Letters to the Editor

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The Atomic Masses of H^1, C^{12}, and S^{32}

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December 6, 1950

THE masses of H^1, C^{12}, and S^{32} have been determined relative to O^{16} by the doublet method with the double-focusing mass spectrometer developed in this laboratory.[1] Table I lists the doublets studied together with the number of runs on each and the results obtained. As in previous work, each run consists of ten determinations. Mass differences involving hydrocarbon ions of the form $(C^{12})_n(H^1)_m$ are corrected for the presence of unresolved $(C^{12})_{n-1}C^{13}(H^1)_{m-1}$ ions. The probable error given indicates the consistency between runs. From the data in Table I, one finds:[2]

TABLE I. Mass doublets from which masses of H^1, C^{12}, and S^{32} are calculated.

Doublet	Source of ions	No. of runs	$\Delta M\times10^4$amu
a. $(C^{12})_4-S^{32}O^{16}$	C_4H_6 SO_2	4	331.82 ± 0.07
b. $C^{12}(O^{16})_2-C^{12}S^{32}$	CO_2 CS_2	6	177.82 ± 0.25
c. $(C^{12})_3(H^1)_8-C^{12}(O^{16})_2$	C_3H_8 CO_2	6	729.67 ± 0.41
d. $(C^{12})_6(H^1)_4-C^{12}(S^{32})_2$	C_6H_6 CS_2	4	873.26 ± 0.58

$$S^{32}=32-b=31.982218\pm25$$
$$C^{12}=12+(a-b)/4=12.003850\pm6$$
$$H^1=1+(a+7b+8c-4d)/48=1.0081685\pm90$$

or

$$H^1=1+(5c+4b-2d)/32=1.008166\pm8$$

or

$$H^1=1+(2d+3c-4a)/32=1.008151\pm6.$$

The result for S^{32} substantiates the value 31.9823 ± 3 given by Aston[3] rather than that of Okuda and Ogata,[4] 31.98089 ± 7. The new value is consistent with 31.98199 ± 21 computed by Penfold[5] from disintegration and some mass spectrographic data, and the number 31.9823 ± 10 found by Smith[6] in his new "synchrometer" mass spectrometer.

The weighted average of the three values for H^1 is 1.008159 ± 4. An examination of the computations which lead to the three individual values shows that all three depend rather strongly upon the value of the doublet c, the first two more so than the last. If one arbitrarily weights the three in the ratio 1:1:2, respectively, in computing the average, one again obtains 1.008159. Because of the strong dependence of the three separate errors upon the error in the common doublet c it may be safer to assume 6, the lowest probable error of the three separate values, as the probable error in the final answer. This has been done in the computations which follow.

The present values for H^1 and C^{12} are in good agreement with the values 1.0081686 ± 52 and 12.003803 ± 13, respectively, found by Roberts while considering an entirely different cycle. His results are given separately.[7] The weighted averages of his and the present results for H^1 and C^{12} are given in Table II. Also given in Table II are masses for other isotopes based upon doublet measurements reported in the present two letters and in the paper referred to under reference 1.

TABLE II. Summary of atomic masses determined by mass spectrometry.

H^1	1.008165 ± 4
H^2	2.014778 ± 8[a]
He^4	4.003944 ± 19[b]
C^{12}	12.003842 ± 6
N^{14}	14.007564 ± 7[c]
Ne^{20}	19.998835 ± 43[d]
S^{32}	31.982218 ± 25
A^{36}	$35.97926\ \pm8$[e]
A^{40}	$39.97524\ \pm3$[f]

[a] From $H_2-D=(15.519\pm0.017)\times10^{-4}$amu.
[b] From $D_2-He^4=256.12\pm0.09$.
[c] Weighted average from $C^{12}H_2-N^{14}=125.86\pm0.13$; $(N^{14})_2-C^{12}O^{16}=112.80\pm0.13$; $(C^{12})_3H_8-(N^{14})_2O^{16}=617.6\pm0.9$.
[d] From $D_2O^{16}-Ne^{20}=307.21\pm0.39$.
[e] From $H_2O^{16}-A^{36}/2=267.02\pm0.40$.
[f] Weighted average from $Ne^{20}-A^{40}/2=112.80\pm0.18$; $(C^{12})_3H^4-A^{40}=688.77\pm0.35$; $D_2O-A^{40}/2=419.67\pm0.18$.

The assistance of Walter H. Johnson and Ruth C. Boe in making the determinations is gratefully acknowledged. The construction of the apparatus used in this research was aided by grants from the Graduate School and the Minnesota Technical Research Fund subscribed to by General Mills, Inc., *Minneapolis Star* and *Tribune*, Minnesota Mining and Manufacturing Company, Northern States Power Company, and Minneapolis Honeywell Regulator Company.

* This work supported by joint program of the ONR and AEC.
[1] Preliminary reports on the apparatus and some results already have been given: Phys. Rev. **75**, 346 (1949); **77**, 746 (1950). A more complete report on the apparatus and measurements on 13 mass doublets will be found in a paper appearing elsewhere in this issue, Phys. Rev. **81**, 507 (1951).
[2] Except in Table I, probable errors given in this letter apply to the last significant figures in the values to which the probable errors are attached.
[3] F. W. Aston, Nature **138**, 1094 (1936); Proc. Roy. Soc. (London) **A163**, 391 (1937).
[4] T. Okuda and K. Ogata, Phys. Rev. **60**, 690 (1941).
[5] A. S. Penfold, Phys. Rev. **80**, 116 (1950).
[6] L. G. Smith, Phys. Rev. **81**, 295 (1951).
[7] T. R. Roberts, Phys. Rev. **81**, 624 (1951).

The H_2-D Mass Difference and the Determination of Secondary Atomic Mass Standards*

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December 6, 1950

THE physical table of isotopic weights is determined relative to O^{16}. As summarized by Tollestrup, Fowler, and Lauritsen[1] key light elements H, C^{12}, and N^{14} have not yet been compared directly with O^{16} by nuclear reactions and are dependent only upon mass doublet measurements. The low probable errors of Mattauch's and Jordan's fundamental doublets H_2-D, $C^{12}H_4-O^{16}$, and $D_3-C^{12}/2$ have weighted their data predominantly in the mass values recommended by Bainbridge,[2] and are shown in Table I.

TABLE I. Secondary atomic mass standards.

Isotope	Bainbridge report[a]	Present results
H	1.0081283 ±0.0000026	1.0081686 ±0.0000052
D	2.0147186 ±0.0000055	2.014785 ±0.000010
C^{12}	12.003856 ±0.000019	12.003803 ±0.000013
N^{14}	14.007536 ±0.000022	14.007544 ±0.000010
n	1.0089383 ±0.0000057	1.0090087 ±0.0000056

[a] See reference 2.