Z. Phys. A - Atomic Nuclei 324, 487-488 (1986)

Zeitschrift für Physik A
Atomic Nuclei

Short Note

Beta Decay of ^{17}C, ^{19}N, ^{22}O, ^{24}F, ^{26}Ne, ^{32}Al, ^{34}Al, $^{35-36}Si$, $^{36-37-38}P$, ^{40}S

J.P. Dufour, R. Del Moral, A. Fleury, F. Hubert, D. Jean, and M.S. Pravikoff
Centre d'Etudes Nucléaires de Bordeaux-Gradignan, Le Haut Vigneau, F-33170 Gradignan, France

H. Delagrange
GANIL, B.P. 5027, F-14021 Caen Cedex, France

H. Geissel and K.-H. Schmidt
Gesellschaft für Schwerionenforschung, D-6100 Darmstadt, Federal Republic of Germany

Received June 27, 1986

Abstract :
The thirteen above-listed isotopes have been produced at GANIL by fragmentation of a ^{40}Ar beam at 60 MeV/nucleon. The LISE spectrometer allowed us to isotopically separate these nuclei. Beta delayed gamma spectroscopy was carried out for the first time for eleven isotopes and additional information was obtained for another two.

The GANIL intermediate energy heavy-ion beams recently have proved very efficient at producing exotic light nuclei (1). We report here on the first measurements of beta-gamma spectroscopy performed on neutron-rich projectile fragments produced with a ^{40}Ar beam of 2×10^{11} particles/s at 60 MeV/nucleon reacting on a 190mg/cm^2 Be target. The key device for this experiment was the LISE spectrometer. It was first shown (2) that LISE could be operated with an intermediate energy degrader foil preserving the achromatism of the apparatus. In this way the produced nuclei can be separated according to A/Z and $A^{2.5}/Z^{1.5}$ in the first and second parts of the spectrometer, respectively. The details of the Projectile Fragments Isotopic Separation (PFIS) that we have obtained are given in ref. 2. The nuclei transmitted by LISE were slowed down by aluminium foils placed one metre in front of the counting area and only those having the proper range were implanted in a thin foil. This foil was a movable film (35 mm photocinema) for the nuclei with $Z \geq 12$ and a fixed aluminium foil for lighter ions. The decay of the implanted nuclei was observed with a 1 mm thick plastic scintillator placed on a photomultiplier and a 174 cm^3 intrinsic Ge detector in close geometry (1.2% absolute efficiency at 1.33MeV). The beam was pulsed according to the presumed half-life of the searched nuclei. Gammas in coincidence with betas were recorded during beam-on cycles as well as during the beam-off periods.

In the approximation of velocity conservation in the reaction mechanism and neglecting relativistic corrections, a simplification in the correspondence between A, Z and the experimentally measured magnetic rigidities $B\rho_1$ and $B\rho_2$ is obtained :

$$A = \frac{k_1}{B\rho_1^{\lambda-2}} \cdot \frac{B\rho_1^{\lambda} - B\rho_2^{\lambda}}{d}$$

$$Z = \frac{k_2}{B\rho_1^{\lambda-1}} \cdot \frac{B\rho_1^{\lambda} - B\rho_2^{\lambda}}{d}$$

where d is the thickness of the degrader, k_1, k_2, λ are constants characterizing the slowing-down process in the material ($\lambda \simeq 3.5$ for Al) at intermediate energies.

While the above formulae show the main influence of $B\rho_1$, $B\rho_2$ and d, the tuning of LISE was calculated with the more accurate relations described in ref. 2. A calibration on a known isotope was necessary to precisely determine the scaling factor in the slowing-down process. In this experiment the chosen isotope was ^{30}Mg, identified through its characteristic gammas following beta-decay. Subsequent tunings on other isotopes ^{37}P, ^{25}Ne, ^{21}O, ^{15}C, proved accurate to better than 0.1 mass unit. When the optimum transmission for the ^{A}Z nucleus is achieved, one observes the presence of contaminants which are always the same in the specific case of this experiment : $^{A+3}Z+2$, $^{A+1}$,$^{A+2}Z+1$, $^{A-2}Z-1$, while the ^{A-1}Z and $^{A}Z+1$ isotopes are highly rejected, having transmissions less than 2.5% and 1% respectively. Series of tunings on a large number of isotopes having unknown or incompletely known decay properties in the $6 \leq Z \leq 16$ domain allowed us to identify most of the detected peaks. The attribution of a gamma ray

3349 and 3590 are not observed by 1988DUZS

ISOTOPE : HALF-LIFE (s)	Gamma Energy (keV)	Relative Intensity	
^{40}S ; $T_{1/2}$=8.8(2.2)			
	211.6 (4)	100	(10)
	431.9 (4)	51	(10)
	677.5 (5)	38	(10)
	888.6 (4)	50	(12)
^{38}P ; $T_{1/2}$=0.64(14)			
	1292.3 (4)	100	(6)
	2224.3 (10)	23	(4)
	3516.0 (10)	13	(4)
	3698.0 (10)	11	(3)
	4713.3 (10)	10	(3)
^{37}P ; $T_{1/2}$=2.31(13)			
*	646.2 (3)	100	(4)
*	751.2 (3)	7.2	(6)
*	1582.9 (4)	74.4	(30)
	2100.8 (4)	6.1	(8)
	2254.1 (4)	8.2	(10)
^{36}P ; $T_{1/2}$=5.33(53)			
	185.8 (4)	2.1	(1)
	579.8 (4)	0.4	(1)
	757.5 (4)	1.6	(2)
	812.0 (4)	4.9	(3)
	826.9 (4)	15.7	(3)
	902.7 (4)	71.0	(20)
	1012.3 (4)	0.7	(2)
	1058.8 (4)	5.2	(3)
	1256.9 (4)	4.5	(3)
	1284.3 (4)	4.1	(3)
	1439.6 (5)	0.6	(2)
	1638.3 (4)	35.5	(10)
	1729.0 (5)	0.9	(2)
	1960.9 (5)	14.7	(5)
	2066.1 (5)	0.7	(2)
	2019.3 (5)	5.0	(3)
	2251.4 (5)	1.5	(2)
	2320.1 (5)	1.8	(3)
	2540.3 (5)	20.0	(8)
	3076.6 (5)	3.0	(10)
	3290.3 (5)	100.0	(30)
	3681.5 (6)	0.8	(2)
^{36}Si ; $T_{1/2}$=0.54(15)			
	174.7 (3)	106.	(6)
	250.3 (4)	100.	(5)
	424.8 (4)	60.	(10)
	878.2 (5)	64.	(12)
	921.8 (5)	19.	(7)
	1856.2 (6)	45.	(10)
^{35}Si ; $T_{1/2}$=0.87(17)			
	241.4 (3)	100	(4)
	392.3 (3)	59	(5)
	633.7 (5)	27	(4)
	1473.4 (5)	19	(6)
	1714.7 (6)	24	(6)
	1994.8 (6)	36	(6)
	2386.4 (6)	127	(12)
	3173.5 (10)	41	(7)
	3349.1 (10)	46	(6)
	3590.0 (11)	60	(7)
	3859.5 (10)	117	(9)
	4100.8 (10)	146	(10)
^{34}Al; $T_{1/2}$=0.050(25)			
	123.8 (4)	100	
^{32}Al ; $T_{1/2}$=0.031(6)			
	1941.4 (5)	100	(7)
	2289.4 (8)	11	(3)
	3042.1 (10)	36	(5)
	3844.0 (15)	10	(3)
	4230.0 (15)	14	(3)
^{26}Ne ; $T_{1/2}$=0.25(20)			
	233.4 (5)	100	
^{24}F ; $T_{1/2}$=0.34(8)			
	1981.6 (4)	100	
^{22}O ; $T_{1/2}$=2.9(15) or $T_1 \simeq T_2 \simeq 0.8(4)$			
	637.5 (4)	100	(8)
	917.9 (4)	43	(7)
	1862.0 (5)	67	(10)
^{19}N ; $T_{1/2}$=0.32(10)			
	96.0 (10)	100	(10)
	709.2 (8)	63	(21)
	3137.8 (10)	76	(21)
^{17}C ; $T_{1/2}$=0.22(8)			
	475.6 (4)	22	(7)
	619.6 (5)	18	(8)
	1374.7 (5)	100	(20)
	1848.7 (6)	75	(13)
	1906.0 (6)	49	(13)

Table 1 : List of the energies, relative intensities, and half-lives of the beta-delayed gammas observed in the decay of the nuclei studied. Numbers in parenthesis following any value represent the uncertainty in the last place or places. See text for definition of the asterisk and for the special case of the half-life of ^{22}O.

was primarily deduced from the evolution of its counting rate for different $B\rho_1$-$B\rho_2$ tunings. The maximum value was always obtained for the expected $B\rho_1$-$B\rho_2$ for known isotopes and this property was assumed to hold for the newly studied isotopes. The identification was confirmed with : i) the half-life measured on individual gamma-rays when available, ii) the check that the relative intensities of all the peaks attributed to the same isotope remained constant in the data corresponding to the different $B\rho_1$-$B\rho_2$ tunings allowing this isotope to be transmitted as a contaminant, iii) in the cases of $^{36-37-38}P$, ^{32}Al, ^{24}F, ^{19}N, ^{17}C some or all of the measured beta-delayed gammas had already been observed through in-beam gamma spectroscopy carried on the daughters. For ^{40}S, $^{35-36}Si$, ^{26}Ne, ^{22}O some gammas can be associated to transitions between the first known levels of the daughters.

The half-lives have been mostly determined from the decay activity of individual gammas during the beam-off period. The correctness of the measurements was checked on the following isotopes : ^{36}P(5.33±0.53)s, ^{32}Al(31±6)ms, ^{30}Mg(340±20)ms, ^{25}Ne(620±50)ms, ^{27}Na(295±20)ms. All of these values are compatible with the previous determinations (3). Another half-life determination was obtained by comparing the integrated activities during the beam-on and the beam-off period. Due to low statistics the quoted half-life of ^{26}Ne has been obtained in this way only. For the isotopes other than ^{26}Ne and ^{22}O the results of this method agree well with the values extracted from the decay curves. In the case of ^{22}O the beam-off activity in the 637.5 keV peak exceeds the beam-on one by 30%. This surprising result can be interpreted in two ways : i) the decay of the 637.5 keV line during the beam-off period yields $T_{1/2}$ = 2.9±1.5s from a single exponential fit. But then the excess of beam-off activity can be explained only by a less than 1% probable statistical fluctuation, ii) the high beam-off activity of the 637.5 keV is delayed by an undetected isomeric transition in ^{22}O. The beam-off decay can be described with an isomeric half-life T_1 close to that of the ground state T_2 and in the range 0.8±0.4s.

The individual gamma energies and half-lives are listed in table 1 for the isotopes for which new data have been obtained. Except where marked with an asterisk, the given intensities have not been corrected for partial summing effects in the case of cascading gammas. These corrections are estimated to be less than 10% of the quoted intensities.

More complete data and their interpretation will be presented in forthcoming papers.

References :

1 - M. Langevin et al. Phys. Lett. 150B (1985) 71 and Guillemaud-Mueller et al. Zeit. Phys. A322 (1985) 415.
2 - J.P. Dufour et al. Nucl. Inst. Meth. (1986) In press.
3 - Chart of nuclides (1984) compiled by Y. Yoshizawa et al. Japan, Atomic Energy Research Institute.