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Total β-decay energies and mass systematics of neutron-rich silver and cadmium isotopes

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Experimental total beta-decay energies of neutron-rich silver and cadmium isotopes are presented. The sources have been produced as mass-separated fission products by means of the on-line—isotope-separator technique. Beta spectra have been recorded in coincidence with different gamma transitions, and Q_β values for $^{116-121}$Ag, ^{119}Cd, and ^{121}Cd have been deduced. The atomic mass excess is derived for these nuclei, and comparisons are made with mass formula predictions.

RADIOACTIVITY $^{116-121}$Ag, ^{119,121}Cd. Measured coincident beta spectra, deduced total beta-decay energies, atomic mass excesses; comparison with mass formulas. Mass-separated fission products. Si(Li) detectors, Ge(Li) detectors.

I. INTRODUCTION

The knowledge of total beta-decay energies and atomic masses is essential for the understanding of the nuclear forces. The determination of these quantities for neutron rich isotopes far away from beta stability is an important part of the experimental program at the on-line isotope separator OSIRIS.[1,2] So far, isotopes of zinc, gallium, germanium, arsenic,[3,4] bromine,[5,6] indium,[7] tin, antimony, and tellurium[8,9] have been investigated. These series are now extended with isotopes of silver and cadmium in the mass region $A=116-121$.

This mass interval is of particular interest when considering the behavior of the proton separation energy approaching the $Z=50$ proton shell closure, as silver and cadmium have 47 and 48 protons, respectively. In the same mass interval, different mass formulas disagree as to whether ^{120}Ag and ^{121}Ag are delayed neutron precursors or not.

The isotope separator facility OSIRIS, connected to the R2-0 reactor at Studsvik, is an excellent tool for producing neutron rich fission products. Although the silver and cadmium isotopes have low thermal fission yields, the efficiency of the ion source for these elements is high enough to give sufficient intensities even of short-lived nuclides in the mass region $A=116-121$.

The experimental technique is briefly outlined in Sec. II. In Sec. III, the results of the Q_β measurements are reported. The experimental Q_β values

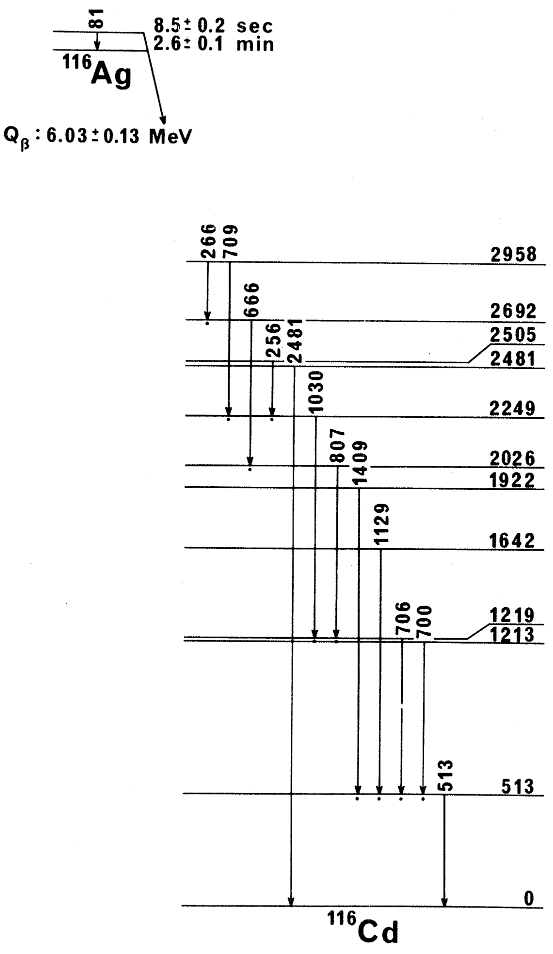

FIG. 1. A fragmentary level scheme of ^{116}Cd.

TABLE I. Summary of Q_β determination for ^{116}Ag.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
256	2505	1.1–2.7	3.01±0.56	5.52±0.56
266	2958	1.1–2.7	3.13±0.52	6.09±0.52
666	2692	1.1–2.6	3.23±0.62	5.92±0.63[a]
666	2692	0.7–2.8	3.13±0.27	5.82±0.27[a]
709	2958	1.1–2.7	3.20±0.33	6.16±0.33
709	2958	0.7–2.7	3.30±0.17	6.26±0.17
2481	2481	1.1–2.7	3.15±0.42	5.63±0.42
2481	2481	1.3–2.9	3.44±0.48	5.92±0.47
			Mean value	6.11±0.13

[a] Not included in the mean value calculation because of contributions from both direct and indirect feeding in the beta decay. Two independent measurements have been performed for the gamma gates at 666, 709, and 2481 keV.

and corresponding mass excesses are then compared with the predictions of different mass formulas in Sec. IV.

II. EXPERIMENTAL TECHNIQUE

The total beta-decay energies have been determined by means of $\beta\gamma$-coincidence measurements. Reference is made to earlier reports[7,10] for detailed descriptions. The β particles were detected using a Si(Li)-detector system and the γ rays by means of two Ge(Li) detectors (80 cm^3 each) in a multiplexing mode. The time resolution was of the order of 20 ns, and the accidental coincidence rate was negligible. Contributions from the Compton background were corrected for by subtracting background spectra obtained by setting gates near the chosen γ lines.

III. EXPERIMENTAL RESULTS

A. The nuclide ^{116}Ag

Two isomers of ^{116}Ag are known with the half-lives 8.5±0.2 s and 2.6±0.1 min, respectively.[11]

The level structure of ^{116}Cd has been investigated by Fogelberg, Bäcklin, and Nagarajan[12] up to an excitation energy of 2250 keV. Several levels up to

TABLE II. Summary of Q_β determination for ^{117}Ag.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
$\frac{7}{2}^+$ isomer (5.3 s)				
298	820	2.16–3.32	3.38±0.11	4.20±0.11
322	820	1.42–3.14	3.31±0.12	4.13±0.12
482	820	1.00–3.09	3.15±0.24	3.97±0.24
685	820	1.51–3.23	3.32±0.07	4.14±0.07
820	820	0.86–3.09	3.43±0.27	4.25±0.27
558/582/ 637/786[a]	1080	1.19–3.09	3.20±0.11	4.28±0.11
			Mean value	4.17±0.05
$\frac{1}{2}^-$ isomer (73 s)				
1658/1995[a]	1995	0.72–2.02	2.20±0.21	4.20±0.21
1878/2013[a]	2013	0.72–2.02	2.28±0.24	4.29±0.24
2057	2192	0.72–1.79	2.03±0.33	4.22±0.33
2192	2192	0.72–1.98	2.08±0.31	4.27±0.31
2246	2382	0.72–1.79	1.92±0.28	4.30±0.28
2888	2888	0.49–1.23	1.47±0.39	4.36±0.39
			Mean value	4.26±0.11

[a] The beta spectra in coincidence with these gamma gates were added before the Fermi-Kurie analysis.

TABLE III. Summary of Q_β determination for ^{118}Ag.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
2789	2789	0.85–3.73	4.33±0.24	7.12±0.24
2694	3182	1.00–3.16	3.99±0.72	7.17±0.72
1939	3224	0.94–3.64	4.04±0.31	7.26±0.31
2737	3224	0.82–3.44	3.85±0.49	7.07±0.49
3224	3224	1.07–3.73	3.94±0.22	7.16±0.22
2101	3266	1.48–3.55	3.86±0.23	7.13±0.23
2778	3266	0.89–3.46	3.78±0.19	7.05±0.19
2894	3382	0.91–3.16	3.91±0.63	7.29±0.63
			Mean value	7.13±0.10

3200 keV in ^{116}Cd have also been established by means of nuclear reactions.[13]

We previously reported[14] the total beta-decay energy of ^{116}Ag to be 5.3±0.2 MeV. This result was based on the decay scheme in Ref. 12, suggesting that the levels at 2249 and 2026 keV in ^{116}Cd are directly populated in the beta decay of ^{116}Ag. The resulting Q_β value seemed to be about 1 MeV too low compared to mass systematics. Recent studies of the 8.5 s isomer have shown that the levels at 2249 and 2026 keV are mainly populated by indirect feeding in the beta decay,[15] which invalidates our earlier measurements.

The Q_β values for the 8.5 s isomer given in Table I and based on the fragmentary decay scheme of Fig. 1, have an average value of 6.11±0.13 MeV. According to Ref. 12 this isomer lies 81 keV above the ground state, and the Q_β value of ^{116}Ag is consequently 6.03±0.13 MeV.

B. The nuclide ^{117}Ag

Two isomers of ^{117}Ag were found by Fogelberg *et al.*,[16] one with spin $\frac{7}{2}^+$ and half-life 5.3 s and the other with spin $\frac{1}{2}^-$ and half-life 73 s. It was not possible to determine the relative order of the isomers, but the authors suggested the energy difference between them to be less than 25 keV. In the present investigation the isomers are treated individually, and the Q_β value is determined for both isomers. The low spin isomer predominantly feeds

TABLE IV. Summary of Q_β determination for ^{119}Ag.

Gate energy keV	β feeding %	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
483	1.9	1054	0.76–4.04	4.40±0.25	5.45±0.25
626	10.5	1054	0.84–4.18	4.27±0.07	5.32±0.07
654/660[a]	9.0	1054	0.94–4.13	4.30±0.10	5.35±0.10
825	2.2	1054	0.98–4.04	4.32±0.23	5.37±0.23
1027	5.9	1054	1.52–4.18	4.35±0.13	5.40±0.13
851	1.7	1279	0.89–3.64	4.08±0.26	5.36±0.26
1252	0.7	1279	0.80–3.54	3.90±0.33	5.18±0.33
1003/1009[a]	2.4	1402	0.94–3.64	4.01±0.22	5.41±0.22
1173	0.9	1402	1.25–3.55	3.83±0.35	5.23±0.35
1375	1.1	1402	1.12–3.32	3.90±0.35	5.30±0.35
1402	0.8	1402	1.12–3.55	3.85±0.39	5.25±0.39
1527	0.3	1925	0.89–2.96	3.51±0.45	5.44±0.45
1898	2.4	1925	1.21–3.01	3.59±0.46	5.52±0.46
1925	0.9	1925	1.03–3.01	3.68±0.49	5.60±0.49
1689/1696[a]	1.5	2088	0.94–3.32	3.59±0.38	5.68±0.38
2061	4.4	2088	0.76–3.01	3.20±0.20	5.29±0.20
2786	2.1	2813	0.89–2.29	2.61±0.34	5.42±0.34
			Mean value		5.35±0.04

[a] The beta spectra in coincidence with these gamma gates were added before the Fermi-Kurie analysis.

TABLE V. Summary of Q_β determination for ^{119}Cd.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
Ground state				
1317	1921	0.43–1.69	1.73±0.17	3.65±0.17
1610	1921	0.46–1.82	1.93±0.15	3.85±0.15
1734	2338	0.46–1.46	1.52±0.19	3.86±0.19
1764	2368	0.43–1.32	1.50±0.24	3.87±0.24
			Mean value	3.80±0.09
Isomeric state				
923	2127	0.59–1.62	1.73±0.20	3.86±0.20
1102	2127	0.49–1.59	1.74±0.24	3.86±0.24
2121	2121	0.56–1.62	1.82±0.19	3.94±0.19
1364	2389	0.39–1.29	1.50±0.23	3.89±0.23
1669	2389	0.48–1.61	1.64±0.18	4.03±0.18
2423	2423	0.41–1.54	1.61±0.43	4.03±0.43
1344	2487	0.43–1.39	1.48±0.21	3.97±0.21
			Mean value	3.94±0.08

highly excited states in ^{117}Cd, and transitions depopulating levels at 1995, 2013, 2192, 2382, and 2888 keV have been used for gating the beta spectra. The results are given in Table II. The Q_β value obtained for this isomer is

$$Q_\beta(\tfrac{1}{2}^-)=4.26\pm0.11 \text{ MeV} .$$

The $\frac{7}{2}^+$ isomer feeds lower lying levels and the end point energies of beta branches populating levels at 820 and 1080 keV have been used for the Q_β determination (see Table II). A small contribution from the long-lived isomer to the 820 keV γ transition did not disturb the measurement. The Q_β value of the 5.3 s isomer was found to be

$$Q_\beta(\tfrac{7}{2}^+)=4.17\pm0.05 \text{ MeV} .$$

It is impossible to state from the present study whether the $\frac{1}{2}^-$ or the $\frac{7}{2}^+$ state is the ground state of ^{117}Ag.

C. The nuclide ^{118}Ag

Fogelberg, Bäcklin, and Nagarajan[13] have observed two isomers in ^{118}Ag with half-lives 2.8 s and 3.7 s, respectively. The 3.7 s activity was assigned to the ground state, and the other one to an isomeric state at 128 keV. The most complete decay studies so far have been reported by Hill.[17] In the present determination only transitions depopulating the levels at 2789, 3182, 3224, 3266, and 3382 keV were used. These levels are all fed directly

TABLE VI. Summary of Q_β determination for ^{120}Ag.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
1246	2449	3.04–5.11	5.56±0.61	8.01±0.61
2823	3329	1.65–4.30	4.85±0.45	8.18±0.45
1330	3423	1.55–4.34	4.75±0.24	8.17±0.24
1524	3423	1.67–4.55	4.86±0.48	8.29±0.48
1407	3500	1.58–4.83	4.92±0.32	8.42±0.32
2297	3500	1.63–4.60	5.00±0.68	8.50±0.68
2995	3500	1.74–4.25	4.51±0.31	8.01±0.31
3030	3536	1.58–4.37	4.78±0.61	8.32±0.61
3536	3536	1.67–4.18	4.59±0.54	8.13±0.54
2346	3550	1.74–4.39	4.61±0.20	8.16±0.20
3044	3550	1.58–4.39	4.88±0.58	8.43±0.58
3053	3559	1.58–4.09	4.49±0.57	8.05±0.57
3880	3880	1.58–4.09	4.62±0.53	8.50±0.53
			Mean value	8.20±0.10

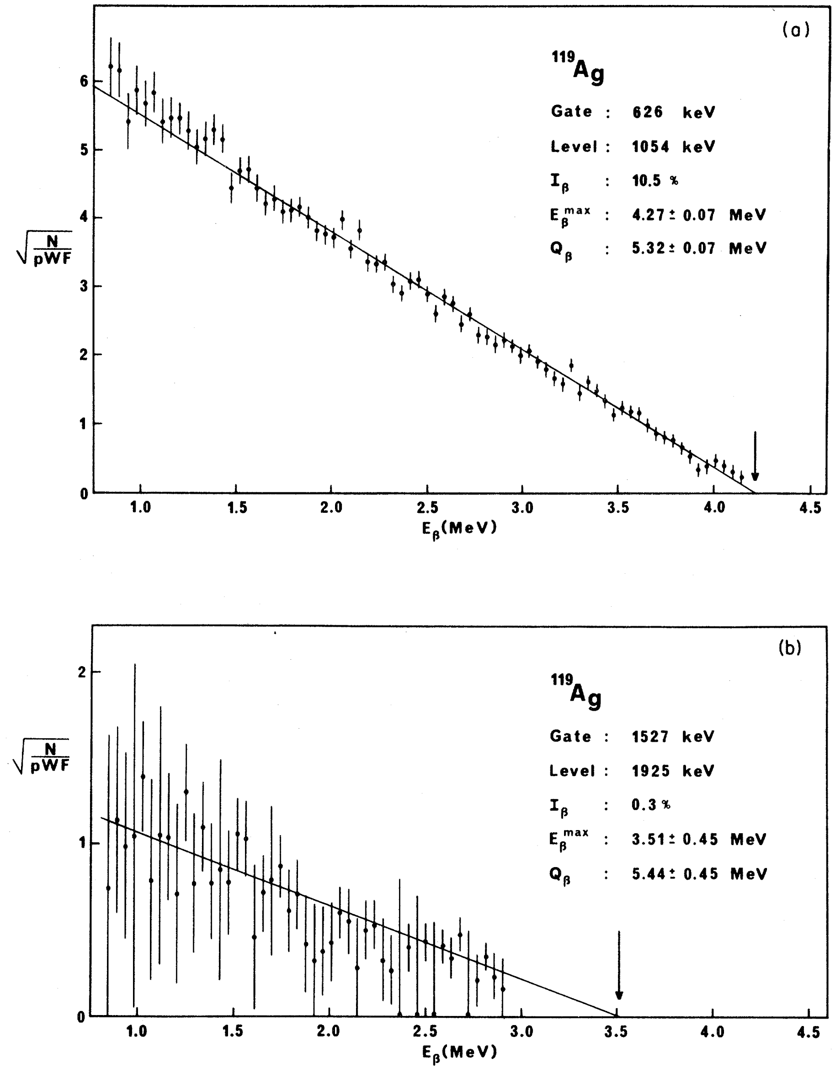

FIG. 2. (a) Fermi-Kurie plot of the beta spectra in coincidence with the gamma gate at 626 keV ($I_\beta=10.5\%$) in the decay of ^{119}Ag. (b) Fermi-Kurie plot of the beta spectra in coincidence with the gamma gate at 1527 keV ($I_\beta=0.3\%$).

from the beta decay of the ground state of ^{118}Ag.

Results from the Q_β determination are collected in Table III. The mean value is

$$Q_\beta=7.13\pm0.10 \text{ MeV} .$$

D. The nuclides ^{119}Ag and ^{119}Cd

The decays of the nuclides ^{119}Ag and ^{119}Cd have been studied at OSIRIS by McDonald *et al.*[18] and Kawase *et al.*[19] The half-life of ^{119}Ag was found to be 2.1 s. Strongly fed levels in ^{119}Cd are at 1054, 1279, 1402, 1925, 2088, and 2813 keV. In our measurements we have used transitions from these levels as gates in the analysis of the $\beta\gamma$-coincidence data. The results are collected in Table IV. The Fermi-Kurie plots of the β spectra in coincidence with gates at 626 (10.5%) and 1527 (0.3%) keV show that very weak β branching can be used for these Q_β-value measurements (see Fig. 2). Though the weak β branches are less accurate they agree within experimental error with the stronger ones and contribute to a more precise mean value for the total beta decay energy. The mean value of the Q_β values determined for ^{119}Ag is

$$Q_\beta=5.35\pm0.04 \text{ MeV} .$$

Two isomers in ^{119}Cd have been found with half-lives 2.6 and 1.9 min.[18] The 1.9 min activity is an isomeric state 146 keV above the ground state.[18]

TABLE VII. Summary of Q_β determination for ^{121}Ag.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ MeV	Q_β value MeV
430	745	3.43–5.12	5.54±0.65	6.29±0.65
856	1171	2.02–4.39	5.15±0.70	6.32±0.70
817	1171	1.84–4.86	5.17±0.29	6.34±0.29
801	1171	2.30–4.67	5.35±0.55	6.52±0.53
1510	1511	1.37–4.29	5.01±0.39	6.52±0.39
1196	1511	1.93–4.35	4.90±0.31	6.41±0.31
1157	1511	1.19–4.39	4.90±0.34	6.41±0.34
785	1511	1.67–4.37	4.86±0.58	6.37±0.58
2518/2204[a]	2518	0.91–3.64	3.85±0.24	6.37±0.24
			Mean value	6.40±0.12

[a] The beta spectra in coincidence with these gamma gates were added before the Fermi-Kurie analysis.

Our measurements used transitions depopulating levels fed by the decay from both the ground state and the isomeric state. The results are collected in Table V. By subtracting 146 keV from the Q_β value of the isomer, 3.94±0.08 MeV, a value of 3.79±0.08 MeV is obtained for the ground state. The average of this value and the ground state values of 3.80±0.09 MeV is

$$Q_\beta = 3.79 \pm 0.06 \text{ MeV} .$$

E. The nuclide ^{120}Ag

The nuclide ^{120}Ag was first studied by Fogelberg, Bäcklin, and Nagarajan[13] using the OSIRIS mass-separator facility. They observed a low-spin ground-state isomer with $T_{1/2} = 1.17$ s and a high-spin isomer at 203 keV with $T_{1/2} = 0.32$ s. The most complete decay studies of these isomers have been reported by Li, Hill, and McCullagh[20] and we have used their ground state decay scheme in our

TABLE VIII. Summary of Q_β determination for ^{121}Cd.

Gate energy keV	Level energy keV	Range of fit MeV	$E_\beta^{\max}$ keV	Q_β value keV
Ground state				
1647	1961	0.88–2.48	2.70±0.44	4.66±0.44
1096	2136	0.90–2.36	2.63±0.36	4.77±0.26
1584	2222	0.61–2.48	2.69±0.32	4.91±0.32
1277	2265	0.75–2.17	2.59±0.61	4.86±0.61
1699	2337	0.61–2.32	2.65±0.36	4.99±0.36
1854	2523	0.61–2.28	2.71±0.40	5.23±0.40
		Mean value		4.89±0.15
Isomeric state				
2059	2059	0.90–2.67	2.83±0.14	4.89±0.14
2115	2115	0.84–2.42	2.73±0.41	4.84±0.41
1139	2160	0.88–2.54	2.83±0.36	4.99±0.36
1271	2292	1.01–2.34	2.89±0.60	5.18±0.60
2292	2292	0.98–2.35	2.66±0.31	4.95±0.31
2332	2332	0.73–2.27	2.76±0.42	5.09±0.42
2365	2365	0.69–2.44	2.67±0.23	5.04±0.23
1382	2370	0.68–2.14	2.46±0.36	4.83±0.36
2455	2455	0.69–2.27	2.64±0.30	5.09±0.30
1457	2478	0.59–2.00	2.32±0.40	4.80±0.40
2511	2511	0.73–1.98	2.64±0.55	5.15±0.55
2562	2562	0.90–2.23	2.51±0.30	5.07±0.30
		Mean value		4.96±0.08

TABLE IX. Summary of Q_β values obtained in the present work and comparison with different mass formulas predictions.

Nuclide	Q_β value (MeV)			$Q_{\beta,\mathrm{exp}}$-$Q_{\beta,\mathrm{pred}}$ (MeV)				
		a	b	c	d	e	f	g
^{116}Ag	6.03±0.13	0.51	0.80	0.08	0.22	−0.20	0.04	−0.11
^{117}Ag	4.17±0.05	0.21	0.69	0.15	0.31	−0.10	0.12	0.02
^{118}Ag	7.13±0.10	0.64	0.89	0.06	0.49	−0.15	0.17	0.01
^{119}Ag	5.35±0.04	0.43	0.65	0.26	0.59	0.03	0.35	0.21
^{120}Ag	8.20±0.10	0.78	0.72	−0.34	0.76	−0.07	0.17	0.09
^{121}Ag	6.40±0.12	0.53	0.49	−0.25	0.75	0.11	0.28	0.29
^{119}Cd	3.79±0.06	0.23	−0.22	−0.82	0.10	0.15	0.25	0.27
^{121}Cd	4.89±0.15	0.38	−0.23	−0.72	0.29	0.26	0.49	0.36
Root mean square deviation		0.46	0.59	0.34	0.44	0.13	0.23	0.17

[a] Reference 23(a).
[b] Reference 23(b).
[c] Reference 24.
[d] Reference 23(c).
[e] Reference 23(d).
[f] Reference 23(e).
[g] Reference 25.

determination of the Q_β value for ^{120}Ag. The results are collected in Table VI. The mean Q_β value was found to be

$$Q_\beta = 8.20 \pm 0.10 \text{ MeV} .$$

F. The nuclides ^{121}Ag and ^{121}Cd

The decay of the nuclides ^{121}Ag and ^{121}Cd has recently been studied by Fogelberg and Hoff.[21,22] The half-life of ^{121}Ag has been reported to be 0.72±0.10 s. In the present investigation, γ transitions depopulating levels at 745, 1171, 1511, and 2518 keV were used for gating the β spectra. These levels are strongly fed in the decay of ^{121}Ag, while the population of other levels is too weak to give sufficient statistics.

The results are collected in Table VII, and the resulting mean value for the total beta decay energy of ^{121}Ag is

TABLE X. Summary of experimental mass excesses obtained for $^{116-121}$Ag, ^{119}Cd, and ^{121}Cd.

Nuclide	Mass excess (MeV)			M_{exp}-M_{pred} (MeV)				
		a	b	c	d	e	f	g
^{116}Ag	−82.68±0.13	0.99	0.9	0.18	0.07	−0.15	0.30	−0.05
^{117}Ag	−82.25±0.05	1.11	1.0	0.16	0.23	−0.10	0.31	0.01
^{118}Ag	−79.58±0.10	1.42	0.9	0.07	0.26	−0.17	0.30	0.03
^{119}Ag	−78.59±0.08	1.78	1.1	0.34	0.69	0.16	0.67	0.44
^{120}Ag	−75.77±0.10	1.95	0.7	−0.16	0.68	0.01	0.57	0.23
^{121}Ag	−74.56±0.19	2.21	0.7	0.04	1.03	0.30	0.99	0.61
^{119}Cd	−83.94±0.06	1.35	0.4	0.08	0.10	0.13	0.32	0.23
^{121}Cd	−80.95±0.15	1.69	0.3	0.22	0.29	0.20	0.72	0.33
Root mean square deviation		1.57	0.75	0.16	0.42	0.15	0.53	0.24

[a] Reference 23(a).
[b] Reference 23(b).
[c] Reference 24.
[d] Reference 23(c).
[e] Reference 23(d).
[f] Reference 23(e).
[g] Reference 25.

TABLE XI. Delayed neutron window, Q_β-S_n (MeV) compared to three different mass formula predictions.

Precursor	Q_β exp (MeV)	Emitter	Mass excess (MeV)	S_n (MeV)	Neutron window Q_β-S_n (MeV) exp	b	c	d
		^{119}Cd	-83.94 ± 0.06					
^{120}Ag	8.20 ± 0.10	^{120}Cd	-84.05 ± 0.15[a]	8.12 ± 0.16	0.08 ± 0.19	-0.50	-0.44	0.24
^{121}Ag	6.39 ± 0.12	^{121}Cd	-80.95 ± 0.15	4.71 ± 0.21	1.68 ± 0.24	0.30	0.19	1.12

[a] Taken from the mass formula prediction of Jänecke [Ref. 23(d)] which has shown to be the most accurate one in the mass region.
[b] Reference 23(a).
[c] Reference 23(c).
[d] Reference 23(d).

$$Q_\beta=6.40\pm0.12 \text{ MeV} .$$

Two isomers were found in the decay of ^{121}Cd, the ground state with half-life 12.5 s and one isomer with half-life 8.3 s. The total beta decay energies for the two isomers are given in Table VIII. The mean Q_β value for the 12.5 s ground state is

$$Q_\beta=4.89\pm0.15 \text{ MeV} ,$$

and for the 8.3 s isomer

$$Q_\beta=4.96\pm0.08 \text{ MeV} .$$

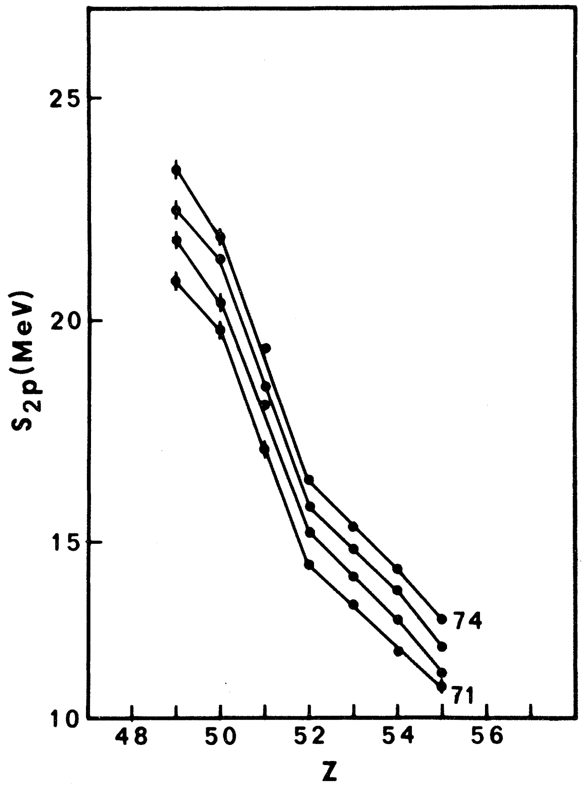

FIG. 3. Double proton separation energies as a function of Z in the vicinity of $Z=50$.

The energy of the isomeric state is not known, but level systematics indicates a value around 120 keV.

IV. DISCUSSION

A. Total beta-decay energies

The experimental ground-state Q_β values presented in Sec. III are compiled in Table IX. Predictions from seven different mass formulas are given for comparison. The mass formulas chosen are by Myers,[23(a)] Seeger and Howard,[23(b)] Möller and Nix,[24] the semiempirical shell-model formula by Liran and Zeldes,[23(e)] and the empirical mass relations by Jänecke,[23(d)] Comay and Kelson,[23(e)] and Monahan and Serduke.[25] The average uncertainty of the experimental Q_β values in the present work is 0.10 MeV. This should be compared to the root mean square deviation ranging from 0.13 to 0.59 MeV for the different mass formulas.

The empirical mass relations of Jänecke and of Monahan and Serduke yield the best Q_β predictions for the mass region discussed in this paper. The Monahan and Serduke predictions are well within the experimental errors for the Q_β values of $^{116-118}$Ag, but are less accurate for more neutron-rich nuclides.

B. Masses

Starting from a member of an isobaric chain whose mass is known,[27] the masses of isobars further away from the β stability can be calculated by adding the measured total β-decay energies (or mass differences) to the known mass. In this way the mass excesses for the neutron rich silver and cadmium isotopes ($A=116-121$) have been deduced and the results are given in Table X. These mass excesses are also compared with predictions from the mass formulas mentioned above.

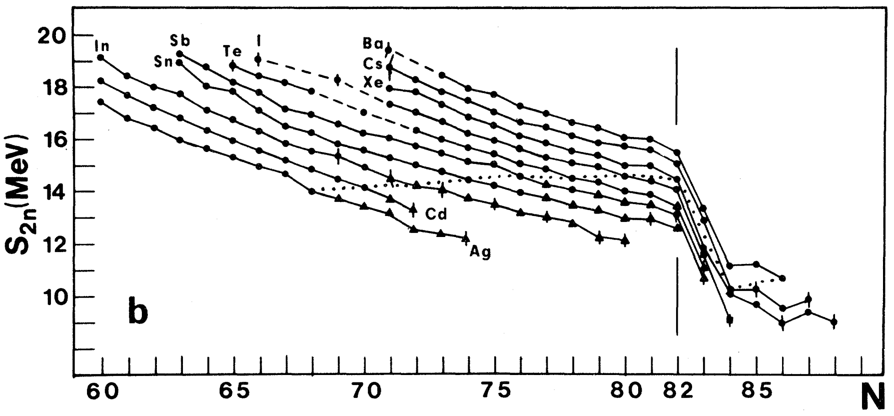

FIG. 4. Double neutron separation energies as a function of N. Isotopes connected by a line. Values indicated by triangles deduced from experiments at OSIRIS, values indicated by dots taken from Ref. 27.

The average uncertainty of the mass excesses is 0.11 MeV and the root mean square deviation between the predicted values and the experimental ones varies from 0.14 to 1.58 MeV. The mass relations of Jänecke and of Monahan and Serduke and the droplet formula by Möller and Nix give the best predictions for neutron rich silver and cadmium isotopes. Our experiments show that all seven mass formulas tend to predict nuclei in this region to be too strongly bound.

C. Predictions about delayed neutron precursors

In earlier experiment at OSIRIS, ^{122}Ag and ^{123}Ag were shown to be delayed neutron precursors.[26] At mass number 121, a weak neutron activity was detected with a statistical significance of 97.5%. The activity was much too small to make a half-life determination possible. At mass number 120, no neutron activity was observed. As is shown in Table XI, the theoretical mass formulas by Myers and by Liran and Zeldes give a negative neutron window (i.e., Q_β-S_n) for ^{120}Ag and a very narrow window for ^{121}Ag. The mass formula by Jänecke predicts both ^{120}Ag and ^{121}Ag to be delayed neutron precursors. The present investigation gives experimental Q_β values resulting in a statistically insignificant positive value for the neutron window for ^{120}Ag. For ^{121}Ag, the width of the neutron window was measured to be 1.68 MeV and this nuclide is probably a delayed neutron precursor. Since delayed neutron emission is energetically possible for this nuclide, the low neutron activity detected at this mass number is probably due to strong population of low-lying levels in ^{121}Cd.

D. Mass systematics

These experimental masses of neutron rich silver and cadmium isotopes also give some new information about the nuclear structure. It is possible to determine the slope of the isotonic S_{2p} line just before the discontinuity at the magic number $Z=50$ (see Fig. 3). In this calculation we have used the mass excesses experimentally determined by us for $^{120-123}$In (Ref. 7) and for the Sn, Sb, Te, and I isotopes the values from the 1975 mass evaluation by Wapstra and Bos.[27]

Figure 4 shows the $2n$ separation energies for the silver and cadmium isotopes investigated here together with earlier results[7-9] of neighboring elements and known masses of lighter isotopes.

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