correction to the measured 913–374 kev pair anisotropy was +0.011 and the final corrected result was 0.398±0.011. This is, within the experimental error, the same as the anisotropy for the 913–899 kev pair, and both numbers are consistent with 0.408 which is the calculated anisotropy of the first and second and the first and third gamma rays of the scheme $9(E5)4(E2)2(E2)0$.

The previous result[1] for the anisotropy of the 913–374 kev pair was 0.34±0.02 which is inconsistent with the above scheme. Efforts to find fault with this measurement have been unsuccessful. Revision of the correction for the contribution of the 913–899 kev pair to conform to the method used in the present experiment raises this result to 0.35±0.02 which is a trivial change. However, the present result is more precise and is consistent with the $9(E5)4(E2)2(E2)0$ scheme which explains the other anisotropy measurements and the internal conversion coefficients.[2] Hence, we feel justified in ignoring the previous measurement.

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Atomic Masses from C^{12} to Ne^{22}†

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Doublets leading to mass values of the stable isotopes from C^{12} to Ne^{22} have been measured with a double-focusing mass spectrometer. In the determination of C^{12}, two new cycles have been used, $(\frac{1}{2}C_4H_4O-O^{18}O)-(H_3O-HO^{18})$ and $(\frac{1}{2}C_4H_2O-O^{17}O)-(H_3O-H_2O^{17})$, resulting in the value $C^{12}=12.003814\pm6$ amu.

An analysis of the available data pertinent to the investigated mass region is presented in an effort to uncover specific measurements most likely responsible for the discrepancies in mass values reported from the various sources of investigation. It is found that a generally improved agreement is obtained if adjustments are made in the following reactions: $O^{18}(p,\alpha)N^{15}$, $F^{19}(d,\alpha)O^{17}$, $Ne^{21}(d,\alpha)F^{19}$, and $Ne^{20}(d,\alpha)F^{18}$.

INTRODUCTION

THIS paper presents the results of mass measurements of the stable isotopes from $A=12$ to 22 undertaken with a double-focusing mass spectrometer developed at the University of Minnesota. Among the light nuclides, the list of precise nuclear reaction energy measurements is extensive.[1] Upon such data, generally overdetermined, two different computations, the first by Li *et al.*[2] and Li,[3] the other by Wapstra,[4] have given closely similar results. Substantially less abundant are the data in the present mass region reported by mass spectroscopic investigators[5] who, except for Ewald[6] and Ogata and Matsuda,[7] have confined their measurements in this region to C^{12} and N^{14}. The randomness in the pattern of agreement or lack of it found on comparing Ewald's and Ogata's results with each other as well as with nuclear values (see Tables I and II) leaves inconclusiveness, to an extent greater than desirable, at most of these mass values. More disturbing has been the divergence in values reported for the mass spectroscopic secondary standard C^{12}, where the nuclear value is lower than any mass spectroscopic value.[5]

The need for more mass spectroscopic data is clearly indicated; in particular, since the errors associated with nuclear mass determinations are cumulative, it would appear that a critical comparison with nuclear data ought to be most sensitive in the vicinity of the O^{16} standard. Such a comparison will be presented in this report in an effort to indicate specific measurements considered most likely responsible for the major existing discrepancies.

THE INSTRUMENT

A schematic drawing of the present instrument is given in Fig. 1. The second of its kind constructed in this laboratory, it is essentially a duplicate of the mass-measuring spectrometer described in previous reports.[8–10] The only alteration in instrument design has

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[1] See review article by D. M. Van Patter and W. Whaling, Revs. Modern Phys. **26**, 402 (1954).

[2] Li, Whaling, Fowler, and Lauritsen, Phys. Rev. **83**, 512 (1951).

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[7] K. Ogata and H. Matsuda, Phys. Rev. **89**, 27 (1953).

[8] A. O. Nier and T. R. Roberts, Phys. Rev. **81**, 507 (1951).

[9] Collins, Nier, and Johnson, Phys. Rev. **84**, 717 (1951).

[10] A. O. Nier, National Bureau of Standards Circular 522 (U. S. Government Printing Office, Washington, D. C., 1953), p. 29.

TABLE I. Doublets measured.

Doublet	Source of ions	No. of runs	Present results	ΔM in mMU Ewald[a]	Ogata[b]
$\frac{1}{2}C_4H_2O-O^{17}O$	Furan (C_4H_4O), enriched O_2	14	11.224± 9		
$\frac{1}{2}C_4H_4O-O^{18}O$	enriched O_2	14	19.040±13		
$H_3O-H_2O^{17}$ [c]	enriched H_2O	14	3.601± 6	3.610± 5	
H_3O-HO^{18} [c]	enriched H_2O	14	11.405± 8	11.413±12	11.407±18
$C^{13}H_4-HO$[d]	CH_4, H_2O	6	31.943±11	31.875±16	31.931±13
$N^{14}H_3-HO$[d]	NH_3, H_2O	6	23.833± 8	23.807±16	23.833± 8
$N^{15}H_3-H_2O$	NH_3, H_2O	7	13.019± 5	13.063±23	13.038±10
$H_2O^{18}-HF$	HF, enriched H_2O	7	8.582± 2	8.587±19	
$H_2O^{18}-Ne^{20}$	Ne, enriched H_2O	7	22.392± 5	22.391±10[e]	22.401±21
$\frac{1}{2}C_2H_2O-Ne^{21}$	Acetaldehyde (C_2H_2O), Ne	7	11.429± 5		
$\frac{1}{2}CO_2-Ne^{22}$	Ne, CO_2	7	3.521±12	3.576±19	

[a] See reference 6.
[b] See reference 7.
[c] Run as triplet.
[d] Run as triplet.
[e] Value shown is for $H_2O^{18}-Ne^{20}$. From $(D_2O-Ne^{20})-(D_2O-H_2O^{18})$, one obtains 22.376±16 mMU.

been the conversion from dc to ac operation in the control tube ion beam detection, where the "feedback loop" sensing signal originates (see Fig. 1). The resulting improvement in spectrometer stabilization is about a factor of 2. The measured doublet peaks have a width at half-height of $\Delta M/M=1/11\,000$. The theoretical value based on slit widths alone and assuming perfect angular and energy focusing is 1/14 000.

In all other respects, the over-all instrument performance is found to be quite similar to the earlier spectrometer, for which discussion in reference 9 bearing on systematic errors, energetic ion fragments, testing procedures, etc., may be considered to apply to the present instrument as well.

MEASUREMENTS

The doublets measured are listed in Table I, where their values are compared with those obtained by Ewald and Ogata wherever the comparison can be made directly or in terms of equivalent sets involving no more than 2 doublet measurements.

The selection of doublets was governed by the following considerations: (1) that the C^{12} mass be independent of all but the O^{16} mass standard; thus $2C-\frac{3}{2}O=(\frac{1}{2}C_4H_4O-O^{18}O)-(H_3O-HO^{18})$ or $(\frac{1}{2}C_4H_2O-O^{17}O)-(H_3O-H_2O^{17})$;[11] (2) that the derived mass values depend only on an assumed value for H[12–14] or on the value of C^{12} determined from the unweighted average of the cycles in (1) above; (3) that the measured doublet

TABLE II. Masses from C^{12} to Ne^{22}.

		$M-A$ in μMU							
M	Present	Wapstra[a] (nuclear)	Δ	Li[b] (nuclear)	Δ	Ewald[c]	Δ	Ogata[d]	Δ
C^{12}	3814± 6[e]	3803± 5	−11	3804±17	−10	3807±11	−7	3844± 6	30
C^{13}	7511±11	7478± 5	−33	7473±14	−38			7505±12	−6
N^{14}	7545± 8	7520± 3	−25	7515±11	−30	7525±15	−20	7550± 5	5
N^{15}	4875± 5	4862± 5	−13	4863±12	−12	4928±65	53	4902± 9	27
O^{17}	4542± 6	4534± 5	−8	4533± 7	−9	4507±15	−35		
O^{18}	4883± 8	4855± 8	−28	4857±23	−26	4875±13	−8	4833±20	0
F^{19}	4445± 8	4448± 7	3	4456±15	11	4414±17	−31	4444±22	−1
Ne^{20}	−1221± 9	−1231± 9	−10	−1223±21	−2	−1229±12	−8	−1228±13	−7
Ne^{21}	529± 8	499±10	−30	504±22	−25	393±22	−136		
Ne^{22}	−1614±12	−1646±12	−32	−1642±25	−28	−1671±19	−57	−1618±24	−4

[a] See reference 4.
[b] See references 2, 3.
[c] See reference 6.
[d] See reference 7.
[e] The unweighted average of 3811±5 and 3817±7 μMU obtained from the C^{12} cycles $(\frac{1}{2}C_4H_2O-O^{17}O)-(H_3O-H_2O^{17})$ and $(\frac{1}{2}C_4H_4O-O^{18}O)-(H_3O-HO^{18})$, respectively.

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[11] Other C^{12} cycles investigated but not included in this report: (1) $(\frac{1}{2}C_4H_4O-H_2S)-(O_2-S)$; $O^{18}O$ impurity suspected. (2) C_4-O_3; feeble but measurable O_3^+ ions observed from O_2. Unable to resolve CH_4S^+ impurity peak from C_4^+ peak. This impurity believed to be responsible for high C^{12} value previously reported[9] by this laboratory. (3) $\frac{1}{2}C_4H_4O-H_2O_2$; preliminary investigation indicates availability of $H_2O_2^+$ ions from H_2O_2 using modified gas inlet system.

[12] Assumed value: H=1.008144±1 amu, based on values obtained by Li *et al.*,[2] Wapstra,[4] Mattauch and Bieri,[13] Quisenberry, Scolman, and Nier.[14]

[13] J. Mattauch and R. Bieri, Z. Naturforsch. **9a**, 303 (1954).

[14] Quisenberry, Scolman, and Nier, following paper [Phys. Rev. **102**, 1071 (1956)].

ions be molecular or molecular fragments comprising most of the parent-molecule mass (to minimize errors due to slight deviation from perfect adjustment of the energy focus).

Throughout the investigation, frequent tests were made for possible sources of systematic error that could arise from polarization of electrostatic analyzer plates, nonohmic leakage currents by-passing a portion of the calibrated resistance network and excessive source pressures. Doublet peaks were matched in intensity except for the $N^{15}H_3-H_2O$ doublet in which the $N^{15}H_3/H_2O$ intensity ratio was about 1%. Runs of a given doublet set were made as independent of each other as possible by alternating the runs of several doublet sets. The energy focus was checked and adjusted before every run. Appropriate corrections have been applied for partially unresolved "close" doublets and for associated isotopic impurity peaks containing C^{13} and D.

The assigned doublet values are the unweighted averages of the set of runs. The associated error is the square root of the sum of the squares of (a) the standard error of the mean associated with the unweighted average of the set of runs (b) a fixed error of 2 parts in 10 000 of the doublet mass difference (resistance network calibration and variation, leakage currents) and (c) if any unresolved peaks are present, 5% of the correction needed to remove their effects.

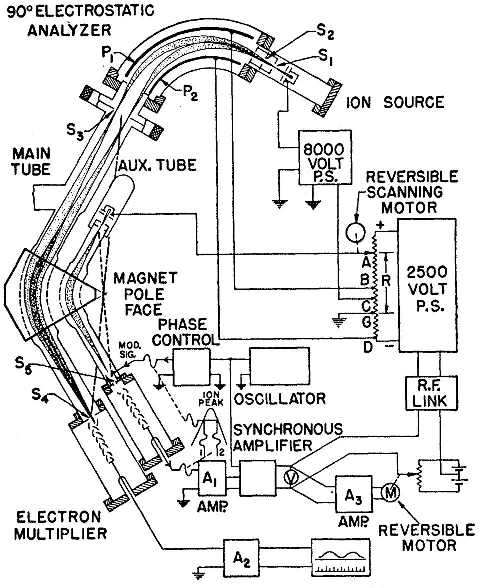

FIG. 1. Schematic drawing of mass spectrometer tubes showing action of regulation circuit. The control-tube ion beam is modulated by applying a 5000-cps signal from the oscillator to a set of parallel plates mounted in front of the collector slit S_5. Depending on whether the ion beam is to one side of the collector slit or the other, one of two opposite phases, shown as 1 and 2, is generated. The synchronous amplifier consists of a double-channel ac amplifier followed by a rectification unit whose dc output is proportional to the arithmetic average of the signals in each channel. A phase-inverting stage and a signal-mixer stage provide for identical-magnitude signal injection in the two channels of the modulated signal and a reference signal from the oscillator. The dc output is proportional to the magnitude of the modulation signal and its sign is determined by the phase, which is adjusted to give the desired stabilizing feedback action. The remaining components function as previously described.[9,10]

TABLE III. Experimental reaction energies pertinent to the present investigation taken from Wapstra.[a]

No.[b]	Reaction	Q in kev[b]
12.*a*	$C^{12}(d,p)C^{13}$	*2719±2*$_2$ 2717±5*M* 2718±3*B* 2722±4*H*
12.*b*	$C^{12}(n,\gamma)C^{13}$	4949±6
13.*a*	$C^{13}(d,t)C^{12}$	*1311±3* 1311±6*M* 1311±3*P*
14.1	$N^{14}(d,p)N^{15}$	*8618±7* 8618±9*M* 8618±11*P*
14.2	$N^{14}(n,\gamma)N^{15}$	10 832±6
15.*a*	$N^{15}(p,\alpha)C^{12}$	*4961±3* 4962±7*M* 4963±6*P* 4959±4*B*
16.1′	$O^{16}(d,\alpha)N^{14}$	*3116±2*$_6$ 3113±6*M* 3115±4*W* 3119±5*H*
16.*a*	$O^{16}(d,p)O^{17}$	*1918±4* 1918±5*M* 1918±8*H*
17.*A*	$O^{17}(d,p)O^{18}$	5824±10*S*
17.*B*	$O^{17}(d,\alpha)N^{15}$	9812±12*S*
18.1′	$O^{18}(p,\alpha)N^{15}$	3969±9*S*
18.*a*	$O^{18}(p,n)F^{18}$	−*2455±4* −2455±4
18.*b*	$(F^{18}(\beta^+)O^{18})$	−2454±9
19.*a*	$F^{19}(p,\alpha)O^{16}$	*8117±8* 8121±9*M* 8110±14*P* 8112±11
19.*b*	$F^{19}(d,\alpha)O^{17}$	10 054±10*M*
19.1	$F^{19}(d,p)F^{20}$	4375±7*M*
19.*A*	$F^{19}(\alpha,p)Ne^{22}$	1674±11*M*
20.*a*	$Ne^{20}(d,\alpha)F^{18}$	2792±9*S*
20.*b*	$F^{20}(\beta^-)Ne^{20}$	*7046±9* 7038±8 7046±12
20.1	$Ne^{20}(d,p)Ne^{21}$	*4530±6* 4531±7*M* 4528±9*S*
21.1	$Ne^{21}(d,\alpha)F^{19}$	6435±10*P*
21.*A*	$Ne^{21}(d,p)Ne^{22}$	8140±11*M*

[a] See table 3.1 of reference 4.

[b] The reactions selected by Wapstra (see reference 4) have been coded to facilitate checks on the least squares computation; the code is as follows: 14.1 reactions directly giving initial equations; 16.1′ reactions which in combinations with reactions coded *a*, *b* give initial equations; 17.*A* reactions published after the least square adjustment which should be included in a future computation. The values measured by the groups in Massachusetts, Pasadena, Houston, Wisconsin, Birmingham, and Stockholm are indicated by self-explaining capitals. Values obtained by averaging the given experimental results are italicized.

It is suspected that some of the $C^{13}H_4-N^{14}H_3-OH$ triplet runs were taken at less than optimum adjustment of the energy focus. For the 6 measured runs, both the $C^{13}H_4-OH$ values and $N^{14}H_3-OH$ values display a separation into two equal groups averaging 15 and 13 μMU, respectively, on either side of their calculated means, while the $C^{13}H_4-N^{14}H_3$ values tend to a normal distribution. Of the remaining 77 runs, only one has been rejected as inconsistent.

TABLE IV. Reaction cycles pertinent to the present investigation taken from Wapstra.[a]

No.	Reaction cycle	Σ kev	Closure error μMU
	Reaction cycles giving sum 0		
8.2[b]	$O^{17}(d,\alpha)-N^{14}(d,p)'+O^{16}(d,p)-O^{16}(d,\alpha)$	4±15	4±16
9.2	$O^{17}(d,\alpha)-O^{17}(d,p)-O^{18}(p,\alpha)$	19±18	20±19
10.2	$F^{19}(d,\alpha)-F^{19}(p,\alpha)-O^{16}(d,p)$	19±14	20±15
11.2	$Ne^{20}(d,\alpha)+F^{18}(\beta^-)-O^{17}(d,p)-F^{19}(d,\alpha)+F^{19}(d,p)+F^{20}(\beta^-)$	7±21	8±22
12.2	$Ne^{21}(d,p)-F^{19}(\alpha,p)-Ne^{21}(d,\alpha)$	31±18	33±19
13.2	$Na^{23}(p,\alpha)-Na^{23}(d,\alpha)+Ne^{20}(d,p)$	4±12	4±13
	Reaction cycles giving sum d^c		
3.3	$C^{12}(n,\gamma)-C^{12}(d,p)$	2230±10	3±11
	Average (8 cycles)	2227± 4	
12.3	$N^{14}(\gamma,n)-N^{14}(d,p)$	2214±11	−13±12
	Adjusted value (4 cycles)	2226± 2	
	Reaction cycles giving sum $H^2(d,p)H^3$		
5.4	$C^{12}(d,p)+C^{13}(d,t)$	4030± 4	1± 4
	Average (5 cycles)	4031± 3	
	Reaction cycles giving sum α^d-2d^c		
6.5	$F^{19}(d,p)+F^{20}(\beta^-)+Ne^{20}(d,p)+Ne^{21}(d,\alpha)+d^c-(n-H)$	23 829±16	−16±17
	Adjusted value (10 cycles)	23 844± 4	

[a] See tables 3.2 to 3.5 of reference 4.
[b] Minor change in notation, e.g., 8.2 refers to cycle 8 table 3.2 of reference 4.
[c] d is the binding energy of D.
[d] α is the binding energy of He^4.

The measured values of 6 doublets whose components have differed by one hydrogen mass have averaged 1.0082 amu; this is regarded as constituting a satisfactory check on instrument performance. No obvious uncertainties in the data other than those mentioned, suggest themselves. Although every effort has been made to uncover other systematic errors, the possibility of their existence can neither be denied nor affirmed.

CRITICAL COMPARISON OF RESULTS

Atomic mass values derived from the measured doublets are listed in Table II where they are compared with values obtained by Li, Wapstra, Ewald, and Ogata. Wapstra has taken into account reactions published after Li's computation. He has also had more precisely determined data to draw from, and he has made allowances for recently recalibrated standardization energies that apply to many reactions. For these reasons, in the comparison with nuclear data which follows, reference will be made exclusively to Wapstra's treatment of the data and his results.

The reaction energies and cycles considered by Wapstra which bear on the present work are collected in Tables III and IV. Of particular interest are four recently measured reactions: $O^{17}(d,p)O^{18}$, $O^{17}(d,\alpha)N^{15}$, $F^{19}(\alpha,p)Ne^{22}$, and $Ne^{21}(d,p)Ne^{22}$, designated by Wapstra as "reactions published after our least squares adjustment which should be included in a future computation." These reactions, hereafter referred to as "late" reactions, provide independent test points on the computation and are most useful.

TABLE V. Analysis of cycle 9.2[a]; closure error 20±19 μMU.

Mass difference	ΔM in μMU			
	Wapstra[b]	Present[b]	Q^c	Reaction[c]
$O^{17}-N^{15}-2$	328	333	329	17.*B*[d]
$O^{18}-O^{17}-1$	321	341	341	17.*A*[d]
$O^{18}-N^{15}-3$	−7	−9	8	18.1′

[a] See Table IV.
[b] See Table II.
[c] See Table III.
[d] "Late" reactions not included in Wapstra's computation.

The comparison of mass spectroscopic measurements with Q-values has been made by constructing, from the reaction, $X(ab)Y=Q$, the mass difference $X-Y=Q+b-a$. To minimize uncertainties introduced by the choice of one or another of the values reported for the light nuclides a, b, it has generally been possible, by adding or subtracting multiples of one or more of n, H, D, and He, to obtain $b-a$ in terms of light nuclide masses and/or their differences, whose values, as reported from the several investigators, stand in essentially good agreement. Wapstra's values were then arbitrarily chosen as those used for these light nuclides and their differences, specifically, n, H, D, $n+H-D$, H_2-D, D_2-He. The conversion factor obtained by DuMond and Cohen,[15] 1 amu=931,162±24 kev, has been used both in present calculations and by Wapstra. Errors associated with the $X-Y$ differences are omitted, since they are of no service to the intent of the analysis.

Cycle 9.2 is analyzed in Table V. Both Wapstra's and present values compare favorably with the "late" reaction $O^{17}(d,\alpha)N^{15}$ to be found also in cycle 8.2 whose closure error is 4±16.[16] If $O^{17}(d,\alpha)N^{15}$ is accepted, the

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[15] J. W. M. DuMond and E. R. Cohen, Revs. Modern Phys. **25**, 691 (1953).

[16] Units in μMU (micromass units); hereafter all values are in μMU except where other units are given.

cycle 9.2 closure error of 20 must be accounted for in $O^{17}(d,p)O^{18}$ and/or $O^{18}(d,\alpha)N^{15}$. It is significant that Wapstra's computed values disagree with $O^{17}(d,p)O^{18}$ (another "late" reaction) by 20 and in the direction needed to obtain perfect cycle closure. All other evidence bearing on this reaction tends to support it. Thus: (a) $O^{17}(d,p)O^{18}$ is a member of cycle 11.2[17] whose closure error is 7±22. (b) The most direct path from O^{18} to O^{16} is via $O^{17}(d,p)O^{18}$ and $O^{16}(d,p)O^{17}$. These reactions yield 4876 for the O^{18} mass excess, a value which is 21 higher than obtained by Wapstra but only 4 lower than the average mass spectroscopic determinations of Ewald, Ogata, and present values (see Table II). (c) Wapstra's and present values compare as follows with the $(O^{17}-O^{16})/(O^{18}-O^{16})$ ratio 0.5010420 ±80[18] determined by microwave techniques: Wapstra 0.5010507±20; present 0.5010477±25.

The implication is, therefore, that $O^{18}(p,\alpha)N^{15}$, which rests on a single determination, needs to be adjusted by +20, with the following consequences: (a) The adjustment from −9 to +11 in $O^{18}-N^{15}-3$ is essentially in the correct magnitude and direction needed for better agreement with present value +8. (b) The most direct path from O^{18} to C^{12} is by the reactions $O^{18}(p,\alpha)N^{15}$ and $N^{15}(p,\alpha)C^{12}$. An analysis of this path is given in Table VI. The effect on the C^{12} mass excess is to be found by subtracting the $O^{18}-C^{12}-6$ value obtained from the adjusted $O^{18}(p,\alpha)N^{15}$, i.e., 1067, from the mass spectroscopically determined O^{18} mass excess (the unweighted average of Ewald's, Ogata's, and present values), i.e., 4880; the resulting C^{12} mass excess is 3813, a value that stands in much better agreement not only with the present value of 3814 but also with the results of the most recent mass spectroscopic determinations and redeterminations.[19–21]

TABLE VI. Analysis of data giving $O^{18}-C^{12}-6$.

Source of data	$O^{18}-C^{12}-6$ in μMU
Wapstra[a]	1052
Reactions 15.*a*, 18.1′[b] (unadjusted)	1047
Present[a]	1069
Reactions 15.*a*, 18.1′[b] (adjusted)[c]	1067

[a] Determined from values in Table II.
[b] Determined from values in Table III.
[c] Reaction 18.1′ is adjusted in the amount 20 μMU needed to obtain perfect closure in cycle 9.2 (see Table V).

Oddly enough, evidence that the C^{12} mass excess is higher than Wapstra's computed value 3803 is to be found among reactions connecting C^{12} and O^{16} that were included in Wapstra's computation. For the 3 most direct paths, the following values are obtained: (1) 3804 via $N^{15}(p,\alpha)C^{12}$, $N^{14}(d,p)N^{15}$, $O^{16}(d,\alpha)N^{14}$, (2) 3817 via $N^{15}(p,\alpha)C^{12}$, $N^{14}(n,\gamma)N^{15}$, $O^{16}(d,\alpha)N^{14}$, and (3) 3808 via $N^{15}(p,\alpha)C^{12}$, $O^{17}(d,\alpha)N^{15}$, $O^{16}(d,p)O^{17}$. These results are strongly interdependent in that $N^{15}(p,\alpha)C^{12}$ is common to the three paths and the other reactions are to be found in cycles 8.2, 12.3, and 5.4. In fact, it appears that in consideration of these dependencies, Wapstra has adjusted the values of $N^{14}(d,p)N^{15}$ by −8 kev and $N^{14}(n,\gamma)N^{15}$ by −4 kev to form the new values $N^{14}(d,p)N^{15\prime}$ and $N^{14}(n,\gamma)N^{15\prime}$, respectively, that appear in his cycles 8.2 and 5.4. These adjustments have a doubly gratifying effect: first, improving the closure sums by 0 in cycle 8.2, by 13 in cycle 12.3, and by 4 in cycle 5.5, and second, yielding C^{12} mass excess values of (1) 3813, (2) 3813, and (3) 3808 along the three respective paths.

TABLE VII. Analysis of cycle 11.2[a]; closure error 8±22 μMU.

Mass difference	ΔM in μMU Wapstra[b]	Present[b]	Q[c]	Reactions[c]
$2+O^{18}-Ne^{20}$	6086	6104	6073	18.*a*, 20.*a*
$O^{18}-O^{17}-1$	321	341	341	17.*A*[d]
$2+O^{17}-F^{19}$	86	97	69	19.*b*
$1+F^{19}-Ne^{20}$	5679	5666	5670 5666[e]	19.1, 20.*b*

[a] See Table IV.
[b] See Table II.
[c] See Table III.
[d] "Late" reaction not included in Wapstra's computation.
[e] This value obtained from the unweighted average of the two values listed at 20.*b* Table III.

For the comparison of F^{19}, Ne^{20}, Ne^{21}, and Ne^{22} reference must be made to cycles 11.2, 12.2, 10.2, and 6.5, analyzed in Tables VII, VIII, IX, and X respectively. In Tables VII and X, F^{20} is eliminated by combining $F^{19}(d,p)F^{20}$ and $F^{20}(\beta^-)Ne^{20}$; in Table VII, F^{18} is eliminated by combining $Ne^{20}(d,\alpha)F^{18}$ and $F^{18}(\beta^-)O^{18}$. Present values in this group are in considerable variance with certain nuclear reactions; the largest discrepancies are to be found in the comparison with the following reactions and in the amounts as indicated: $Ne^{20}(d,\alpha)F^{18}+F^{18}(\beta^-)O^{18}$, 31; $F^{19}(d,\alpha)O^{17}$, 28; $Ne^{21}(d,\alpha)F^{19}$, 40; $Ne^{20}(d,p)Ne^{21}$, 20. For these comparisons, $Ne^{20}(d,p)Ne^{21}$ and $F^{18}(\beta^-)O^{18}$ rest on two determinations, the other reactions on one.

From the analysis of cycle 11.2 in Table VII, it

TABLE VIII. Analysis of cycle 12.2[a]; closure error 33±19 μMU.

Mass difference	ΔM in μMU Wapstra[b]	Present[b]	Q[c]	Reaction[c]
$1+Ne^{21}-Ne^{22}$	2145	2143	2147	21.*A*[d]
$3+F^{19}-Ne^{22}$	6094	6059	6069	19.*A*[d]
$2+F^{19}-Ne^{21}$	3949	3916	3956	21.1

[a] See Table IV.
[b] See Table II.
[c] See Table III.
[d] "Late" reactions not included in Wapstra's computation.

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[17] See Table VII and discussion of cycle 11.2.

[18] Geschwind, Gunther-Mohr, and Townes, Revs. Modern Phys. **26**, 444 (1954).

[19] Most recent mass spectroscopic values for C^{12} mass excess are: 3807±10, Ewald[20] (1955); 3816.7±0.8, Quisenberry, Scolman, and Nier[14] (1955); 3821.2±3.8, L. G. Smith[21] (1954); 3823.1±3.3, Mattauch and Bieri[13] (1954).

[20] H. Ewald, Third Annual Meeting, Committee E-14, American Society for Testing Materials, 1955 (unpublished).

[21] L. G. Smith, Third Annual Meeting, Committee E-14, American Society for Testing Materials, 1955 (unpublished).

TABLE IX. Analysis of cycle 10.2[a]; closure error 20±15 μMU.

Mass difference	ΔM in μMU Wapstra[b]	Present[b]	Q[c]	Reaction[c]
$F^{19}-O^{16}-3$	4448	4445	4446	19.*a*
$2-O^{17}-F^{19}$	86	97	69	19.*b*
$O^{17}-O^{16}-1$	4534	4542	4535	16.*a*

[a] See Table IV.
[b] See Table II.
[c] See Table III.

would appear that the small closure error might not be representative of the quality of its member reactions; at any rate, the cycle closure is of no help towards resolving the large variances, +31 at $2+O^{18}-Ne^{20}$ and +28 at $2+O^{17}-F^{19}$ between nuclear and present values, since it is their difference which contributes to the cycle sum. However, cycle 10.2 (see Table IX) supports the present values at $2+O^{17}-F^{19}$ as is evident in the improvement from +20 to −8 in the cycle closure obtained if $F^{19}(d,\alpha)O^{17}$ is replaced by its equivalent in present values. Furthermore, in Table VII it is to be observed that Wapstra's least-squares adjustment has had the effect of reducing both variances by rather substantial amounts. Finally, for $2+O^{18}-Ne^{20}$, values obtained by Ewald and Ogata, 6104 and 6111, respectively, are to be compared with 6073, the nuclear value, and 6104, the present value. (A similar comparison for $2+O^{17}-F^{19}$ is not given. Ewald's values at O^{17} and F^{19} are substantially lower than Wapstra's and present values; Ogata did not measure O^{17}.)

The two remaining "late" reactions are found in cycle 12.2 (see Table VIII). One, $Ne^{21}(d,p)Ne^{22}$, agrees essentially both with Wapstra's and present values. The other, $F^{19}(\alpha,p)Ne^{22}$, supports present values much better than Wapstra's. Wapstra has rejected this reaction as inconsistent, but his grounds for doing so appear arbitrary. Considering that for $3+F^{19}-Ne^{22}$ Ogata gets 6062, in good agreement with the present 6059, it seems reasonable to reject, instead, $Ne^{21}(d,\alpha)F^{19}$. By adjusting this reaction to agree with present values, the cycle closure error is improved from +33 to −7.

Referring to Table X, the cycle 6.5 closure error −16 becomes −20 if one takes 5666 rather than 5670 for $1+F^{19}-Ne^{20}$. It is then tempting to argue that by substituting present values for both $Ne^{20}(d,p)Ne^{21}$ and $Ne^{21}(d,\alpha)F^{19}$ the closure error is reduced to zero. The evidence presented in connection with $Ne^{21}(d,\alpha)F^{19}$ supports such a view. But contrary evidence is to be found with respect to $Ne^{20}(d,p)Ne^{21}$. First, the two determinations given in Table III are in good agreement. Second, the reaction is a member of cycle 13.2 whose closure error is small. If an adjustment is to be made to present values of Ne^{20} or Ne^{21}, it would destroy the existing agreement with $Ne^{21}(d,p)Ne^{22}$ on the one hand or with $F^{19}(d,p)F^{20}+F^{20}(\beta^-)Ne^{20}$ as well as with Ogata and Ewald for $O^{18}-Ne^{20}$ on the other hand. If an adjustment is to be made to $Ne^{20}(d,p)Ne^{21}$, it must be in the direction of a lower Q-value. Three other determinations[1] do indeed give lower Q-values, but the precision of the measurements (±50 kev for the most precise) is scarcely comparable with those of the two determinations (Table III) selected by Wapstra. It appears that the satisfactory resolution of this uncertainty will have to await new data.

In view of the uncertainty associated with the $C^{13}H_4-N^{14}H_3-OH$ triplet runs, the analysis will not be extended to C^{13} and N^{14} except to mention that on comparing with the very consistent results of the reactions $C^{12}(d,p)C^{13}$, $C^{12}(n,\gamma)C^{13}$, and $C^{13}(d,t)C^{12}$ (see Table III) and the precise NH_2-O determinations by Smith and Damm,[22] it appears likely that present C^{13} and N^{14} values are high by 15 or 20.

TABLE X. Analysis of cycle 6.5[a]; closure error −16±17 μMU.

Mass difference	ΔM in μMU Wapstra[b]	Present[b]	Q[c]	Reaction[c]
$1+F^{19}-Ne^{20}$	5679	5666	5670 5666[d]	19.1, 20.*b*
$Ne^{21}-Ne^{20}-1$	1730	1750	1730	20.1
$2+F^{19}-Ne^{21}$	3949	3916	3956	21.1

[a] See Table IV.
[b] See Table II.
[c] See Table III.
[d] See Table VII.

From the foregoing analysis of the remaining masses investigated, indications are that (1) the major discrepancies with nuclear data and (2) the inconsistencies in nuclear data (evident in cycle closures) are simultaneously and for the greater part removed by adjusting the following reactions: $O^{18}(p,\alpha)N^{15}$, $F^{19}(d,\alpha)O^{17}$, $Ne^{21}(d,\alpha)F^{19}$, and $Ne^{20}(d,\alpha)F^{18}$.

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[22] L. G. Smith and C. C. Damm, Phys. Rev. **90**, 324 (1953).

[23] Now at Physics Department, Harvard University, Cambridge, Massachusetts.