Lawrence Berkeley National Laboratory

Recent Work

Title

OBSERVATION OF THE NEW ISOTOPE 17C USING A COMBINED TIME-OF-FLIGHT,
PARTICLE-IDENTIFICATION TECHNIQUE

Permalink

<https://escholarship.org/uc/item/1pn1w2b9>

Authors

Poskanzer, A.M.
Butler, Gilbert W.
Hyde, Earl K.
et al.

Publication Date

1968-05-01

UCRL-18207

University of California

Ernest O. Lawrence
Radiation Laboratory

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 5545*

OBSERVATION OF THE NEW ISOTOPE ^{17}C USING A COMBINED TIME-OF-FLIGHT,
PARTICLE IDENTIFICATION TECHNIQUE

A. M. Poskanzer, Gilbert W. Butler, Earl K. Hyde, Joseph Cerny,
D. A. Landis, and F. S. Goulding

May 1968

RECEIVED
LAWRENCE
RADIATION LABORATORY

JUN 13 1968

LIBRARY AND
DOCUMENTS SECTION

Berkeley, California

18207

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

to be submitted to Phys. Rev. Letters

UCRL-18207
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

OBSERVATION OF THE NEW ISOTOPE ^{17}C USING A COMBINED TIME-OF-FLIGHT,
PARTICLE-IDENTIFICATION TECHNIQUE

A. M. Poskanzer, Gilbert W. Butler, Earl K. Hyde, Joseph Cerny,
D. A. Landis, and F. S. Goulding

May 1968

OBSERVATION OF THE NEW ISOTOPE ^{17}C USING A COMBINED TIME-OF-FLIGHT,
PARTICLE-IDENTIFICATION TECHNIQUE*

A. M. Poskanzer, Gilbert W. Butler, Earl K. Hyde, Joseph Cerny,
D. A. Landis, and F. S. Goulding

Nuclear Chemistry Division, Lawrence Radiation Laboratory
University of California
Berkeley, California

May 1968

A telescope of silicon semiconductor detectors has been used to study light nuclei ejected from a uranium target bombarded with 5.5-GeV protons. Addition of time-of-flight to the previously used particle-identification technique has established the existence of ^{17}C and the particle instability of ^{13}Be .

The interaction of GeV protons with a high-Z target leads to the copious production of isotopes of the light elements with energy distributions peaking near or somewhat below the nominal Coulomb barrier for the target element but extending to much higher energies. We are engaged in a systematic study of the energy and angular distribution characteristics of these fragments with a particle identifier system which is based on the measurement of energy losses in thin semiconductor detectors. Studies of fragment production have made it clear that all isotopes of the light elements are made in such reactions and, consequently, that a systematic search for previously unreported particle-stable isotopes can be carried out. In a previous publication¹ we demonstrated the utility of the technique by proving the existence of ^{11}Li , ^{14}B , and ^{15}B , the particle instability of ^{10}Li , and the probable particle instability of ^{13}Be . In the present note we report new results which depend

upon an extension of the earlier technique to include mass identification by a time-of-flight measurement in addition to particle identification by energy-loss measurements.

The experiment was performed by using the Bevatron's 5.5-GeV external proton beam to bombard a uranium metal target of 27 mg/cm^2 thickness placed in the center of an evacuated 36-in. diameter scattering chamber. Beam pulses 0.6 sec long and containing about 3×10^{11} protons occurred every six seconds. In a preliminary experiment not involving time-of-flight a telescope of phosphorus-diffused silicon counters was located 22 cm from the target at an angle of 30 degrees to the beam; it consisted of two ΔE detectors (61 and 46 μ thick), an E detector (195 μ), and a rejection detector. A small magnet (to deflect electrons) and a 1.2-mg/cm^2 nickel foil (to stop spallation recoils) were placed in front of the telescope. The first and third detectors were collimated to $4 \times 6 \text{ mm}$. Details of the circuitry employed with the detectors to effect the particle identification can be found elsewhere.² Figure 1 shows the particle spectrum covering the region of the Be, B, C, and N isotopes which resulted from 35 hr of data collection. The improved resolution in the carbon region over our previous work is due to a decrease in the power-law exponent of the particle identifier from 1.7 to 1.6 and an increase in the minimum energy required from the E detector from 20 to 30 MeV. The isotopes ^{14}B and ^{15}B are nicely reproduced in Fig. 1 and it is now quite clear that ^{13}Be does not exist.³ However, in an attempt to determine the existence of other isotopes a difficulty arose in that the particle-identifier signals corresponding to the heaviest isotopes of one element overlapped those for the lightest isotopes of the next element. Hence it is clear that measurement of energy losses in thin

detectors is not sufficient for an unambiguous identification. For example, in Fig. 1 the expected position of ^{14}Be is under the low side of the ^8B peak and that expected for ^{18}C lies very near the known isotope ^{12}N . There appears to be evidence for a ^{17}C peak in this figure but in order to verify this and to resolve some of the other ambiguities we decided to change our apparatus to permit measurement of an additional parameter, the time-of-flight of the fragments, and from this and their energy to obtain an independent determination of fragment mass.

The telescope used for the combined time-of-flight, particle-identification measurements consisted of five detectors at an angle of 45° to the beam. The first, at a distance of 18 cm from the target, was 31 μ thick and was used only to obtain a start time signal. The second detector, at a distance of 38 cm from the target, was 60 μ thick and was used both to obtain a stop time signal and a ΔE signal for the particle identifier. The next counter was a 46 μ thick ΔE detector, followed by a 195 μ E detector, and finally by a rejection detector. The preamplifiers used for the detectors from which timing signals were derived were integrally mounted with the detectors in the vacuum chamber. The signals were sent to fast amplifiers with 30 ns double delay-line shaping and then to tunnel-diode discriminators operating on the zero-crossing signal. The discriminator outputs then went to a time-to-amplitude converter. In a preliminary experiment a flight path of only three cm was used in order to determine the zero time and the time resolution. The net walk of time with pulse height was found to be less than 0.05 ns for the energies deposited by all fragments from ^7Be to ^{15}N . The time resolution varied from 1/3 ns for ^{15}N up to 1/2 ns for ^7Be . The time-of-flight signal t , and E_T , the total energy deposited in the E

detector and the two ΔE detectors, were sent to a circuit which performed the analogue calculation $E_T \times t^2$ and thus produced a signal proportional to the mass of the fragment. The mass signal and the particle signal were then stored in a 4096-channel two-parameter analyzer. The data obtained in 2 days of data collection are presented as a particle spectrum in Fig. 2 and show clear evidence for a ^{17}C peak. Mass spectra were then summed for the ten indicated regions in the particle spectrum and these are plotted in Fig. 3. Actually, because of radiation damage to the detectors which caused a slight degradation of the particle spectrum but not the mass spectrum, the data in Fig. 3 correspond to a running time $2\frac{1}{2}$ times longer than the data in Fig. 2. Almost all the events which fell in the ^{17}C region of the particle spectrum also fell in the mass 17 region of the mass spectrum, thus clearly proving the existence of ^{17}C .

By looking at Fig. 1, one might have been tempted to ascribe a peak to ^{18}C but the time-of-flight data indicate fewer events and most of them do not fall in the mass 18 region. Assuming a yield ratio of $^{18}\text{C}/^{17}\text{C}$ similar to the $^{16}\text{C}/^{15}\text{C}$ or $^{15}\text{B}/^{14}\text{B}$ ratios one would have expected about ten ^{18}C events. In fact only three events are consistent with ^{18}C so that we are presently unable to determine experimentally whether ^{18}C is particle stable. It is likely that most of the other events are ^{12}N fragments even though for some unknown reason their masses appear slightly high.

In a separate experiment with a different version of the equipment which gave somewhat worse mass resolution a search was made for ^{14}Be . A limit could be set only a factor of four lower than the number expected assuming the $^{14}\text{Be}/^{12}\text{Be}$ yield ratio was the same as the observed $^{12}\text{Be}/^{10}\text{Be}$ ratio. Thus our

results are inconclusive concerning the particle stability of ^{14}Be . However, this same experiment easily exhibited mass peaks for ^{11}Li and ^{15}B as expected.

Garvey and Kelson⁴ predicted the instability of ^{13}Be but were unable to make a clear prediction for ^{17}C . Of course the existence of ^{17}C makes it certain that ^{18}C , an even-even isotope, also is particle stable.

We wish to thank R. P. Lothrop and M. D. Roach for making the detectors.

FOOTNOTES AND REFERENCES

* This work performed under the auspices of the U. S. Atomic Energy Commission.

1. A. M. Poskanzer, S. W. Cospér, E. K. Hyde, and J. Cerny, Phys. Rev. Letters 17, 1271 (1966).
2. G. W. Butler, J. Cerny, S. W. Cospér, and R. L. McGrath, Phys. Rev. 166, 1096 (1968), and references therein.
3. We also have another spectrum where the yield ratio $^{12}\text{Be}/^{13}\text{Be}$ is greater than 100 whereas if ^{13}Be exists this ratio should be similar to the $^{10}\text{Be}/^{11}\text{Be}$ or $^{13}\text{B}/^{14}\text{B}$ ratios which are about 10.
4. G. T. Garvey and I. Kelson, Phys. Rev. Letters 16, 197 (1966).

Figure Captions

Fig. 1. Particle spectrum derived from energy loss measurements in semiconductor detectors. The fragments were produced by the bombardment of uranium by 5.5 GeV protons. The three arrows indicate in order the positions that would be expected for ^{17}C , ^{18}C , and ^{12}N . (Peak areas do not accurately reflect relative yields because of the narrow and different ranges of total energy accepted for each isotope.)

Fig. 2. Particle spectrum obtained during the combined time-of-flight, particle-identification experiment. The double-headed arrows indicate the regions for which the mass spectra are summed and presented in Fig. 3.

Fig. 3. Mass spectra derived from time-of-flight and energy measurements. Each mass spectrum corresponds to a region in the particle spectrum indicated in Fig. 2.

Fig. 1

Fig. 2

XBL684-2517

Fig. 3

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.