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Abstract

Full Text

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Study of the Decay of Pd^{101}, Rh^{101*}, Rh^{101}

The radiation of Pd^{101}, Rh^{101*}, and Rh^{101}, which decay in the chain

$$Pd^{101} \xrightarrow{8.5\ hr} Rh^{101*} \begin{array}{l} \xrightarrow{4.7\ d} Rh^{101} \\ \searrow \quad \swarrow \\ Ru^{101} \end{array} \qquad Rh^{101} \xrightarrow{5\ yr} Ru^{101}$$

was investigated by us with a magnetic spectrometer of the "KETRON" type ($\Delta H_\rho / H_\rho = 0.5\%$) with scintillation registration of electrons and by means of scintillation γ-spectrometers: a single spectrometer, a double spectrometer for studying γ-γ coincidences, and a "total-absorption" spectrometer with a NaI crystal of dimensions 70×70 mm with a well.

Decay of Pd^{101}

The isotope Pd^{101} was obtained by chemical separation from Ag or Cd targets irradiated with protons of energy 660 MeV. The separation of the Pd fraction

Table 1

Energy of γ transitions, relative intensities of conversion electrons, energies of sum transitions of Pd^{101}

No.	From conversion-electron spectrum: $h\nu$, keV	From conversion-electron spectrum: shells or lines	From conversion-electron spectrum: K/K_{299} 100	From γ spectrum	Energies of peaks in the sum spectrum	$h\nu$, keV (*), γ spectrum	No.	From conversion-electron spectrum: $h\nu$, keV	From conversion-electron spectrum: shells or lines	From conversion-electron spectrum: K/K_{299} 100	From γ spectrum	Energies of peaks in the sum spectrum	$h\nu$, keV (*), γ spectrum
1	43.0±0.5	K	250±50	40	40	—	18	764±3	K	5±1	730	760	—
2	130±2	K	—	150	—	—	19	780±3	—	5±1	—	—	—

No.	From conversion-electron spectrum: $h\nu$, keV	From conversion-electron spectrum: shells or lines	From conversion-electron spectrum: K/K_{249} 100	From conversion-electron spectrum: γ spectrum	Energies of peaks in the sum spectrum	Energies $h\nu$, keV (*), γ spectrum	No.	From conversion-electron spectrum: $h\nu$, keV	From conversion-electron spectrum: shells or lines	From conversion-electron spectrum: K/K_{249} 100	From conversion-electron spectrum: γ spectrum	Energies of peaks in the sum spectrum	Energies $h\nu$, keV (*), γ spectrum
3	153± 2	K	30± 5	150	–	–	20	–	–	–	850	–	–
4	170± 2	K	–	–	–	–	21	–	–	–	890	–	–
5	275± 2	K	30± 5	300	–	288± 9	22	–	–	not measured	1000	–	–
6	290± 2	K	35± 5	300	–	–	23	–	–	not measured	1040	1040	–
7	299± 2	K, L	100	300	–	–	24	–	–	not measured	1200	1200	1190± 20
8	315± 3	K	–	–	–	–	25	–	–	not measured	1310	–	1280± 20
9	325± 2	K	18± 2	–	–	–	26	–	–	–	–	1360	–
10	410± 2	K	8± 1	440	340	–	27	1471± 7	K	1.5± 0.5	1500	–	–
11	420± 2	K	10± 1	440	–	–	28	1482± 7	K	1.5± 0.5	1500	1500	–
12	432± 2	K	15± 2	440	–	–	29	1513± 7	K	2± 0.4	1500	–	–
13	464± 3	K	–	–	–	–	30	1526± 8	K	2± 0.4	1500	–	–
14	472± 3	K	5± 1	590	–	–	31	1640± 8	K	3.5± 0.3	1650	–	–
15	566± 3?	K	6± 1	590	–	–	32	1672± 8	K	2± 0.4	1650	1650	–
16	590± 3	K	–	–	–	590± 18							
17	721± 3	K	6± 1	–	630	720± 20							

was carried out approximately 15 hours after irradiation of the target. In the Pd

fraction the isotopes observed were: Pd^{100} ($T_{1/2} = 4.1$ d), Pd^{101} ($T_{1/2} = 8.5$ hr), and Pd^{103} ($T_{1/2} = 17$ d).

The presence of the isotope Pd^{100} makes the study of the γ radiation of Pd^{101} difficult, since the γ spectrum of the daughter substance Rh^{100} ($T_{1/2} = 20.8$ hr) is very rich

by γ transitions in the energy range from 300 to 3000 keV (2), and the buildup of the corresponding γ lines in the Pd fraction occurs very intensively.

To avoid this difficulty, we studied the γ spectra of Pd^{101} about 5–10 min after separation of the Pd fraction from the target, when the amount of daughter Rh was insignificant and could easily be taken into account. The Pd fraction was then purified from daughter Rh isotopes and studied again.

Fig. 1. Proposed decay scheme of Pd^{101}

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Thus the γ transitions belonging to the decay of Pd^{101} were identified. The value obtained by us, $T_{1/2} \simeq 10$ h, agrees with the literature data (1).

Before the present work, the γ spectrum of Pd^{101} had been investigated only by Katkova and Abrash (3) (see Table 1). In the present work, in the γ spectrum, in addition to the γ transitions observed in (3), new γ transitions with energies 40, 440 (complex), 850, 890, 1040, 1500, and 1650 keV were found. From the measured value of $T_{1/2}$ they are assigned to the decay of Pd^{101}. The spectrum of conversion electrons of Pd^{101} was studied in the present work for the first time.

In the energy ranges from 10 to 850 keV and from 1400 to 1700 keV, a number of conversion lines were observed that correspond to γ transitions in Rh^{101}. The obtained values of the energies of the γ transitions and the relative intensities of the conversion electrons are given in Table 1. The same table gives the energy values of the summed γ transitions corresponding to the energy levels of Rh^{101}. From a comparison of the single spectra and the "total absorption" spectra, we conclude that levels of Rh^{101} exist with energies: 158, 200, 500, 790, 920, 1200, 1360, 1530, and 1650 keV.

On the basis of the results obtained, a decay scheme of Pd^{101} is proposed, shown in Fig. 1. The level energies and γ-transition energies are given according to the data of the conversion-electron spectrum of Pd^{101}.*

Decay of Rh^{101*} and Rh^{101}

In the present work the isotopes Rh^{101*} and Rh^{101} were obtained as daughter products of the decay of Pd^{101} (see above). Three to four days after separation of the Pd fraction, an activity with $T_{1/2} \simeq 5$ days was observed in the conversion-electron spectrum. From comparison with literature data and, in a number of

cases, from the values of $K-L$, this activity was assigned by us to the decay of Rh^{101*} ($T_{1/2}$ = 4.7 days) (1). Before the present work, the conversion-electron spectrum of Rh^{101*} had not been studied in detail by anyone. Only two γ-transitions with energies 158 and 307 keV were known (1).

The γ-transition energies and relative intensities of conversion electrons obtained by us are given in Table 2. In comparison–

Table 2

Energies of γ-transitions, relative intensities of conversion electrons, and energies of total γ-transitions of Rh^{101*}

No.	$h\nu$, keV (from conversion-electron spectrum)	Observed lines	$\frac{K}{K_{309}} \cdot 100$	$h\nu$, keV, γ-spectrum	Energies of total γ-transitions	$h\nu$, keV (4), γ-transitions	$\frac{I}{I_{\gamma 307}}$ (4)	No.	$h\nu$, keV (from conversion-electron spectrum)	Observed lines	$\frac{K}{K_{309}} \cdot 100$	$h\nu$, keV, γ-spectrum	Energies of total γ-transitions	$h\nu$, keV (4), γ-transitions	$\frac{I}{I_{\gamma 307}}$ (4)
1	128±2	K	~ 2	130	130	127±5	7.6	20	370±2	K	~ 2	400	–	–	–
2	131±2	K	50± 10	130	130	130±3	26	21	385±3	K	4.3± 1.0	400	–	385±8	18
3	150±2	K	5± 0.3	–	–	–	–	22	398±2	K	7.0± 2	400	–	–	–
4	158±2	K, L,	350± 40	–	–	–	–	23	417±2	K	3.4± 0.7	400	–	410± 10	4
5	160±2	K	4± 0.4	–	–	–	–	24	435±3	K	~ 3	–	–	–	–
6	175±2	K	6± 0.6	–	–	–	–	25	481±3	K	~ 6	–	–	–	–
7	222±2	K	13± 2	250	–	186±4	23	26	525±3	K	~ 3	545	545	545±5	83
8	227±2	K	12± 2	250	–	–	–	27	548±3	K	8.0± 2.0	545	545	545±5	83
9	239±2	K	9± 2	250	–	235± 5	8	28	565±3	K	~ 4	545	545	–	–
10	247±2	K	10± 2	250	–	–	–	29	576±3	K	3.4± 0.4	–	–	–	–
11	255±2	K	9± 2	–	–	–	–	30	612±4	K	–	620	620	635±10	10
12	270±2	K	6± 1	–	–	–	–	31	707±3	K	2.6± 0.3	735	710	–	–
13	288±2	K	6± 1	–	–	–	–	32	731±3	K	2.0± 0.3	735	–	720±8	12

No.	$h\nu$, keV (from conversion-electron spectrum)	Observed lines $\frac{K}{K_{309}} \cdot 100$	$h\nu$, keV, γ-spectrum	Energies of total γ-transitions	$h\nu$, keV (4), γ-spectrum	$\frac{I}{I_{\gamma 307}}$ (4)	No.	$h\nu$, keV (from conversion-electron spectrum)	Observed lines $\frac{K}{K_{309}} \cdot 100$	$h\nu$, keV, γ-spectrum	Energies of total γ-transitions	$h\nu$, keV (4), γ-spectrum	$\frac{I}{I_{\gamma 307}}$ (4)
14	298±2	6±1	–	–	–	–	33	751±3	2.3±0.3	735	–	–	–
15	303±2	7±2	310	310	307±4	1000	34	803±4	1.5±0.2	735	–	–	–
16	309±2	100 (K, L 310 10)	310	310	307±4	1000	35	834±4	1.5±0.2	845	850	846±9	3.6
17	314±3	2.7±0.6	310	–	–	–	36	860±4	1.0±0.2	–	–	–	–
18	318±3	2.6±0.6	310	–	–	–	37	934±4	1.0±0.2	930	930	939±10	2.5
19	335±3	∼2	–	–	–	–							

–with the available works, the values of the γ-transition energies and, correspondingly, of the energy levels have been refined, and a number of new γ-transitions have been found. In the γ-spectrum of Rh^{101*}, studied in (6), 3 γ-transitions were found. In the present work a number of new γ-rays were found (Table 2), which agrees well with the data obtained from the conversion-electron spectrum and with the results of works (4, 5), obtained in studying the decay of $Tc^{101} \rightarrow Ru^{101}$ and by Coulomb excitation of the levels of Ru^{101}.

Analysis of the spectra of total absorption of γ-radiation of Rh^{101*} made it possible to determine the energies of the levels of Ru^{101}, which are given in Table 2. From comparison of the results obtained, and taking into account the data on $\gamma - \gamma$ coincidences (4, 5), the decay scheme of Rh^{101*}, shown in Fig. 2, is proposed.

* We note that we do not exclude the possibility of the existence of levels with energies 458 and 748 keV instead of the levels 500 and 790 keV. This variant may occur if the γ-transition with energy 299 keV goes to the 158-keV level and not to the 200-keV level.

Investigation of the γ radiation of the Pd fraction, carried out with a scintillation γ spectrometer 8–10 months after separation of the fraction

Fig. 2. Proposed decay scheme of Rh101* and Rh101

Fig. 2. Proposed decay scheme of Rh^{101*} **and** Rh^{101}

from the target showed the presence of 3 γ transitions with energies of 130, 200, and 330 keV, corresponding to the decay

$$\mathrm{Rh}^{101} \xrightarrow[5\ \mathrm{yr}]{} \mathrm{Ru}^{101}.$$

The 130- and 200-keV transitions are in cascade. The 330-keV γ transition is a direct transition from the 330-keV level.

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Note: Figure translations are in progress. See original paper for figures.