



Fig. 1: Known experimental values for heavy particle emission of the odd-Z $T_z = +47/2$ nuclei.

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Table 1

Observed and predicted β -delayed particle emission from the odd- Z , $T_z = +47/2$ nuclei. Unless otherwise stated, all Q -values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	J^π	$T_{1/2}$	Q_ϵ	Q_{β^-}	$Q_{\beta^- \alpha}$	Experimental
^{209}Tl		$1/2^+$	2.161(7) m	-5.04(15)#	3.970(6)	6.398(7)	[1993El08]
^{213}Bi		$9/2^-$	45.61(4) m**	-2.028(8)	1.422(5)	10.138(5)	[2013Su13, 1973Po16]
^{217}At		$9/2^-$	32.8(3) ms	-1.489(8)	0.736(6)	8.804(6)	[2013Su13]
^{221}Fr		$5/2^-$	4.806(6) m	-1.194(7)	0.313(6)	7.373(6)	[2017Su13]
^{225}Ac		$(3/2^-)$	9.9176(18) d***	-0.356(5)	-0.356(5)	6.428(7)	[2024Ga01, 2023Br08, 2020Ko06, 2012Po14]
					$Q_{\epsilon p}$	$Q_{\epsilon \alpha}$	
^{229}Pa		$(5/2^+)$	1.50(5) d	0.311(4)	-6.287(4)	5.479(4)	[1987Ah05]
^{233}Np		$(5/2^+)$	36.2(1) m	1.030(50)	-5.287(52)	5.938(51)	[1973We08]
^{237}Am		$5/2^-$	73.0(10) m	1.480(60)#	-4.097(78)#	7.226(60)#	[1975Ah05]
^{241}Bk		$(7/2^+)$	4.6(4) m	2.28(17)#	-2.82(17)#	8.46(17)#	[2003As01]
^{245}Es		$(3/2^-)$	66(6) s	2.93(17)#	-1.69(17)#	10.19(17)#	[1989Ha27]
^{249}Md		$(7/2^-)$	26(1) s	3.66(16)	-0.41(17)#	11.37(16)	[2019Br06]
^{253}Lr		$(7/2^-)$	520^{+29}_{-32} ms	4.16(16)	0.77(19)	12.58(17)	[2017BrXX]
^{253m}Lr	x	$(1/2^-)$	$2.00^{+0.16}_{-0.19}$ s	4.16(16)+x	0.77(19)+x	12.58(17)+x	[2017BrXX]
^{257}Db		$(9/2^+)$	1.6(2) s [⊗]	4.29(16)	1.12(18)	13.37(17)	[2009He20, 2001He35]
^{257m}Db	x	$(1/2^-)$	670(60) ms	4.29(16)+x	1.12(18)+x	13.37(17)+x	[2009He20]
^{261}Bh		$(5/2^-)$	$11.8^{+3.9}_{-2.4}$ ms	5.07(18)	2.12(20)#	14.79(18)	[2020He11]
^{265}Mt				5.72(44)#	3.38(47)#	16.20(44)#	

* 100% β^- emitter.

** Weighted average of 45.62(6) m [2013Su13] and 45.59(6) m [1973Po16].

*** Weighted average of 9.914(4) d [2024Ga01], 9.9150(63)) d [2023Br08] 9.9179(30) d [2020Ko06] and 9.920(3) d [2012Po14].

⊗ Weighted average of 2.3(2) s [2009He20] and $1.50^{+0.19}_{-0.15}$ s [2001He35].

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z, $T_z = +47/2$ nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	S_p	Q_α	BR_α	BR_{SF}	$BR_{cluster}$	type	Experimental
^{209}Tl	7.668(31)	2.50(20)#					
^{213}Bi	4.972(5)	5.988(3)	2.140(10)%				[2013Ma13, 1998Ar03, 1997Ch53, 1997ChZS, 1986He06, 1967Dz02, 1964Gr11, 1950Ha52]
^{217}At	4.677(5)	7.201(1)	99.32(24) %				[1997Ch19, 1997Ch53, 2013Su13, 1996GrZT, 1969LeZW, 1967Dz02, 1964Vo05, 1963Di05, 1962Di08, 1960Vo05, 1955St04, 1950Ha52, 1949SeZU, 1947Ha02]
^{221}Fr	4.624(5)	6.458(1)	100%		$1.0(2) \times 10^{-10}$ %	^{14}C	[1994Bo35, 2002Gr36, 1968Le07, 1995Sh01, 2020Go11, 2013Su13, 2002GrZY, 2001GrZU, 1999Gr33, 1999Se17, 1997Ch53, 1997ChZS, 1997GrZY, 1995Bu17, 1994Ar23, 1994Bo28, 1994NiZZ, 1992Li26, 1981Di14, 1969Dz06, 1969Le09, 1969LeZW, 1967LoZZ, 1964Va20, 1962Wa28, 1960Vo05, 1955St04, 1950Ha52, 1949SeZU, 1947En03, 1947Ha02]
^{225}Ac	4.477(5)	5.935(1)	100%		$5.3(10) \times 10^{-10}$ %	^{14}C	[2003Ku44, 2001Ga33, 1993Bo26, 1967Ba51, 1967Dz02, 2024Ga01, 2023Br08, 2023Mo25, 2012Po14, 2002Ku25, 2000Ar23, 1999GrZW, 1994Gr20, 1994NiZZ, 1993BoZN, 1993Bu26, 1993GrZQ, 1992BoZT, 1991Ko12, 1990Ko14, 1990Li46, 1978AgZX, 1978LiZN, 1977LiYX, 1975PeZO, 1972Dz14, 1970Dz12, 1969ArZV, 1969Dz06, 1969LeZW, 1967Dz03, 1966Dz17, 1964Va20, 1962Dz08, 1962Wa28, 1960Dz16, 1956Hu96, 1950Ha52, 1949SeZU, 1947En03, 1947Ha02]
^{229}Pa	4.163(3)	5.835(4)	0.48(5)%				[1987Ah05, 1963Su10, 1973Ag01, 1964Ge08, 1964Su03, 1958Hi78, 1949Hy01]
^{233}Np	3.950(51)	5.627(51)	<0.003%				[1958Le73]
^{237}Am	3.621(59)	6.146(5)**	0.025(3)%				[1975Ah05, 1972PoZS, 1952Hi63]
^{241}Bk	3.03(17)#	6.986(18)#					
^{245}Es	2.45(17)#	7.909(3)	54(7)%				[2019Br06, 1989Ha27, 1989HaZG, 1986HaZM, 1985He22, 1985MaZK, 1973Es01, 1967Mi06, 1964GhZZ]
^{249}Md	2.01(17)#	8.441(18)	75(5)%				[2019Br06, 2005He27, 2023Ni02, 2021Go26, 2009He20, 2008Ga25, 2005KuZZ, 2001He35, 1991FuZZ, 1990FuZW, 1985He22, 1973Es01]
^{253}Lr	1.64(17)	8.932(7)***	$98.7^{+1.0}_{-3.0}$ %	$1.3^{+1.0}_{-3.0}$ %			[2017BrXX, 2001He35, 2022Hu21, 2010He11, 2009He20, 2005KuZZ, 2000Ho27, 1986He28, 1985He22]
^{253m}Lr	1.64(17)-x	8.932(7)+x***	92(5)%	8(5)%			[2017BrXX, 2001He35, 2022Hu21, 2010He11, 2009He20, 2005KuZZ, 2000Ho27, 1986He28, 1985He22]
^{257}Db	1.36(17)	9.206(20)	$\approx 100\%$	< 6%			[2010He11, 2009He20, 2005KuZZ, 2001He35, 2023Ni02, 2021NiZW, 2008Ga25, 2006Fo02, 2004HeZZ, 1999He07, 1999He11, 1999HeZX, 1992An16, 1986He28, 1985He25]
^{257m}Db	1.36(17)-x	9.206(20)+x	$\approx 100\%$	< 13%			[2010He11, 2009He20, 2005KuZZ, 2001He35, 2008Ga25, 2004HeZZ, 1999He07, 1999He11, 1999HeZX]
^{261}Bh	0.76(18)	10.500(72)	100%	< 5%			[2010He11, 2006Fo02, 1989Mu09, 1988MuZX, 1986MuZX]
^{265}Mt	0.23(44)#	11.12(40)#					

* Weighted average of $4.5(14) \times 10^{-10}$ % [2001Ga33] and $6.0(13) \times 10^{-10}$ % [1993Bo26].

** Deduced from α energies, 6.196(30) MeV in [2021Wa16].

*** Deduced from α energies, 8.918(20) MeV in [2021Wa16].

Table 3

direct α emission from ^{213}Bi , $J^\pi = 9/2^-$, $T_{1/2} = 45.61(4)$ m**, $BR_\alpha = 2.140(10)$ %.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π ***	$E_{daughter}(^{209}\text{Tl})$ ***	coincident γ -rays***	R_0 (fm) [@]	HF
5.666(4)	5.560(4)	9.23(12)%	0.181(3)%	$3/2^+$	0.3238	0.3238	≈ 1.48	≈ 53
5.990(4)	5.878(4)	100%	1.96(1)%	$1/2^+$	0.0	—	≈ 1.48	≈ 155

* All values from [2013Ma13], except where noted.

** Weighted average of 45.62(6) m [2013Su13] and 45.59(6) m [1973Po16].

*** [2015Ch30].

@ $R_0 = 1.485(11)$ fm for ^{211}Bi , ≈ 1.48 fm used for ^{213}Bi

Table 4direct α emission from ^{217}At , $J^\pi = 9/2^-$, $T_{1/2} = 32.8(3)$ ms, $BR_\alpha = 99.32(24)$ %**.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{213}\text{Bi})$	coincident γ -rays	R_0 (fm)	HF
6.4407(16)	6.3220(16)	0.005(1)%	0.0050(1)%		0.7589(23)	0.7589	1.55090(15)	36_{-6}^{+10}
6.6065(16)	6.4847(16)	0.021(2)%	0.021(2)%		0.5931(23)	0.2579, 0.3355, 0.5931	1.55090(15)	39(4)
6.9418(16)	6.8138(16)	0.036(3)%	0.036(3)%	$7/2^-$	0.2579(23)	0.2579	1.55090(15)	413(35)
7.1996(16)	7.0669(16)	100%	99.94(4)%	$9/2^-$	0.0	—	1.55090(15)	1.184(17)

* All values from [1997Ch19], except where noted.

** [1997Ch53].

Table 5direct α emission from ^{221}Fr , $J^\pi = 5/2^-$, $T_{1/2} = 4.806(6)$ m**, $BR_\alpha = 100$ %.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π ***	$E_{\text{daughter}}(^{217}\text{At})$ ***	coincident γ -rays***	R_0 (fm)	HF
5.601(25)	5.500(25) [@]	$4.0(11) \times 10^{-4}$ %	$3.3(9) \times 10^{-4}$ % [@]		0.857(25) [@]		1.55234(95)	100_{-30}^{+50}
5.632(40)	5.530(40) [@]	$1.1(3) \times 10^{-3}$ %	$9(2) \times 10^{-4}$ % [@]		0.826(40) [@]		1.55234(95)	52_{-22}^{+35}
5.794(3)	5.690(3)	0.002(1)%	0.002(1)%	$5/2^-$	0.6644	0.1002, 0.1178, 0.2180 0.2819, 0.3821, 0.4463, 0.5623	1.55234(95)	150_{-50}^{+150}
5.803(4)	5.698(4)	≈ 0.001 %	≈ 0.001 %		0.655		1.55234(95)	≈ 340
5.883(3)	5.777(3)	0.07(1)%	0.06(1)%	$7/2^-$	0.5770	0.1002, 0.1178, 0.2180, 0.359, 0.5770	1.55234(95)	$13.5_{-2.0}^{+2.7}$
5.890(4)	5.784(4)	0.006(2)%	0.005(2)%	$(7/2, 9/2)$	0.5688	0.1002, 0.4690, 0.5684	1.55234(95)	180_{-50}^{+120}
5.9212(25)	5.8140(25)	0.005(2)%	0.004(2)%	$(9/2^+)$	0.5377	0.1002, 0.4378, 0.5375	1.55234(95)	310_{-110}^{+310}
6.0352(25)	5.9260(25)	0.04(1)%	0.03(1)%	$(5/2, 7/2, 9/2)^-$	0.4242	0.1002, 0.3240	1.55234(95)	140_{-40}^{+70}
6.049(20)	5.940(20)	0.20(4)%	0.17(3)%	$13/2^-$	0.4104	0.4104	1.55234(95)	29_{-5}^{+6}
6.076(25)	5.967(25)	0.10(1)%	0.08(1)%	$(7/2)^-$	0.3821	0.1002, 0.2819, 0.3821	1.55234(95)	83_{-10}^{+12}
6.091(20)	5.981(20)	0.59(4)%	0.49(3)%	$3/2^-$	0.3681	0.0538, 0.096, 0.1002, 0.1178, 0.150, 0.2180	1.55234(95)	15.6(10)
6.149(3)	6.038(3)	0.004(2)%	0.003(2)%	$(13/2^+)$	0.3100		1.55234(95)	$5_{-2}^{+9} \times 10^3$
6.189(20)	6.077(20)	0.18(4)%	0.15(3)%	$3/2^-$	0.2718	0.0538, 0.1002, 0.1178, 0.2180	1.55234(95)	138_{-23}^{+35}
6.2399(20)	6.1270(20)	18.1(3)%	15.1(2)%	$5/2^-$	0.2180	0.1002, 0.1178, 0.2180	1.55234(95)	2.36(6)
6.3584(20)	6.2433(20)	1.61(10)%	1.34(10)%	$7/2^-$	0.1002	0.1002	1.55234(95)	86(7)
6.4582(20)	6.3413(20)	100(1)%	83.4(8)%	$9/2^-$	0.0	—	1.55234(95)	3.62(11)

* All values from [1968Le07], except where noted. Values of E_α are adjusted by +1.5 keV from [1991Ry01].

** [2017Su13].

*** [1995Sh01].

[@] [2002Gr36].

Table 6direct α emission from $^{225}\text{Ac}^*$ (1 of 2), $J^\pi = (3/2^-)$, $T_{1/2} = 9.9176(18)$ d^{**}, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π [@]	$E_{\text{daughter}}(^{221}\text{Fr})$ [@]	coincident γ -rays [@]	HF ^a
4.990(5)	4.901(5)	0.004(1)%	0.0020(5)%		0.945(5) ^{@@@}		$1.3^{+0.4}_{-0.3}$
5.158(5)	5.066(5)	0.006(2)%	0.003(1)%		0.777(5) ^{@@@}		9^{+5}_{-3}
5.183(4)	5.091(4)	0.012(2)%	0.006(1)%		0.7493	0.0106, 0.0367, 0.0462, 0.1199, 0.0629, 0.0735, 0.0996, 0.6035, 0.6495	$6.8^{+1.4}_{-1.0}$
5.223(5)	5.13(5)	0.004(2)%	0.0020(8)%		0.7142	0.0462, 0.1199, 0.5683	33^{+22}_{-10}
5.253(5)	5.16(5)	0.004(2)%	0.0020(8)%		0.681(5) ^{@@@}		52^{+35}_{-15}
5.295(5)	5.201(5)	0.004(1)%	0.0020(5)%		0.6375	0.0106, 0.0367, 0.0629, 0.0643, 0.0714, 0.0735, 0.0746, 0.0996, 0.1008, 0.1084, 0.1262, 0.1336, 0.1349, 0.1979, 0.4033, 0.691, 0.6371	93^{+31}_{-19}
5.305(3)	5.211(3)	0.006(6)%	0.003(3)%	(5/2)	0.6306	0.0106, 0.0367, 0.0385, 0.0543, 0.0643, 0.0714, 0.0746, 0.0874, 0.0949, 0.1008, 0.1084, 0.1573, 0.1958, 0.435, 0.5221, 0.5297, 0.5312, 0.5914, 0.5942	≈ 68
5.333(4)	5.238(4)	0.006(2)%	0.0030(8)%		0.6023	0.0106, 0.0367, 0.5656	100^{+40}_{-20}
5.366(4)	5.271(4)	0.017(4)%	0.0090(22)%	(5/2 ⁺ , 7/2)	0.5708	0.0106, 0.0367, 0.0385, 0.0491, 0.0543, 0.0578, 0.0629, 0.0643, 0.0714, 0.0735, 0.0746, 0.0874, 0.0949, 0.0996, 0.1008, 0.1036, 0.1084, 0.1115, 0.1452, 0.1501, 0.1526, 0.1539, 0.1573, 0.1958, 0.2169, 0.2282, 0.2535, 0.3174, 0.375, 0.4624, 0.4695, 0.571	50^{+16}_{-10}
5.382(3)	5.286(3)	0.45(2)%	0.23(1)%	(3/2 ⁻ , 5/2)	0.5520	0.0106, 0.0367, 0.0385, 0.0462, 0.0491, 0.0543, 0.0578, 0.0629, 0.0643, 0.0714, 0.0735, 0.0739, 0.0746, 0.0874, 0.0949, 0.0996, 0.0998, 0.1008, 0.1036, 0.1084, 0.1115, 0.1199, 0.1452, 0.1501, 0.1526, 0.1539, 0.1573, 0.1958, 0.2169, 0.2282, 0.2535, 0.2986, 0.3174, 0.3566, 0.4062, 0.4501, 0.4524, 0.5125, 0.5153, 0.5261, 0.552	2.50(11)
5.418(3)	5.322(3)	0.13(2)%	0.068(8)%	(5/2 ⁺)	0.5177	0.0106, 0.0367, 0.0385, 0.0491, 0.0543, 0.0629, 0.0714, 0.0735, 0.0746, 0.0874, 0.0949, 0.0996, 0.1008, 0.1084, 0.1115, 0.1501, 0.1573, 0.1958, 0.3218, 0.3683, 0.4179, 0.4811, 0.4926, 0.5179	$13.2^{+1.8}_{-1.4}$
5.489(4)	5.391(4)	0.002(1)%	0.0010(5)%		0.446(4) ^{@@@}		$2.2^{+2.2}_{-0.8} \times 10^3$
5.509(4)	5.411(4)	0.004(1)%	0.0020(5)%		0.426(4) ^{@@@}		$1.4^{+0.5}_{-0.3} \times 10^3$
5.525(4)	5.427(4)	0.016(6)%	0.008(3)%		0.4111	0.0106, 0.0367, 0.1376, 0.236	430^{+260}_{-120}
5.535(4)	5.437(4)	0.14(4)%	0.07(2)%	(7/2 ⁻)	0.4007	0.0106, 0.0367, 0.0385, 0.0543, 0.0643, 0.0714, 0.0746, 0.0874, 0.0949, 0.1008, 0.1084, 0.1128, 0.1573, 0.1798, 0.1872, 0.1958, 0.2047, 0.2496, 0.3622	56^{+23}_{-13}
5.543(3)	5.444(3)	0.25(2)%	0.13(1)%	(5/2, 7/2) ⁺	0.3932	0.0106, 0.0367, 0.0385, 0.0462, 0.0491, 0.0543, 0.0578, 0.0629, 0.0643, 0.0714, 0.0735, 0.0739, 0.0746, 0.0788, 0.0874, 0.0949, 0.0996, 0.0998, 0.1008, 0.1036, 0.1084, 0.1115, 0.114, 0.1199, 0.1238, 0.1248, 0.1292, 0.1396, 0.1452, 0.1501, 0.1526, 0.1539, 0.1573, 0.1691, 0.1707, 0.1783, 0.1861, 0.1880, 0.1958, 0.1974, 0.1984, 0.2169, 0.2247, 0.2282, 0.2407, 0.2432, 0.248, 0.2535, 0.2793, 0.3549	33.2(26)
5.588(4)	5.489(4)	0.004(1)%	0.0020(7)%		0.346(4) ^{@@@}		$3.9^{+2.1}_{-1.0} \times 10^3$
5.596(4)	5.497(4)	0.006(2)%	0.003(1)%		0.338(4) ^{@@@}		$2.8^{+1.4}_{-0.7} \times 10^3$
5.626(5)	5.526(5)	0.019(4)%	0.010(2)%		0.308(5) ^{@@@}		$1.2^{+0.3}_{-0.2} \times 10^3$
5.640(5)	5.540(5)	0.08(2)%	0.04(1)%	(9/2) ⁺	0.2946	0.0385, 0.256	360^{+120}_{-70}
5.646(4)	5.546(4) ^{***}	0.06%	0.03% ^{***}	(9/2 ⁻)	0.2881	0.0106, 0.0367, 0.0385, 0.0643, 0.0714, 0.0746, 0.1008, 0.1084, 0.1798, 0.1872, 0.2496	520
5.655(4)	5.554(4) ^{***}	0.030%	0.015% ^{***}	(7/2) ⁺	0.2792	0.0106, 0.0367, 0.0385, 0.0491, 0.0643, 0.0714, 0.0746, 0.1008, 0.1084, 0.1115, 0.1292, 0.1501, 0.1707, 0.1783, 0.2407, 0.2793	1.2×10^{-3}

* All values from [1967Dz02], unless otherwise noted.

** Weighted average of 9.914(4) d [2024Ga01], 9.9150(63) d [2023Br08] 9.9179(30) d [2020Ko06] and 9.920(3) d [2012Po14].

*** [1967Ba51], values adjusted by +1.3 keV as suggested in [1991Ry01].

@ 2003Ku44

@@ Likely a multiplet feeding the (3/2)⁻ 99.6 keV, (3/2)⁺ 99.8 keV and (5/2)⁻ 100.9 keV states@@@ Deduced from α energies.^a R₀ (= 1.53983(27) fm).

Table 7direct α emission from $^{225}\text{Ac}^*$ (2 of 2), $J^\pi = (3/2^-)$, $T_{1/2} = 9.9176(18)$ d^{**}, $BR_\alpha = 100$ %.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π [@]	$E_{\text{daughter}}(^{221}\text{Fr})$ [@]	coincident γ -rays [@]	HF ^a
5.664(2)	5.563(2) ^{***}	0.066%	0.034% ^{***}	(7/2, 9/2) ⁻	0.2735	0.0106, 0.0367, 0.236	550
5.678(3)	5.577(3)	2.3(2)%	1.2(1)%	(5/2) ⁺	0.2535	0.0106, 0.0367, 0.0385, 0.0491, 0.0543, 0.0578, 0.0629, 0.0714, 0.0735, 0.0746, 0.0874, 0.0949, 0.0996, 0.1008, 0.1036, 0.1084, 0.1115, 0.1452, 0.1501, 0.1526, 0.1539, 0.1573, 0.1958, 0.2169, 0.2282, 0.2535	19.8(17)
5.700(4)	5.599(4) ^{***}	0.1%	0.04% ^{***}	(5/2) ⁺	0.2345	0.0106, 0.0367, 0.0629, 0.0643, 0.0714, 0.0735, 0.0746, 0.0996, 0.1008, 0.1084, 0.1262, 0.1336, 0.1349, 0.1979	740
5.710(3)	5.608(3)	2.1(2)%	1.1(1)%	(3/2, 5/2) ⁺	0.2246	0.0106, 0.0367, 0.0385, 0.0462, 0.0643, 0.0739, 0.0746, 0.0788, 0.0998, 0.1008, 0.1199, 0.1238, 0.1248, 0.1861, 0.1880, 0.1984, 0.2247	30.4(28)
5.739(3)	5.637(3)	8.7(6)%	4.5(3)%	(5/2, 7/2) ⁻	0.1958	0.0106, 0.0367, 0.0385, 0.0543, 0.0714, 0.0746, 0.0874, 0.0949, 0.1008, 0.1084, 0.1573, 0.1958	10.4(7)
5.784(3)	5.681(3)	2.7(4)%	1.4(2)%	(7/2) ⁺	0.1500	0.0106, 0.0367, 0.0385, 0.0491, 0.0714, 0.1084, 0.1115, 0.1501	57 ⁺¹⁰ ₋₇
5.827(3)	5.723(3)	5.6(10)%	2.9(5)%	(7/2) ⁻	0.1083	0.0106, 0.0367, 0.0714, 0.1084	45 ⁺⁹ ₋₇
5.835(3)	5.731(3) ^{@@}	19.4(6)%	10.0(1)%	(3/2) ⁻	0.0996	0.0106, 0.0367, 0.0629, 0.0735, 0.0996	14.37(17)
5.897(3)	5.792(3)	51.7(35)%	26.7(10)%	(3/2) ⁻	0.0366	0.0106, 0.0367	11.0(4)
5.910(2)	5.805(2) ^{***}	0.6%	0.3% ^{***}	(1/2) ⁻	0.0259	—	1.1 \times 10 ³
5.935(2)	5.829(2)	100(3)%	51.6(15)%	5/2 ⁻	0.0	—	8.59(32)

* All values from [1967Dz02], unless otherwise noted.

** Weighted average of 9.914(4) d [2024Ga01], 9.9150(63) d [2023Br08] 9.9179(30) d [2020Ko06] and 9.920(3) d [2012Po14].

*** [1967Ba51], values adjusted by +1.3 keV as suggested in [1991Ry01] (due to energy changes in calibration sources).

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@@ Likely a multiplet feeding the (3/2)⁻ 99.6 keV, (3/2)⁺ 99.8 keV and (5/2)⁻ 100.9 keV states@@@ Deduced from α energies.^a R_0 (= 1.53983(27) fm).**Table 8**direct α emission from ^{229}Pa , $J^\pi = (5/2^+)$, $T_{1/2} = 1.50(5)$ d^{*}, $BR_\alpha = 0.48(5)$ %^{*}.

E_α (c.m.)	E_α (lab) ^{**}	I_α (rel)	I_α (abs)	J_f^π [*]	$E_{\text{daughter}}(^{225}\text{Ac})$ [*]	coincident γ -rays [*]	R_0 (fm)	HF
5.415	5.310	0.14%	0.02%		0.422 ^{***}		1.53293(31)	52
5.509	5.413	0.41%	0.07%		0.328 ^{***}		1.53293(31)	59
5.518	5.422	0.19%	0.03%		0.319 ^{***}		1.53293(31)	140
5.576	5.479	4.7%	0.82%	(9/2) ⁺	0.2569	0.0678, 0.0751, 0.1119, 0.1520, 0.1584, 0.1799	1.53293(31)	13
5.599	5.501	1.9%	0.34%	(9/2) ⁻	0.2355	0.1584	1.53293(31)	41
5.615	5.517	1.6%	0.29%		0.222 ^{***}		1.53293(31)	57
5.634	5.536	24.1%	4.22%	(7/2) ⁺	0.1999	0.0348, 0.0401, 0.0647, 0.0751, 0.0790, 0.0806, 0.0949, 0.1208, 0.1228, 0.1352, 0.1699	1.53293(31)	5.1
5.664	5.565	10.68%	1.87%	(7/2) ⁻	0.1708	0.936, 0.1409	1.53293(31)	16
5.679	5.580	100%	17.52%	(5/2) ⁺	0.1557	0.0348, 0.0401, 0.0806, 0.1156, 0.1208, 0.1557	1.53293(31)	2.1
5.690	5.591	12.6%	2.21%	(9/2) ⁺	0.1449	0.0678	1.53293(31)	19
5.715	5.615	36.4%	6.38%	(5/2) ⁻	0.1208	0.0401, 0.0806, 0.1208	1.53293(31)	8.9
5.730	5.630	26.6%	4.66%	(7/2) ⁻	0.1051	0.0771	1.53293(31)	15
5.771	5.670	50.7%	8.88%	(5/2) ⁺	0.0647	0.0348, 0.0647	1.53293(31)	13
5.796	5.695	4.1%	0.72%	(3/2) ⁺	0.0401	0.0401	1.53293(31)	210
5.837	5.735	1.4%	0.24%	(3/2) ⁻	0.0	—	1.53293(31)	1000

* [1987Ah05].

** [1963Su10]. E_α values are adjusted by 5.2 keV as suggested in [1991Ry01] (due to energy changes in calibration sources).*** Deduced from α energies.

Table 9direct α emission from ^{237}Am , $J^\pi = 5/2^-$, $T_{1/2} = 73.0(10)$ m, $BR_\alpha = 0.025(3)\%$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{daughter}$ (^{233}Np)	coincident γ -rays	R_0 (fm)	HF
6.146(5)	6.042(5)	0.025(3)%	(5/2 ⁺)	0.0	—	1.4954(46)	0.85 ^{+0.17} _{-0.14}

* All values taken from [1975Ah05].

Table 10direct α emission from $^{245}\text{Es}^*$, $J^\pi = (3/2^-)$, $T_{1/2} = 66(6)$ s, $BR_\alpha = 54(7)\%^{**}$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π	$E_{daughter}$ (^{241}Bk)	coincident γ -rays	R_0 (fm)	HF
7.781(6)	7.654(6)	4(1)%	2(1)%		0.128		1.502(36)	30 ⁺⁴⁰ ₋₂₀
7.827(5)	7.699(5)	16(5)%	7(2)%		0.082		1.502(36)	2.3 ^{+3.2} _{-1.4}
7.858(1)	7.730(1)	100(11)%	43(6)%		0.051		1.502(36)	18 ⁺²⁷ ₋₁₂
7.909(3)	7.780(3)	6(1)%	3(1)%	(7/2 ⁺)	0.0		1.502(36)	70 ⁺¹⁰⁰ ₋₅₀

* All values taken from [1989Ha27], unless otherwise noted.

** [2019Br06].

Table 11direct α emission from $^{249}\text{Md}^*$, $J^\pi = (7/2^-)$, $T_{1/2} = 26(1)$ s^{**}, $BR_\alpha = 75(5)\%^{**}$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{daughter}$ (^{245}Es)	coincident γ -rays	R_0 (fm)	HF
8.157(10)	8.026(10)	75(5)% ^{**}		x	0.2004, 0.2232, 0.2532	1.493(14)	1.1 ^{+0.4} _{-0.3}

* All values taken from [1989Ha27], unless otherwise noted.

** [2019Br06].

Table 12direct α emission from ^{253}Lr , $J^\pi = (7/2^-)^*$, $T_{1/2} = 520^{+29}_{-32}$ ms^{**}, $BR_\alpha = 98.7^{+1.0}_{-3.0}\%^{***}$.

E_α (c.m.)	E_α (lab)	I_α (rel)*	I_α (abs)	J_f^π *	$E_{daughter}$ (^{217}At)	coincident γ -rays	R_0 (fm)	HF
8.842(20)	8.660(20)*	4(1)%	4(1)%	(11/2 ⁻)			1.478(29)	16 ⁺¹⁸ ₋₉
8.932(7)	8.791(7) [@]	100%	94.6 ^{+1.0} _{-3.0}	(7/2 ⁻)	0.0	—	1.478(29)	0.7 ^{+0.8} _{-0.4}

* [2022Hu21].

** [2017BrXX].

*** [2001He35].

[@] Weighted average of 8.788(10) MeV [2017BrXX] and 8.794(10) MeV [2001He35]**Table 13**direct α emission from ^{253m}Lr , Ex. = unk., $J^\pi = (1/2^-)^*$, $T_{1/2} = 2.00^{+0.16}_{-0.19}$ s^{**}, $BR_\alpha = 92(5)\%^{***}$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π [@]	$E_{daughter}$ (^{217}At)	coincident γ -rays	R_0 (fm)	HF
8.858(7)	8.718(7) [@]		94.6 ^{+1.0} _{-3.0}	(1/2 ⁻)		1.478(29)	3.0 ^{+3.0} _{-1.6}

* [2022Hu21].

** [2017BrXX].

*** [2001He35].

[@] Weighted average of 8.713(10) MeV [2017BrXX] and 8.722(10) MeV [2001He35]

Table 14direct α emission from ^{257}Db , $J^\pi = (9/2^+)$, $T_{1/2} = 1.6(2)$ s*, $BR_\alpha \approx 100$ %.

E_α (c.m.)	E_α (lab)**	I_α (rel)	I_α (abs)	$J_f^{\pi***}$	$E_{\text{daughter}}(^{217}\text{At})^{***}$	coincident γ -rays	R_0 (fm)	HF
9.014(20)	8.874(20) [@]		weak [@]	(9/2 ⁺) 0.201		1.465(39)		
9.089(15)	8.948(15)		$\approx 50\%^{***}$	(1/2 ⁻) 0.126	0.102	1.465(39)	≈ 2.1	
9.215(10)	9.072(10)		$\approx 50\%^{***}$	(7/2 ⁻)	0.0	—	1.465(39)	≈ 5

* Weighted average of 2.3(2) s [2009He20] and $1.50_{-0.15}^{+0.19}$ s [2001He35].

** Weighted average of values from [2010He11], [2009He20], [2005KuZZ] and [2001He35].

*** [2001He35].

[@] [2009He20].**Table 15**direct α emission from ^{257m}Db , E. = unk., $J^\pi = (1/2^-)$, $T_{1/2} = 670(60)$ ms*, $BR_\alpha \approx 100$ %.

E_α (c.m.)	E_α (lab)**	I_α (abs)	$J_f^{\pi***}$	$E_{\text{daughter}}(^{217}\text{At})^{***}$	coincident γ -rays	R_0 (fm)	HF
9.308(10)	9.163(10)**	$\approx 100\%$	(7/2 ⁻)	0.0	—	1.465(39)	$1.9_{-1.2}^{+3.1}$

* [2009He20].

** Weighted average of values from [2010He11], [2009He20], [2005KuZZ] and [2001He35].

Table 16direct α emission from ^{261}Bh , $J^\pi = (5/2^-)$, $T_{1/2} = 11.8_{-2.4}^{+3.9}$ ms, $BR_\alpha = 100$ %.

E_α (c.m.)	E_α (lab)**	I_α (abs)	J_f^{π}	$E_{\text{daughter}}(^{257}\text{Db})$	coincident γ -rays	R_0 (fm)	HF
≈ 10.2	≈ 10.0	100%	(5/2 ⁻)	> 0.350		1.461(22)	≈ 1.8

* All values from [2010He11].

** [1989Mu09] report three α transitions with energies of 10.03, 10.10 and 10.40. The later two are shown to be α peaks summed with conversion electrons in [2010He11].**References used in the Tables**

- [1] **1947En03** A. C. English, T. E. Cranshaw, P. Demers, J. A. Harvey, E. P. Hincks, J. V. Jelley, A. N. May, Phys. Rev. **72**, 253 (1947). <https://doi.org/10.1103/PhysRev.72.253>
- [2] **1947Ha02** F. Hagemann, L. I. Katzin, M. H. Studier, A. Ghiorso, G. T. Seaborg, Phys. Rev. **72**, 252 (1947). <https://doi.org/10.1103/PhysRev.72.252>
- [3] **1949Hy01** E. K. Hyde, M. H. Studier, H. H. Hopkins, Jr., A. Ghiorso, The Transuranium Elements: Research Papers, Book 2, Vol. 14B, paper 19. 17, G. T. Seaborg ed., p. 1439 (1949).
- [4] **1949SeZU** G. T. Seaborg, The Transuranium Elements: Research Papers, Book 2, Vol. 14B, paper 22. 3, G. T. Seaborg ed., p. 1572 (1949).
- [5] **1950Ha52** F. Hagemann, L. I. Katzin, M. H. Studier, G. T. Seaborg, A. Ghiorso, Phys. Rev. **79**, 435 (1950). <https://doi.org/10.1103/PhysRev.79.435>
- [6] **1952Hi63** G. H. Higgins, Thesis, Univ. California (1952).; UCRL-1796 (1952).
- [7] **1955St04** F. S. Stephens, Jr., Thesis, Univ. California (1955); UCRL-2970 (1955).
- [8] **1956Hu96** J. P. Hummel, Thesis, Univ. California (1956).; UCRL-3456 (1956).
- [9] **1958Hi78** M. W. Hill, Thesis, Univ. California (1958); UCRL-8423 (1958).
- [10] **1958Le73** R. M. Lessler, Thesis, Univ. California (1958).; UCRL-8439 (1958).
- [11] **1960Dz16** B. S. Dzhelepov, R. B. Ivanov, L. N. Moskvina, Repts. Third Conf. Neutron-Deficient Isotopes, Dubna (June 1960).; NP-13165, Vol. 2, p. 79 (1964).
- [12] **1960Vo05** A. A. Vorobev, A. P. Komar, V. A. Korolev, Zhur. Eksptl. i Teoret. Fiz. **39**, 70 (1960).; Soviet Phys. JETP **12**, 50 (1961).
- [13] **1962Di08** H. Diamond, J. E. Gindler, TID-16202 (1962); Nucl. Sci. Abstr. 17, 1511, Abstr. 11632 (1963).

- [14] **1962Dz08** B. S. Dzhelepov, R. B. Ivanov, L. N. Moskvina, Zhur. Eksptl. i Teoret. Fiz. **43**, 2077 (1962).; Soviet Phys. JETP **16**, 1469 (1963).
- [15] **1962Wa28R**. J. Walen, Compt. Rend. **255**, 1604 (1962).
- [16] **1963Di05** H. Diamond, J. E. Gindler, J. Inorg. Nucl. Chem. **25**, 143 (1963). [https://doi.org/10.1016/0022-1902\(63\)80001-9](https://doi.org/10.1016/0022-1902(63)80001-9)
- [17] **1963Su10** V. B. Subrahmanyam, Thesis, Univ. California (1963); UCRL-11082 (1963).
- [18] **1964Ge08C**. Gerschel, M. Pautrat, R. Ricci, J. Vanhorenbeeck, J. Teillac, Phys. Nucl. Annuaire 1962-63, Faculte Sci. L'Univ. Paris Inst. Rad., p. 47 (January 1964).
- [19] **1964GhZZ** A. Ghiorso, T. Sikkeland, A. E. Larsh, R. M. Latimer, The Nuclear Properties of the Heavy Elements, Vol. II, Prentice-Hall, Inc., Englewood Cliffs, N. J. p. 945 (1964).
- [20] **1964Gr11** G. Graeffe, K. Valli, J. Aaltonen, Ann. Acad. Sci. Fenn., Ser. A VI, No. 145 (1964).
- [21] **1964Su03** V. Subrahmanyam, F. Asaro, I. Perlman, UCRL-11213, p. 17 (1964).
- [22] **1964Vo05** F. von Hippel, P. P. Divakaran, Phys. Rev. Lett. **12**, 128 (1964).; Erratum Phys. Rev. Lett. **12**, 497 (1964). <https://doi.org/10.1103/PhysRevLett.12.128>
- [23] **1964Va20** K. Valli, Ann. Acad. Sci. Fennicae, Ser. A VI, No. 165 (1964).
- [24] **1966Dz17** B. S. Dzhelepov, R. B. Ivanov, L. N. Moskvina, V. F. Rodionov, Izv. Akad. Nauk SSSR, Ser. Fiz. **30**, 1322 (1966).; Bull. Acad. Sci. USSR, Phys. Ser. **30**, 1380 (1967).
- [25] **1967Ba51** G. Bastin-Scoffier, Compt. Rend. **265B**, 863 (1967).
- [26] **1967Dz02** B. S. Dzhelepov, R. B. Ivanov, M. A. Mikhailova, L. N. Moskvina, O. M. Nazarenko, V. F. Rodionov, Izv. Akad. Nauk SSSR, Ser. Fiz. **31**, 568 (1967).; Bull. Acad. Sci. USSR, Ser. Fiz. **31**, 563 (1968).
- [27] **1967Dz03** B. S. Dzhelepov, R. B. Ivanov, L. N. Moskvina, V. F. Rodionov, Izv. Akad. Nauk SSSR, Ser. Fiz. **31**, 151 (1967).; Bull. Acad. Sci. USSR, Phys. Ser. **31**, 143 (1968).
- [28] **1967LoZZ** W. Lourens, Thesis, Technische Hogeschool Delft (1967).
- [29] **1968Le07** C. -F. Leang, G. Bastin-Scoffier, Compt. Rend. **266B**, 629 (1968).
- [30] **1969ArZV** R. Arlt, B. S. Dzhelepov, R. B. Ivanov, M. A. Mikhailova, L. N. Moskvina, V. O. Sergeev, L. G. Tsaritsyna, K. Shturynyi, Program and Theses, Proc. 19th Ann. Conf. Nucl. Spectroscopy and Struct. of At. Nuclei, Erevan, p. 152 (1969).
- [31] **1969Dz06** B. S. Dzhelepov, A. V. Zolotavin, R. B. Ivanov, M. A. Mikhailova, V. O. Sergeev, Izv. Akad. Nauk SSSR, Ser. Fiz. **33**, 1607 (1969).; Bull. Acad. Sci. USSR, Phys. Ser. **33**, 1475 (1970).
- [32] **1969Le09** C. -F. Leang, F. Gautier, J. Phys. (Paris). **30**, 296 (1969).
- [33] **1969LeZW** C. -F. Leang, Thesis, Univ. Paris (1969).
- [34] **1970Dz12** B. S. Dzhelepov, A. V. Zolotavin, R. B. Ivanov, M. A. Mikhailova, V. O. Sergeev, M. I. Sovtsov, Izv. Akad. Nauk SSSR, Ser. Fiz. **34**, 2127 (1970).; Bull. Acad. Sci. USSR, Phys. Ser. **34**, 1897 (1971).
- [35] **1972Dz14** B. S. Dzhelepov, R. B. Ivanov, M. A. Mikhailova, V. O. Sergeev, Izv. Akad. Nauk SSSR, Ser. Fiz. **36**, 2080 (1972).; Bull. Acad. Sci. USSR, Phys. Ser. **36**, 1832 (1973).
- [36] **1972PoZS** J. C. Post, Thesis, Univ. Amsterdam (1972).
- [37] **1973Ag01** P. Aguer, A. Peghaire, C. F. Liang, Nucl. Phys. A**202**, 37 (1973). [https://doi.org/10.1016/0375-9474\(73\)90239-X](https://doi.org/10.1016/0375-9474(73)90239-X)
- [38] **1973Es01** P. Eskola, Phys. Rev. C**7**, 280 (1973). <https://doi.org/10.1103/PhysRevC.7.280>
- [39] **1973Po16** P. Polak, Radiochim. Acta **19**, 148 (1973).
- [40] **1973We08** R. Weiss-Reuter, H. Munzel, G. Pfennig, J. Inorg. Nucl. Chem. **35**, 2145 (1973). [https://doi.org/10.1016/0022-1902\(73\)80277-5](https://doi.org/10.1016/0022-1902(73)80277-5)
- [41] **1975Ah05** I. Ahmad, F. T. Porter, M. S. Freedman, R. K. Sjoblom, J. Lerner, R. F. Barnes, J. Milsted, P. R. Fields, Phys. Rev. C**12**, 541 (1975). <https://doi.org/10.1103/PhysRevC.12.541>
- [42] **1975PeZO** A. Peghaire, P. Aguer, C. F. Liang, CSNSN-1973-1975, p. 38 (1975).
- [43] **1977LiYX** C. F. Liang, A. Peghaire, Proc. Intern. Conf. Nucl. Structure, Tokyo, Vol. 1, p. 460 (1977).
- [44] **1978AgZX** P. Aguer, C. F. Liang, A. Peghaire, CSNSM-1976-1977, p. 25 (1978).
- [45] **1978LiZN** C. F. Liang, A. Peghaire, CSNSM-1976-1977, p. 27 (1978).
- [46] **1981Di14** J. K. Dickens, J. W. McConnell, Radiochem. Radioanal. Lett. **47**, 331 (1981).

- [47] **1985He22** F. P. Hessberger, G. Munzenberg, S. Hofmann, Y. K. Agarwal, K. Poppensieker, W. Reisdorf, K. -H. Schmidt, J. R. H. Schneider, W. F. W. Schneider, H. J. Schott, P. Armbruster, B. Thuma, C. -C. Sahn, D. Vermeulen, *Z. Phys.* **A322**, 557 (1985).
- [48] **1985He25** K. Heck, G. Grawert, D. Mukhopadhyay, *Nucl. Phys.* **A437**, 226 (1985). [https://doi.org/10.1016/0375-9474\(85\).90234-9](https://doi.org/10.1016/0375-9474(85).90234-9)
- [49] **1985MaZK** M. Magara, K. Sueki, H. Nakahara, H. Kudo, Y. Hamajima, I. Kohno, RIKEN-84, p. 37 (1985).
- [50] **1986HaZM** Y. Hatsukawa, M. Magara, T. Otsuki, M. Nakata, K. Sueki, H. Nakahara, I. Kohno, RIKEN-85, p. 44 (1986).
- [51] **1986He06** R. G. Helmer, C. W. Reich, M. A. Lee, I. Ahmad, *Int. J. Appl. Radiat. Isotop.* **37**, 139 (1986). [https://doi.org/10.1016/0883-2889\(86\)90062-6](https://doi.org/10.1016/0883-2889(86)90062-6)
- [52] **1986He28** F. P. Hessberger, G. Munzenberg, S. Hofmann, P. Armbruster, Y. K. Agarwal, W. Reisdorf, K. Poppensieker, K. -H. Schmidt, J. R. H. Schneider, W. F. W. Schneider, H. J. Schott, C. -C. Sahn, D. Vermeulen, B. Thuma, *J. Less-Common Met.* **122**, 445 (1986). [https://doi.org/10.1016/0022-5088\(86\).90440-6](https://doi.org/10.1016/0022-5088(86).90440-6)
- [53] **1986MuZX** G. Munzenberg, S. Hofmann, F. P. Hessberger, K. -H. Schmidt, G. Berthes, H. Folger, H. Geissel, J. G. Keller, P. Lemmert, M. Montoya, K. Poppensieker, B. Quint, H. -J. Schott, I. Zychor, P. Armbruster, M. E. Leino, U. Gollerthan, GSI-86-1, p. 31 (1986).
- [54] **1987Ah05** I. Ahmad, J. E. Gindler, A. M. Friedman, R. R. Chasman, T. Ishii, *Nucl. Phys.* **A472**, 285 (1987). [https://doi.org/10.1016/0375-9474\(87\).90211-9](https://doi.org/10.1016/0375-9474(87).90211-9)
- [55] **1988MuZX** G. Munzenberg, S. Hofmann, F. P. Hessberger, D. Ackermann, H. Folger, V. Ninov, K. Poppensieker, A. B. Quint, W. Reisdorf, K. -H. Schmidt, H. -J. Schott, K. Summerer, P. Armbruster, U. Gollerthan, E. Hanelt, W. Morawek, Y. Fujita, T. Schwab, M. E. Leino, GSI-88-1, p. 13 (1988).
- [56] **1989Ha27** Y. Hatsukawa, T. Ohtsuki, K. Sueki, H. Nakahara, I. Kohno, M. Magara, N. Shinohara, H. L. Hall, R. A. Henderson, C. M. Gannett, J. A. Leyba, R. B. Chadwick, K. E. Gregorich, D. Lee, M. J. Nurmia, D. C. Hoffman, *Nucl. Phys.* **A500**, 90 (1989). [https://doi.org/10.1016/0375-9474\(89\)90131-0](https://doi.org/10.1016/0375-9474(89)90131-0)
- [57] **1989HaZG** Y. Hatsukawa, T. Ohtsuki, K. Sueki, H. Nakahara, I. Kohno, M. Magara, N. Shinohara, K. E. Gregorich, D. Lee, D. C. Hoffman, *Inst. Nucl. Study, Univ. Tokyo, Ann. Rept.*, 1988, p. 26 (1989).
- [58] **1989Mu09** G. Munzenberg, P. Armbruster, S. Hofmann, F. P. Hessberger, H. Folger, J. G. Keller, V. Ninov, K. Poppensieker, A. B. Quint, W. Reisdorf, K. -H. Schmidt, J. R. H. Schneider, H. -J. Schott, K. Summerer, I. Zychor, M. E. Leino, D. Ackermann, U. Gollerthan, E. Hanelt, W. Morawek, D. Vermeulen, Y. Fujita, T. Schwab, *Z. Phys.* **A333**, 163 (1989).
- [59] **1990FuZW** I. Fujiwara, S. Shibata, H. Kudo, K. Tsukada, T. Ohtsuki, N. Shinohara, S. -I. Ichikawa, H. Iimura, *Japan Atomic Energy Res. Inst. Tandem Linac VDG, Ann. Rept.*, 1989, p. 123 (1990).
- [60] **1990Ko14** M. C. Kouassi, J. Dalmaso, H. Maria, G. Ardisson, M. Hussonnois, *J. Radioanal. Nucl. Chem.* **144**, 387 (1990). <https://doi.org/10.1007/BF02218147>
- [61] **1990Li46** C. F. Liang, A. Peghaire, R. K. Sheline, *Mod. Phys. Lett. A* **5**, 1243 (1990). <https://doi.org/10.1142/S0217732390001402>
- [62] **1991FuZZ** I. Fujiwara, S. Shibata, H. Kudo, K. Tsukada, T. Ohtsuki, Y. Hatsukawa, N. Shinohara, S. -I. Ichikawa, M. Magara, *Japan Atomic Energy Res. Inst. Tandem Linac VDG, Ann. Rept.*, 1990, p. 87 (1991).
- [63] **1991Ko12** M. C. Kouassi, J. Dalmaso, M. Hussonnois, V. Barci, G. Ardisson, *J. Radioanal. Nucl. Chem.* **153**, 293 (1991). <https://doi.org/10.1007/BF02202649>
- [64] **1992An16** A. N. Andreyev, D. D. Bogdanov, V. I. Chepigin, A. P. Kabachenko, O. N. Malyshev, Yu. Ts. Oganessian, R. N. Sagaidak, G. M. Ter-Akopian, A. V. Yeremin, F. P. Hessberger, S. Hofmann, V. Ninov, M. Florek, S. Saro, M. Veselsky, *Z. Phys.* **A344**, 225 (1992).
- [65] **1992BoZT** R. Bonetti, C. Chiesa, A. Guglielmetti, R. Matheoud, C. Migliorino, *Contrib. 6th Intern. Conf. on Nuclei Far from Stability + 9th Intern. Conf. on Atomic Masses and Fundamental Constant, Bernkastel-Kues, Germany, D7* (1992).
- [66] **1992Li26** M. Lindroos, P. Richards, J. Rikavska, N. J. Stone, I. Oliveira, K. Nishimura, M. Booth, and the NICOLE and ISOLDE Collaborations, *Hyperfine Interactions* **75**, 323 (1992). <https://doi.org/10.1007/BF02398989>
- [67] **1993Bo26** R. Bonetti, C. Chiesa, A. Guglielmetti, R. Matheoud, C. Migliorino, A. L. Pasinetti, H. L. Ravn, *Nucl. Phys.* **A562**, 32 (1993). [https://doi.org/10.1016/0375-9474\(93\).90030-2](https://doi.org/10.1016/0375-9474(93).90030-2)
- [68] **1993BoZN** R. Bonetti, C. Chiesa, A. Guglielmetti, R. Matheoud, C. Migliorino, *Proc. 6th Intern. Conf. on Nuclei Far from Stability + 9th Intern. Conf. on Atomic Masses and Fundamental Constants, Bernkastel-Kues, Germany, 19-24 July, 1992, R. Neugart, A. Wöhr, Eds.*, p. 459 (1993).

- [69] **1993Bu26** T. Butz, *Hyperfine Interactions* **80**, 1079 (1993). <https://doi.org/10.1007/BF00567468>
- [70] **1993El08** O. El Samad, J. Dalmasso, G. Barci-Funel, G. Ardisson, *Radiochim. Acta* **62**, 65 (1993).
- [71] **1993GrZQ** K. Ya. Gromov, M. Ya. Kuznetsova, Yu. V. Norseev, V. I. Fominykh, V. G. Chumin, M. B. Yuldashev, Yu. V. Yushkevich, A. V. Potempa, Program and Thesis, Proc. 43rd Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Dubna, p. 114 (1993).
- [72] **1994Ar23** G. Ardisson, V. Barci, O. El Samad, *Nucl. Instrum. Methods Phys. Res.* **A339**, 168 (1994). [https://doi.org/10.1016/0168-9002\(94\)91799-X](https://doi.org/10.1016/0168-9002(94)91799-X)
- [73] **1994Bo28** R. Bonetti, C. Chiesa, A. Guglielmetti, C. Migliorino, P. Monti, A. L. Pasinetti, H. L. Ravn, *Nucl. Phys.* **A576**, 21 (1994). [https://doi.org/10.1016/0375-9474\(94\)90736-6](https://doi.org/10.1016/0375-9474(94)90736-6)
- [74] **1994Bo35** R. Bonetti, C. Chiesa, A. Guglielmetti, C. Migliorino, P. Monti, *Z. Phys.* **A349**, 309 (1994). <https://doi.org/10.1007/BF01288982>
- [75] **1994Gr20** K. Ya. Gromov, M. Ya. Kuznetsova, Yu. N. Norseev, N. I. Rukhadze, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, M. B. Yuldashev, Yu. S. Butabaev, R. A. Niyazov, *Bull. Rus. Acad. Sci. Phys.* **58**, 29 (1994).
- [76] **1994NiZZ** R. A. Niyazov, Yu. S. Butabaev, A. Kh. Kholmatov, K. Ya. Gromov, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, M. B. Yuldashev, Yu. V. Norseev, Program and Thesis, Proc. 44th Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Kharkov, p. 88 (1994).
- [77] **1995Bu17** Yu. S. Butabaev, I. Adam, K. Ya. Gromov, S. S. Eliseev, R. A. Niyazov, Yu. V. Norseev, V. I. Fominykh, A. Kh. Kholmatov, V. V. Tsupko-Sitnikov, V. G. Chumin, M. B. Yuldashev, *Bull. Rus. Acad. Sci. Phys.* **59**, 5 (1995).
- [78] **1995Sh01** R. K. Sheline, C. F. Liang, P. Paris, *Phys. Rev.* **C51**, 1192 (1995). <https://doi.org/10.1103/PhysRevC.51.1192>
- [79] **1996GRZT** K. Ya. Gromov, M. Ya. Kuznetsova, Yu. V. Norseev, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, M. B. Yuldashev, Program and Thesis, Proc. 46th Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Moscow, p. 80 (1996).
- [80] **1997Ch19** V. G. Chumin, V. I. Fominykh, K. Ya. Gromov, M. Ya. Kuznetsova, V. V. Tsupko-Sitnikov, M. B. Yuldashev, *Z. Phys.* **A358**, 33 (1997). <https://doi.org/10.1007/s002180050273>
- [81] **1997Ch53** V. G. Chumin, J. K. Jabber, K. V. Kalyapkin, S. A. Kudrya, V. V. Tsupko-Sitnikov, K. Ya. Gromov, V. I. Fominykh, T. A. Furyaev, *Bull. Rus. Acad. Sci. Phys.* **61**, 1606 (1997).
- [82] **1997ChZS** V. G. Chumin, V. I. Fominykh, T. A. Furyaev, K. Ya. Gromov, J. K. Jabber, K. V. Kalyapkin, S. A. Kudrya, V. V. Tsupko-Sitnikov, *JINR-E6-97-189* (1997).
- [83] **1997GrZY** K. Ya. Gromov, T. A. Islamov, N. T. Kambarova, V. V. Tsupko-Sitnikov, V. G. Chumin, M. B. Yuldashev, Program and Thesis, Proc. 47th Ann. Conf. on Nucl. Spectrosc. Struct. At. Nuclei, Obninsk, p. 52 (1997).
- [84] **1998Ar03** G. Ardisson, V. Barci, O. El Samad, *Phys. Rev.* **C57**, 612 (1998). <https://doi.org/10.1103/PhysRevC.57.612>
- [85] **1999Gr33** K. Ya. Gromov, J. K. Jabber, Sh. R. Malikov, V. I. Fominykh, Yu. V. Kholnov, V. V. Tsupko-Sitnikov, V. G. Chumin, *Bull. Rus. Acad. Sci. Phys.* **63**, 685 (1999).
- [86] **1999GrZW** K. Ya. Gromov, S. A. Kudrya, Sh. R. Malikov, V. A. Sergienko, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, Program and Thesis, Proc. 49th Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Dubna, p. 94 (1999).
- [87] **1999He07** F. P. Hessberger, *Acta Phys. Slovaca* **49**, 43 (1999).
- [88] **1999He11** F. P. Hessberger, *J. Phys. (London)* **G25**, 877 (1999). <https://doi.org/10.1088/0954-3899/25/4/059>
- [89] **1999HeZXF** F. P. Hessberger, S. Hofmann, V. Ninov, P. Armbruster, G. Munzenberg, Ch. Stodel, A. Yu. Lavrentev, A. G. Popeko, A. V. Yeregin, S. Saro, M. E. Leino, *GSI 99-1*, p. 11 (1999).
- [90] **1999Se17** R. K. Seto, H. Xiang, for the E917 Collaboration, *Nucl. Phys.* **A661**, 506c (1999). [https://doi.org/10.1016/S0375-9474\(99\)85076-3](https://doi.org/10.1016/S0375-9474(99)85076-3)
- [91] **2000Ar23** G. Ardisson, J. Gasparro, V. Barci, R. K. Sheline, *Phys. Rev.* **C62**, 064306 (2000). <https://doi.org/10.1103/PhysRevC.62.064306>
- [92] **2000Ho27** N. E. Holden, D. C. Hoffman, *Pure Appl. Chem.* **72**, 1525 (2000).; Erratum *Pure Appl. Chem.* **73**, 1225 (2001). <https://doi.org/10.1351/pac200072081525>
- [93] **2001Ga33** J. E. Garcia-Ramos, C. De Coster, R. Fossion, K. Heyde, *Nucl. Phys.* **A688**, 735 (2001). [https://doi.org/10.1016/S0375-9474\(00\)00592-3](https://doi.org/10.1016/S0375-9474(00)00592-3)
- [94] **2001GrZU** K. Ya. Gromov, S. A. Kudrya, Sh. R. Malikov, Yu. V. Norseev, V. A. Sergienko, V. I. Fominykh, V. G. Chumin, Program and Thesis, Proc. 51st Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Sarov, p. 179 (2001).

- [95] **2001He35** F. P. Hessberger, S. Hofmann, D. Ackermann, V. Ninov, M. Leino, G. Munzenberg, S. Saro, A. Lavrentev, A. G. Popeko, A. V. Yeremin, Ch. Stodel, *Eur. Phys. J. A* **12**, 57 (2001). <https://doi.org/10.1007/s100500170039>
- [96] **2002Gr36** K. Ya. Gromov, S. A. Kudrya, Sh. R. Malikov, V. A. Sergienko, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, *Bull. Rus. Acad. Sci. Phys.* **66**, 1519 (2002).
- [97] **2002GrZY** K. Ya. Gromov, S. A. Kudrya, Sh. R. Malikov, V. A. Sergienko, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, *JINR-P6-2002-17* (2002).
- [98] **2002Ku25** P. Kulesa, W. Cassing, L. Jarczyk, B. Kamys, H. Ohm, K. Pysz, Z. Rudy, O. W. B. Schult, H. Stroher, *J. Phys. (London). G* **28**, 1715 (2002). <https://doi.org/10.1088/0954-3899/28/7/324>
- [99] **2003As01** M. Asai, K. Tsukada, S. Ichikawa, M. Sakama, H. Haba, Y. Nagame, I. Nishinaka, K. Akiyama, A. Toyoshima, T. Kaneko, Y. Oura, Y. Kojima, M. Shibata, *Eur. Phys. J. A* **16**, 17 (2003). <https://doi.org/10.1140/epja/i2002-10112-y>
- [100] **2003Ku44** S. A. Kudrya, V. M. Gorozhankin, K. Ya. Gromov, Sh. R. Malikov, L. A. Malov, V. A. Sergienko, V. I. Fominykh, V. V. Tsupko-Sitnikov, V. G. Chumin, E. A. Yakushev, *Bull. Rus. Acad. Sci. Phys.* **67**, 7 (2003).
- [101] **2004HeZZ** F. P. Hessberger, S. Hofmann, D. Ackermann, S. Antalic, P. Cagarda, I. Kojouharov, P. Kuusiniemi, R. Mann, S. Saro, *GSI 2004-1*, p. 3 (2004).
- [102] **2005He27** F. P. Hessberger, S. Antalic, B. Streicher, S. Hofmann, D. Ackermann, B. Kindler, I. Kojouharov, P. Kuusiniemi, M. Leino, B. Lommel, R. Mann, K. Nishio, S. Saro, B. Sulignano, *Eur. Phys. J. A* **26**, 233 (2005). <https://doi.org/10.1140/epja/i2005-10171-6>
- [103] **2005KuZZ** P. Kuusiniemi, *Proc. Nuclei at the Limits*, Argonne, Illinois, D. Seweryniak and T. L. Khoo, eds., p. 231 (2005); *AIP Conf. Proc* **764** (2005). <https://doi.org/10.1063/1.1905316>
- [104] **2006Fo02** C. M. Folden III, S. L. Nelson, Ch. E. Dullmann, J. M. Schwantes, R. Sudowe, P. M. Zielinski, K. E. Gregorich, H. Nitsche, D. C. Hoffman, *Phys. Rev. C* **73**, 014611 (2006). <https://doi.org/10.1103/PhysRevC.73.014611>
- [105] **2008Ga25** J. M. Gates, S. L. Nelson, K. E. Gregorich, I. Dragojevic, Ch. E. Dullmann, P. A. Ellison, C. M. Folden III, M. A. Garcia, L. Stavsetra, R. Sudowe, D. C. Hoffman, H. Nitsche, *Phys. Rev. C* **78**, 034604 (2008). <https://doi.org/10.1103/PhysRevC.78.034604>
- [106] **2009He20** F. P. Hessberger, S. Hofmann, B. Streicher, B. Sulignano, S. Antalic, D. Ackermann, S. Heinz, B. Kindler, I. Kojouharov, P. Kuusiniemi, M. Leino, B. Lommel, R. Mann, A. G. Popeko, S. Saro, J. Uusitalo, A. V. Yeremin, *Eur. Phys. J. A* **41**, 145 (2009). <https://doi.org/10.1140/epja/i2009-10826-2>
- [107] **2010He11** F. P. Hessberger, S. Antalic, D. Ackermann, S. Heinz, S. Hofmann, J. Khuyagbaatar, B. Kindler, I. Kojouharov, B. Lommel, R. Mann, *Eur. Phys. J. A* **43**, 175 (2010). <https://doi.org/10.1140/epja/i2010-10913-3>
- [108] **2012Po14** S. Pomme, M. Marouli, G. Suliman, H. Dikmen, R. Van Ammel, V. Jobbagy, A. Dirican, H. Stroh, J. Paepen, F. Bruchertseifer, C. Apostolidis, A. Morgenstern, *Appl. Radiat. Isot.* **70**, 2608 (2012). <https://doi.org/10.1016/j.apradiso.2012.07.014>
- [109] **2013Ma13** M. Marouli, G. Suliman, S. Pomme, R. Van Ammel, V. Jobbagy, H. Stroh, H. Dikmen, J. Paepen, A. Dirican, F. Bruchertseifer, C. Apostolidis, A. Morgenstern, *Appl. Radiat. Isot.* **74**, 123 (2013). <https://doi.org/10.1016/j.apradiso.2012.12.005>
- [110] **2013Su13** G. Suliman, S. Pomme, M. Marouli, R. Van Ammel, H. Stroh, V. Jobbagy, J. Paepen, A. Dirican, F. Bruchertseifer, C. Apostolidis, A. Morgenstern, *Appl. Radiat. Isot.* **77**, 32 (2013). <https://doi.org/10.1016/j.apradiso.2013.02.008>
- [111] **2017BrXX** P. Brionnet, Ph. D. thesis, University of Strasbourg, Strasbourg, France, 2017.
- [112] **2019Br06** R. Briselet, Ch. Theisen, M. Vandebrouck, A. Marchix, M. Airiau, K. Auranen, H. Badran, D. Boilley, T. Calverley, D. Cox, F. Dechery, F. Defranchi Bisso, A. Drouart, B. Gall, T. Goigoux, T. Grahn, P. T. Greenlees, K. Hauschild, A. Herzan, R. D. Herzberg, U. Jakobsson, R. Julin, S. Juutinen, J. Konki, M. Leino, A. Lightfoot, A. Lopez-Martens, A. Mistry, P. Nieminen, J. Pakarinen, P. Papadakis, J. Partanen, P. Peura, P. Rahkila, J. Rubert, P. Ruotsalainen, M. Sandzelius, J. Saren, C. Scholey, J. Sorri, S. Stolze, B. Sulignano, J. Uusitalo, A. Ward, M. Zielinska, *Phys. Rev. C* **99**, 024614 (2019). <https://doi.org/10.1103/PhysRevC.99.024614>
- [113] **2020Ko06** K. Kossert, M. P. Takacs, O. Nahle, *Appl. Radiat. Isot.* **156**, 109020 (2020). <https://doi.org/10.1016/j.apradiso.2019.109020>
- [114] **2020He11** X. -y. He, Q. Dong, L. Ou, *Chin. Phys. C* **44**, 054108 (2020). <https://doi.org/10.1088/1674-1137/44/5/054108>
- [115] **2020Og11** R. S. Gomes, J. U. Delgado, C. J. da Silva, R. L. da Silva, P. A. L. da Cruz, A. L. Ferreira Filho, M. C. M. de Almeida, A. Iwahara, A. E. de Oliveira, L. Tauhata, *Appl. Radiat. Isot.* **166**, 109323 (2020). <https://doi.org/10.1016/j.apradiso.2020.109323>

- [116] **2021Go26** T. Goigoux, Ch. Theisen, B. Sulignano, M. Airiau, K. Auranen, H. Badran, R. Briselet, T. Calverley, D. Cox, F. Dechery, F. Defranchi Bisso, A. Drouart, Z. Favier, B. Gall, T. Grahn, P. T. Greenlees, K. Hauschild, A. Herzan, R. -D. Herzberg, U. Jakobsson, R. Julin, S. Juutinen, J. Konki, M. Leino, A. Lightfoot, A. Lopez-Martens, A. Mistry, P. Nieminen, J. Pakarinen, P. Papadakis, J. Partanen, P. Peura, P. Rahkila, E. Rey-Herme, J. Rubert, P. Ruotsalainen, M. Sandzelius, J. Saren, C. Scholey, J. Sorri, S. Stolze, J. Uusitalo, M. Vandebrouck, A. Ward, M. Zielinska, P. Jachimowicz, M. Kowal, J. Skalski, *Eur. Phys. J. A* **57**, 321 (2021). <https://doi.org/10.1140/epja/s10050-021-00631-4>
- [117] **2021NIZW** T. Niwase, Thesis, Kyushu Univ, (2021).
- [118] **2021Wa16** M. Wang, W. J. Huang, F. G. Kondev, G. Audi, S. Naimi, *Chin. Phys. C* **45**, 030003 (2021). <https://doi.org/10.1088/1674-1137/abddaf>
- [119] **2022Hu21** T. Huang, D. Seweryniak, B. B. Back, P. C. Bender, M. P. Carpenter, P. Chowdhury, R. M. Clark, P. A. Copp, X. -T. He, R. D. Herzberg, D. E. M. Hoff, H. Jayatissa, T. L. Khoo, F. G. Kondev, G. Morgan, C. Morse, A. Korichi, T. Lauritsen, C. Muller-Gatermann, D. H. Potterveld, W. Reviol, A. M. Rogers, S. Saha, G. Savard, K. Sharma, S. Stolze, S. Waniganeththi, G. L. Wilson, J. Wu, Y. -F. Xu, S. Zhu, *Phys. Rev. C* **106**, L061301 (2022). <https://doi.org/10.1103/PhysRevC.106.L061301>
- [120] **2023Br08** R. Broda, T. Ziemek, J. Marganec-Galazka, M. Czudek, K. Kossert, A. Listkowska, E. Lech, Z. Tyminski, P. Saganowski, R. Coulon, C. Michotte, *Appl. Radiat. Isot.* **201**, 110987 (2023). <https://doi.org/10.1016/j.apradiso.2023.110987>
- [121] **2023Mo25** K. -ichi. Mori, T. Yamada, Y. Sato, K. Nagatsu, H. Kikunaga, *Appl. Radiat. Isot.* **202**, 111061 (2023). <https://doi.org/10.1016/j.apradiso.2023.111061>
- [122] **2023Ni02** T. Niwase, P. Schury, M. Wada, for the SHE-Mass Collaboration, *J. Nucl. Radiochem. Sci.* **23**, 1 (2023).
- [123] **2024Ga01** R. Galea, K. Moore, *Appl. Radiat. Isot.* **203**, 111105 (2024). <https://doi.org/10.1016/j.apradiso.2023.111105>