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NUCLEAR ORIENTATION STUDY OF THE DECAY OF ^{205}BiGd

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1. INTRODUCTION

The level structures of the lead isotopes have been of particular interest because they offer the opportunity to study single-particle orbitals in nuclei with several particles or holes outside doubly magic ^{208}Pb. The shell-model predictions of level energies below 2 MeV and gamma-transition probabilities were performed by McGrory et al. /1/. The level properties were carefully investigated in various nuclear reactions and in the study of α-decay of ^{209}Po and EC-decay of ^{205}Bi. A compilation of all the data was published by Schmorak in Nuclear Data Sheets /2/.

A comprehensive study of the EC-decay of ^{205}Bi was performed by Hamilton et al. /3/. They provided measurements of energies and intensities of gamma-transitions, $\gamma\gamma$-coincidence and conversion-electron measurements. A lot of gamma-transitions were placed in a level scheme, several spin and parity assignments were made. Some multipole mixing ratios were determined by Ahluwalia et al. /4/ using γ-γ angular correlation measurements of the decay of ^{205}Bi.

In spite of such extensive studies of the level structure of ^{205}Pb spin assignements of some of the levels remain either unknown or only tentative. Most of the data on the multipole mixing ratios are still missing, too. The aim of our work was to try to fill in the vacancies in the set of experimental data of this nuclide.

In our earlier study of the decay of ^{206}Bi /5/ we have used the method of low temperature nuclear orientation in gadolinium and iron matrices. Here we report on the results of the angular distribution measurements of the decay of ^{205}Bi oriented at low temperatures in a gadolinium host.

2. EXPERIMENTAL

The bismuth radionuclides were prepared by bombarding natural lead by 17 MeV deuterons on the cyclotron U-120 M of the Institute of Nuclear Physics of Czechoslovak Academy of Sciences. The bulk of the target was removed by precipitation as lead nitrate in 14 N nitric acid at 0°C. The bismuth activity was coprecipitated from the supernatant on lanthanum hydroxide. The final purification and isolation of carrier-free radiobismuth was done by cation exchange chromatography /6/.

The ^{205}Bi<u>Gd</u> sample was prepared by melting the radiobismuth activity with gadolinium metal in a helium atmosphere. The sample was cooled down to the temperature of T~15 mK in the combined ^{3}He-^{4}He dilution refrigerator of the SPIN facility in JINR Dubna /7/. An external magnetic field of 1.3 T was applied to polarize the domains of the polycrystalline host.

The gamma radiation was detected by two coaxial Ge(Li) detectors having the active volume 32 cm^3 and the resolution of about 2.3 keV FWHM at 1.3 MeV gamma-ray energy. The spectra were taken simultaneously at emission angles $\vartheta=0^{\circ}$ and $\vartheta=90^{\circ}$ relative to the external magnetic field direction. Typical gamma-ray spectra obtained are shown in Fig. 1. The peak areas were evaluated using a gaussian fitting routine SAPY /8/. The gamma-ray intensities were normalized to those found in the "warm" measurements using the spectra taken at the sample temperature of ~0.8 K when the nuclear ensembles were considered to be completely random.

3. RESULTS AND DISCUSSION

As the radioisotopes of bismuth were not mass-separated after the chemical separation, the sample contained both the ^{205}Bi ($T_{1/2}$= 15.3 d) and the ^{206}Bi ($T_{1/2}$= 6.24 d) radioisotopes. Though the independent study of the decay of ^{206}Bi was reported by us recently /5/ we have evaluated the results of the present experiment for both the isotopes in parallel. The multipole mixing ratios obtained here for ^{206}Bi<u>Gd</u> are in a good agreement with those found earlier for this isotope oriented in gadolinium as well as in iron hosts /5/.

From the measured intensities of gamma-rays following the decay of the ^{205}Bi isotope (I^{π}= 9/2$^-$) the normalized intensities were calculated as a ratio of averaged corrected peak areas found in "cold" and "warm" measurements. The anisotropies obtained for 17 gamma-transitions in ^{205}Pb are shown in Table 1.

The further analysis was performed using a multiparameter fitting routine WHIM that enables simultaneous fitting of orientation parameters B_k, multipole mixing ratios δ of the gamma-transitions and attenuation parameters G_k for long-living levels /8/. The decay scheme of ^{205}Bi shown in Fig. 2 /2/ was taken into account in the analysis of the experimental data. The orientation parameter B_2 calculated from the observed anisotropies of the 1903.4 keV, 1861.7 keV and 549.8 keV transitions using an assumption about their E1-character together with several preliminarily calculated values of δ (E2/M1) were used as starting parameters of the optimization procedure.

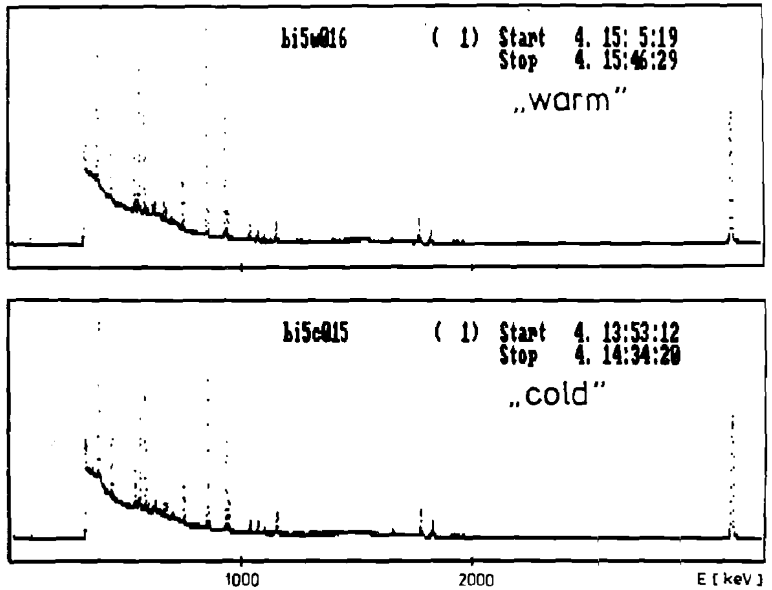

Fig. 1 The gamma-ray spectra of ^{205}Bi measured at ≃ 800 mK and at 15 mK

Table 1
The normalized intensities of gamma-transitions in ^{205}Pb

E_γ[keV]	W(0)-1	1-W(90)	E_γ[keV]	W(0)-1	1-W(90)
493.6	-.25(13)	-.11(20)	1190.0	.03(4)	.01(3)
511.5	-.21(4)	-.09(4)	1208.7	.23(6)	.13(5)
549.8	.17(11)	.11(5)	1351.5	-.35(6)	-.19(6)
570.6	-.27(3)	-.11(3)	1614.3	.71(5)	.30(2)
579.8	-.12(2)	-.07(2)	1764.3	.13(1)	.06(1)
703.4	-.145(7)	-.108(7)	1775.8	.15(5)	.07(4)
987.6	-.228(9)	-.114(9)	1861.7	.19(2)	.08(1)
1013.4	-.05(7)	-.07(5)	1903.4	.20(2)	.09(2)
1043.7	.14(2)	.08(1)			

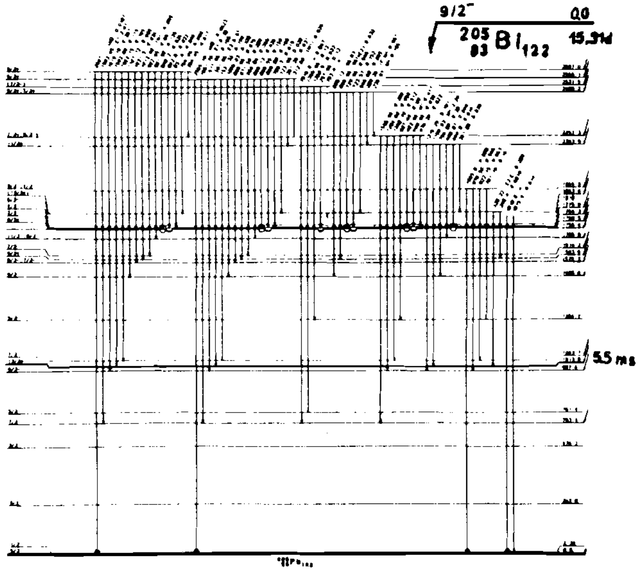

Fig. 2 (Part 1) The decay scheme of ^{205}Bi - Part 1 /2/

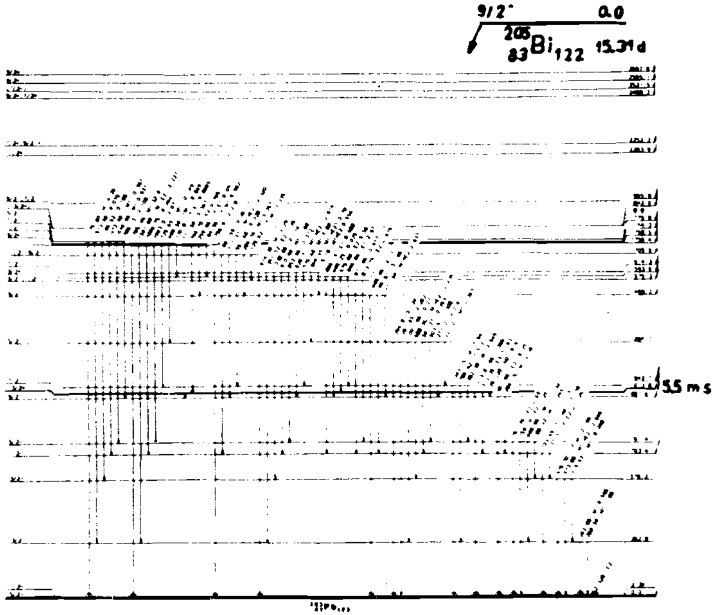

Fig. 2 (Part 2) The decay scheme of ^{205}Bi - Part 2 /2/

The orientation parameters of the initial state of ^{205}Bi nuclide in the gadolinium matrix determined in this way are

$B_2 = 0.65(1)$ and $B_4 = 0.10(2)$.

From these data and the observed anisotropy of the 1208.7 keV transition the unique spin assignment of the positive-parity level at 2252.3 keV earlier assigned as 7/2 or 9/2 could be done. For spin I = 7/2 the calculated admixture of M2 to E1 transition would not be consistent with the assumption of the pure E1-character of this transition. Thus we assign the spin of this level to be 9/2.

No attenuation was observed for the isomeric level at 1013.8 keV ($T_{1/2}$= 5.5 nsec, $I^\pi = 13/2^+$). The attenuation factor for this level was determined as $G_2 = 1.03(6)$.

Multipole mixing ratios δ for ten M1+E2 and four E1(+M2) gamma-transitions in ^{205}Pb were calculated. The values of δ together with angular distribution coefficients A_2 and A_4 for these gamma-transitions are listed in Table 2.

Table 2.
Multipole mixing ratios for gamma-transitions in ^{205}Pb

E_i [keV]	E_γ [keV]	I_i^π	I_f^π	M	A_2	A_4	δ
2607.0	1903.5	$9/2^+$	$7/2^-$	M2/E1	.32(2,-3)	.000	.01(2,-1)
	1013.4	$9/2^+$	$9/2^+$	E2/M1	-.13(9,-9)	-.07(3,-4)	-.4(1,-1)
2565.1	1861.7	$9/2^+$	$7/2^-$	M2/E1	.30(1,-4)	.000	.002(19,-6)
2252.3	1208.7	$9/2^+$	$7/2^-$	M2/E1	.44(9,-9)	.003(6,-3)	-.08(6,-5)
	493.7	$9/2^+$	$9/2^+$	E2/M1	-.3(1,-2)	-.01(1,-4)	-.1(19,-2)
2203.9	1190.0	$11/2^+$	$13/2^+$	E2/M1	.04(5,-5)	.002(2,-1)	-.08(3,-3)
1775.9	1775.8	$7/2^-$	$5/2^-$	E2/M1	.26(6,-7)	.001(2,-1)	.03(4,-3)
1764.3	1764.3	$7/2^-$	$5/2^-$	E2/M1	.22(2,-2)	.002(1,-1)	.055(10,-8)
1614.3	1614.3	$7/2^-$	$5/2^-$	E2/M1	1.09(1,-4)	.26(8,-7)	-.84(17,-23)
	570.6	$7/2^-$	$7/2^-$	E2/M1	-.43(3,-7)	-.000	-.01(10,-3)
1593.6	549.8	$9/2^+$	$7/2^-$	M2/E1	.3(1,-1)	.000(2,-2)	-.01(6,-6)
1499.0	511.5	$9/2^-$	$9/2^-$	E2/M1	-.39(6,-6)	-.003(3,-9)	-.08(9,-9)
1043.7	1043.7	$7/2^-$	$5/2^-$	E2/M1	.27(2,-2)	.001(1,-1)	.03(1,-1)
703.4	703.4	$7/2^-$	$5/2^-$	E2/M1	-.33(1,-1)	.625(1,-1)	7.2(3,-4)

The multipole mixing ratios for the 511.5 keV, 1043.7 keV and 703.4 keV transitions were determined earlier by Ahluwalia et al. /4/ in γ-γ angular correlation measurements. They reported their values to be -0.4(1), -0.15(15) and 6(1), respectively. The agreement of the last two ratios with our values (see Table 2) is fairly good. The very high admixture of E2 to M1 for the 703.4 gamma-transition found by Ahluwalia /4/ was confirmed in our experiment, too (our value ~98%). This result is in agreement with the EC data /2/ which state this transitions to be E2.

The experimental values of angular distribution coefficients for the 1351.5 keV ($7/2^- \rightarrow 3/2^-$) and 579.8 keV ($9/2^+ \rightarrow 13/2^+$) transitions depopulating the levels at 1614.3 keV and 1593.6 keV, respectively, were deduced as

$$A_2\,(1351) = -0.63(14) \quad \text{and} \quad A_2\,(580) = -0.22(5).$$

The values of A_2 calculated assuming the pure E2 character of these transitions

$$A_2^{th}(1351) = -0.47 \quad \text{and} \quad A_2^{th}(580) = -0.24$$

are in good agreement with the experimental values given above which is consistent with the placement of both the transitions in the level scheme.

4. CONCLUSIONS

As expected from the results of our previus work, the hyperfine magnetic field acting on the bismuth nuclei in a gadolinium host was sufficiently high to perform the low temperature nuclear orientation measurements.

Seven new values of multipole mixing ratios of E2/M1 gamma-transitions in ^{205}Pb were determined, two earlier measured values were confirmed. The δ parameters found for four gamma-transitions between the levels having opposite parity are within the frame of the experimental errors equal to zero which demonstrates the nearly pure E1 character of these transitions.

The observed anisotropy of the 1208.7 keV transition depopulating the positive-parity level at 2252.3 keV enabled us to make a unique assignment of the spin of this level as 9/2.

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