THE INTERNAL CONVERSION ELECTRON AND GAMMA SPECTROSCOPY IN THE $^{14}N + {}^{197}Au$ REACTION MEASUREMENTS*

A. Krol, J. Andrzejewski, J. Perkowski, K. Sobczak

Faculty of Physics and Applied Informatics, University of Łódź, Łódź, Poland

M. Kisieliński, M. Kowalczyk, J. Kownacki

Heavy Ion Laboratory, Warsaw University, Warsaw, Poland

A. Korman

The A. Soltan Institute for Nuclear Studies, Świerk, Poland

(Received January 14, 2008)

The first "in-beam" spectra of the internal conversion electrons were collected in the $^{197}Au(^{14}N, 5n)^{206}Rn$ fusion evaporation reaction by new constructed electron spectrometer. The measurements were carried out in electron–gamma and gamma–gamma coincidence mode with use of electron spectrometer coupled to OSIRIS II gamma array at Heavy Ion Laboratory (HIL) of the Warsaw University. The analysis of the data for γ–γ coincidence measurement disclosed new transitions in ^{206}Rn excited nucleus. Experimentally obtained internal conversion coefficient allowed to determine multipolarity of the new observed transition in ^{206}Rn nucleus.

PACS numbers: 27.80+w, 23.20.Lv, 29.30.Dn

1. Introduction

Large interest in internal conversion electron (ICE) "in-beam" spectroscopy results from possibility of determination of radiation transition multipolarities in many questionable and difficult to determine by other methods cases [1,2]. A few experimental results in ICE "in-beam" spectroscopy result from essential experimental difficulty in carrying out such study. To defeat

* Presented at the XXX Mazurian Lakes Conference on Physics, Piaski, Poland, September 2–9, 2007.

them, recently built [3] electron spectrometer was combined with multi detector gamma array OSIRIS-II, that allowed to perform ICE and gamma "in-beam" spectroscopy at HIL. The operation of the array was checked in study of the decay of excited states in ^{206}Rn nucleus produced in the ^{197}Au(^{14}N, $5n$)^{206}Rn reaction. The results of gamma-ray spectroscopy for ^{204,206,208}Rn nuclei were published by Horn *et al.* [4], and no new paper concerned mentioned above nuclei has appeared since 1981. The only one experimental work by Backe *et al.* concerned ICE spectroscopy for three Rn isotopes was published in [5]. It was stimulus for our group to carry out the measurements to verify transition multipolarities in ^{206}Rn by experimentally determined internal conversion coefficients.

2. Experiment

In OSIRIS II array 11 HPGe detectors with anti-Compton shielding and electron spectrometer including 5 silicon detectors were used. The construction details of electron spectrometer are shown in paper to be published in the *Nucl. Instrum. Methods A* journal [6]. Calculations of the ^{197}Au(^{14}N, $5n$) ^{206}Rn reaction cross section done with use of EMPIRE II code [7] show that at energy of 82 MeV a broad maximum in the cross section with value of about 47 mb exists. In the experiment, Au foil with thickness of 3 mg/cm^2 was used for which energy loss for ^{14}N ions at energy of 80 MeV is about 1.2 MeV/(mg/cm^2). It allows to produce ^{206}Rn nuclei in the whole target volume. The gamma and electron spectroscopy for ^{206}Rn was performed in "in-beam" time interval (2 ms width of the macro-structure cyclotron pulse) and for the daughter nuclei in "off-beam" time (4 ms break in the beam duration). The beam current of ^{14}N^{+3} ions at energy of 80 MeV was about 20 pnA.

3. Results

Accurate analysis of gamma–gamma coincidence data allowed to observed five new lines of energy 217.3, 409.9, 426.2, 516.2 and 693.5 keV for nucleus ^{206}Rn, supplementing known lines presented in paper [6]. Four of them are shown in Fig. 1 and Fig. 2. The existence of transitions (217.3, 409.9 and 693.5 keV) was confirmed in ICE spectra gated by gamma lines, what is shown in Fig. 3. The efficiency of the spectrometer for energy range from 0 to 100 keV is relatively low. For this reason, for the 217.3 keV transition L peak is only present and K electron line was not observed. The ICE lines derived from 516.2 and 693.5 keV unfortunately overlap with electron lines from the main transitions in ^{206}Rn. Conversion coefficient (multipolarity) for new transitions was determined only for energy 693.5 keV line as $\alpha = 0.014 \pm 0.03$ (for E2 $\alpha_{\text{theory}} = 0.0126$) because insufficient statistics had been obtained for others lines in both electron and/or gamma peaks.

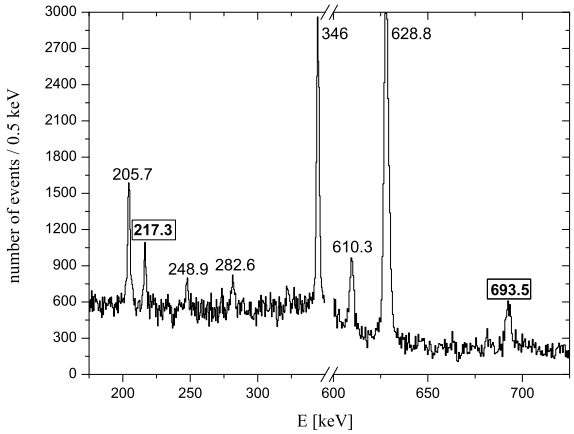

Fig. 1. The γ-ray "in beam" spectrum showing the new lines of energy 217.3 keV and 693.5 keV and other known ^{206}Rn lines. The spectrum is the sum of spectra gated by 559, 629, 161 and 346 keV γ-rays.

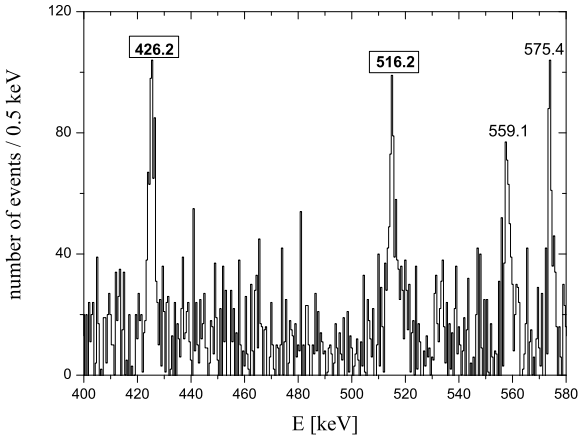

Fig. 2. The γ-ray "in-beam" spectrum showing the new gamma lines of energy 426.2 and 516.2 keV and other known ^{206}Rn lines gated by 684 keV line.

The internal conversion coefficient for line 575 keV from ^{206}Rn was used as a normalization parameter. Location of new lines in level scheme of ^{206}Rn (see Fig. 4) was determined taking into consideration the ratio of transition intensity and used gates. Determination of experimental coefficients was only possible on the base of electron spectra gated by gamma lines due to considerable density of excited states in ^{206}Rn and moderately good energy resolution for electrons. ICE coefficients obtained for ^{206}Rn nucleus are presented in the forthcoming paper [6].

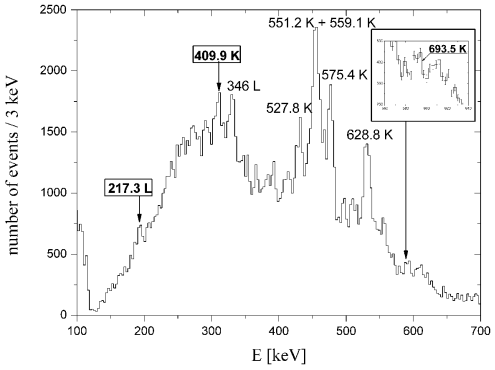

Fig. 3. Electron "in-beam"spectrum is the sum of spectra gated by 559, 629, 161 and 346 keV γ-rays. Peaks of internal conversion electron for the new transitions — 217.3 L, 409.9 K and 693.5 K as well as other electron peaks are shown.

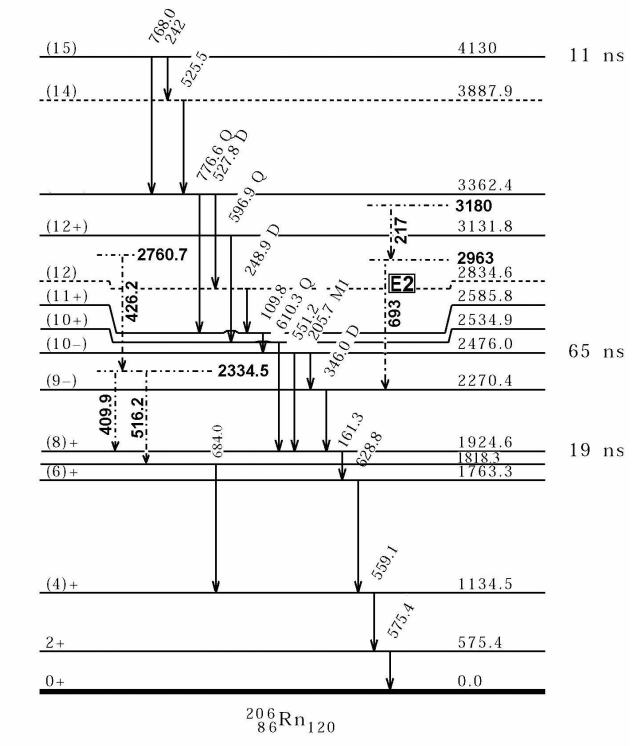

Fig. 4. A schematic view of excited levels for ^{206}Rn [8] with localization of new levels and transitions (dot-dashed lines) and the new multipolarity shown in the rectangle. The unconfirmed level postulated in [4] is shown as a dash line. A dipole and quadruple types of transitions are labeled as D and Q, respectively.

4. Summary

The new spectroscopic information was obtained for the scheme of excite levels of ^{206}Rn in a electron-gamma and a gamma–gamma coincidence measurements performed by the OSIRIS II HPGe detector array combined with the electron spectrometer at HIL.

REFERENCES

[1] P.A. Butler *et al., Phys. Rev. Lett.* **89**, 202501 (2002).
[2] H. Kankaanpaa *et al., Nucl. Instrum. Methods* **A534**, 503 (2004).
[3] J. Andrzejewski *et al.*, Annual Report 2006, HIL, Warsaw University, p. 15.
[4] D. Horn, C. Baktash, C.J. Lister, *Phys. Rev.* **C24**, 2136 (1981).
[5] H. Backe *et al., Annual Report*, Max Plank Institut, Heidelberg 1979, p. 93.
[6] J. Andrzejewski *et al.,* accepted to be published in *Nucl. Instrum. Methods.*
[7] `http://www-nds.iaea.org/empire/`
[8] *Nuclear Data Sheets* **88**, 29 (1999).