Fine structure in the α - decay of radium isotopes $^{212\text{-}209}$Ra

F.P. Heßberger, S. Hofmann, D. Ackermann[1]

GSI, Darmstadt, Germany, [1] also Johannes Gutenberg - Universität, Mainz, Germany

Although Ra - isotopes with mass numbers 207≤ A ≤212 had been synthesized first by Valli et al. more than thirty years ago [1] little knowledge on their decay properties has been added since then. The successful application of α-γ-coincidence measurements to detect α-decay branches with low intensity in ^{214}Ra and $^{214\text{-}216}$Ac [2] motivated us also to investigate Ra-isotopes with A ≤212. We therefore chose the reaction ^{204}Pb(^{12}C,xn)$^{216\text{-}x}$Ra at incident beam energies of E_{lab}= (78-137) MeV. New decay data were obtained for ^{212,211,210,209}Ra. The results are listed in table 1.

For the even - even nuclei ^{212}Ra and ^{210}Ra we observed α-decay into the first excited 2^+ - levels of the daughter nuclides. Our γ - energies of E_γ = (635.1 ± 0.2) keV for ^{212}Ra and E_γ = (574.9 ± 0.2) keV for ^{210}Ra fit well to the excitation energies of the first 2^+ - levels of ^{208}Rn (635.8 keV) and ^{206}Rn (575.3 keV) reported in literature [3].

Two weak γ - lines of E_γ = (387.0 ± 0.5) keV and E_γ = (633.7 ± 1.1) keV were attributed to the decay of ^{209}Ra. Unlike the case of the N=119 isotone ^{207}Rn, whose α-decay populates low lying states at E^* = 62.54 keV and E^* = 133 keV with relative intensities of 0.007 and 0.001, respectively, we did not observe α-γ - coincidences with E_γ < 200 keV that could be attributed to the decay of ^{209}Ra.

Altogether, six γ - lines were assigned to the decay of ^{211}Ra. While five of them fulfilled the relation $Q_\alpha + E_\gamma \approx Q_\alpha$ (gs), where Q_α and Q_α(gs) denote the Q-values for the observed transition and the ground - state transition, respectively, the 162.9 keV line delivered a considerably lower Q - value. It is, therefore, interpreted to be the transition between the E^* = 283.0 keV and E^* = 120.0 keV - levels, since it perfectly fits to the energy difference. The energy of coincident α-particles, however, is shifted by ≈20 keV as compared to α-particles coincident with E_γ = 283.0 keV. This we attribute to energy summing with conversion electrons from the transition 120 keV → 0 keV (g.s.). From the intensities of the 120 keV - line and the K_α - and K_β -lines of Rn we obtained a conversion coefficient of α = 4.5 ± 0.5 which agrees best with the value α = 6.5 expected for an M1 - transition [4]. Taking $5/2^-$ as the ground state configuration of ^{207}Rn [3], we obtain $3/2^-$ as spin and parity for the 120 keV - level. Due to the high background of x-rays from the decay by internal conversion of the 110 keV - level in ^{213}Ra, which are coincident to α - particles with energies very similar to that of α - particles coincident with the 283 keV - level in ^{211}Ra, we were not able to determine the conversion coefficient and to make a spin and parity assignment.

In the lighter N = 117 isotones ^{203}Pb and ^{205}Po two low lying levels with spins and parities $1/2^-$ and $3/2^-$ are known. While $3/2^-$ was assigned to the 120 keV level in our experiment, we did not observe a γ - line that could be attributed to the decay of a $1/2^-$ level. It should be remarked, that in our experiment we observed γ -decays from the $3/2^-$ (142.7 ± 0.5 keV) - as well as from the $1/2^-$ - level (154.5±0.5 keV) in ^{205}Po, both being populated by (^{213}Ra – α →) ^{209}Rn – α → ^{205}Po.

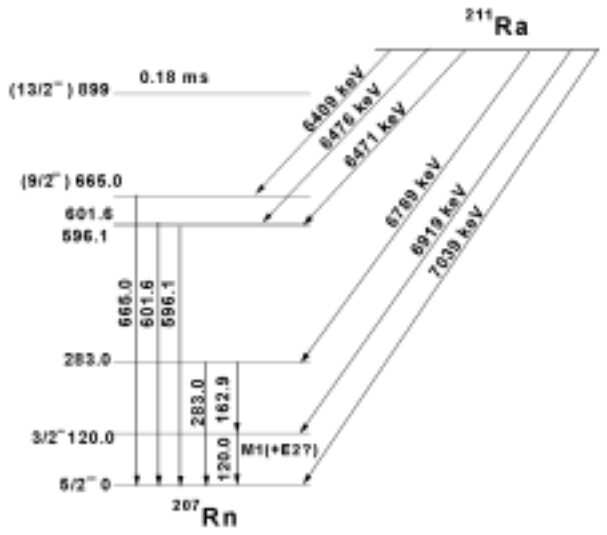

Fig. 1: Experimental decay scheme of ^{211}Ra; the energies denote the Q_α - values

Table 1: Results of α-γ - coincidence measurements for radium isotopes.

Isotope	E_α / keV	E_γ / keV
^{212}Ra	6902 ± 5	(gs)
	6269 ± 5	635.1 ± 0.2
^{211}Ra	6907 ± 5	(gs)
	6788 ± 5	120.0 ± 0.2
	(6648 ± 5)	162.9 ± 0.2
	6627 ± 5	283.0 ± 0.2
	6320 ± 10	596.1 ± 0.4
	6315 ± 10	601.6 ± 0.4
	6255 ± 5	665.0 ± 0.2
^{210}Ra	7003 ± 10	(gs)
	6447 ± 5	574.9 ± 0.2
^{209}Ra	7003 ± 10	(gs)
	6625 ± 5	387.0 ± 0.6
	6376 ± 10	633.7 ± 1.1

References:

[1] K. Valli et al. Phys. Rev 161, 1284 (1968)
[2] F.P. Heßberger et al. EPJ A 8, 521 (2000)
[3] R. Firestone et al (eds.) Table of Isotopes, 1996
[4] R.S. Hager, E.C. Seltzer Nucl. Data A4 (1968)