Precise Atomic Mass Differences Involving Isotopes of Nd, Sm, Cd, and Pb*

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(Z. Naturforschg. **21 a**, 63—68 [1966]; received 20 September 1965)

Dedicated to Prof. J. Mattauch *on his 70th birthday*

During the past year, certain of our experimental techniques have been re-evaluated and modified. In the course of these investigations, we have re-determined two atomic mass differences involving isotopes of cadmium and one involving isotopes of lead. The new values are consistent with reaction data and with our older measurements. Thirteen mass differences involving isotopes of neodymium and samarium have also been determined, several for the first time. These new results are consistent with reaction data and with other recent mass spectroscopic data, but indicate that our previously-reported mass differences in the neodymium-samarium region are systematically too large by small but real amounts. An unusually concordant situation now exists in this region of the mass table.

Over the past three and one-half years our high resolution mass spectrometer [1] has been used to determine many atomic mass differences of the type

$$^{A+2}X_1\,{}^{35}Cl - {}^{A}X_2\,{}^{37}Cl$$

where, at various times, $^{A+2}X_1$ and $^{A}X_2$ have been isotopes of tin [2, 3], antimony [3], zirconium [4], tellurium [5], molybdenum, cadmium [6], titanium, vanadium, zinc, germanium, selenium [7], mercury, thallium, lead, bismuth [8], neodymium, samarium [9, 10], gadolinium and dysprosium [9]. Prior to the work involving the rare earth elements, we had no reason to question the validity of our results, but for neodymium and samarium a body of reaction data [11–14] has gradually emerged which differs systematically from our mass differences. In addition, other recent mass spectroscopic work involving neodymium [15] differs systematically in the same direction. As a result of these discrepancies, we have modified and improved our techniques in a manner to be described below, and have discovered that our previously-reported neodymium and samarium mass differences are indeed too large by several times the stated errors. But the new determinations confirm the accuracy of the work done immediately prior to the rare earth studies, and suggest that the systematic error made its appearance after that time.

The new determinations, together with the other existing data, represent an unusually reliable body of data which should be useful in predicting decay energies, reaction-Q's, etc. for various nuclides in the region $142 \leqq A \leqq 154$.

1. Improvements in Experimental Technique

A detailed description of the instrument and the measuring techniques is given in reference 1. The

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* Supported by the U. S. Air Force Office of Scientific Research and by the National Research Council of Canada.

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[1] R. C. Barber, R. L. Bishop, L. A. Cambey, H. E. Duckworth, J. D. Macdougall, W. McLatchie, J. H. Ormrod, and P. Van Rookhuyzen, Proc. 2nd Internat. Conf. Nuclidic Masses, Vienna, July 1963, Springer-Verlag, 1964.

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following discussion relates only to those elements deemed pertinent in the light of the modifications made.

Our instrument is a large double focusing DEMPSTER-type mass spectrometer with an electron bombardment ion source and an electron multiplier detector. The ion beam is periodically swept across the detector by the amplified sawtooth time base of the oscilloscope on which the detector output is displayed. On alternate sweeps the voltage V between the plates of the electrostatic analyser and the accelerating voltage V_a are increased by identical fractional amounts to $V+\Delta V$ and $V_a+\Delta V_a$ respectively. These voltage increments displace a given doublet member from its position on the previous sweep. With proper choice of ΔV and ΔV_a one can displace the first member of the doublet to that point in the sweep which was occupied by the second doublet member when no voltage increments were present. When this condition is achieved, the mass difference ΔM between the two members is given by

$$\Delta M/M = \Delta V/V$$

for small ΔM, where M is the mass of the lighter doublet member.

In our previous work the beam was swept by applying the sawtooth voltage directly to the electrostatic analyser. This raised the possibility of AC pick-up by the ΔV circuit from that applying the sweep voltage. This difficulty has been overcome by installing a pair of deflection plates between the electrostatic and magnetic analysers. The sweep circuit is now physically and electrically isolated from the electrostatic analyser circuitry. The isolation of the sweep and ΔV circuits allowed the latter circuit to be re-designed in such a manner as to reduce the possibility of AC pick-up from other sources.

An improvement has also been made in the method by which one member of a mass doublet is matched to the other. A 1024-channel digital memory [16] with a continuous oscilloscope display of the memory content is now used to determine the matched condition. This technique was first used by W. H. JOHNSON and J. L. BENSON [17] at the University of Minnesota. The digital memory oscilloscope consists of a voltage digitizer which feeds a 1024-channel magnetic core memory. The sweeps of the memory channels, the ion beam, and the two coscilloscopes are synchronized so that each channel corresponds to a definite time after the start of the sawtooth voltage which sweeps the ion beam.

One member of the mass doublet is fed to the memory in the add mode, and on the next sweep the other member of the doublet is subtracted from the memory. Thus, when the two peaks occur at the same stage of the oscilloscope trace, and the more intense peak is attenuated to the same amplitude as the less intense peak, a null is observed on the read-out oscilloscope. When the two peaks occur at different stages of the oscilloscope trace an error signal is observed.

By using the magnetic memory one is able to employ many more sweeps of the peaks in determining the matched condition. Also, by averaging the signal for a reasonable period (typically 15 to 40 seconds), one improves the signal to noise ratio since the peaks recur periodically, whereas the noise from the multiplier and electronics is essentially random. As a result, the precision of a single determination of the matched condition is improved by approximately a factor of ten.

The sawtooth voltage sweeping the ion becam can be either increased or decreased linearly, and ΔV can be either added to or subtracted from the voltage across the electrostatic analyzer plates. Two settings of ΔV are made for each of the four permutations of these two possibilities. The mean of these eight values of ΔV is used to compute a value of ΔM for this "run". Several runs are made over a period of no less than two days and the mean of these runs is quoted as our final value of the mass difference.

2. Results

a) Repetition of Some Earlier Work Involving Isotopes of Cadmium and Lead

Having modified the sweep system and the ΔV circuit in the manner described above, it was desirable to compare the present performance of the mass spectrometer with its performance at a much earlier date. To this end we redetermined the mass differences for three doublets which had been studied prior to our work on the rare earth elements. In this redetermination we employed the same visual peak-matching technique which had been used in the earlier work. The new and the old results are shown

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[16] Nuclear Data N.D. 800 „Enhancetron" (Modified Version).

[17] J. L. BENSON, Thesis, University of Minnesota 1965.

in Table 1. The good agreement between them suggests that the modified instrument is now performing as it did in the spring and summer of 1963.

Mass Doublet	ΔM (in mu)	
	McMaster, 1963	Present Redetermination
^{208}Pb ^{35}Cl — ^{206}Pb ^{37}Cl	$5.136 \pm 3 \cdot 10^{-3}$[a]	$5.136 \pm 3 \cdot 10^{-3}$
^{114}Cd ^{35}Cl ^{37}Cl — ^{112}Cd ^{37}Cl ^{37}Cl	$3.547 \pm 2 \cdot 10^{-3}$[b]	$3.546 \pm 3 \cdot 10^{-3}$
^{116}Cd ^{35}Cl ^{37}Cl — ^{114}Cd ^{37}Cl ^{37}Cl	$4.353 \pm 2 \cdot 10^{-3}$[b]	$4.347 \pm 3 \cdot 10^{-3}$

[a] Reference [8], [b] Reference [6].

Table 1. Comparison of old and new results for the doublets indicated. In all cases the visual peak-matching technique was used.

Not only are these new and old results consistent with one another, they appear to be consistent with whatever other comparison data exist. In order to facilitate the comparison, the new values are expressed in Table 2 as double neutron separation energies (S_{2n}) for the heavier isotopes, using the relationship

$$S_{2n} = [2n - (^{37}\mathrm{Cl} - ^{35}\mathrm{Cl}) - \Delta M]\,\mathrm{u}$$

and the values

$$n = (1.008\,665\,2 \pm 1 \cdot 10^{-7})\,\mathrm{u}\ ^{18},$$
$$^{37}\mathrm{Cl} - ^{35}\mathrm{Cl} = (1.997\,049\,3 \pm 4 \cdot 10^{-7})\,\mathrm{u}\ ^{19,\,20},$$
$$1\mathrm{u} = (931.478 \pm 0.015)\,\mathrm{MeV}\ ^{21}.$$

Also shown in Table 2 are the accurate reaction and mass spectroscopic data which are available for comparison. The agreements shown in Tables 1 and 2 suggest that neither our earlier work with cadmium and lead nor our present redeterminations contains a systematic error that is greater than the experimental uncertainty. Furthermore, whatever systematic error was present for the rare earth measurements in late 1963 and early 1964 had not appeared in the earlier work up to and including Pb. Since the Pb region was studied immediately before the rare earth work, this left only the published rare earth mass differences in doubt.

Nuclide	S_{2n} (in MeV)	
	Present Redetermination	Previous (external) work
^{208}Pb	$14.108 \pm 3 \cdot 10^{-3}$	$14.108 \pm 11 \cdot 10^{-3}$[a] $14.114 \pm 9 \cdot 10^{-3}$[b]
^{114}Cd	$15.588 \pm 3 \cdot 10^{-3}$	$15.587 \pm 10 \cdot 10^{-3}$[c] $15.580 \pm 4 \cdot 10^{-3}$[d]
^{116}Cd	$14.842 \pm 3 \cdot 10^{-3}$	$14.842 \pm 10 \cdot 10^{-3}$[c] $14.836 \pm 3 \cdot 10^{-3}$[d]

[a] A. H. Wapstra, Nucl. Phys. **28**, 29 [1961].
[b] B. B. Kinsey, G. A. Bartholomew, and W. H. Walker, Phys. Rev. **82**, 380 [1951].
[c] H. Marchant and S. Hinds, private communication.
[d] R. A. Damerow, R. R. Ries, and W. H. Johnson, Jr., Phys. Rev. **132**, 1673 [1963].

Table 2. Comparison of redetermined double neutron separation energies with other reaction and mass spectroscopic data.

b) Use of the Enhancetron to Redetermine Some Mass Differences Involving Isotopes of Cadmium

The reliability of the instrument having been established, the Enhancetron was installed. As a test of this technique of peak matching, two Cd doublets were remeasured. The individual runs made and their means are shown in Table 3. The error associated with each run in Table 3 is the standard deviation for the eight settings constituting that run. The error associated with the mean is the standard deviation calculated from the individual runs. To this error we add arithmetically the uncertainty (0.035%) in the instruments used to measure V and ΔV. This method, which is used to calculate the errors on all subsequent mass differences in this paper, is believed to be a conservative estimate of the error.

^{114}Cd ^{35}Cl ^{37}Cl—^{112}Cd ^{37}Cl$_2$	^{116}Cd ^{35}Cl ^{37}C —^{114}Cd ^{37}Cl$_2$
$3.5480 \pm 32 \cdot 10^{-4}$	$4.3432 \pm 24 \cdot 10^{-4}$
$3.5456 \pm 25 \cdot 10^{-4}$	$4.3438 \pm 10 \cdot 10^{-4}$
	$4.3453 \pm 21 \cdot 10^{-4}$
	$4.3427 \pm 25 \cdot 10^{-4}$
Mean: $3.5468 \pm 12 \cdot 10^{-4}$	*Mean*: $4.3438 \pm 6 \cdot 10^{-4}$

Table 3. New cadmium mass differences (in mu) obtained using the enhancetron for peak-matching.

Mass Difference	ΔM (mu)	
	Visual Peak-matching	Enhancetron
^{116}Cd ^{35}Cl — ^{114}Cd ^{37}Cl	$4.347 \pm 3 \cdot 10^{-3}$ (20 runs)	$4.344 \pm 2 \cdot 10^{-3}$ (4 runs)
^{114}Cd ^{35}Cl — ^{112}Cd ^{37}Cl	$3.546 \pm 3 \cdot 10^{-3}$ (20 runs)	$3.547 \pm 3 \cdot 10^{-3}$ (2 runs)

Table 4. Comparison of present results obtained by visual peak-matching and by use of enhancetron.

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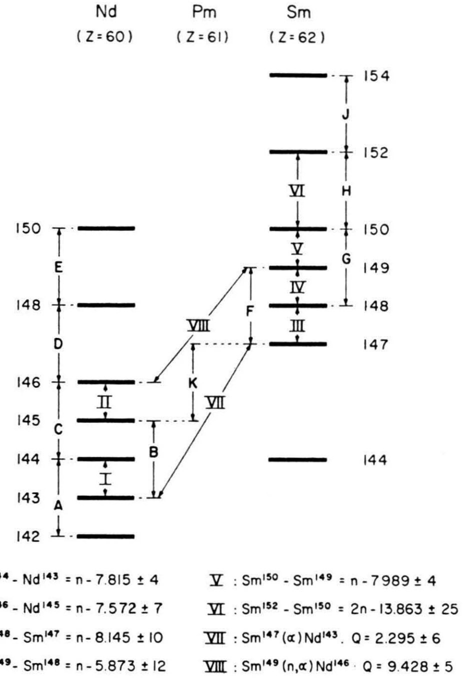
In Table 4, the values obtained using the Enhancetron are compared with those obtained using the visual matching technique. Both techniques yield the same results and, moreover, the inherently greater precision of the Enhancetron is exhibited by the fact that only two runs obtained by this method yield roughly the same precision as twenty runs using the visual technique.

c) Use of the Enhancetron to Determine Mass Differences Involving Isotopes of Neodymium and Samarium

Having justified the use of the Enhancetron, we then measured thirteen mass differences involving Nd and Sm. The results are shown in Table 5 where our earlier values are included for comparison. From the table we conclude that our previously reported values for mass differences involving Nd and Sm are systematically high. But the Cd and Pb results, which were given in Tables 1 – 4 and which are summarized again in Table 5, suggest the presence of this systematic error was restricted to the rare earth work.



I : $Nd^{144} - Nd^{143} = n - 7.815 \pm 4$

II : $Nd^{146} - Nd^{145} = n - 7.572 \pm 7$

III : $Sm^{148} - Sm^{147} = n - 8.145 \pm 10$

IV : $Sm^{149} - Sm^{148} = n - 5.873 \pm 12$

V : $Sm^{150} - Sm^{149} = n - 7989 \pm 4$

VI : $Sm^{152} - Sm^{150} = 2n - 13.863 \pm 25$

VII : $Sm^{147}(\alpha)Nd^{143}$. $Q = 2.295 \pm 6$

VIII : $Sm^{149}(n,\alpha)Nd^{146}$ $Q = 9.428 \pm 5$

Fig. 1 is a schematic diagram of the region of interest, showing the various stable isotopes of Sm and Nd and their positions relative to one another. The new mass differences are designated by capital letters – A, B, C, etc. Pertinent reaction and decay data which can be compared with the mass differences reported here are designated by Roman numerals – I, II, III, etc. Data I and II are derived from neutron capture experiments. Datum I is the average of the values $(7.816 \pm 5 \cdot 10^{-3})$ MeV obtained by KENNETT et al.[22] and $(7.814 \pm 8 \cdot 10^{-3})$ MeV by CAMPION et al.[23]. Datum II is the average of the two values

Mass Difference	Present Work		Previous Values	ΔM (previous) $-\Delta M$ (present work)
	ΔM (mu)	Number of Runs	ΔM (mu)	
$^{114}Cd\,^{35}Cl - ^{112}Cd\,^{37}Cl$	$3.547 \pm 3 \cdot 10^{-3}$	2	$3.547 \pm 2 \cdot 10^{-3a}$	0
$^{116}Cd\,^{35}Cl - ^{114}Cd\,^{37}Cl$	$4.344 \pm 2 \cdot 10^{-3}$	4	$4.353 \pm 2 \cdot 10^{-3a}$	+ 9
$^{208}Pb\,^{35}Cl - ^{206}Pb\,^{37}Cl$	$5.136 \pm 3 \cdot 10^{-3}$	32*	$5.136 \pm 3 \cdot 10^{-3b}$	0
$^{144}Nd\,^{35}Cl - ^{142}Nd\,^{37}Cl$	$5.308 \pm 3 \cdot 10^{-3}$	3	$5.329 \pm 3 \cdot 10^{-3c}$	+ 21
$^{145}Nd\,^{35}Cl - ^{143}Nd\,^{37}Cl$	$5.702 \pm 4 \cdot 10^{-3}$	4	$5.744 \pm 4 \cdot 10^{-3c}$	+ 42
$^{146}Nd\,^{35}Cl - ^{144}Nd\,^{37}Cl$	$5.966 \pm 4 \cdot 10^{-3}$	3	$6.003 \pm 4 \cdot 10^{-3c}$	+ 37
$^{148}Nd\,^{35}Cl - ^{146}Nd\,^{37}Cl$	$6.721 \pm 4 \cdot 10^{-3}$	3	$6.740 \pm 4 \cdot 10^{-3c}$	+ 19
$^{150}Nd\,^{35}Cl - ^{148}Nd\,^{37}Cl$	$6.939 \pm 4 \cdot 10^{-3}$	2	$7.006 \pm 5 \cdot 10^{-3c}$	+ 67
$^{148}Nd\,^{35}Cl_2 - ^{144}Nd\,^{37}Cl_2$	$12.690 \pm 9 \cdot 10^{-3}$	1	—	—
$^{150}Nd\,^{35}Cl_2 - ^{146}Nd\,^{37}Cl_2$	$13.654 \pm 9 \cdot 10^{-3}$	1	—	—
$^{149}Sm\,^{35}Cl - ^{147}Sm\,^{37}Cl$	$5.231 \pm 3 \cdot 10^{-3}$	4	$5.257 \pm 4 \cdot 10^{-3c}$	+ 26
$^{150}Sm\,^{35}Cl - ^{148}Sm\,^{37}Cl$	$5.400 \pm 4 \cdot 10^{-3}$	4	$5.452 \pm 4 \cdot 10^{-3c}$	+ 52
$^{152}Sm\,^{35}Cl - ^{150}Sm\,^{37}Cl$	$5.396 \pm 4 \cdot 10^{-3}$	5	$5.429 \pm 4 \cdot 10^{-3c}$	+ 33
$^{154}Sm\,^{35}Cl - ^{152}Sm\,^{37}Cl$	$5.417 \pm 4 \cdot 10^{-3}$	4	$5.479 \pm 3 \cdot 10^{-3c}$	+ 62
$^{152}Sm\,^{35}Cl_2 - ^{148}Sm\,^{37}Cl_2$	$10.802 \pm 10 \cdot 10^{-3}$	1	—	—
$^{147}Sm\,^{35}Cl - ^{145}Nd\,^{37}Cl$	$5.264 \pm 4 \cdot 10^{-3}$	4	—	—

* visual, [a] Reference [6], [b] Reference [8], [c] Reference [9].

Table 5. New atomic mass differences compared with earlier values reported from this laboratory. All values are expressed in mu, except those in the final column, which are expressed in μu. Except as indicated for the lead doublet, all the listed present values have been obtained using the enhancetron for peak-matching. All present values, save those for lead, were obtained using ions of the di-chloride. For lead, ions of the mono-chloride were used.

Nuclide	This Work		Minnesota (Reference 15)		Reaction Data	
	S_{2n}	Mass Difference Used	S_{2n}	Mass Difference Used	S_{2n}	Data Used
^{144}Nd	$13.947 \pm 3 \cdot 10^{-3}$	A	$13.944 \pm 5 \cdot 10^{-3}$	A		
^{145}Nd	$13.580 \pm 4 \cdot 10^{-3}$	B	$13.577 \pm 5 \cdot 10^{-3}$	B		
^{146}Nd	$13.334 \pm 4 \cdot 10^{-3}$	C	$13.330 \pm 5 \cdot 10^{-3}$	C		
^{148}Nd	$12.631 \pm 3 \cdot 10^{-3}$	D	$12.628 \pm 5 \cdot 10^{-3}$	D		
^{150}Nd	$12.428 \pm 3 \cdot 10^{-3}$	E	$12.428 \pm 7 \cdot 10^{-3}$	E		
^{149}Sm	$14.019 \pm 3 \cdot 10^{-3}$	F			$14.018 \pm 14 \cdot 10^{-3}$	III, IV
^{150}Sm	$13.862 \pm 3 \cdot 10^{-3}$	G			$13.862 \pm 11 \cdot 10^{-3}$	IV, V
^{152}Sm	$13.865 \pm 4 \cdot 10^{-3}$	H			$13.863 \pm 25 \cdot 10^{-3}$	VI
^{154}Sm	$13.845 \pm 4 \cdot 10^{-3}$	J				

Table 6. Comparison of Double Neutron Separation Energies (S_{2n}). All values are expressed in MeV.

$(7.565 \pm 10 \cdot 10^{-3})$ MeV and $(7.580 \pm 10 \cdot 10^{-3})$ MeV obtained by Bartholomew *et al.* [24, 25]. Data III to V are derived from the (d, p) Q-values of Kenefick and Sheline [12, 13]. Datum VI is derived from a (t, p) Q-value determined by Hinds et al. [4]. The remaining two data, VII and VIII, were obtained by Macfarlane and his colleagues [26, 27] by determining accurately the energies of alpha particles emitted in the ^{149}Sm (n, α) reaction and in the decay of ^{147}Sm.

We may also compare certain of the new results with mass spectroscopic mass differences recently obtained at the University of Minnesota [15]. These differences involve the isotopes of neodymium and are designated in Fig. 1 as A, B, C, D and E.

Table 6 presents comparative values for double neutron separation energies. Thus, we include in the table all of the double neutron separation energies which can be calculated directly from the new data reported here. Also, we include the five S_{2n} values which can be calculated from the Minnesota data. Finally, we include the three comparison values which can be calculated from the reaction data shown in Fig. 1. The agreement is extremely good and, amongst other things, suggests that the errors associated with the reaction Q-values represent very conservative estimates.

It is of interest to calculate the energy available for the ^{147}Sm alpha-decay and compare it with the observed value. The mass differences B and K give the Q-value for the alpha-decay directly as $Q_\alpha = (2.293 \pm 5 \cdot 10^{-3})$ MeV. This agrees well with Gupta and Macfarlane's recent precision value of $Q_\alpha = (2.295 \pm 6 \cdot 10^{-3})$ MeV [26].

We can discover whether the present mass differences are consistent with data I, II and VIII by calculating the residuals of two closed loops involving these data and four of our mass differences. The closed loops and their residuals are

$$\mathrm{F} + \mathrm{K} - \mathrm{II} - \mathrm{VIII} = (2 \pm 10)\,\mathrm{keV},$$
$$\mathrm{B} - \mathrm{I} - \mathrm{C} + \mathrm{II} = (2 \pm 10)\,\mathrm{keV}.$$

The closure of these two loops indicates that the four mass differences involved are consistent with Q-values found for reactions induced by slow neutron capture (I and II are n,γ reactions and VIII is an n,α reaction).

As a test of the internal consistency of our mass differences, we have studied doublets of the type

$$\Delta M = {}^{A+4}\mathrm{X}\,{}^{35}\mathrm{Cl}_2 - {}^{A}\mathrm{X}\,{}^{37}\mathrm{Cl}_2\,.$$

This type of doublet yields a mass difference which is equal to the sum of two of the ordinary mass differences, viz.,

$$\Delta M_1 = {}^{A+4}\mathrm{X}\,{}^{35}\mathrm{Cl}_2 - {}^{A+2}\mathrm{X}\,{}^{35}\mathrm{C}\,{}^{37}\mathrm{Cl}\,,$$
$$\Delta M_2 = {}^{A+2}\mathrm{X}\,{}^{35}\mathrm{Cl}\,{}^{37}\mathrm{Cl} - {}^{A}\mathrm{X}\,{}^{37}\mathrm{Cl}_2\,.$$

Table 7 shows a comparison of three such direct determinations and their component sums.

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Mass Difference	Direct	Sum of Two Doublets	Direct-Sum
^{148}Nd ^{35}Cl$_2$ $-$ ^{144}Nd ^{37}Cl$_2$	$12.690 \pm 9 \cdot 10^{-3}$	$12.687 \pm 6 \cdot 10^{-3}$	$(+3 \pm 11) \cdot 10^{-3}$
^{150}Nd ^{35}Cl$_2$ $-$ ^{146}Nd ^{37}Cl$_2$	$13.654 \pm 9 \cdot 10^{-3}$	$13.660 \pm 5 \cdot 10^{-3}$	$(-6 \pm 10) \cdot 10^{-3}$
^{152}Sm ^{35}Cl$_2$ $-$ ^{148}Sm ^{37}Cl$_2$	$10.802 \pm 10 \cdot 10^{-3}$	$10.796 \pm 5 \cdot 10^{-3}$	$(+6 \pm 11) \cdot 10^{-3}$

Table 7. Internal Consistency Test.

3. Summary

Our large double focusing mass spectrometer has been modified and the quality of its performance subjected to a searching examination. In the case of the elements cadmium and lead, our most recent work is in satisfactory agreement with our published values and with precision reaction data. Our most recent work with the elements neodymium and samarium, however, indicates that our previously published values are systematically high by 18 to 67 keV. The new mass differences are in good agreement with other recent mass spectroscopic data, with charged-particle reaction Q-values, with neutron-capture Q-values, and with alpha-decay Q-values. Furthermore, the new results have been found to be internally consistent in so far as we have been able to subject them to test. The now-existing concordance between several types of mass data in the Nd-Sm region is without parallel among the heavier elements, and may be a good omen for the future.

Acknowledgements

We much appreciate receiving pre-publication information from T. J. Kennett, W. H. Johnson, Jr., R. D. Macfarlane, H. Marchant, and R. K. Sheline. Also, we are happy to acknowledge the advice and assistance in this work of R. C. Barber, Ivan Rival and Paul Van Rookhuyzen.

A Correction to the 1964 Mass Table

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(Z. Naturforschg. **21 a**, 68—69 [1966]; received 15 September 1965)

Dedicated to Prof. J. Mattauch *on his 70th birthday*

Very probably, the masses of all nuclides decaying by an $\alpha-\beta$ decay chain into ^{213}Bi are low by about 150 keV.

In all mass adjustments purporting to derive a consistent set of atomic masses of nuclides from experimental data, items occur among the last ones that cannot be reconciled. A choice has then to be made on the basis of physical probabilities; but often it cannot be guaranteed that the choice is correct. For this reason, the more important data in this class have always been mentioned in a separate table in the mass adjustments made by Professor Dr. J. H. E. Mattauch and his collaborators together with the present author [1, 2].

One of these cases is Macefield and Middleton's measurement [3] of the ^{238}U(p, d)^{237}U reaction, yielding a value of $-(3951 \pm 20)$ keV instead of $-(3827 \pm 28)$ keV as obtained in the 1964 mass table. Closer inspection teaches that the value in the last mass table is mainly determined by Wagner et al.'s [4] value of 1.39 MeV for the beta decay energy of ^{213}Bi, to which King [5] assigned an error of 0.01 MeV; the reaction energy $-(5970 \pm 100)$ keV [6] for ^{238}U(γ, n)^{237}U reaction would even suggest a larger deviation from the result of Macefield and Middle-

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