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Decay spectroscopy of ²²⁵Pa: Toward laser spectroscopy of neutron-deficient actinides

Emmanuel Rey-herme CEA/Irfu/DphN

Supervised by M. Vandebrouck (CEA/Irfu/DPhN) In collaboration with I. Moore, I. Pohjalainen and A. Raggio (University of Jyväskylä)

> Vth ISOL-France Workshop 22 March 2023





Prediction of strong octupole deformations in the ground state of neutron-deficient actinides:



S. E. Agbemava et al. PRC 96 (2017)





Prediction of strong octupole deformations in the ground state of neutron-deficient actinides:



L. P. Gaffney et al. Nature 497 (2013)

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I262 experiment at IGISOL





Analysis : ^{225}Pa \rightarrow ^{221}Ac \rightarrow ^{217}Fr

Existing literature:

²²⁵Pa decay data

Element	Our work						
	$\overline{E_{\alpha}(\text{keV})}$	<i>I</i> (%)					
²²⁵ Pa	7170(5)	17(1)					
	7235(5)	30(2)					
	7261(5)	53(2)					
²²¹ Ac							
	7373(5)	6(1)					
	7437(5)	20(2)					
	7641(5)	74(3)					
²¹⁷ Fr	8312(5)						
²¹³ At	9080(5)						

(1988) Nuclear Inst. and Methods in Physics Research, B, 31 (3), pp. 483-486

Excited State

Ground State

Daughter nuclei

Ε_γ



Main tool for the analysis:

Q_α(gs-to-gs)

$$Q_{\alpha}(gs - to - gs) = Q_{\alpha} + E_{\gamma}$$
$$Q_{\alpha} = \frac{m_d + m_{\alpha}}{m_d} \times E_{\alpha}$$
Ground State
Parent nuclei

Alpha-gamma coincidences for mass 225





Alpha-gamma coincidences for mass 225

Analysis process:



E. Rey-herme

22/03/2023

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²²¹Ac level scheme



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$$HF = \frac{T_{1/2, \exp}}{T_{1/2, th}}$$



²²¹Ac level scheme





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$$HF = \frac{T_{1/2, \exp}}{T_{1/2, th}}$$

Measure the impact of structure effects on the alpha transition probability



7/2+

5/2+

9.6

(75.4)

14

(196.7)

223.7

(132.5)

(152.6)

149.4

5/2+_180.0

11.5

(88.7)

22/03/2023

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Measure the impact of structure effects on the alpha transition probability

Typical low HF are between 1 and 10 for similar initial and final states. High HF can be above 1000.



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²²⁵Pa decay spectroscopy





Sheline RK, Liang CF, Paris P. Int J Mod Phys A. 1990;05(14):2821-31.

22/03/2023

²²⁵Pa decay spectroscopy



5/2+ 180.0

(180.0)

0

11.5

(88.7)

(160.7)

91.5

K = 3/2





4.6

7/2+

5/2+

9.6

(121.8) (149.4)

(75.4)

14

(196.7) (223.7) 223.7

(132.5)

(152.6)

(72.4)

5/2-

6.5

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(64.1)

(91.5)

Sheline RK, Liang CF, Paris P. Int J Mod Phys A. 1990;05(14):2821-31.

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Submitted to PRC









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Study of ²²¹Ac through ²²⁵Pa α -decay:

→ New Q_{α} (gs-to-gs) = 7388 ± 1 keV (Previous value: Q_{α} (gs-to-gs) = 7390 ± 50 keV)

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SEASON @S3-LEB : Exploration of more exotic neutron-deficient actinides

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Thank you for your attention !

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Backup

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Proton induced fusion-evaporation reaction ²³²Th(p,x)Y at IGISOL

	²¹⁷ Ρa α	²¹⁸ Ρa α	²¹⁹ Ρа α	²²⁰ Ρa α	²²¹ Ρa α	²²² Ρa α	²²³ Pa ª	²²⁴ Pa α	²²⁵ Ρa α	²²⁶ Ρa α	²²⁷ Ρа α	²²⁸ Ρa _{β+}	²²⁹ Pa e- capture	²³⁰ Ρa _{β+}	²³¹ Ρa α	²³² Ρa β-	²³³ Ρa β-
Proton Number Z	²¹⁶ Th α	²¹⁷ Th ۵	²¹⁸ Th ۵	²¹⁹ Th ۵	²²⁰ Th ۵	²²¹ Th ۵	²²² Th ۹	²²³ Th ª	²²⁴ Th ª	²²⁵ Th ۹	²²⁶ Th ۵	²²⁷ Th ۵	²²⁸ Th ۵	²²⁹ Th ª	²³⁰ Th ۵	²³¹ Th β-	²³² Th
	²¹⁵ Αс α	²¹⁶ Ac a	²¹⁷ Ac ª	²¹⁸ Ac a	²¹⁹ Ac a	²²⁰ Ac a	²²¹ Ac a	²²² Ac a	²²³ Ac a	²²⁴ Αс _{β+}	²²⁵ Ac a	²²⁶ Αс β-	²²⁷ Ac β-	²²⁸ Ac β-	²²⁹ Ac β-	²³⁰ Ac β-	²³¹ Ac β-
	²¹⁴ Ra م	²¹⁵ Ra م	²¹⁶ Ra ª	²¹⁷ Ra م	²¹⁸ Ra α	²¹⁹ Ra α	²²⁰ Ra ª	²²¹ Ra م	²²² Ra a	²²³ Ra ª	²²⁴ Ra °	²²⁵ Ra β-	²²⁶ Ra °	²²⁷ Ra β-	²²⁸ Ra β-	²²⁹ Ra β-	²³⁰ Ra β-
	²¹³ Fr م	²¹⁴ Fr م	²¹⁵ Fr م	²¹⁶ Fr م	²¹⁷ Fr م	²¹⁸ Fr م	²¹⁹ Fr م	²²⁰ Fr م	²²¹ Fr م	²²² Fr β-	²²³ Fr β-	²²⁴ Fr β-	²²⁵ Fr β-	²²⁶ Fr β-	²²⁷ Fr β-	²²⁸ Fr β-	²²⁹ Fr _{β-}
	²¹² Rn α	²¹³ Rn م	²¹⁴ Rn م	²¹⁵ Rn α	²¹⁶ Rn α	²¹⁷ Rn م	²¹⁸ Rn م	²¹⁹ Rn م	²²⁰ Rn α	²²¹ Rn β-	²²² Rn م	²²³ Rn β-	²²⁴ Rn β-	²²⁵ Rn β-	²²⁶ Rn β-	²²⁷ Rn β-	²²⁸ Rn β-
	²¹¹ At e- capture	²¹² At a	²¹³ At م	²¹⁴ At a	²¹⁵ Αt α	²¹⁶ Αt α	²¹⁷ At م	²¹⁸ Αt α	²¹⁹ At م	²²⁰ At β-	²²¹ At β-	²²² At β-	²²³ At β-	²²⁴ At β-	²²⁵ Αt β-	²²⁶ At β-	²²⁷ Αt β-
	²¹⁰ Ρο α	²¹¹ Ρο α	²¹² Po a	²¹³ Ρο α	²¹⁴ Ρο α	²¹⁵ Ρο α	²¹⁶ Po a	²¹⁷ Ρο α	²¹⁸ Ρο α	²¹⁹ Ρο β-	²²⁰ Ρο _{β-}	²²¹ Ρο _{β-}	²²² Ρο _{β-}	²²³ Ρο _{β-}	²²⁴ Ρο β-	²²⁵ Ρο _{β-}	²²⁶ Ρο _β -
	²⁰⁹ Βi α	²¹⁰ Βi β-	²¹¹ Βi α	²¹² Βi β-	²¹³ Βi β-	²¹⁴ Βi β-	²¹⁵ Βi β-	²¹⁶ Βi β-	²¹⁷ Βi β-	²¹⁸ Βi β-	²¹⁹ Βi β-	²²⁰ Βi β-	²²¹ Βi β-	²²² Βi _{β-}	²²³ Βi β-	²²⁴ Βi β-	
	²⁰⁸ Ρb α	²⁰⁹ Pb β-	²¹⁰ Pb β-	²¹¹ Pb β-	²¹² Pb β-	²¹³ Pb β-	²¹⁴ Pb β-	²¹⁵ Pb β-	²¹⁶ Pb β-	²¹⁷ Pb β-	²¹⁸ Pb β-	²¹⁹ Pb _{β-}	²²⁰ Pb _{β-}				

Neutron Number N

Data analysis for mass 225

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- Infe

Alpha spectrum for mass 225



²²⁵Pa decay spectroscopy – Preliminary results











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Cez

Literature for 223Ac





Sheline RK, Liang CF, Paris P. Int J Mod Phys A. 1990;05(14):2821-31.



Ac : 219 : 9/2-221 : 5/2-223 : 5/2-225 : 3/2-227 : 3/2DE LA RECHERCHE À L'INDUSTR







Charge radii