DELAYED γ RAYS IN THE REACTION $^{40}\text{Ca} + ^{16}\text{O}$

P. FINTZ, A. GALLMANN, G. GUILLAUME, K. W. JONES*, F. JUNDT
and I. ORDÓÑEZ

Laboratoire de Physique Nucléaire et d'Instrumentation Nucléaire,
Centre de Recherches Nucléaires et Université Louis Pasteur,
Strasbourg, France

MASTER

ABSTRACT

The $^{40}\text{Ca} + ^{16}\text{O}$ reaction, obtained with a beam of 52 MeV $^{16}\text{O}^{6+}$ ions from the Strasbourg MP Tandem, on a thick target of natural calcium (97 % ^{40}Ca) has been used to measure delayed γ rays with a fast rabbit system and a 56 cc Ge(Li) γ ray detector placed in a shielded counting area. After particle evaporation the isotopes which are principally formed are ^{50}Mn , ^{52}Fe and the isomeric states of ^{53}Fe and ^{54}Co . This preliminary study yields information on γ ray energy values, relative intensities, half-lives and relative cross sections. The following half-lives are obtained : ^{50}Mn : 1.73 ± 0.15 min , ^{53m}Fe : 2.65 ± 0.06 min , ^{54m}Co : 1.49 ± 0.13 min. The E4 ($3.04 \rightarrow 2.34$ MeV) and M5 ($3.04 \rightarrow 1.33$ MeV) transition strengths in ^{53m}Fe are respectively 0.26 and 0.23 Moszkowski units.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or 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.

*

Permanent address : Brookhaven National Laboratory, Building 901 A,
UPTON, L.I., N.Y. 11973 (U.S.A.)

269

DELAYED γ RAYS IN THE REACTION $^{40}\text{Ca} + ^{16}\text{O}$

P. FINTZ, A. GALLMANN, G. GUILLAUME, K.W. JONES,* F. JUNDT,
and I. ORDÓÑEZ

Laboratoire de Physique Nucléaire et d'Instrumentation Nucléaire,
Centre de Recherches Nucléaires et Université Louis Pasteur,
Strasbourg, France

Heavy ion induced reactions are now commonly being used to produce isotopes far from the stability region. Limits for production of new proton-rich nuclei by a heavy-ion compound-nucleus mechanism have been predicted ¹⁾. Numerous experimental studies led to the discovery of new β -delayed γ emitters and β -delayed particle emitters and have permitted in particular to obtain spectroscopic information on the residual nuclei. In the s-d shell many nuclei have been studied ²⁾; in the f-p shell the experiments have been limited to some nuclei ³⁾.

In this work, we report a study of the $^{40}\text{Ca} + ^{16}\text{O}$ reactions which lead, after particle evaporation of the compound nucleus and eventually positron decay, to proton rich isotopes. Studies of this nature provide valuable information on the binding energies and level structures of the isotopes. Here we will discuss essentially the γ ray spectroscopy aspect and the cross sections of producing the different isotopes identified through the specific γ lines and through the half-life.

We have used the MP Tandem Accelerator from the CRN, Strasbourg, to produce an incident beam of 52 MeV $^{16}\text{O}^{6+}$ ions (~ 150 nA) and bombard a thick target of natural calcium (97 % ^{40}Ca). The delayed γ rays were detected with a 56 cm^3 Ge(Li) detector placed in a shielded

* Permanent address : Brookhaven National Laboratory, Building 901 A,
UPTON, L.I., N.Y. 11973 (U.S.A.)

counting area. The absolute efficiency of the detector was obtained by using calibrated ^{56}Co and ^{88}Y sources. In order to eliminate neutron damage to the Ge(Li) detector and activities induced in material near the target, the delayed γ rays were enregistered in an adjacent target room. A fast rabbit system and a multi-channel control programmer, similar to those existing ⁴⁾, were used to realise a time sequence for a complete irradiate-count cycle. Technical details are given in a previous paper ⁵⁾. Many different timing sequences were programmed in our work in order to cover a wide domaine of half-lives. Target irradiation times ranged from 2 to 900 s ; the transfer time was 0.2 s. In each case, the radiation was counted in seven equal consecutive intervals. The length of the intervals was as short as one second and as long as one hour. The delayed γ ray spectra were recorded in the memory of an analyser working in multispectra mode of 2048 channels. Fig. 1 gives an example of a delayed γ ray spectrum obtained with ^{16}O ions on a natural calcium target.

In the $^{40}\text{Ca} + ^{16}\text{O}$ system and at the bombarding energy we have used, the isotopes formed after particle evaporation, are principally ^{50}Mn , ^{52}Fe , $^{53\text{m}}\text{Fe}$ and $^{54\text{m}}\text{Co}$. Other isotopes are certainly produced to a much lesser extent and no evidence was found for their delayed γ rays. A preliminary analysis of our results gives the following half-lives (table I). The values obtained in the present work are similar to values reported previously ⁶⁾ with other reactions. In the table are summarized also the results we obtained for the γ rays, corrected for summing effects, in the Ge(Li) detector, resulting of the close geometry used. Results concerning $^{53\text{m}}\text{Fe}$ are consistent with some data of ref. ⁷⁾ in our case. However, the strengths of the $E_4: E_4 \rightarrow 1.14 \rightarrow 1.14 \text{ MeV}$ and $M5: 1.14 \rightarrow 1.13 \text{ MeV}$ transitions are respectively 0.26 and 0.23 Moszkowski units. From the delayed- γ spectrum analysis, it appears that the strongest activity is for $^{53\text{m}}\text{Fe}$ suggesting that for proton-rich isotopes the 2 pn evaporation dominates. Similar conclusions were obtained with the $^{39}\text{K} + ^{16}\text{O}$ reactions ³⁾ which give a strong activity for ^{52}Mn .

The analysis of weaker activities, are underway and the study of the reaction mechanism through the ^{56}Ni compound nucleus are planned for the $^{40}\text{Ca} + ^{16}\text{O}$ system. Analysis of other reactions such as $^{45}\text{Sc} + ^{16}\text{O}$ would be certainly interesting to reach isotopes of the f-p shell and to complete the present investigation.

REFERENCES

- 1) W.G. WINN, H.H. GUTBROD and M. BLANN, Nucl. Phys. A188 (1972) 423.
- 2) D.R. GOOSMAN and D.E. ALBURGER, Phys. Rev. C7 (1973) 2409 and ref. from this paper.
- 3) S. KOCHAN, B. ROSNER, I. TSERRUYA and R. KALISH, Nucl. Phys. A204 (1973) 165 and ref. from this paper.
- 4) D.R. GOOSMAN and D.E. ALBURGER, Phys. Rev. C5 (1972) 1252 and G.E. SCHWENDER, D.R. GOOSMAN and K.W. JONES, Rev. Sci. Inst. 43 (1972) 832.
- 5) S. KOCHAN, B. ROSNER, I. TSERRUYA and R. KALISH, Nucl. Phys. (to be published).
- 6) W.W. BOWMAN and K.W. Mac MURDO, Atom. Data and Nucl. Data Tables 13 (1974) 89.
- 7) J.N. BLACK, Wm. C. Mc HARRIS and W.H. KELLY, Phys. Rev. Lett. 26 (1971) 451.

Fig. 1 : Delayed γ ray spectrum observed in a 56 cm^3 Ge(Li) detector, with the rabbit system, with ^{16}O ions on a natural calcium target. This spectrum represents the sum of all the seven spectra of the cycle of 10 seconds intervals accumulated during half an hour. Lines are labeled by energy in keV and parent source.

Table I : Summary of experimental results.

	E_{γ} (keV)	Relative γ intensity	$T_{1/2}$ (min)		Production	Relative cross section
			this work	other a)		
$^{50}\text{Mn} (\beta\gamma) ^{50}\text{Cr}$	783.9 ± 0.6	100 ^{b)}	1.73 ± 0.15	1.75	$^{40}\text{Ca} (^{16}\text{O}, 3p3n) ^{50}\text{Mn}$	0.12
	1098.2 ± 0.6	100 ± 10				
$^{53\text{m}}\text{Fe} (\gamma) ^{53}\text{Fe}$	701.5 ± 0.6	100 ^{b)}	2.65 ± 0.06	2.53	$^{40}\text{Ca} (^{16}\text{O}, 2pn) ^{53\text{m}}\text{Fe}$	1 ^{b)}
	1010.9 ± 0.5	79 ± 8				
	1328.6 ± 0.6	82 ± 8				
	1711.8 ± 1.0	1.3 ± 0.2				
	2339.7 ± 0.6	20 ± 3				
	3041.2 ± 2.0	- ^{c)}				
$^{54\text{m}}\text{Co} (\beta\gamma) ^{54}\text{Fe}$	1130.7 ± 0.7	97 ± 10	1.49 ± 0.13	1.5	$^{40}\text{Ca} (^{16}\text{O}, pn) ^{54\text{m}}\text{Co}$	0.05
	1408.5 ± 0.7	100 ^{b)}				

a) ref. 6

b) normalised intensity

c) presence of a contaminated peak