as the current level increased. Third, quenching phenomena were evident and were characteristic of CdS photoconduction.[3] Finally, atomic hydrogen destroyed the effects, presumably because the surface conductivity was increased by reduction of the CdS.

One expects other phenomena that are absent in metals to play a role in this kind of emission. Barrier layers are present. It is conceivable that a Zener type of breakdown may occur in a p-type semiconductor when emission is drawn from it. Further evaluation of these possibilities can perhaps best await theoretical treatment of field emission under these unusual conditions.

We are indebted to Malcolm H. Hebb and John K. Bragg for many interesting discussions

[3] E. Taft and M. H. Hebb, J. Opt. Soc. Am. 42, 249 (1952).

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Nuclear Mass Determinations from Disintegration Energies: Oxygen to Sulfur

C. W. Li
Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California
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Values of the atomic masses from O^{18} to S^{33} have been derived from the Q-values of nuclear reactions with a procedure of statistical adjustment. Tables are given of the most probable Q-values and the atomic masses. In combination with a previous calculation, they give a set of consistent mass values from n^1 to S^{33}, based on nuclear disintegration energies.

In a previous calculation[1] the atomic masses from n^1 to F^{20} relative to $O^{16}=16.000\,000$ have been derived from the Q-values of nuclear reactions. Following a similar procedure, the atomic masses from $A=17$ to 33 are derived in the present work from recently available Q-value measurements.

Table I lists the Q-values used in deriving the masses. In most of these measurements, electrostatic or magnetic analysis has been used to determine the energy of the incident particles and emitted particles: electrons, heavy particles, or pairs or converted electrons produced by gamma-rays. In some cases, reaction thresholds or radiative capture transition energies of thermal neutrons have been involved. Except in a few reactions, there is yet only one accurate measurement for each reaction. Fortunately, enough cross checks have been established to provide a test on the internal consistency of the data. In this calculation 46 reactions have been used to determine the masses of 29 nuclei. The extensive magnetic analysis work by W. W. Buechner's group at the Massachusetts Institute of Technology accounts for almost half of the reactions listed in Table I. Three connections between the heretofore very loosely linked Ne and F isotopes have been furnished by recent measurements: $F^{20}(\beta^-)Ne^{20}$, $Ne^{20}(d,\alpha)F^{18}$, and $Ne^{21}(d,\alpha)F^{19}$. The second one is a range measurement in photographic emulsion. However, in view of its accuracy and its consistency with other data, it has been included, in contrast to the practice in I. This is the only range measurement which is used in these calculations. Another difference from I is that measurements with reported errors up to 40 kev have been included, instead of the earlier limit of 30 kev. The error of the heavier of the resultant masses turns out to be of the order of 40 kev.

Figure 1 illustrates graphically the interconnections between the nuclei which are of interest in this discussion. The solid lines represent reactions forming nuclear cycles. As in I, these cycles are useful in that (1) they give values of certain fundamental mass differences (or zero); (2) these fundamental mass differences can serve as tests of internal consistency of the nuclear data; and (3) they can be used to make regional least-squares adjustment of the experimental Q-values and thereby to obtain the values of masses which are numerically consistent and, presumably, have some improved precision. The improvement in precision is a possible result of the adjustment of overdetermined but statistically consistent data.

Table II exhibits the simplest set of independent nuclear cycles in the region of interest in the present discussion. It can be seen that, while the general precision is somewhat inferior to that of reactions in I, the present data are statistically consistent and the values of fundamental mass differences computed from them are consistent with those derived from I, namely, $n-H^1=0.7823\pm0.001$ Mev, $n+H^1-H^2=2.225\pm0.002$ Mev, and $2H^2-He^4=23.834\pm0.007$ Mev. An exception is the fourth cycle in Group 4 of Table II. This cycle gives a value for $2H^2-He^4$ which is inconsistent with the other values for $2H^2-He^4$, the discrepancy being many times the average error of the other cycles. Therefore we have omitted this cycle in the adjustment of the Q-values. In order to calculate the masses of Ne^{22} and Ne^{23} we have adopted the (d,p) reaction Q-values without adjustment and have omitted the beta-

[1] Li, Whaling, Fowler, and Lauritsen, Phys. Rev. 83, 512 (1951) (referred to as I).

TABLE I. Nuclear reaction energies used in evaluating masses.

Reaction	Experimental Q-value (Mev)	Weighted mean of experimental Q (Mev)	Adjusted value of Q (Mev)	Reference*
[a]$Li^7(t,\alpha)He^6$	9.79 ±0.03		(unadjustable)	De 52
$O^{16}(d,n)F^{17}$†	−1.631 ±0.003		−1.631 ±0.003	Bo 51
$O^{18}(p,n)F^{18}$†	−2.453 ±0.004		−2.453 ±0.004	Ri 50p
$O^{18}(p,\alpha)N^{15}$	3.96 ±0.04		3.969 ±0.023	Se 51
$F^{17}(\beta^+)O^{17}$	2.742 ±0.03		2.767 ±0.006	Pe 50
$F^{18}(\beta^+)O^{18}$†	1.657 ±0.015	1.667 ±0.008	1.671 ±0.004	Bl 49a
	1.671 ±0.009			Ru 51
$F^{19}(n,\gamma)F^{20}$	6.63 ±0.03		6.600 ±0.007	Ki 51
$F^{19}(p,n)Ne^{19}$	−4.039 ±0.005		−4.038 ±0.005	Wi 52
$F^{19}(d,p)F^{20}$†	4.373 ±0.007		4.375 ±0.007	St 51
$F^{20}(\beta^-)Ne^{20}$	7.038 ±0.018		7.052 ±0.012	Al 52
$Ne^{19}(\beta^+)F^{19}$	3.202 ±0.03		3.256 ±0.005	Sc 52
$Ne^{20}(d,p)Ne^{21}$	4.529 ±0.007		4.530 ±0.006	Va 52
$Ne^{20}(d,\alpha)F^{18}$	2.78 ±0.02		2.781 ±0.018	Mi 51
$Ne^{21}(d,p)Ne^{22}$	8.137 ±0.011		(unadjustable)	Mi 52
$Ne^{21}(d,\alpha)F^{19}$	6.432 ±0.010		6.434 ±0.009	Mi 52
$Ne^{22}(d,p)Ne^{23}$	2.964 ±0.007		(unadjustable)	Va 52
$Na^{21}(\beta^+)Ne^{21}$	3.522 ±0.03		(unadjustable)	Sc 52
$Na^{22}(\beta^+)Ne^{22}$	2.841 ±0.006		(unadjustable)	Al 49, Ma 50
$Na^{23}(p,n)Mg^{23}$	−4.877 ±0.010		(unadjustable)	Wi 52a
$Na^{23}(p,\alpha)Ne^{20}$	2.372 ±0.008		2.372 ±0.007	Va 52
$Na^{23}(d,p)Na^{24}$	4.731 ±0.009	4.727 ±0.006	4.730 ±0.006	St 51
	4.723 ±0.008			Mi 52
$Na^{23}(d,\alpha)Ne^{21}$	6.902 ±0.010		6.902 ±0.007	St 51
$Na^{24}(\beta^-)Mg^{24}$	5.526 ±0.008[b]		5.531 ±0.007	Si 46, Wo 50
$Mg^{24}(d,p)Mg^{25}$	5.097 ±0.007		5.099 ±0.006	Va 52
$Mg^{25}(d,p)Mg^{26}$	8.880 ±0.012		(unadjustable)	Va 52
$Mg^{25}(d,\alpha)Na^{23}$	7.019 ±0.013		7.031 ±0.010	Va 52
$Mg^{26}(d,p)Mg^{27}$	4.207 ±0.006		(unadjustable)	Va 52
$Al^{27}(n,\gamma)Al^{28}$	7.724 ±0.010		7.722 ±0.007	Ki 51
$Al^{27}(p,\alpha)Mg^{24}$	1.585 ±0.015	1.593 ±0.006	1.594 ±0.005	Fr 50
	1.595 ±0.007			Va 52
$Al^{27}(d,p)Al^{28}$	5.494 ±0.010		5.497 ±0.007	En 51
$Al^{27}(d,\alpha)Mg^{25}$	6.694 ±0.010		6.693 ±0.007	En 51
$Al^{28}(\beta^-)Si^{28}$	4.647 ±0.014		4.650 ±0.011	Mo 52a
$Si^{28}(n,\gamma)Si^{29}$	8.51 ±0.04		8.472 ±0.008	Ki 51
$Si^{28}(d,p)Si^{29}$	6.246 ±0.008		6.247 ±0.007	St 51
$Si^{29}(d,p)Si^{30}$	8.388 ±0.013		8.386 ±0.010	Va 52
$Si^{29}(d,\alpha)Al^{27}$	5.994 ±0.011		5.997 ±0.010	Va 52
$Si^{30}(d,p)Si^{31}$	4.364 ±0.007		4.367 ±0.007	Va 52
$Si^{30}(d,\alpha)Al^{28}$	3.120 ±0.010		3.108 ±0.009	St 51
$Si^{31}(\beta^-)P^{31}$	1.486 ±0.012	1.476 ±0.007	1.480 ±0.007	Wa 52
	1.471 ±0.008			Mo 52
$P^{31}(n,\gamma)P^{32}$	7.94 ±0.03		7.930 ±0.008	Ki 52
$P^{31}(d,p)P^{32}$	5.704 ±0.008		5.705 ±0.008	Va 52
$P^{31}(p,\alpha)Si^{28}$	1.909 ±0.010		1.911 ±0.008	Va 52
$P^{31}(d,\alpha)Si^{29}$	8.158 ±0.011		8.158 ±0.008	Va 52
$P^{32}(\beta^-)S^{32}$	1.712 ±0.008	1.707 ±0.004	(unadjustable)	Si 46
	1.689 ±0.01			La 49
	1.718 ±0.01			Ag 50
	1.708 ±0.008			Wa 50
	1.704 ±0.008			Je 52
$P^{33}(\beta^-)S^{33}$	0.26 ±0.02	0.265 ±0.014	(unadjustable)	Je 52
	0.27 ±0.02			Sh 51
$S^{32}(n,\gamma)S^{33}$	8.64 ±0.02		8.645 ±0.010	Ki 52
$S^{32}(d,p)S^{33}$	6.422 ±0.011		6.420 ±0.010	St 51

[a] See text, p. 000.
† Occurred in *I*. The value has been changed here.
[b] Error assigned.

* References:
Ag 50 H. M. Agnew, Phys. Rev. **77**, 655 (1950).
Al 49 D. E. Alburger, Phys. Rev. **76**, 435 (1949).
Al 52 D. E. Alburger (to be published).
Bl 49a Blaser, Boehm, and Marmier, Phys. Rev. **75**, 1953 (1949).
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En 51 Enge, Buechner, Sperduto, and Van Patter, Phys. Rev. **83**, 31 (1951).
Fr 50 J. M. Freeman, Proc. Phys. Soc. (London) **A63**, 668 (1950).
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Pe 50 V. Perez-Mendez and P. Lindenfeld, Phys. Rev. **80**, 1097 (1950).
Ri 50p Richards, Smith, and Browne, Phys. Rev. **80**, 524 (1950).
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Sh 51 Sheline, Holtzman, and Fan, Phys. Rev. **83**, 919 (1951).
Si 46 K. Siegbahn, Phys. Rev. **70**, 127 (1946).
St 51 Strait, Van Patter, Buechner, and Sperduto, Phys. Rev. **81**, 747 (1951).
Va 52 Van Patter, Sperduto, Endt, Buechner, and Enge, Phys. Rev. **85** 142 (1952).
Wa 50 Warshaw, Chen, and Appleton, Phys. Rev. **80**, 288 (1950).
Wa 52 A. H. Wapstra, Phys. Rev. **86**, 562 (1952).

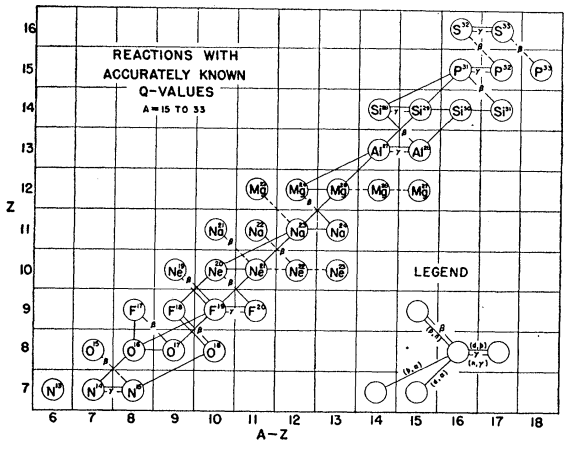

FIG. 1. The nuclear reactions with accurately known Q-values are represented on this chart by lines connecting target nucleus and residual nucleus. Solid lines: Q-values which form cycles, adjustable; dashed lines: unadjustable Q-values.

measurement, believing that the latter is more susceptible to error.

At first thought, it would seem that the next step should be to calculate the values of the fundamental mass differences from the present data alone or, better, from all data from S^{33} down to n^1. In view of the lower precision of the present data, the first alternative would not be so reliable and the second alternative, after considerably more work, would give essentially the same results as those given by I. Therefore, we have instead used the values of fundamental mass differences from I to adjust the present data.

The assumptions or approximations regarding the input data and the procedure of adjustment are exactly the same as those discussed in I. The adjusted values are listed in column 4 of Table I. Among the 37 adjustable reactions, there are two adjustments which are outside the respective reported errors. The adjustments are slightly on the positive side, i.e., there are more Q's whose absolute values have been increased than Q's whose absolute values have been decreased.

The adjusted Q-values and unadjustable ones (indicated by dashed lines in Fig. 1) were then combined with the fundamental mass differences and the adjusted data from I to yield the atomic masses listed in Table III. In all cases the Q-values were taken as the difference in atomic masses (not nuclear) on the two sides of a nuclear reaction equation. This is believed to be a very good approximation for reactions involving nuclei with $A \gtrsim 16$. The errors quoted are determined by a Gaussian compounding of the errors in the Q-values entering into the evaluation of each mass. Together with I, the present work gives a consistent set of masses from n^1 to S^{33}, based on nuclear data.[2]

[2] See also H. A. Wilson, Phys. Rev. **84**, 836 (1951).

Wi 52 Willard, Bair, Kington, Hahn, Snyder, and Green, Phys. Rev. **85**, 849 (1952).
Wi 52a Willard, Kington, and Bair, Phys. Rev. **86**, 259 (1952).
Wo 50 J. L. Wolfson, Phys. Rev. **78**, 176 (1950).

TABLE II. Nuclear cycles and fundamental mass differences.

Cycle	Mass difference from experimental Q (Mev)
Group 1. Nuclear cycles giving a sum of zero.	
$Na^{23}(d,\alpha)Ne^{21}$, $Ne^{20}(d,p)Ne^{21}$, $Na^{23}(p,\alpha)Ne^{20}$	0.001±0.015
$Al^{27}(d,\alpha)Mg^{25}$, $Mg^{24}(d,p)Mg^{25}$, $Al^{27}(p,\alpha)Mg^{24}$	0.004±0.014
$P^{31}(d,\alpha)Si^{29}$, $Si^{28}(d,p)Si^{29}$, $P^{31}(p,\alpha)Si^{28}$	0.003±0.017
$Si^{30}(d,\alpha)Al^{28}$, $Al^{27}(d,p)Al^{28}$, $Si^{29}(d,\alpha)Al^{27}$, $Si^{29}(d,p)Si^{30}$	0.020±0.022
Group 2. Nuclear cycles giving $n-H^1$.	
$O^{18}(p,n)F^{18}$, $F^{18}(\beta^+)O^{18}$	0.786 ±0.009
$F^{19}(p,n)Ne^{19}$, $Ne^{19}(\beta^+)F^{19}$	0.837 ±0.030
$O^{16}(d,p)O^{17}$, $O^{16}(d,n)F^{17}$, $F^{17}(\beta^+)O^{17}$	0.806 ±0.024
From I	*0.7823±0.001*
Group 3. Nuclear cycles giving $n+H^1-H^2$.	
$F^{19}(d,p)F^{20}$, $F^{19}(n,\gamma)F^{20}$	2.257±0.031
$Al^{27}(d,p)Al^{28}$, $Al^{27}(n,\gamma)Al^{28}$	2.230±0.014
$Si^{28}(d,p)Si^{29}$, $Si^{28}(n,\gamma)Si^{29}$	2.264±0.041
$P^{31}(d,p)P^{23}$, $P^{31}(n,\gamma)P^{32}$	2.236±0.031
$S^{32}(d,p)S^{33}$, $S^{32}(n,\gamma)S^{33}$	2.218±0.023
From I	*2.225±0.002*
Group 4. Nuclear cycles giving $2H^2-He^4$.	
$Ne^{20}(d,p)Ne^{21}$, $Ne^{21}(d,\alpha)F^{19}$, $F^{19}(d,p)F^{20}$, $F^{20}(\beta^-)Ne^{20}$, with $2H^1-H^2$ [a]	23.815±0.023
$Mg^{24}(d,p)Mg^{25}$, $Mg^{25}(d,\alpha)Na^{23}$, $Na^{23}(d,p)Na^{24}$, $Na^{24}(\beta^-)Mg^{24}$, with $2H^1-H^2$ [a]	23.812±0.018
$Si^{28}(d,p)Si^{29}$, $Si^{29}(d,\alpha)Al^{27}$, $Al^{27}(n,\gamma)Al^{28}$, $Al^{28}(\beta^-)Si^{28}$, with $n-H^1$ [a]	23.829±0.022
$Na^{23}(d,\alpha)Ne^{21}$, $Ne^{21}(d,p)Ne^{22}$, $Ne^{22}(d,p)Ne^{23}$, $Ne^{23}(\beta^-)Na^{23}$, with $2H^1-H^2$ [a]	23.656±0.025[c]
$P^{31}(d,\alpha)Si^{29}$, $Si^{29}(d,p)Si^{30}$, $Si^{30}(d,p)Si^{31}$, $Si^{31}(\beta^-)P^{31}$, with $2H^1-H^2$ [a]	23.829±0.020
$F^{19}(p,\alpha)O^{16}$,[b] $O^{16}(d,\alpha)N^{14}$,[b] $N^{14}(d,p)N^{15}$,[b] $O^{18}(p,\alpha)N^{15}$, $O^{18}(p,n)F^{18}$, $Ne^{20}(d,\alpha)F^{18}$, $Ne^{20}(d,p)Ne^{21}$, $Ne^{21}(d,\alpha)F^{19}$, with $n+H^1-H^2$ [a]	23.841±0.048
From I	*23.834±0.007*

[a] $n-H^1=0.7823\pm0.001$ Mev, $n+H^1-H^2=2.225\pm0.002$ Mev, $2H^1-H^2=(n+H^1-H^2)-(n-H^1)=1.443\pm0.002$ Mev; from I.
[b] From I, adjusted values.
[c] This cycle has not been included in the adjustment. $Ne^{23}(\beta^-)Na^{23}=4.21\pm0.015$ Mev, H. Brown and V. Perez-Mendez, Phys. Rev. **78**, 812 (1950).

The masses F^{17} and F^{20} have been recalculated in the present work. Since the calculation of I, many new Q measurements pertinent to the masses from $A=1$ to 16 have been made, in different laboratories. No essential discrepancy has appeared except in the case of He^6, which was connected to Li^6 by an unadjustable beta-measurement. Using the new measurement $Li^7(t,\alpha)He^6=9.79\pm0.03$ Mev[3] and the adjusted data of I, the atomic mass of He^6 becomes 6.020 833 (±39), and the He^6-Li^6 mass difference becomes 3.549±0.032 Mev.

DISCUSSION: COMPARISON WITH MASS SPECTROMETRIC DETERMINATIONS

Table IV gives a comparison between the mass values from nuclear data and the recent mass spectrometric values by Nier[4] and by Ewald.[5] The nuclear data include both those in I and those in the present calculation. The differences between the mass spectrometric values and the corresponding nuclear values, Δ, are listed following the mass spectrometric values. Nier's values are consistently larger than the nuclear values. The disagreement is 3 to 2 times the sum of probable errors for the lighter nuclei. Nier's values for Ne^{20} and S^{32} agree with the nuclear values within the sum of probable errors. Ewald's values differ from nuclear values randomly. The agreement with the nuclear values is excellent for the lighter nuclei. His value for N^{15} [based on his 1946 measurement of the CH_3-N^{15} doublet[5,6]] is larger than the nuclear value by twice the sum of probable errors, and his value for Ne^{21} is smaller by two and one-half times the sum of probable errors. His values for P^{31} and S^{32} are both larger than the nuclear values, while his value for Si^{28} is close to

TABLE III. Table of atomic masses.

	A, mass number	$M-A$, mass defect (Mev)	M, atomic mass from nuclear data (amu)[a]
He†	6	19.399±0.036	6.020 833 (±39)
O	18	4.522±0.022	18.004 857 (±23)
F†	17	6.988±0.005	17.007 505 (±5)
F	18	6.193±0.021	18.006 651 (±22)
F†	20	5.913±0.016	20.006 350 (±17)
Ne	19	7.405±0.014	19.007 952 (±15)
Ne	20	−1.139±0.019	19.998 777 (±21)
Ne	21	0.469±0.021	21.000 504 (±22)
Ne	22	−1.529±0.023	21.998 358 (±25)
Ne	23	1.646±0.023	23.001 768 (±26)
Na	21	3.991±0.037	21.004 286 (±39)
Na	22	1.312±0.023	22.001 409 (±25)
Na	23	−2.742±0.023	22.997 055 (±25)
Na	24	−1.333±0.024	23.998 568 (±26)
Mg	23	1.353±0.024	23.001 453 (±26)
Mg	24	−6.864±0.024	23.992 628 (±26)
Mg	25	−5.824±0.025	24.993 745 (±27)
Mg	26	−8.565±0.027	25.990 802 (±29)
Mg	27	−8.633±0.028	26.992 876 (±30)
Al	27	−9.245±0.028	26.990 071 (±30)
Al	28	−8.603±0.030	27.990 760 (±32)
Si	28	−13.253±0.030	27.985 767 (±32)
Si	29	−13.362±0.032	28.985 650 (±34)
Si	30	−15.609±0.034	29.983 237 (±36)
Si	31	−13.837±0.036	30.985 140 (±39)
P	31	−15.317±0.036	30.983 550 (±39)
P	32	−14.883±0.038	31.984 016 (±41)
P	33	−16.606±0.042	32.982 166 (±44)
S	32	−16.590±0.039	31.982 183 (±42)
S	33	−16.871±0.041	32.981 881 (±44)

† Occurred in I. The value has been changed here.
[a] 1 amu = 931.152 Mev.

[3] See reference De 52 of Table I.

[4] A. O. Nier, Phys. Rev. **81**, 624 (1951).
[5] H. Ewald, Z. Naturforsch. **6a**, 293 (1951).
[6] H. Ewald, Z. Naturforsch. **1**, 136 (1946).

the nuclear value. This discrepancy has already been pointed out by Wapstra[7] with the $P^{31}-Si^{28}$ mass difference computed from nuclear data.

Direct comparison of the mass values between nuclear data and mass spectrometric data is superficial, because neither is the primary experimental data. Nuclear values are calculated from disintegration energies as already discussed, and mass spectrometric values are calculated from mass doublet measurements. In most precision mass spectrometric measurements a system of three easily accessible secondary standards, namely, H^1, H^2, and C^{12}, has been used, relating to the main standard $O^{16}=16.000\,000$. The three fundamental mass doublets $2H^1-H^2$, $3H^2-\frac{1}{2}C^{12}$, and $C^{12}H_4{}^1-O^{16}$, which form a closed ring, are usually used to obtain these secondary standards.[8] A fourth secondary standard is S^{32}, which can be linked to O^{16} directly by the doublet $(O^{16})_2-S^{32}$. Nier[4] has used, in addition, a closed ring containing H^1, C^{12}, S^{32}, and O^{16} to obtain these secondary standards, and thus provided an independent check on the values of these secondary standards. After the determination of these secondary standards, especially H^1, H^2, and C^{12}, they are then considered as established anchor points for computing mass values from other doublets.

Table V gives a comparison between the values of mass doublets as computed from nuclear data and those directly determined in recent mass spectroscopy. Among the fundamental doublets containing the secondary standards, $2H^1-H^2$ is in very good agreement. The doublet $2H^2-He^4$, also one of the fundamental mass differences used in evaluating masses from nuclear data, is essentially in agreement, though it should be further improved. The doublet $(O^{16})_2-S^{32}$ determines the mass of S^{32} directly. The old discrepancy[9–11] of 1 Mev in the mass of S^{32} is removed now, and all data come into agreement by the order of 100 kev. Not listed in Table V, the doublet $(O^{16})_2-S^{32}$ was measured by Aston[9] to be 17.7±0.3 mMU, by Okuta and Ogata[10] to be 19.15±0.11 mMU, and also the doublet $C^{12}(O^{16})_2-C^{12}S^{32}$ was measured by Okuta and Ogata to be 18.94±0.23 mMU; the latter two averaged to 19.11±0.07 mMU.[12] With the new "synchrometer" time-of-flight mass spectrometer, Smith[13] reported a measurement of the mass of S^{32}, representing a doublet value of 17.7±1.0 mMU; later, Hays, Richards, and Goudsmit's measurement[14] represents a doublet value of 17±1 mMU. The nuclear value is higher than all but one of the other measurements, though essentially in agreement with Nier's and several other values. The doublet containing Si^{28} is in good agreement. The doublet containing Al^{27}, heretofore used for the determination of the mass of Al^{27}, shows a large change.

No further analysis of either nuclear data or mass spectrometric data has been attempted here. New independent measurements on both nuclear reaction energies, especially many beta-decay energies, and mass spectrographic doublets would be very desirable. Though present technique does not yet permit the measurement of $n-H^1$ by the mass spectrometer, doublet measurements with radioactive nuclei, like He^3,[15] Be^7, and C^{14}, would be very interesting and of great theoretical importance. Also the fundamental mass difference $2H^2-H^1H^3$ should be measured directly

For convenience of reference, a portion of the table of atomic masses in *I* is reproduced here.

	A, mass number	*M*−*A*, mass defect (Mev)	*M*, atomic mass from nuclear data (amu)
n	1	8.3638±0.0029	1.008 982 (±3)
H	1	7.5815±0.0027	1.008 142 (±3)
H	2	13.7203±0.006	2.014 735 (±6)
He	4	3.6066±0.014	4.003 873 (±15)

TABLE IV. Comparison of masses from nuclear data and from mass spectrograph measurements.

		Nuclear data	Nier (1951)[a]	Δ×10⁶	Ewald (1951)[b]	Δ×10⁶
H	1	1.008 142 (±3)	1.008 165 (±4)	+23	1.008 141 (±2)	−1
H	2	2.014 735 (±6)	2.014 778 (±8)	+43	2.014 732 (±4)	−3
He	4	4.003 873 (±15)	4.003 944 (±19)	+71	4.003 860 (±12)	−13
C	12	12.003 804 (±17)	12.003 842 (±6)	+38	12.003 807 (±11)	+3
N	14	14.007 515 (±11)	14.007 564 (±7)	+49	14.007 525 (±15)	+10
N	15	15.004 863 (±12)			15.004 928 (±20)	+65
O	17	17.004 533 (±7)			17.004 507 (±15)	−26
O	18	18.004 857 (±23)			18.004 875 (±13)	+18
F	19	19.004 456 (±15)			19.004 414 (±17)	−42
Ne	20	19.998 777 (±21)	19.998 835 (±43)	+58	19.998 771 (±12)	−6
Ne	21	21.000 504 (±22)			21.000 393 (±22)	−111
Ne	22	21.998 358 (±25)			21.998 329 (±19)	−29
Si	28	27.985 767 (±32)			27.985 792 (±32)	+25
P	31	30.983 550 (±39)			30.983 622 (±23)	+72
S	32	31.982 183 (±42)	31.982 218 (±25)	+35	31.982 272 (±19)	+89

[a] See reference 4.
[b] See reference 5.

[7] A. H. Wapstra, Phys. Rev. **86**, 561 (1952).
[8] For example, J. Mattauch and S. W. Flügge, *Nuclear Physics Tables* (Interscience Publishers, Inc., New York, 1946), p. 9.
[9] G. H. Aston, Proc. Roy. Soc. (London) **A163**, 391 (1937).
[10] T. Okuta and K. Ogata, Phys. Rev. **60**, 690 (1941).
[11] L. Penfold, Phys. Rev. **80**, 116 (1950); H. T. Motz, Phys. Rev. **81**, 1060 (1951).
[12] This value has been used to give the S^{32} mass in most compilations in recent years.
[13] L. G. Smith, Phys. Rev. **81**, 295 (1951).
[14] Hays, Richards, and Goudsmit, Phys. Rev. **84**, 824 (1951).
[15] Planned by Professor K. T. Bainbridge (private communication).

TABLE V. Mass spectrographic doublets.

	Computed from nuclear data (mMU)[a]	Nier and Roberts[b]	Δ (mMU)	Ewald[c]	Δ (mMU)	Others	Δ (mMU)
$2H^1-H^2$	1.5494±0.0024	1.5519±0.0017	+0.0025	1.5503±0.0015	+0.0009		
$2H^2-He^4$	25.596±0.008	25.612±0.009	+0.016	25.604±0.009	+0.008		
$3H^2-\frac{1}{2}C^{12}$	42.302±0.016			42.292±0.012	−0.010		
$2[(H^2)_2O^{16}-\frac{1}{2}A^{40}]$ $-[(C^{12})_3(H^1)_4-A^{40}]$	14.958±0.033	15.057±0.050	+0.099				
$C^{12}(H^1)_4-O^{16}$	36.372±0.019	36.478±0.022	+0.106	36.371±0.012	−0.001	36.443±0.005[d]	+0.071
$(C^{12})_2(H^1)_4-C^{12}O^{16}$		36.443±0.022	+0.071			36.451±0.006[d]	+0.079
$\frac{1}{2}[(C^{12})_3(H^1)_8-C^{12}(O^{16})_2]$		36.484±0.020	+0.112				
$C^{12}(H^1)_2-N^{14}$	12.573±0.012	12.586±0.013	+0.013	12.564±0.010	−0.009	12.597±0.003[d]	+0.024
$(N^{14})_2-C^{12}O^{16}$	11.227±0.011	11.280±0.013	+0.053				
$(C^{12})_3(H^1)_8-(N^{14})_2O^{16}$	61.517±0.024	61.76±0.09	+0.24				
$C^{12}(H^1)_3-N^{15}$	23.367±0.011			23.302±0.015	−0.065	23.395±0.005[d]	+0.028
$(H^2)_2H^1O^{16}-(H^2)_2O^{17}$	3.610±0.005			3.634±0.015	+0.024		
$(H^2)_2O^{16}-(H^1)_2O^{18}$	8.329±0.026			8.312±0.012	−0.017		
$(H^2)_2O^{16}-F^{19}H^1$	16.872±0.011			16.909±0.015	+0.037		
$(H^2)_2O^{16}-Ne^{20}$	30.693±0.019	30.721±0.039	+0.028	30.688±0.010	−0.005		
$(H^1)_2O^{18}-Ne^{20}$	22.364±0.022			22.391±0.010	+0.027		
$(H^2)_2H^1O^{16}-Ne^{21}$	37.108±0.020			37.212±0.020	+0.104		
$(H^2)_3O^{16}-Ne^{22}$	45.847±0.024			45.867±0.015	+0.020		
$(C^{12})_2(H^1)_3-Al^{27}$	41.963±0.029					42.35±0.065[e]	+0.387
$C^{12}O^{16}-Si^{28}$	18.037±0.031			18.015±0.030	−0.022	18.06±0.08[f]	+0.02
$(C^{12})_2(H^1)_4-Si^{28}$	54.409±0.035					54.46±0.17[f]	+0.05
$C^{12}(H^1)_3-\frac{1}{2}Si^{30}$	36.612±0.019					36.795±0.075[f]	+0.18
$(O^{16})_2-P^{31}H^1$	8.308±0.039			8.249±0.030	−0.059		
$P^{31}H^1-S^{32}$ / $P^{31}(H^1)_3-S^{32}(H^1)_2$	9.509±0.010			9.504±0.020	−0.005		
$(O^{16})_2-S^{32}$	17.818±0.042			17.716±0.020	−0.102	17.63±0.10[f]	−0.19
$C^{12}(O^{16})_2-C^{12}S^{32}$		17.782±0.025	−0.036				
$(C^{12})_4-S^{32}O^{16}$	33.034±0.045	33.182±0.007	+0.148				
$(C^{12})_6(H^1)_4-C^{12}(S^{32})_2$	87.223±0.092	87.326±0.058	+0.103				
$(H^2)_2O^{16}-\frac{1}{2}A^{40}$		41.967±0.018		41.953±0.012			
$Ne^{20}-\frac{1}{2}A^{40}$		11.280±0.018					

[a] 1 amu = 931.152 Mev, J. W. M. DuMond and E. R. Cohen, Phys. Rev. **82**, 555 (1951).
[b] A. O. Nier and T. R. Roberts, Phys. Rev. **81**, 507 (1951); A. O. Nier, Phys. Rev. **81**, 624 (1951); T. R. Roberts, Phys. Rev. **81**, 624 (1951).
[c] H. Ewald, Z. Naturforsch. **6a**, 293 (1951); **5a**, 1 (1950); and **1**, 136 (1946).
[d] K. Ogata and H. Matsuda, Phys. Rev. **83**, 180 (1951).
[e] J. Mattauch and H. Ewald [see S. W. Flügge and J. Mattauch, Physik. Z. **44**, 181 (1943)].
[f] H. E. Duckworth and R. S. Preston, Phys. Rev. **79**, 188, and 402 (1950); and **81**, 268 (1951).

by mass spectrometer, as well as additional measurements on $2H^2-He^4$, to check the accuracy of nuclear data.

It is interesting to compare the present mass values with those in two of the recently most used tables.[16,17] Both tables are based on earlier mass spectrographic data for the main mass scale and use nuclear disintegration energies in an auxilliary way. For most of the masses listed in Table III of the present discussion, Bethe's table quotes errors of the order of 200 to 900 kev, while Wapstra's table[17] quotes errors of the order of 100 to 400 kev. In parallel with recent improvement in mass spectrometric measurements, the present mass values have errors of order of 20 to 40 kev, as an indication of the late improvement of nuclear reaction energy measurements. It is of interest to note that, compared with the present mass values, the number of nuclei whose masses have been changed by more than their respective listed errors in each of the two above-mentioned tables is very close to half of the number of nuclei so compared, just as the definition of "probable error" stipulates.

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[16] H. A. Bethe, *Elementary Nuclear Theory* (John Wiley and Sons, Inc., New York, 1947), p. 123.
[17] L. Rosenfeld, *Nuclear Forces, II* (Interscience Publishers, Inc., New York, 1949), p. 497.