| 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

# A Correction to the 1964 Mass Table

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*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 $(\gamma, n)$ $^{237}$U reaction would even suggest a larger deviation from the result of MACEFIELD and MIDDLE-

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TON. Since it appeared easier to believe that the ground state transition had been missed in MACE-FIELD and MIDDLETON's measurement than that the other data mentioned were incorrect, it was not accepted in the 1964 adjustment.

Recently, however, BRAID et al. [7] found $Q$-values of $(2896 \pm 5)$ keV and $(3014 \pm 5)$ keV for the reactions $^{236}U(d, p)^{237}U$ and $^{240}Pu(d, p)^{241}Pu$ which are $(183 \pm 27)$ keV and $(173 \pm 36)$ keV smaller than the values derived from the 1964 adjustment, indicating an error in the same direction as, and even somewhat larger than that indicated by MACEFIELD and MIDDLE-TON's result. Since their data on excited states in the final nuclides agree well with data known from the $\alpha$-decay of $^{241}Pu$ [8] and $^{245}Cm$ [9], it cannot longer be believed that ground states have been missed.

Checking graphs of binding energies of the last two neutrons [10] it appeared that these would indeed be slightly more regular if the binding energies of all $\alpha - \beta$-decay ancestors of $^{213}Bi$ were about 150 keV lower. This gave us reason to consider the $\alpha - \beta$-cycle $^{213}Bi - ^{213}Po - ^{209}Pb - ^{209}Tl$, with the following results.

The $\alpha$-decay energies of $^{213}Bi$ and $^{213}Po$ accepted in the mass table yield a difference of $(2536 \pm 30)$ keV in the $\beta$-decay energies of $^{209}Tl$ and $^{213}Bi$. The $\beta$-decay of the first isotope is reported [11] to be followed by a cascade of $\gamma$-rays of 120, 450, and 1560 keV. The last two agree well with levels at 1563 and 2015 keV in $^{209}Pb$ recently found [12] in the $^{208}Pb(d, p)^{209}Pb$ reaction; combined, these data point to a daugther level at 2135 keV for the direct $\beta$-decay of $^{209}Tl$. Thus, the difference between the maximum energies of the $\beta$-decay branches in $^{209}Tl$ and $^{203}Bi$ should be $(401 \pm 35)$ keV.

WAGNER et al. [4] report, however, values of 1.99 and 1.39 MeV for these maximum energies, as measured in a sample containing $^{225}Ac$ and all its decay products. The deviation from the energy difference — which cannot be called a discrepancy since the authors themselves do not assign errors to their results — indicates that the error adopted by

KING for the $^{213}Bi$ result is probably very optimistic. It is therefore now very likely that the adopted decay energy is about 140 keV low.

In the mean time, it has also been found [13] that the $\alpha$-decay energy of 5143 keV adopted for $^{229}Th$ does not belong to the ground state transition but to a transition to a state at 25 keV in $^{225}Ra$. It is therefore now suggested that the binding energies of the following nuclides as given in the 1964 tables are about 140 keV high (and that their masses are about 130 $\mu u$ low):

$$^{209}Tl, \ ^{213}Bi, \ ^{217}At, \ ^{221}Fr, \ ^{225}Ra, \ ^{225}Ac, \ ^{229}Pa, \ ^{233}Np, \ ^{237}Am$$

whereas the binding energies of the following nuclides are about 165 keV high:

$$^{229}Th, \ ^{233}Th, \ ^{233}Pa, \ ^{233}U, \ ^{237}Pa, \ ^{237}U, \ ^{237}Np, \ ^{237}Pu$$

and all nuclides with mass numbers 241, 245, 249, 253 and 257.

A curious discrepancy remains as to the binding energy of $^{233}Th$. According to the discussion above, the binding energy of the last neutron in this isotope or, what is the same, the reaction energy of the reaction $^{232}Th(n, \gamma)^{233}Th$ as calculated from the $\beta$-decay energy adopted [2] for the last nuclide now becomes 4780 keV. However, FIEBIGER [14], in recent as yet unfinished coincidence experiments on the last reaction, finds strong indications that the reaction energy should be at least the value $(5110 \pm 50)$ keV reported earlier [15]. He suggests that the wellknown 22 min. $^{233}Th$ might be an isomeric state. Since it has probably a spin 7/2, it would decay by at most an E3 or M3 transition unless the spin of the ground state has the improbable value 15/2 or higher; then the half-life for isomeric transitions should be lower than the reported halflife. Probably, solution of this curious problem will have to wait for completion of FIEBIGER's experiment.

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