Decays and masses of ^{162,163}Ta and some neighboring nuclides

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(Received 9 December 1991)

α groups and γ-ray transitions have been observed from nuclides produced in the bombardment of ^{40}Ca with ^{127}I. Two weak α groups were assigned to ^{162,163}Ta based on their measured half-lives and excitation functions. With an unambiguous assignment of these two α groups the absolute masses of nuclides in two long α chains, for which ^{162,163}Ta form links, can now be deduced with confidence. Absolute masses are thus obtained for some nuclides very far from stability, including ones that are not bound against ground-state proton emission. The simultaneous observation of α groups and γ rays from other nuclides produced in this bombardment also permitted the determination of the upper limits of six new α branching ratios.

PACS number(s): 23.60.+e, 21.10.Dr, 27.70.+q

I. INTRODUCTION

The region of α-decaying nuclides just below the $Z=82$ closed shell is of special interest for systematic studies of atomic masses. Because α decay provides a characteristic signature for identification, a large number of very neutron-deficient isotopes have been identified for each element in this region. In addition, the α-decay mode also offers a simple but precise method for determining parent-daughter mass differences, which extends even to the remotest nuclides. Thus the α-decaying nuclides below the $Z=82$ closed shell form a region of known relative atomic masses. Furthermore, these nuclides are frequently connected by several, sequential α decays and they can therefore be organized in long decay chains. Because the relative masses of the members of these chains are known, their absolute masses can all be deduced if the absolute mass of any one member is established.

Most of the α-decay chains do not contain a nuclide with a known mass. A large body of potentially interesting mass data can therefore not be used to its fullest extent. Considerable effort has been directed in the past decade towards establishing mass connections between members of such decay chains and nuclides with known masses [1–4]. The missing link is usually either a very weak α-decay branch or a connection that can be obtained through reaction or β-decay Q values.

The α-decay branches of ^{162,163}Ta originally formed two such missing links. Their nonobservation meant that the masses of these two nuclides, as well as seven others in their α-decay chains, were unknown. Recently, Runte *et al.* [4] reported on the α decays of ^{162,163}Ta for the first time. However, their data were rather sparse and, furthermore, the weak α group assigned to ^{163}Ta had previously been assigned to ^{164}Ta in a study by a different group [5]. Such discrepancies in assignments of α groups have occurred before in this region and they can be satisfactorily resolved only by further independent investigations (see, for example, the case of rhenium isotopes [6]).

We report here new results on the α decays of ^{162,163}Ta. The main emphasis of our work was to obtain conclusive proof of the identity of the two α groups assigned to these nuclides by Runte *et al.* [4]. Our approach to achieve this goal was to compare decay data for these α groups with data obtained simultaneously on the γ decay of ^{162,163}Ta. The γ rays from these two isotopes have previously been unambiguously assigned through studies with isotope-separated samples from the ISOCELE-2 facility [7].

Some of our data have already been presented in Ref. [8]. In the present work, we describe in detail all our results on the decays of ^{162,163}Ta as well as some findings on the α groups, γ rays, and α branching ratios of other nuclides produced in the bombardment of ^{40}Ca with ^{127}I. The values obtained in the present, more detailed analysis are in some cases slightly different from, and supersede, the ones given in Ref. [8].

II. EXPERIMENTAL METHOD

The nuclides investigated in this study were produced with a beam of ^{127}I from the Chalk River Tandem Accelerator Superconducting Cyclotron (TASCC) facility. A 711 MeV beam was delivered by the cyclotron but the energy of the incident beam on target was varied by the insertion of a series of molybdenum degraders located immediately in front of the target. The target was 1.1-mg/cm^2-thick natural calcium.

The target chamber was electrically isolated from the beam line and the beam current striking the back end of the target chamber was integrated and recorded for excitation-function measurements. After the beam passed through the degraders, the mean charge state was different from the 19^+ state delivered by the cyclotron.

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Immediately before the beginning of each experiment, the beam intensity was therefore measured with a Faraday cup, which was inserted just before the target, and this intensity was compared with the reading from the target chamber to establish a normalization factor.

A He-jet transport system with NaCl aerosol was used to bring the reaction products to a counting location in a shielded room. The target material was evaporated onto the vacuum side of a 2.7-mg/cm^2-thick molybdenum vacuum window at the entrance of the chamber. The energetic reaction products penetrated this window and were further slowed down in a second molybdenum degrader and then thermalized in the interior of a 120-mm-long target chamber which contained helium and NaCl aerosol. The appropriate thickness of the recoil degrader was investigated in a series of tests. It was found that a 7.4-mg/cm^2-thick molybdenum degrader caused all target reaction-products to stop well inside the He-filled target chamber for all incident beam energies used in this work. The NaCl-loaded helium was swept out of the target chamber and transported through a 14-m-long teflon capillary to the counting room in 370 ms. Samples of the transported activities were collected on the tape of a small tape-transport system and periodically moved to the counting location. A 300 mm^2, 100-μm-thick surface-barrier detector and a Ge(Li) detector were positioned in close geometry at this location. Eight sequential spectra of both α particles and γ rays were recorded from the two detectors.

The measured energies of the α groups are sensitive to the energy loss sustained in the accumulated aerosol material of each sample. In the present experiment, the energies of all visible α groups were therefore established relative to that of the prominent and precisely-known [9–11] 5035 keV α group from ^{154}Tm which was produced in-beam. The energy dispersion was determined from the well-known [9,10] α groups of ^{154}Tm, ^{157}Yb, and ^{150}Dy.

Possible background radiations from activities produced in reactions of the beam with materials other than the calcium target were also investigated. The target was removed, but all molybdenum degraders were present and all other parameters were the same as in the subsequent experiments with the target in place. No α groups were observed under these conditions and no γ rays with an energy similar to those reported from ^{162,163}Ta were found.

III. RESULTS ON THE DECAYS OF ^{162,163}Ta

Data were obtained at six different incident beam energies. Some of the α spectra obtained at these energies are shown in Fig. 1. These spectra are quite complex, with many unresolved α groups. A consistent approach was therefore used in our analyses of all spectra. In fitting the α peaks, we used a common peak width for the line shapes of all α groups in the same spectrum. Minor variations in the common width were found from spectrum to spectrum and were accounted for by small changes in the experimental conditions. Initially, all α spectra were fitted with the minimum number of peaks required by a visual inspection of the data. Additional peaks were then added if the agreement was poor.

All α groups that have been assigned to well-known nuclides in Fig. 1 had to meet three criteria. First, the energy determined for the α group had to be consistent for all spectra in which the group was found and it also had to agree with the literature value. This requirement was especially important for the proper decomposition of multiplets. Second, the half-lives determined for a particular α peak at all bombarding energies had to be consistent with one another and in agreement with the literature value. Finally, the deduced production rates of a proposed activity had to be consistent for all spectra obtained with the same incident beam energy, and the excitation function established for that activity had to be in reasonable agreement with that computed with the ALICE code [12]. All significant α groups seen in Fig. 1 could be assigned according to these criteria.

The 4884 and 4635 keV α groups were investigated in more detail. Their energies agree with the two α groups assigned by Runte *et al.* [4] to ^{162}Ta and ^{163}Ta, respectively, and they are labeled accordingly in the figure. Our data on these two α groups are not consistent with any other known α emitters. Our main arguments for the assignment of these two α groups to ^{162,163}Ta are based on their measured excitation functions and half-lives.

The measured excitation functions for the 4884 and 4635 keV α groups are shown in Fig. 2 together with those of selected γ rays from ^{162,163}Ta and ^{162,163}Hf. It is evident from Fig. 2(a) that a mass-162 assignment to the

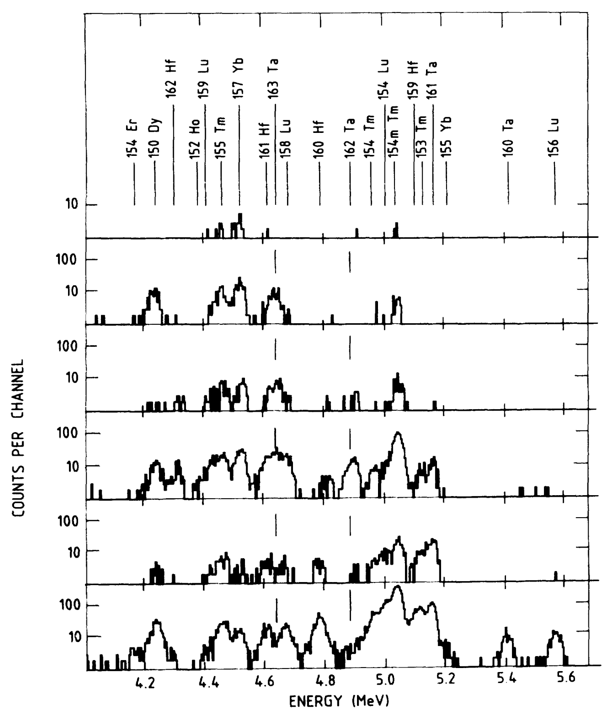

FIG. 1. α spectra from activities produced by ^{127}I bombardment of ^{40}Ca. From top to bottom the six spectra were obtained with bombarding energies of 540 MeV, 558 MeV, 598 MeV, 628 MeV, 670 MeV, and 711 MeV, respectively.

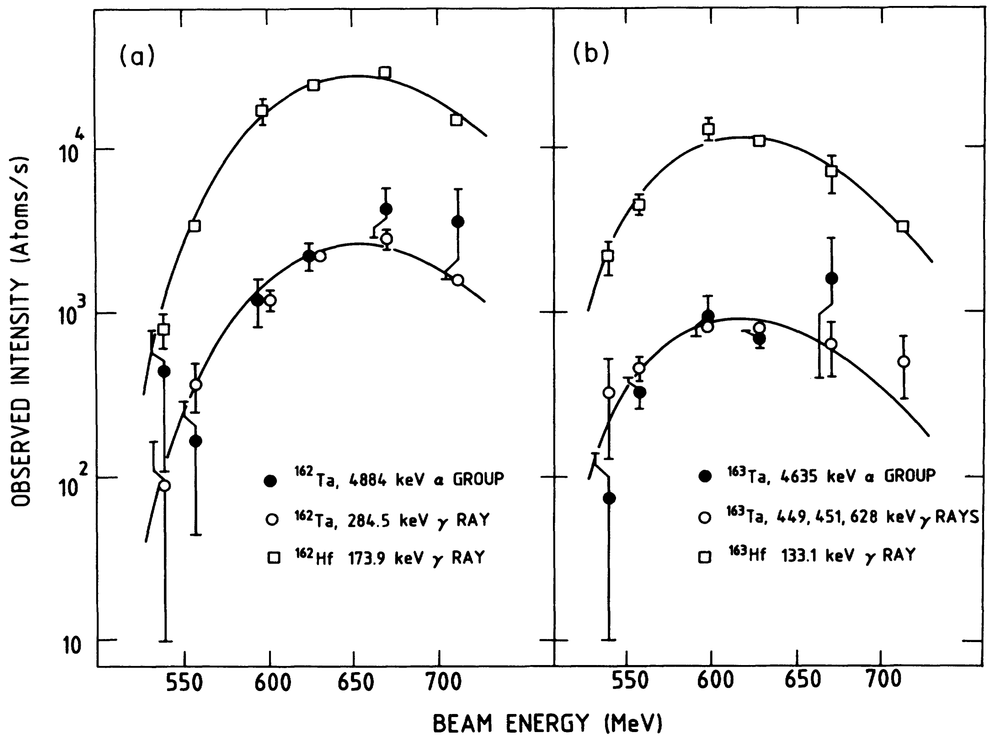

FIG. 2. Yields of ^{162,163}Ta and ^{162,163}Hf deduced from α and γ-ray intensities. The γ-ray yields have been corrected for known branching ratios and detector efficiencies; the α yields are normalized to produce the branching ratios in Table III. In each part of the figure the two smooth curves, intended only to guide the eye, are identical in shape.

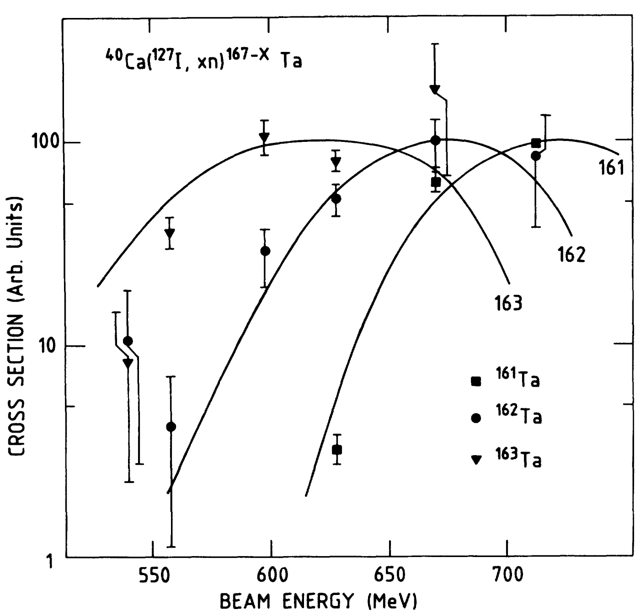

FIG. 3. The data points represent the measured excitation functions for the 4635 keV (^{163}Ta), 4884 keV (^{162}Ta), and 5149 keV (^{161}Ta) α groups. In all cases, the data have been normalized to have an average peak value of 100. The curves show the ALICE predictions of the cross sections for these isotopes, normalized in the same manner. The calculated values incorporate the broadening effects due to the finite target thickness as well as beam straggling in the molybdenum absorbers.

4884 keV α group is appropriate especially when the good agreement between the excitation function for this α group and that of the 284.5 keV γ ray, unambiguously assigned to ^{162}Ta by the ISOCELE separator group [7], is taken into account. Similarly, it is shown in Fig. 2(b) that the 4635 keV α group originates from mass 163. The lower-energy γ rays attributed to ^{163}Ta by the ISOCELE group [7] were found in our work to be partially obscured by γ rays of nearly the same energy from the decays of ^{164}Ta and ^{160,161}Lu. Our excitation function corresponding to γ rays from ^{163}Ta was therefore taken to be the weighted average of the 449, 451, and 628 keV γ rays.

Further support for our assignments is seen in Fig. 3. The excitation functions of the 4635 keV, 4884 keV and the well-known 5149 keV (^{161}Ta) α groups are shown in this figure together with the predicted yields according to the ALICE code [12]. The measured excitation functions

TABLE I. Decay properties of ^{162,163}Ta.

	^{162}Ta		^{163}Ta	
	Present work	Literature	Present work	Literature
E_α (keV)	4884(5)	4880(10)[a]	4635(7)	4630(10)[a]
$T^{\alpha}_{1/2}$ (s)	5.1(11)	5(3)[a]	10(2)	10.9(14)[a]
$T^{\gamma}_{1/2}$ (s)	3.60(15)	3.5(2)[b]	11.2(16)	10.5(18)[b]

[a]Reference [4].
[b]Reference [7].

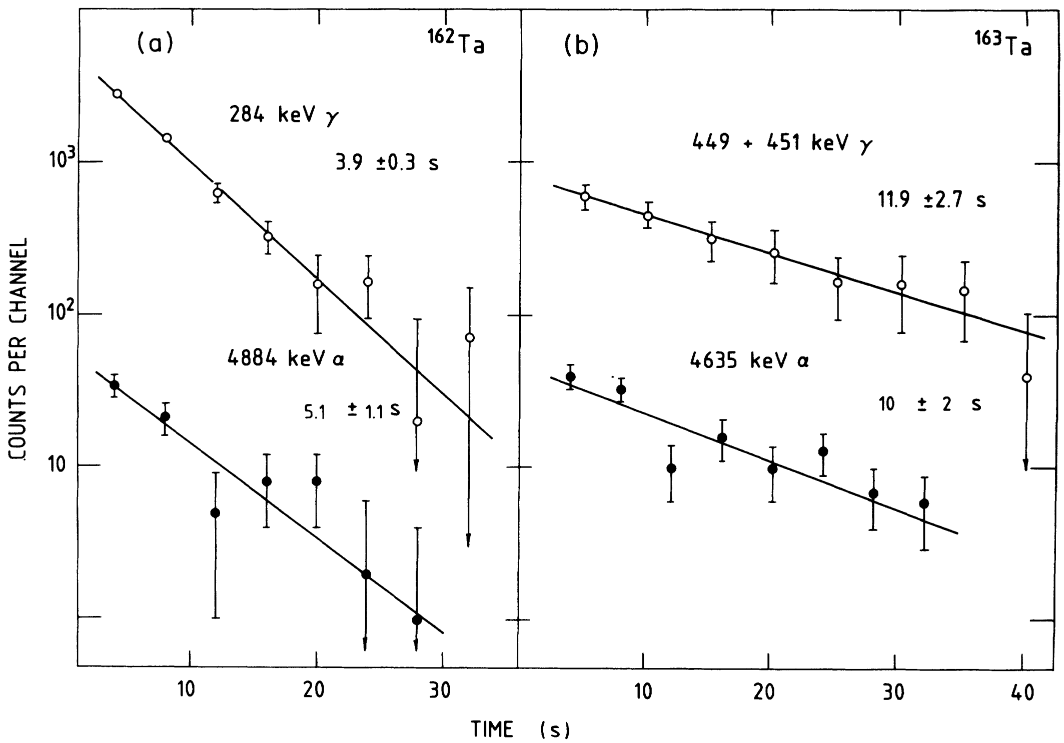

FIG. 4. Half-life curves obtained for ^{162,163}Ta radiations in one experiment accounting for about 30% of all our decay data.

exhibit the trend expected for adjacent masses and they also agree fairly well with the predicted shapes.

The preceding arguments determine the parent mass numbers for the 4884 and 4635 keV α groups; the specific isotope responsible can now be established by half-life comparisons. Possible elements are restricted to Ta, Hf, and Lu since the compound nucleus in our reaction is ^{167}Ta. Some of our measured half-life data are shown in Fig. 4. It is seen in Fig. 4(a) that our measured half-life for the 4884 keV α group agrees well with that measured for the 284.5 keV γ rays from ^{162}Ta. It disagrees strongly with those of ^{162}Hf and ^{162}Lu, which are 37.6 s and 1.4 m, respectively. Our measured half-life for the 4635 keV α group, shown in Fig. 4(b), agrees well with that of the 449 and 451 keV γ rays from ^{163}Ta, but disagrees strongly with those of ^{163}Hf and ^{163}Lu, which are longer than 40 s.

We assign the 4884 keV α group to ^{162}Ta and the 4635 keV α group to ^{163}Ta based on our excitation-function and half-life data. Our assignments confirm those of Runte *et al.* [4], and thus contradict the previous ^{164}Ta assignment of Schrewe *et al.* [5]. Our measured decay data for ^{162,163}Ta are given in Table I together with those that have been obtained elsewhere. The agreement is generally good and the uncertainties have been reduced in many cases. The α-particle branching ratios for ^{162,163}Ta were also deduced and are reported in Sec. IV.

IV. OTHER RESULTS

During the course of these experiments, we also obtained large amounts of data on the decays of many other nuclides. For the most part, our results agree with those obtained from several earlier experiments. In a few cases, we were able to extract new information and in some others our data can be used to confirm or cast into doubt the only previous result. This section details those of our findings that fall into these last two categories.

Some of the information obtained on the decays of neutron-deficient tantalum, hafnium, ytterbium, thulium, and lutetium isotopes is shown in Table II. The results presented for the lightest tantalum isotopes seen in our study, $^{160-162}$Ta, represent the first confirmation of the only previous values found in the literature. In general, there is good agreement between the two sets of data and in many cases we were able to reduce the uncertainties.

Observations of the decay of ^{164}Ta were first reported in 1982 [22,23]. The most complete study of this nuclide has been performed by Hild *et al.* [13] and was published in 1989. Our data for the most intense γ rays from the decay of ^{164}Ta agree well with those of Hild *et al.*

The nuclides $^{159-161}$Hf were first identified as α-particle emitters in 1973 [14,15]. Our measured half-lives and α-particle energies agree with the first observations, but with some improvement in accuracy for data on ^{161}Hf. Two γ rays from the decay of ^{161}Hf have also been reported by Bruchertseifer *et al.* [16], but their relative intensities were not given. The 135.8 keV γ ray is clearly seen in Fig. 5, but we have no indication of the 180 keV γ ray in our data (see limit in Table II). Our results for the half-life and excitation function of the 135.8 keV γ ray support a ^{161}Hf assignment.

The decay of ^{162}Hf has been studied by Schrewe *et al.*

[1] who assigned one α group and three γ rays to the decay of this nucleus. Our results agree with this previous study. A detailed study on the decay of ^{164}Hf has been published by Hild *et al.* [13]. Our data for the most intense γ rays from this nuclide are in agreement with the earlier study.

The isotopes ^{156,157,159}Lu were discovered quite some time ago [18,19,24]. In our study we have contributed the first confirmation of the α branching ratio of ^{156}Lu, the half-life of ^{157}Lu, and the half-life and α-decay energy of ^{159}Lu. With the exception of the half-life of ^{157}Lu, our results are in good agreement with the earlier measurements.

We have confirmed the one previous determination of the α-decay energies of ^{158}Yb and ^{155}Tm. Our measured value for the half-life of ^{155}Tm agrees with that reported by Aguer *et al.* [21] and disagrees with the earlier value of Toth *et al.* [20].

We have deduced the α branching ratios for nine nuclides, six of them for the first time, from the data obtained in our experiments. In one case, that of ^{156}Lu reported in Table II, the branch was determined from the ratio of its observed α particles to those observed from ^{160}Ta, its parent. This was possible in our case because the direct production of ^{156}Lu was very small and, furthermore, after its transportation to our counting location, its short half-life had reduced this directly-produced ^{156}Lu activity to insignificance compared with that "milked" from the longer-lived ^{160}Ta.

In the remaining eight cases, shown in Table III, we have determined the α branching ratios by comparing the intensities of α- and γ-ray groups from the decay of the same nuclide. Unfortunately, the absolute γ-ray intensities have not previously been established for any of the eight. Consequently we quote all α branches based on the assumption that the strongest transition in the corresponding γ-ray spectrum accounts for 100% of the total decay intensity. As such, the quoted α branching ratios must be regarded as upper limits.

The reduced α widths shown in the last column of Table III were calculated from the data shown in other columns of the table. The fact that in most cases the widths have a value of the order of unity, which is normal in this area of the chart of nuclides, leads us to conclude that in those cases the relative γ-ray intensities shown in the table are reasonably close to the as-yet-unknown absolute intensities. In two cases, ^{163}Ta and ^{159}Lu, the reduced widths are much greater than unity, presumably indicating that the absolute γ-ray intensities are much weaker than the reported relative ones. This is consistent with our observation (exemplified in Fig. 6), and that of Runte *et al.* [4], that the γ rays from the decay of ^{162}Ta,

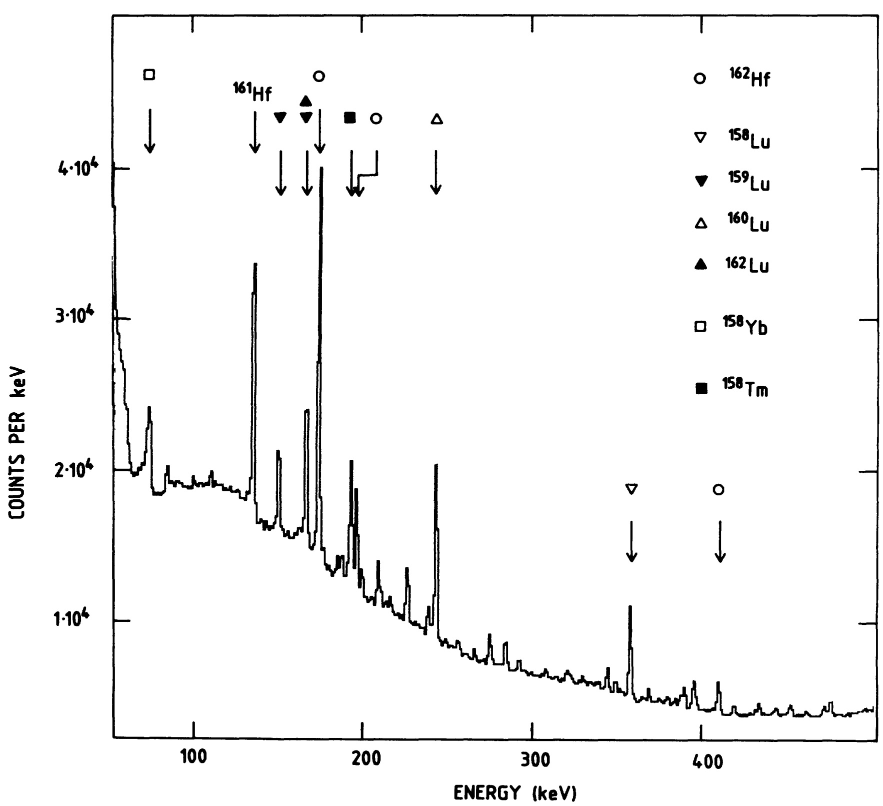

FIG. 5. γ-ray spectrum observed with a bombarding energy of 711 MeV and a tape-cycling time of 16 s. The prominent 135.8 keV γ ray is assigned to ^{161}Hf. A 180 keV γ ray previously assigned to the decay of this nuclide is not visible.

TABLE II. Selected decay data of Ta, Hf, Lu, Yb, and Tm isotopes.

		Half-life			Energy		Intensity[a]	
Isotope	Literature reference	Present experiment (s)	literature (s)	Radiation	Present experiment (keV)	literature (keV)	Present experiment (%)	literature (%)
^{160}Ta	[4,11]	1.7(2)	1.2(3)	α	5400(6)	5413(5)		
^{161}Ta	[4,11]	3.00(15)	2.7(2)	α	5149(5)	5148(5)		
^{162}Ta	[4,7]	3.60(15)	3.5(2)	γ	284.5(2)	284.4	100	100
				γ	443.8(2)	444.0	40(3)	$\simeq$40
^{164}Ta	[13]	13.5(5)	14.9(2)	γ	210.8(3)	210.7(3)	92[b]	92.0
				γ	376.4(3)	376.5(5)	18.6(21)	23.0(20)
				γ	605.3(4)	605.0(5)	14.6(17)	14.0(10)
				γ	816.2(4)	815.7(6)	9.9(18)	8.0(10)
				γ	861.7(4)	862.5(5)	13.4(16)	10.0(5)
^{159}Hf	[11,14]	5.8(9)	5.6(5)	α	5088(6)	5095(5)		12(1)
^{160}Hf	[11,14]	13.0(15)	$\simeq$12	α	4779(6)	4777(5)		2.3(6)
^{161}Hf	[14,15]	16.8(8)	17(2)	α	4599(7)	4600(10)		
	[16]			γ	135.8(3)	135.6	100	
				γ		180.0	<6	
^{162}Hf	[1]		37.6(8)	α	4305(9)	4308(10)		
^{164}Hf	[13]		111(8)	γ	122.4(3)	122.1(3)	207(23)[c]	210.6(198)
					153.6(3)	153.3(3)	100	100(80)
					314.2(4)	313.7(4)	61(9)	46.0(90)
^{156}Lu	[11]		0.18(2)	α	5563(8)	5568(5)	91(12)	100(25)
^{157}Lu	[11,17]	4.4(3)	5.5(3)	α	4995(6)	4996(5)		6(2)
^{159}Lu	[18]	9.2(35)	12.3(10)	α	4417(10)	4420(10)		
^{158}Yb	[19]		99(12)	α	4059(12)	4069(10)		
^{155}Tm	[20,21]	26(3)	39(3),25(4)	α	4452(8)	4450(10)		

[a]Absolute intensities for all α groups as well as γ rays from ^{164}Ta. Relatiive intensities for all other γ rays. With the exception of ^{156}Lu, our α branching ratio measurements are reported in Table III.
[b]Absolute intensity taken from Hild *et al.* [13] and all other γ rays normalized to this value.
[c]The intensity of this γ ray is arrived at by the subtraction of a contribution from a ^{164}Lu γ ray of nearly the same energy. Consequently the second strongest γ ray has been used for normalization.

originating from a $4^+ \to 2^+ \to 0^+$ cascade in ^{162}Hf, are easily seen in the spectrum, whereas those of the odd-even nucleus ^{163}Ta were not seen by Runte *et al.* and only weakly observed in our experiments. It thus appears that the β decay of ^{163}Ta is fractionated among many states or has a sizeable ground-state to ground-state branch.

V. DISCUSSION

With these results, the α-decay chains including ^{162}Ta and ^{163}Ta are now firmly connected to nuclides with known absolute masses. The absolute masses of all nuclides in these two chains can therefore be deduced; they

TABLE III. Measured α branching ratios.

		γ ray used for normalization			α branching ratio		
Nuclide	E_α (keV)	E_γ (keV)	I_γ (%)	Ref.	present experiment (%)	literature (%)	Reduced width[a]
^{162}Ta	4884	284	100		0.081(13)	0.065(14)[b]	0.44
^{163}Ta	4635	449+451	60+70	[7]	0.28(4)		11.7
^{161}Hf	4601	136	100		0.29(5)		3.6
^{162}Hf	4308	174	100	[1]	0.0063(14)	0.0087(7)[c]	1.9
^{158}Lu	4666	358	100	[18]	0.91(20)		2.5
^{159}Lu	4417	151	100	[18]	0.15(3)		8.8
^{158}Yb	4059	253	3.3	[18]	0.0021(12)		0.76
^{155}Tm	4452	227	100	[21]	2.1(3)		3.1

[a]Given in units where ^{212}Po$=1$.
[b]Reference [4].
[c]Reference [1].

TABLE IV. Deduced mass excesses.

Nuclide	E_α (keV)	Refs.	Mass excess (keV)	Nuclide	E_α (keV)	Refs.	Mass excess (keV)
^{150}Ho			−62 214(159)	^{151}Ho			−63 719(60)
^{154}Tm	4956(3)	[10,11]	−54 701(159)	^{155}Tm	4451(7)[a]	[20]	−56 724(61)
^{158}Lu	4666(4)[b]	[17,26][b]	−47 488(159)	^{159}Lu	4419(7)[a]	[18]	−49 767(61)
^{162}Ta	4883(5)[a]	[4]	−40 056(159)	^{163}Ta	4633(6)[a]	[4,5]	−42 592(62)
^{166}Re	5372(10)	[6]	−32 126(159)	^{167}Re	5136(8)	[6]	−34 905(62)
^{170}Ir	6025(5)	[9,27,28]	−23 531(159)	^{171}Ir	5910(5)	[27,28,30]	−26 428(62)
^{174}Au	6626(10)	[29]	−14 324(160)	^{175}Au	6438(8)[c]	[29,31]	−17 224(63)
				^{179}Tl	6560(20)	[29,32]	−8 090(66)
				^{179}Tl^m	7200(10)	[29,32]	−7 435(64)

[a]Includes our measured α-decay energy, given in Tables I and II.
[b]Includes our value for the α-decay energy of ^{158}Lu, 4666(7) keV.
[c]α decay populated 190 keV excited state in ^{170}Ir [29].

are shown in Table IV. We have started our evaluation at ^{150,151}Ho, with mass excesses taken from the evaluation of Wapstra *et al.* [25]. We have updated the information already known on the α-decay energies of other members in these chains with our results, shown in Table II, where applicable. So far, including the two α-decay chains discussed here, four chains have been linked to nuclides with a known mass; they are shown in Figure 7. They provide a good opportunity for the exploration of systematic trends.

The two previously well-established chains [1–3] were both built on even-even nuclides and the absolute masses of their members have already been used to study the trend of two-proton separation energies. With the addition of the chains including ^{162,163}Ta (characterized by $N=Z+16$ and $N=Z+17$, respectively) it is now possible to study the trends of one-proton (S_p) and one-neutron (S_n) separation energies. The derived, experimental values are shown in Fig. 8 together with predictions from a number of atomic-mass formulas [33].

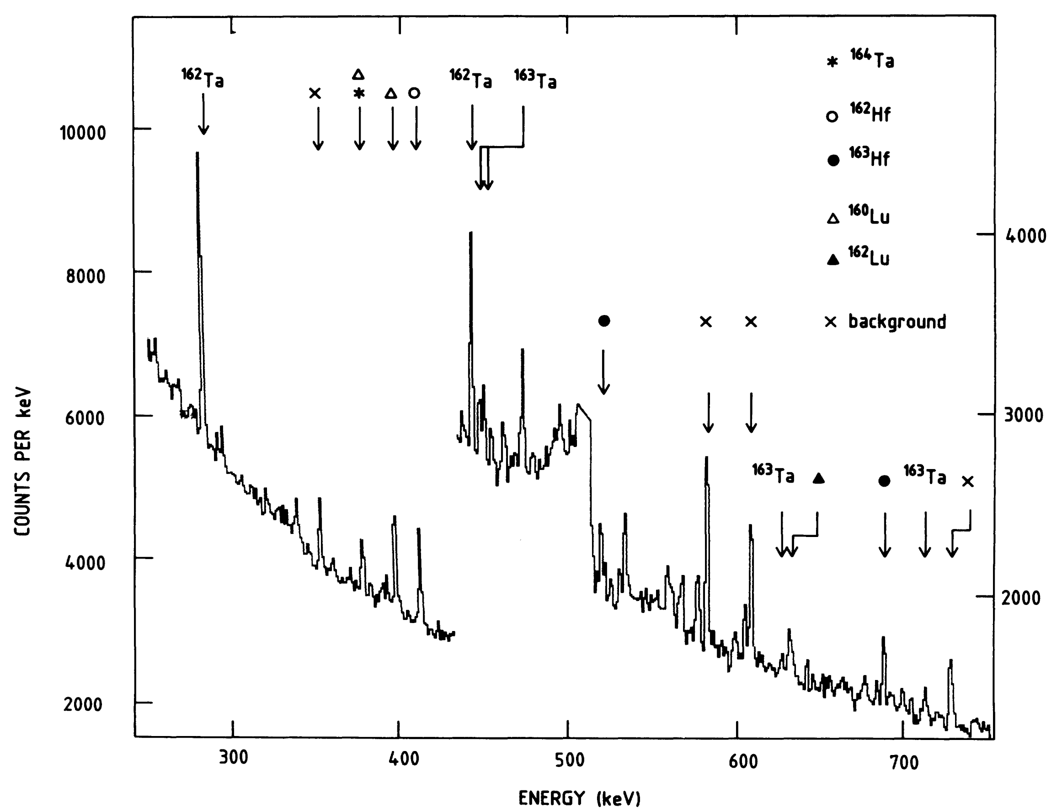

FIG. 6. γ-ray spectrum observed with a bombarding energy of 628 MeV and a tape-cycling time of 6 s. The γ rays from the decay of ^{162}Ta show up prominently whereas the ones from ^{163}Ta are very weak.

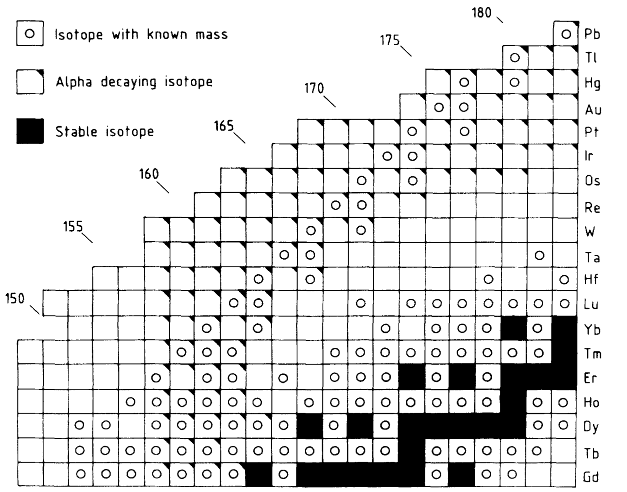

FIG. 7. Chart of nuclides displaying the known α-emitting isotopes in the region of interest as well as the four α-decay chains whose members have a known absolute mass.

It is seen in Fig. 8(a) that the predicted S_p values for the even-even $N=Z+16$ series are generally below the experimental values, but that the opposite trend holds true for the odd-even $N=Z+17$ series. However, it should be noted that if the relevant pairs of S_p values

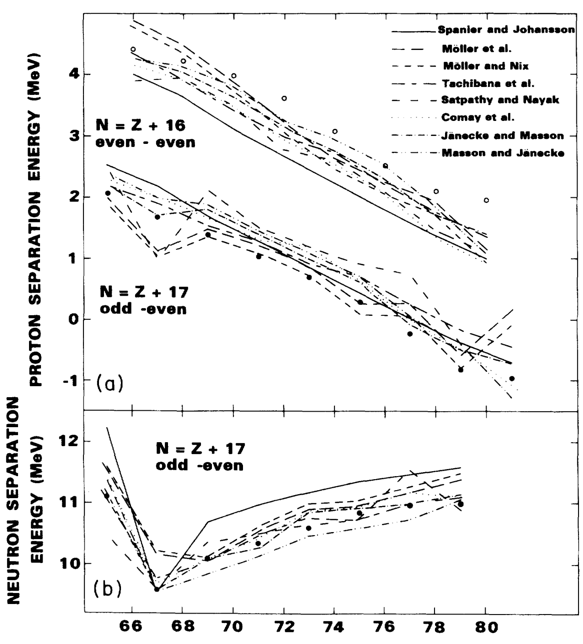

FIG. 8. (a) The data points show the proton separation energies deduced from the experimental mass excesses of the three α-decay chains. The uncertainties are about the size of the points. The lines show the predicted values from a number of mass formulas indicated in the upper right-hand corner of the figure. Symbols including dots are used for formulas based on recursive relations, whereas symbols without dots denote formulas based on liquid-drop-model approaches with shell corrections. (b) Same as (a) but for neutron separation energies. The uncertainties are about twice the size of the points.

from the two series are added to produce a two-proton separation energy, then the predictions scatter randomly around the experimental values. Thus, it appears that the systematic disagreement between predicted and experimental S_p values seen in the figure may be due to the experimental values rather than the consistent failure of all theories. The common link in the deduction of the S_p value of the two series is the α-decay chain containing ^{163}Ta. If all members of this chain had mass excesses that were 300 keV smaller than the quoted experimental values, then the S_p data points for the $N=Z+16$ series would move down by that amount and those of the $N=Z+17$ series would move up. A better agreement between predicted and experimental S_p values would then be achieved and the good agreement for the S_{2p} values would remain unchanged.

Since the α-decay chain including ^{163}Ta is comprised of odd-even nuclei, it is natural to suspect that for one member, the α-decay branch, presumed to be a ground-state connection, actually feeds an excited state. However, if that were the case, the mass excesses of all heavier members would increase and thus the systematic disagreement between predicted and experimental S_p values would become worse. Furthermore, if a nuclide in the middle of the decay chain had such an excited state branch then in Fig. 8(a) a discontinuity would be present in the experimental S_p values at that point. It is also worth noting that even though the last α decay in this chain is quite complex, with isomeric states in both parent and daughter, a thorough study of α-γ coincidences by Liang *et al.* [34] has unraveled the α decays of both isomers in ^{151}Ho.

The most probable cause of the systematic discrepancy between theory and experiments seen in Fig. 8 is a 300 keV overestimate in one of the Q_{EC} measurements that tie the lightest nucleus in the ^{163}Ta α-decay chain, viz. ^{147}Tb, to a stable nuclide with a precisely known mass. There are known problems in the β decay of ^{147}Tb itself. The Q_{EC} measurement of Tidemand *et al.* [35] and the value deduced from the reaction study of Gyufko *et al.* [36] differ by 160 keV [35]. The relative position of the two isomers in ^{147}Tb differ by as much as 180 keV in the studies of Liang *et al.* [34], Tidemand *et al.* [35], Gyufko *et al.* [36], and Alkhazov *et al.* [37], and these studies do not agree on which state is the ground state.

The neutron separation energies shown in Fig. 8(b) show the effect of the $N=82$ shell for the lightest member of the $N=Z+17$ series. The predicted S_n values are generally somewhat higher than the experimental ones but the discrepancy is less than that for the proton separation energies. The neutron separation energies shown are for members of the ^{163}Ta α-decay chain and if the mass excesses of all members were 300 keV lower, the data points would move up by the same amount. The experimental S_n values would then be above the mean of the predictions by about the same amount that they are now below it. However, one should bear in mind that the members of the ^{162}Ta α chain, also involved in the deduction of these neutron separation energies, are all odd-odd. It is in this chain, then, where it is most likely that an error could follow from the attribution of an α group to the ground state of the daughter instead of an excited state. Thus, the S_n values shown in Fig. 8 should be considered somewhat less reliable than the S_p values.

In conclusion, the smooth trends seen in Fig. 8 for the experimental separation energies lends confidence to the α-decay assignments for the four chains involved. There are indications that the mass excesses of all members of the ^{163}Ta α-decay chain are consistently too high by about 300 keV. Such a discrepancy cannot be due to feeding of an unknown excited state by the main α-decay branch from a member of this chain. The most likely origin of the discrepancy is an error in a Q_{EC} measurement, possibly for ^{147}Tb.

Three of the nuclides in the ^{163}Ta α-decay chain, ^{179}Tl, ^{175}Au, and ^{171}Ir, have proton separation energies of $-943(69)$, $-811(65)$, and $-216(65)$ keV, respectively. They therefore join a small group of 12 nuclides, which have been shown conclusively to be unstable towards ground-state proton emission. It is also evident that other known nuclides, which differ from these by the removal of neutron pairs, such as ^{173}Au, ^{169}Ir, and ^{167}Ir, also have negative proton binding energies, although the actual values are not yet known.

Another interesting example of possible proton emission is the isomeric state in ^{179}Tl. The S_p value for ^{179}Tl^m, $-1598(66)$, is quite large. If the proton-decay mode of this isomer were not hindered, the partial half-life would be less than a microsecond and the proton branch close to 100%. However, only its α-decay mode has been observed [29,32] and the measured half-life of 1.4 ms indicates that its proton decay is strongly hindered.

Further experiments will undoubtedly link other α-decay chains in this region to nuclides with known mass. Such studies provide a unique view of the masses of nuclides very far from the stability line and a valuable constraint on the prediction of the masses of less accessible exotic nuclei.

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