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LONG LIVED STATES IN ^{204}Po AND ^{206}Po

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1. Introduction

The purpose of this work was to study the level scheme of ^{204}Po and ^{206}Po nuclei, which are of some theoretical interest. Po has two protons outside the closed shell of 82 and this feature gives interesting scheme of the energetic states in even-even neutron-deficient isotopes. One might hope to understand their level structure in the first approximation, starting from the well known level schemes of ^{210}Po and ^{208}Po. The irregularities we can see is the information about the interaction of the neutron-hole states with the two-proton states $(h9/2)^2$. In the previous paper /1/ we have reported the level scheme of light Po isotopes as the result of EC-decay studies of neutron-deficient isotopes of At. We listed there many γ-lines which were not placed in schemes and the problem of evidence of 8+ state, as the one high-spin member of the band of levels resulting from the proton configuration $(h9/2)^2$, was open/5/. In this paper we give the additional information obtained by delayed-coincidence experiments. A general problem was to investigate the possible occurence of delayed transitions in the decay of ^{204}At and ^{206}At. Lately T. Yamazaki/4/found short-lived isomers in these isotopes of polonium by in-beam studies. Yamazaki established the half-lives of this isomers as 190$\pm$20 nsec in ^{204}Po and 160$\pm$40 nsec in ^{206}Po. This values differ from our results obtained from studies in the decays of ^{204}At and ^{206}At, however one can not say about rough disagreement (143$\pm$5 nsec for ^{204}Po and 212$\pm$5 nsec for ^{206}Po).

2. Experimental Method

The radioactive sources were obtained by irradiations of golden target on the external beam of the heavy-ion cyclotron U-300 in Dubna. Nuclei of At were produced in the reactions $^{197}Au(^{12}C, xn)^{209-x}At$ as described in/ 1/. The energies of ^{12}C were 65 MeV (for ^{206}At obtained) and 82 MeV (for ^{204}At obtained). After the irradiation the samples without chemical separation were transported to the coincidence apparatus /7/. In the $\gamma-\gamma$ coincidence measurement 1.5″ × 1.5″ NaI(Tl) scintillator coupled to RCA 6810A photomultiplier was used as the gate detector and 13 cm^3 Ge(Li) crystal was the analyser detector. As the fast coincidence circuit we used a time-to-amplitude converter (TAC) with time base set at 100 nsec, together with a pulse height descriminator. In order to investigate the γ-transitions connected with an isomeric state and populating the levels just below it, the delay of 170 nsec was put in the Na(Tl) scintillation counter fast branch, and the energy of KX-rays was selected from its energy spectrum. Putting this delay in the Ge(Li) fast branch and analysing by scintillation counter the energy of any transition seen in above described delayed coincidence spectrum, we obtained on resulting analysed coincidence spectrum, the γ-transitions connecting an isomeric state with excited states lying above it in energy. The obtained delayed coincidence spectra are shown in fig. 1 for ^{204}Po and in fig. 2 for ^{206}Po.

Life-time measurements were performed with NaI(Tl) scintillators: 2.5″× 2.5″ and 0.75″×1.25″, coupled to RCA 6810 photomultipliers and a time-to-amplitude converter. The TAC was calibrated with delay cables which delays were known to an accuracy of 2%. The output from the TAC was linear against a delay in the interval from 10 nsec to 400 nsec and all the apparatus was checked many times in previous measurements of the life-times /6/.

3. Results and Decay Scheme

Tables 1 and 2 show the experimental information on the strongest transitions in the ^{204}At and ^{206}At decays respectively in the energy range up to 1200 keV. They were previously reported in/ 1/ but now we give exact energies of the transitions and in the last column results of delayed coincidence are reported. Word "from" stands by transitions which are going from an isomeric level and word "on" means that the transition feeds an isomeric level. Some of the transitions are not observed in coincidence spectra but they can be placed in the scheme on the basis of the energy sums.

The time spectrum is shown in fig. 3. The presence of a "long-lived" component in this time spectrum proves that some unidentified level lying above strong cascade is populated at least partially by At decay. In ^{206}At decay was observed 212±5 nsec component and in ^{204}At decay 143±5 nsec component. The placement of the "long-lived" states is based on the consideration that any level : 2+, 4+, 6+ can not have so long life-time. We have not observed any transition above 80 keV which can be "isomeric". By a comparison of the similar scheme in ^{210}Po and ^{208}Po (2,3) we proposed for this level spin 8+. Theory in this case/ 5/ predicts 0+, 2+, 4+, 6+, 8+ sequence for the lowest lying levels formed from the $(h9/2)^2$ proton configuration. If this is correct the missing γ-ray transition would be of E2 multipolarity. The observed half-life of 200 nsec is quite reasonable for an E2 transition of less than 80 keV.

The decay schemes for ^{204}At and ^{206}At established on the basis of the coincidence spectra/ 1/, delay coincidence spectra and energy sums are shown in fig. 4. Since the energy of an isomeric level is undetermined we do not give the energies of any level built on it.

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R e f e r e n c e s

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TABLE 1

Transitions in ^{204}Po

E_γ	I_γ	Multipolarity	Delay
327	5∓1		
336	6∓1		
426,0	66∓5	E2	from
516,3	95∓9	E2	from
490,0	5∓1		
588,4	9∓1		on
609,5	21∓2	M1	on
684,5	100	E2	from
761,9	5∓1		
842	9∓2		

TABLE 2

Transitions in ^{206}Po

E_γ	I_γ	Multipolarity	Delay
231,2	weak		
255,4	5∓1	M1+E2	
277,6	4∓1		
386,0	4∓1		
395,5	42∓4	E2	from
416	weak		
443	3∓1		on
476,9	82∓8	E2	from
526,7	weak		
615,1	7∓2	M1	on
700,3	100	E2	from
733,3	11∓2		
922,7	6∓2		
956	weak		
961,5	weak		
1013	weak		on
1058	weak		on

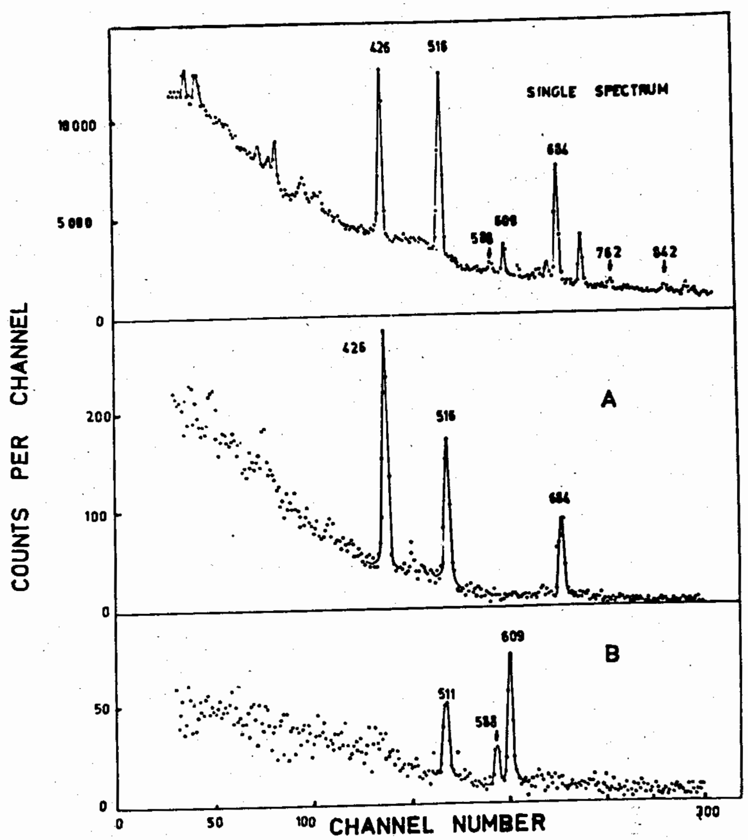

Fig. 1. Results of $\gamma-\gamma$ -delay coincidence measurement of ^{204}At radiations. Curve A shows γ-rays delayed of 170 nsec in respect to KX-rays. Curve B shows transitions feeding the "isomeric" state.

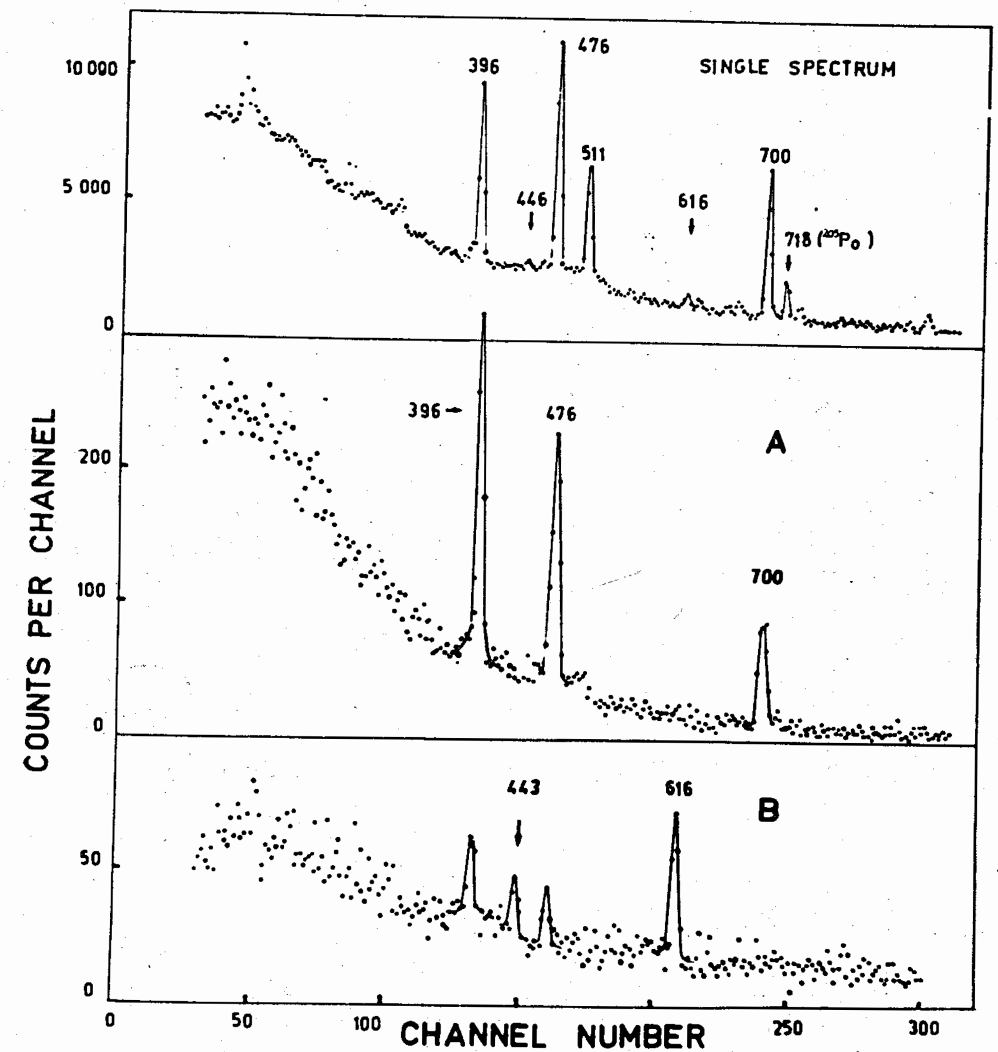

Fig. 2. Results of γ-γ -delay coincidence measurements of ^{206}At radiations. Curve A shows γ -rays delayed of 170 nsec in respect to KX-rays. Curve B shows transitions feeding the "isomeric" state.

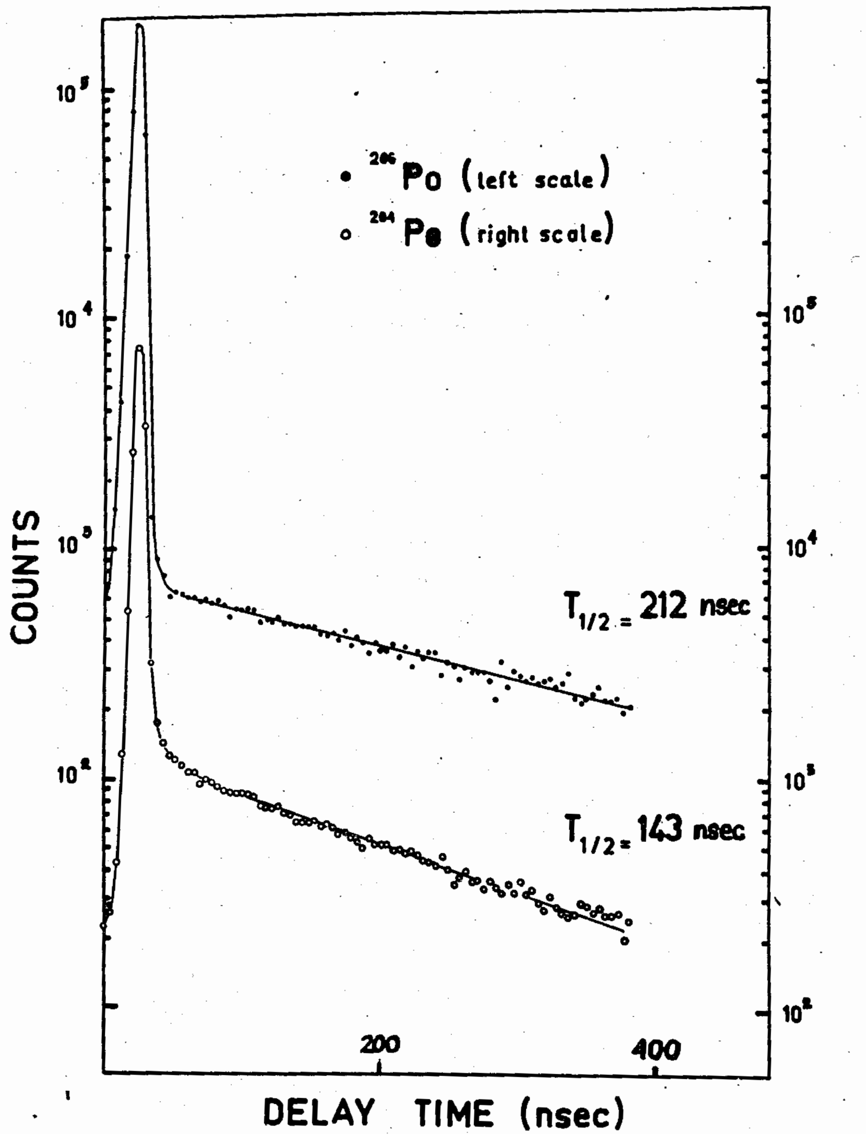

Fig. 3. Time-to-pulse-heigh spectrum of ^{206}At and ^{204}At radiations. The Po X-rays were used as start pulses and the ≈ 700 keV photons as step pulses.

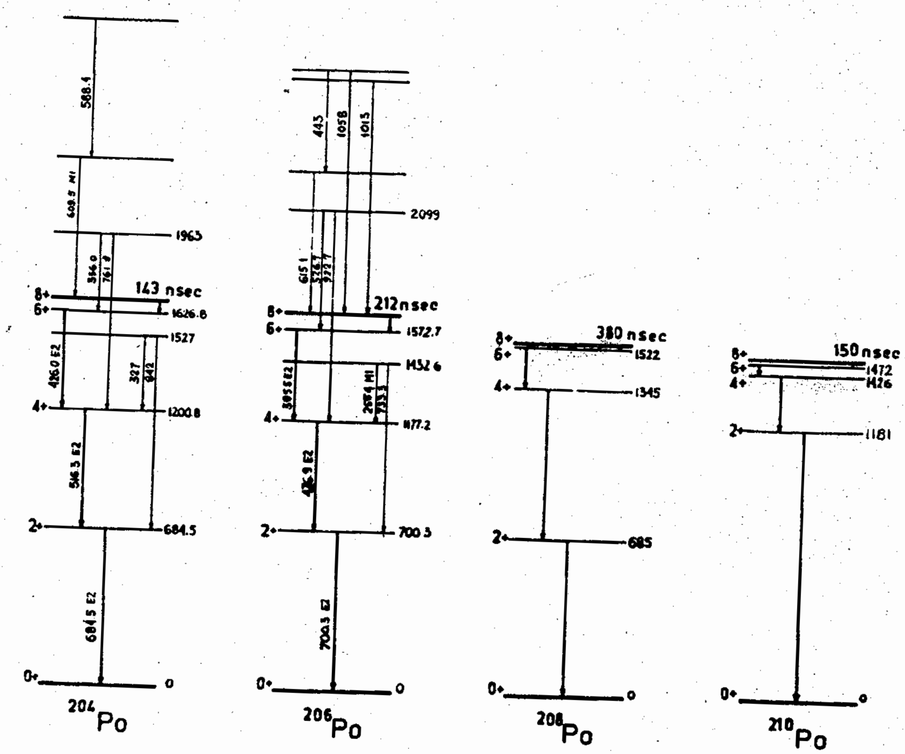

Fig. 4. Level schemes of Po isotopes.