The numbers of counts given in this figure were obtained by summing the counts in a few adjacent ΔE-channels along the line Z = const. on which the peaks corresponding to the isotopes of the element Z should be situated. The arrows point the predicted positions for different isotopes. Fig. 2 shows that apart from a number of already known isotopes, four new isotopes: ^{21}N (about 60 events), ^{23}O (about 130 events), ^{24}O (about 30 events) and ^{25}F (about 40 events) have been obtained.

The only source of background in detection of $^{21}N^{+6}$, $^{23}O^{+7}$, $^{24}O^{+7}$ and $^{25}F^{+7}$ ions would be $^{14,15}O^{+5}$, $^{16,17}F^{+6}$, $^{17,18}F^{+6}$ and $^{18,19}Ne^{+6}$ ions, respectively. However, the yield measurements of totally ionized $^{14,15}O^{+8}$, $^{16,17,18}F^{+9}$ and $^{18,19}Ne^{+10}$ showed that their contribution to the observed effect is smaller than 5%.

According to the conclusions of Vinogradov and Nemirovsky paper/6/ the ^{24}O nuclide is the last particle-stable oxygen isotope, whereas according to estimations of Garvey and Kelson/4,5/ the last particle-stable isotope of oxygen should be ^{28}O. Similar discrepancies exist in the theoretical estimations for isotopes of other elements. Thus only further experiments on the particle-stability of heaviest isotopes, first of all of oxygen and carbon, together with the mass measurements for the extremely neutron-rich isotopes may clear the situation.

The authors are much indebted to Professor G.N. Flerov, Member of the USSR Academy of Sciences for his permanent interest in our work.

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Received by Publishing Department
on February 27, 1970.

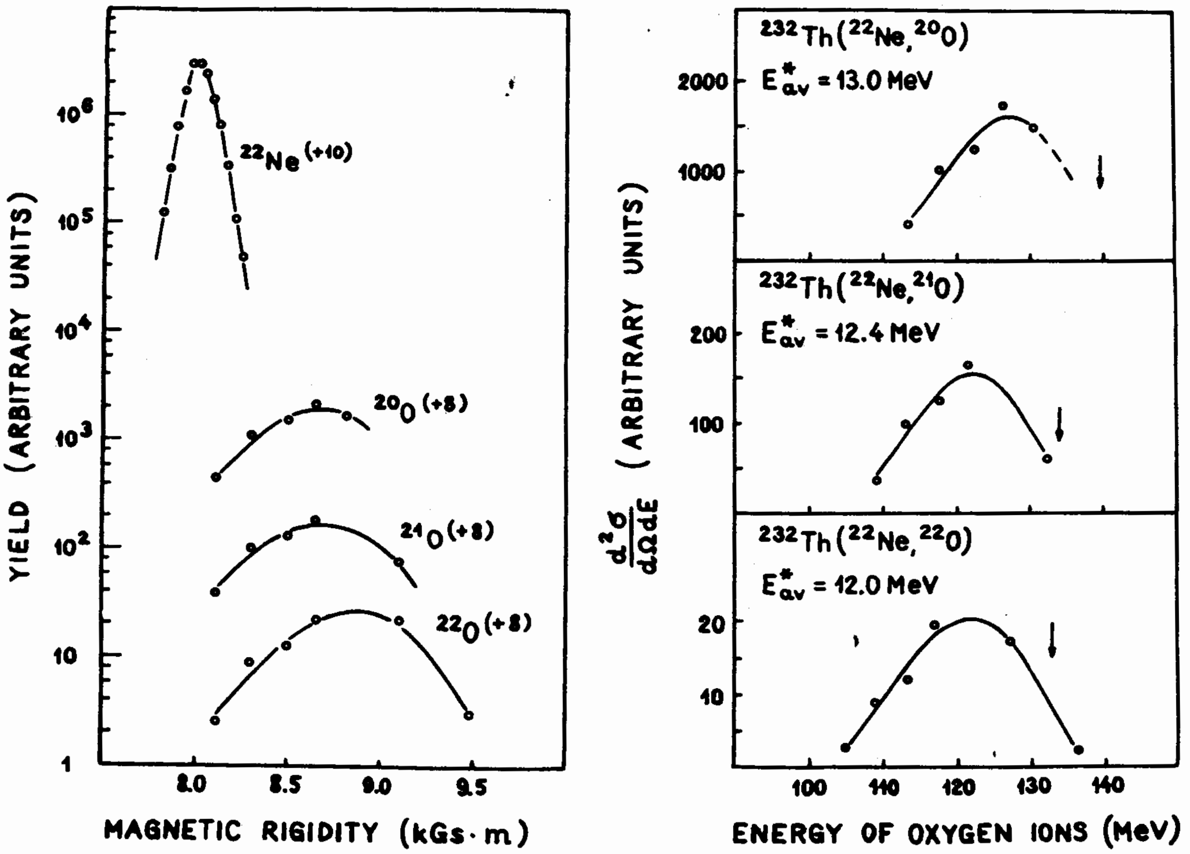

Fig.1. Yields of ^{20}O , ^{21}O and ^{22}O isotopes from the ^{22}Ne + ^{232}Th reaction as a function of magnetic rigidity BR (on the left) and as a function of the outgoing particle energy (on the right). The arrows point the predicted outgoing particle energies for reactions leading to the ground states of the both reaction products.

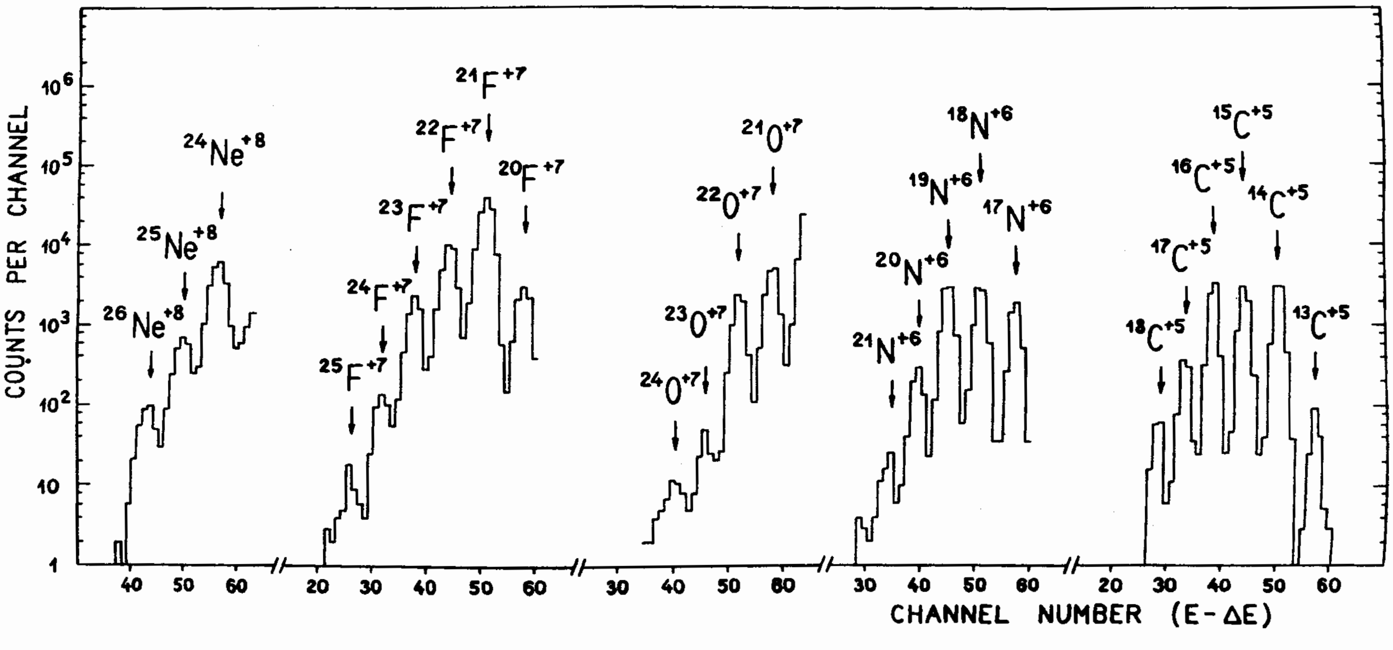

Fig. 2. Yields of neon, fluorine, oxygen , nitrogen and carbon neutron-rich isotopes from the ^{22}Ne + ^{232}Th reaction at E_{lab} = = 174 MeV; BR = 10.4 kGs·m ; the ^{22}Ne flux through the target amounts to $5.1x10^{16}$ particles.