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MASTER

Radiochemical Investigations of Nuclear Properties

Patrick J. Daly, Principal Investigator

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Progress Report for the period October 1974 to September 1975

E.R.D.A. Contract AT(11-1)-1672

Department of Chemistry

Purdue University
Lafayette, Indiana

September 1975

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RADIOCHEMICAL INVESTIGATIONS OF NUCLEAR PROPERTIES

Progress Report

Patrick J. Daly

Purdue University, W. Lafayette, Indiana

Oct. 1, 1974 - Sept. 30, 1975

PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION UNDER CONTRACT NO. AT(11-1)-1672

Abstract

Further studies of the structure of nuclei in the A=180-200 shape transitional region have been performed. The principal project completed during the current year was an extensive in-beam γ-ray investigation of high-spin levels in the nine nuclei ^{186}Pt to ^{194}Pt by (α,xnγ) reactions on enriched Os targets. Acute backbending observed in the positive parity yrast sequences of $^{188,190,192,194}Pt$ has been attributed to the intersection of rotation-aligned $(\nu i^{-2}_{13/2})$ and $(\pi h^{-2}_{11/2})$ bands with the ground bands. In all four odd-A Pt nuclei, decoupled $\nu i^{-1}_{13/2}$ bands and many other low-lying high-spin positive parity levels have been established, and low-spin positive parity levels have been located in complementary decay studies. A model of an $i_{13/2}$ neutron hole coupled to a triaxially deformed core has been found to be rather successful in reproducing these complex level spectra. Other topics dealt with include new μs isomers in $^{187,189,191}Pt$, the decays of ^{191}Au, ^{194m}Ir and 1.7 h ^{186}Ir and the level structure of ^{191}Au from an $^{191}Ir(\alpha,4n\gamma)$ study.

I. Research Activities

In the past year, good progress has been made in our investigations of the structure of transitional nuclei in the A=180-200 mass range. The principal effort was devoted to an intensive study of the nine Pt nuclei A=186-194 by in-beam γ-ray spectroscopy. All the experimental work is now completed and a brief review of the most important results is given below. Several related investigations involving both the in-beam γ-ray and radioactive decay spectroscopy techniques have also been fruitfully pursued and these results also are summarised below.

A. In-beam γ-ray spectroscopy

The level structures of the nine nuclei $^{186-194}$Pt, which span an important nuclear-shape transition have been studied in detail by (α,xnγ) reactions on isotopically enriched Os targets. These experiments were carried out at the Michigan State University cyclotron, in collaboration with C. L. Dors, T. L. Khoo and F. M. Bernthal of M.S.U. The techniques employed included comprehensive prompt and delayed γ-ray singles and γγ coincidence measurements, lifetime measurements, and γ-ray angular-distribution and excitation function determinations. For each of the nuclei, an extensive level scheme incorporating a wealth of new spectroscopic information has been constructed. The simplified level schemes of fig. 1 display only the principal systematic features of the level spectra. We have recently published a brief report[1] attributing the acute backbending behaviour observed in the positive parity yrast sequences of the even-A nuclei to intersections of rotation-aligned bands built on the two-hole structures, $(\nu i^{-2}_{13/2})$ and $(\pi h^{-2}_{11/2})$, with the "normal" ground bands.

In all four odd-A nuclei, decoupled $\nu i_{13/2}^{-1}$ bands strongly resembling the ground bands of the adjacent core nuclei, and many other high-spin positive parity states have been established. Qualitatively these complex level spectra can be accounted for rather well in terms of the coupling of an $i_{13/2}$ neutron hole to a triaxially deformed core[2]. These results and those from other laboratories strongly suggest that the oblate to prolate transition in this region proceeds through a series of stable asymmetric nuclear shapes; the Pt nuclei around A=190 have an asymmetry parameter γ of $\sim 30°$ and hence lie near the midpoint of the shape transition. (fig. 2). The portion of this investigation involving the triaxial rotor calculations included J. Meyer-ter-vehn as a collaborator.

Low-lying $21/2^{(-)}$ bands are also systematically observed in the odd-A nuclei and are attributed to combinations of $\nu i_{13/2}^{-1}$ with members of the $5^-, 7^-, \ldots$ bands identified in the even Pt nuclei[3]. The strongest support for this interpretation is provided by the observed B(E2) values for the $7^- \rightarrow 5^-$ and $25/2^{(-)} \rightarrow 21/2^{(-)}$ transitions in ^{190}Pt-^{194}Pt, which have all been found to be very close to 30 s.p.u.

The yrast cascades in ^{191}Pt, ^{189}Pt and ^{187}Pt terminate in isomeric states with half-lives of 95, 143 and 310 μs, respectively (fig. 3), which contrast with the 4 d half-lives of the $13/2^+$ isomers in ^{193,195}Pt. {The 95 and 143 μs isomers were observed in an earlier study[4], but were incorrectly assigned to ^{190}Pt and ^{192}Pt}. Our data allow us to make a convincing case for interpreting the μs isomers in ^{187,189,191}Pt as $\nu i_{13/2}$ states, de-exciting by M2 transitions to $\nu h_{9/2}$ states lying slightly lower in energy.

Much more complete accounts of the results of these studies will be given in forthcoming papers, three of which are in advanced stages of preparation.

The other in-beam spectroscopy study which is nearing completion concerns the level structure of ^{191}Au. This is really an outgrowth of earlier Purdue Tandem work of ours on odd-mass Au nuclei, which was abandoned when Tjøm et al[5] published results for the same nuclei. However some of our preliminary findings for ^{191}Au conflicted with the Berkeley results and therefore we recently reinvestigated the $^{191}Ir(\alpha,4n\gamma)^{191}Au$ reaction at M.S.U. Besides the known $\pi h^{-1}_{11/2}$ decoupled band, several important spectral features have been established:

a) a second negative parity band which is interpreted as being of $\pi h_{9/2}$ character. While there has been considerable fuss about possible shape coexistence in this region, a more attractive and plausible explanation of the odd Au data is that these nuclei are triaxial and the structural differences between the $\pi h^{-1}_{11/2}$ and $\pi h_{9/2}$ bands can be attributed to the hole and particle character respectively of the two excitations[6].

b) a $27/2^-$ isomeric state with $t_{1/2}$ = 7.2 ns, which very probably has the stretched configuration $(\pi h^{-3}_{11/2})$ $I^{\pi} = 27/2^-$.

c) a third, long-lived, isomeric state ($t_{1/2}$ = 490 ns) which populated members of the three particle $21/2^+$ band is tentatively assigned the three-hole configuration $(\pi h^{-1}_{11/2}, \nu h^{-1}_{9/2}, \nu i^{-1}_{13/2})$ $I^{\pi} = 31/2^+$ in analogy with the long-lived 10^- isomers located in ^{190}Pt and ^{192}Pt (Ref. 7)

B. Nuclear Structure Studies by other Techniques

In the course of the year, several radioactivity studies were undertaken and two of these directly complemented the in-beam γ-ray work described above. The ^{191}Pt and ^{193}Pt level spectra established in-beam consisted of high-spin states only. ($I \geq 11/2$). It soon became obvious that knowledge of the low-spin positive parity states also was essential in order to test rigorously the quality of the particle-plus-triaxial-rotor description of these spectra. The EC decay of 3.2 h ^{191}Au ($I^{\pi} = 3/2^{+}$) was therefore investigated using sources produced in the ^{191}Ir(α,4n) reaction. A complete decay scheme, which differs radically from earlier proposals,[8)] was established. The main decay branch populates a $5/2^{+}$ state above 1 MeV, which then de-excites by many pathways. Of most direct interest to us is a family of low-spin positive parity states located below 1 MeV which are almost certainly of $\nu i_{13/2}^{-1}$ character. These were included and were of considerable importance in the comparisons of experiment with theory (e.g. fig. 2).

Also studied were levels of ^{194}Pt populated in the decay of the high spin isomer[9)] 171 d ^{194m}Ir. In this case, the aim was to elucidate the microscopic composition of the state(s) directly populated in the β-decay and to tie in these findings with our ^{192}Os(α,2nγ)^{194}Pt results. The radioactive source was produced by the (d,α) reaction on enriched ^{196}Pt followed by chemical separation and purification of Ir activities. Extensive coincidence measurements were performed and a complete decay scheme accommodating all the observed transitions was constructed. The most important conclusion that emerged is that the lowest-lying ^{194}Pt 10^{+} state (and an 8^{+} state just below it) are predominantly of ($\pi h_{11/2}^{-2}$) character. It is planned to report the in-beam and decay results on ^{194}Pt together in one paper.

In collaboration with S. W. Yates of Argonne National Laboratory, we performed a study of the decay of the low-spin isomer of ^{186}Ir. The ^{186}Os(p,n) reaction was chosen for activity production to optimise the yield of 1.7 h ^{186}Ir relative to that of high-spin 15.8 h ^{186}Ir. While the experiment was successful and a fairly complete decay scheme was established, the results did not provide as much clear insight into the ^{186}Ir and ^{186}Os level structures as was hoped at the outset. The main conclusions have been summarised in a short paper[10)].

Our investigations of the structure of Os nuclei in collaboration with Raymond Sheline and his group were brought to a conclusion with the appearance of two further publications[11,12)].

Finally, in July of this year, the principal investigator availed of an opportunity to participate (with P. Kleinheinz, A. Stefanini and R. M. Maier) in in-beam spectroscopy experiments using 90-120 MeV α-particle beams from the Jülich cyclotron. These experiments involved the first investigations of the level structures of ^{148}Dy and ^{149}Dy, the N=82 and 83 isotopes of Dy, which were produced by (α,7n) and (α,8n) reactions on ^{152}Gd. While the results appear to be highly interesting, it is still too early to present them here.

Except for the last mentioned investigation, the research performed during this past year followed the outline submitted in our renewal proposal very closely. The principal investigator has devoted approximately 50% of his time and effort to this project during the contract period and he expects that this will continue to the remainder of the year.

References

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8. Nucl. Data Sheets 8 (1972) 389 and 431
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12. Thompson, Ikeda, Sheline, Cunnane, Yates and Daly, Nucl. Phys. A245 (1975) 444

Figure 1. Level schemes of the nuclei $^{186-194}Pt$. Transition energies are given in keV. The $13/2^{+}$ states in the odd-A nuclei are low-lying isomers and not the ground states of these nuclei.

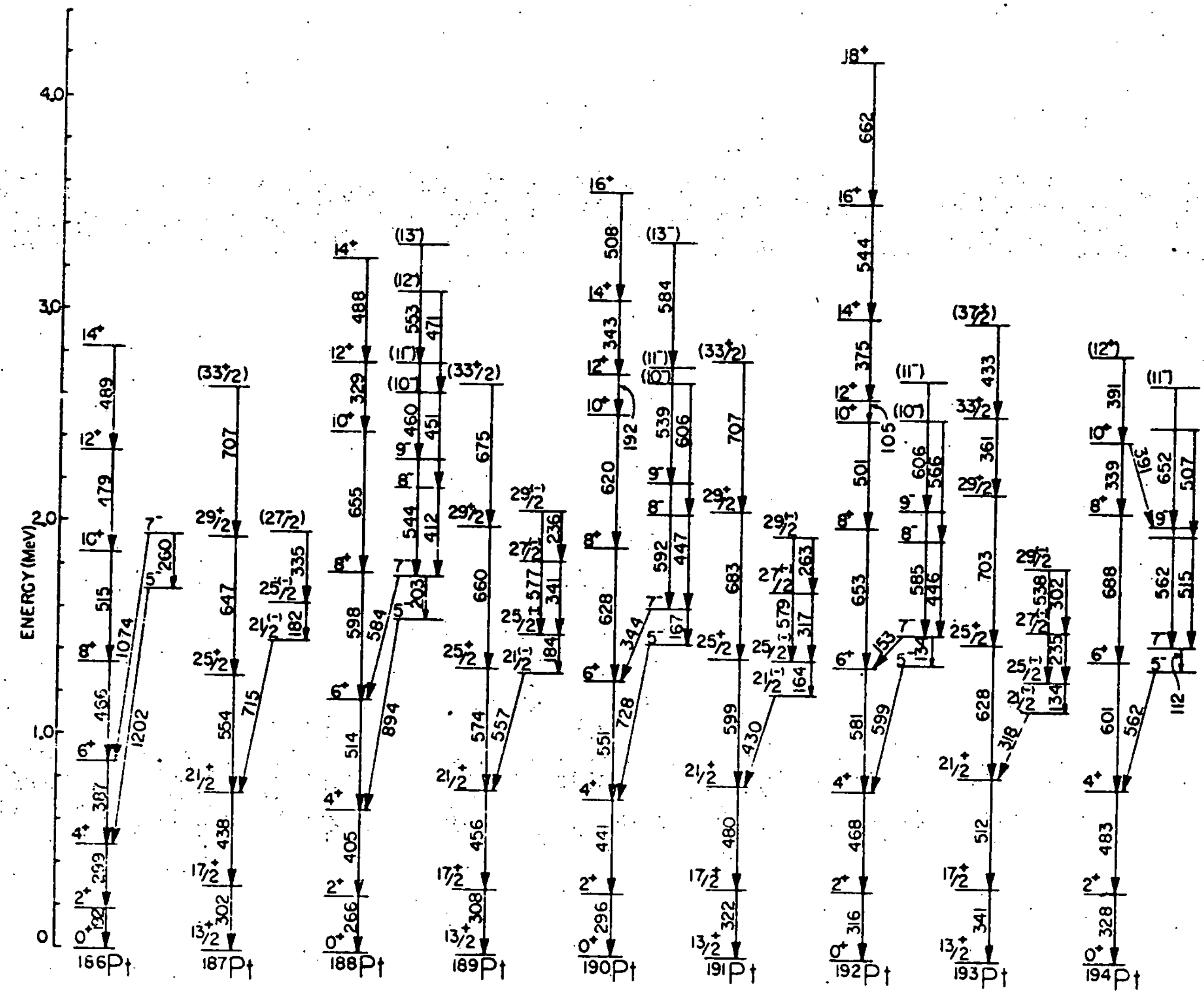
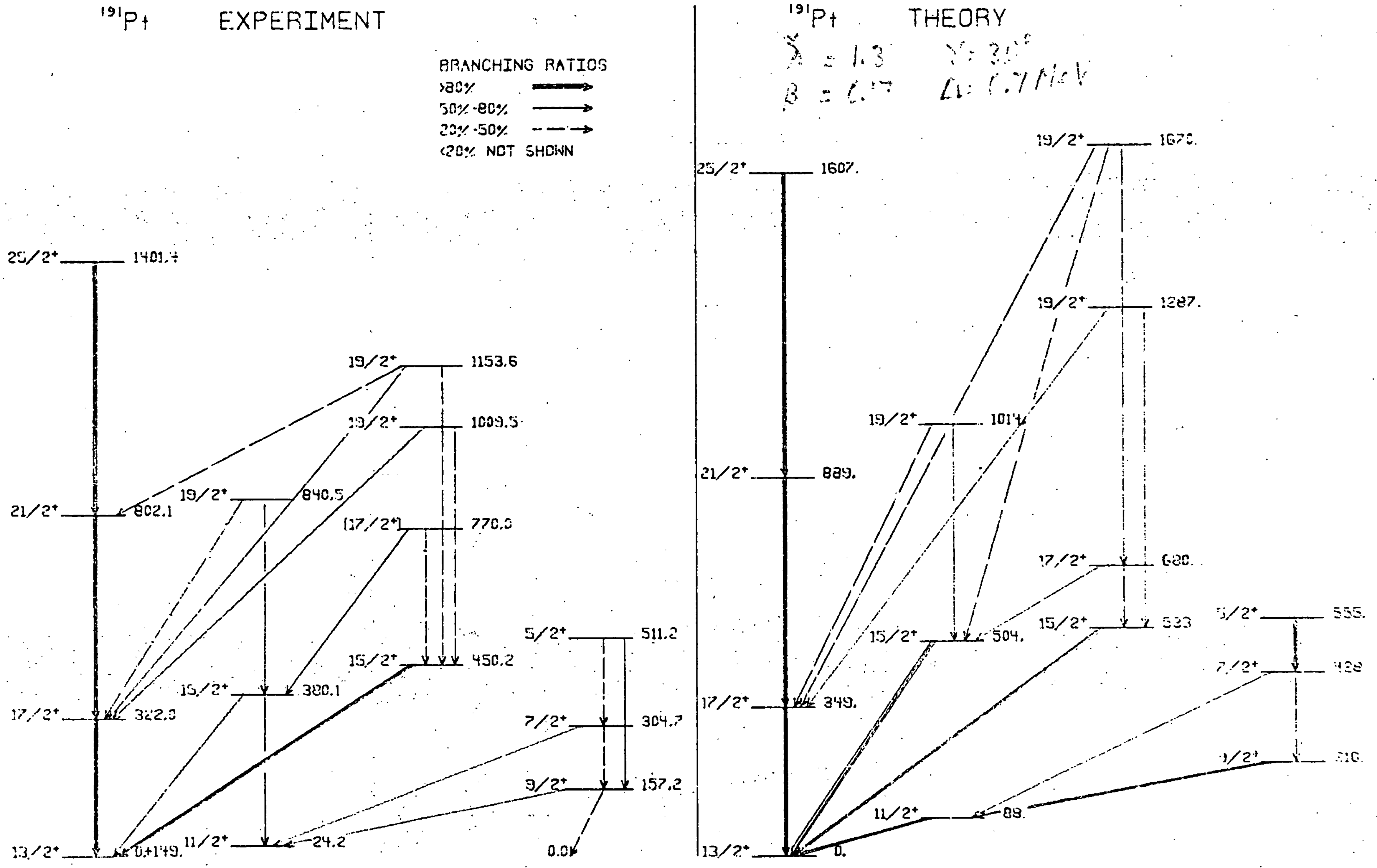

ENERGY (MeV)
0
1.0
2.0
3.0
4.0
186Pt
187Pt
188Pt
189Pt
190Pt
191Pt
192Pt
193Pt
194Pt

Figure 2. A comparison of the low-lying positive parity levels experimentally established in ^{191}Pt with a level spectrum calculated using a model of an $i_{13/2}$ neutron hole coupled to a triaxially deformed core. The parameters used in the calculation are shown.



191Pt EXPERIMENT
BRANCHING RATIOS
>80%
50%-80%
20%-50%
<20% NOT SHOWN
25/2+ 1401.4
21/2+ 802.1
17/2+ 322.3
13/2+ 0+149.
19/2+ 1153.6
19/2+ 1009.5
19/2+ 840.5
[17/2+] 770.3
15/2+ 450.2
15/2+ 380.1
11/2+ 24.2
5/2+ 511.2
7/2+ 304.7
9/2+ 157.2
0.0
191Pt THEORY
25/2+ 1607.
21/2+ 889.
17/2+ 349.
13/2+ 0.
19/2+ 1014
15/2+ 504.
11/2+ 88.
19/2+ 1676.
19/2+ 1287.
17/2+ 680.
15/2+ 533
5/2+ 555.
7/2+ 429
9/2+ 210.

Figure 3. Decay curves for the μs M2 isomers found in odd Pt nuclei measured using the pulsed beam technique.

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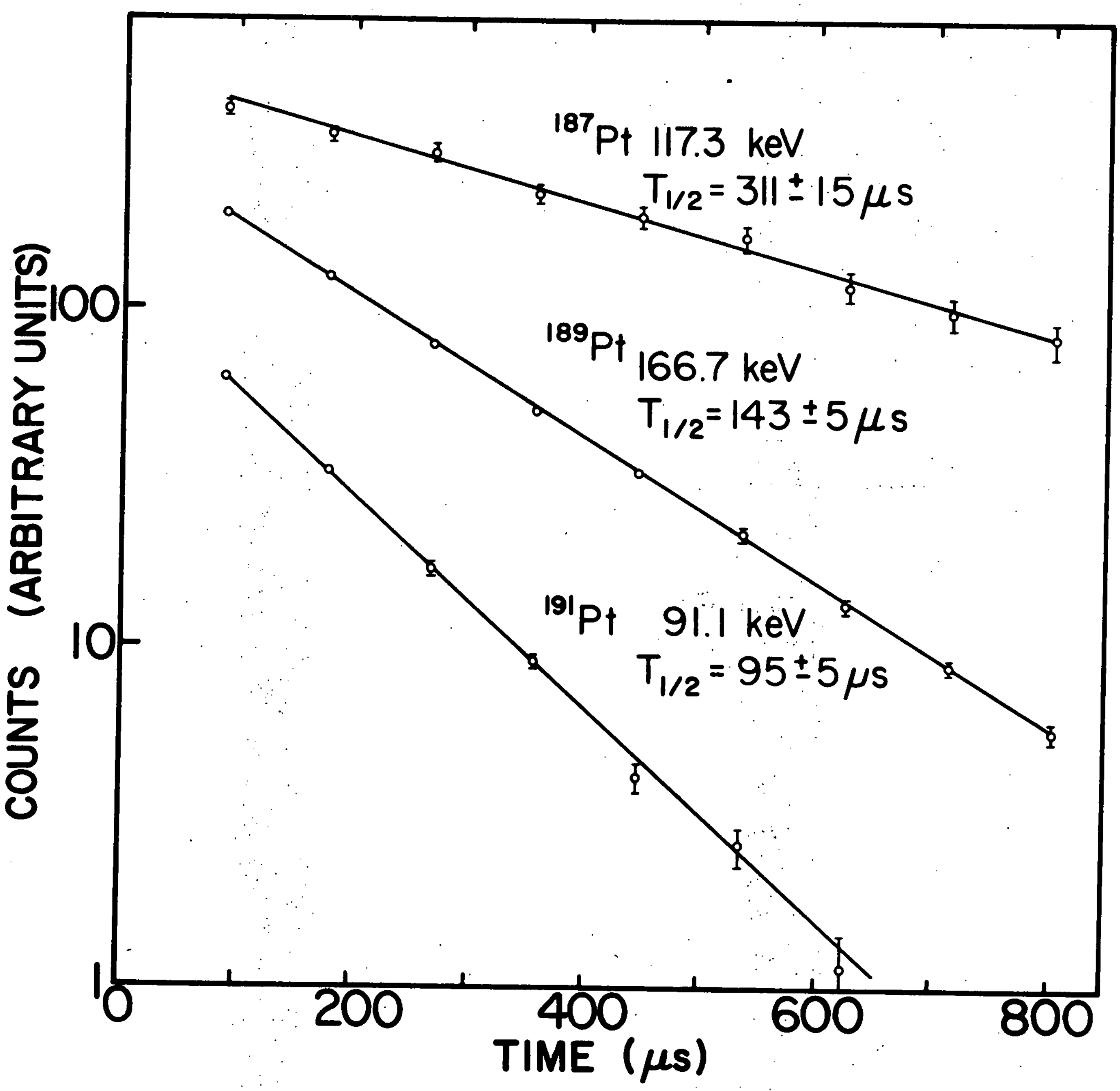

187Pt 117.3 keV
T1/2 = 311 ± 15 μs
189Pt 166.7 keV
T1/2 = 143 ± 5 μs
191Pt 91.1 keV
T1/2 = 95 ± 5 μs
COUNTS (ARBITRARY UNITS)
100
10
1
0
200
400
600
800
TIME (μs)

III. Personnel

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*Terminated in the course of the contract year

IV Publications and Talks

Nucleon Transfer Cross Sections for Mixed Odd-A Targets, R. C. Thompson, A. Ikeda, P. Kleinheinz, R. K. Sheline and P. J. Daly, Phys. Lett. 55B (1975) 447

High-Spin Level Systematics in $^{186-194}Pt$ and Rotation-Alignment Coupling, M. Piiparinen, J. C. Cunnane, P. J. Daly, C. L. Dors, F. M. Bernthal and T. L. Khoo, Phys. Rev. Lett. 34 (1975) 1110

Decay of the 1.7 h isomer of ^{186}Ir, S. W. Yates, J. C. Cunnane and P. J. Daly, Phys. Rev. C 11 (1975) 2034

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High-Spin Level Systematics in $^{186-194}Pt$ and Rotation Alignment Coupling, American Physical Society, Washington, D. C., April 1975, presented by P. J. Daly, Bull. Am. Phys. Soc. 20 (1975) 670

High-Spin Phenomena in Pt Nuclei, Gordon Conference on Nuclear Chemistry, New London, New Hampshire, June 1975, Invited Lecture given by P. J. Daly

Evidence for Triaxial Shapes in Pt Nuclei, International Nuclear Physics Conference, Jyvaskyla, Finland, Aug. 1975, presented by T. L. Khoo

High-Spin Level Structure in $^{186-194}$ Pt, Symposium on Highly Excited States in Nuclei, Jülich, W. Germany, Sept. 1975, Contributed Paper selected for presentation by F. M. Bernthal

Nuclear Models and Nuclear Structure, Physical Chemistry Seminar, Purdue University, Sept. 1975, presented by P. J. Daly