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Indications that the presently accepted value[1] for the mass of Na^{20} is considerably in error[2,3] have stimulated its remeasurement using the $Ne^{20}(He^3,t)Na^{20}$ reaction. It should be noted that the current value has only been reported once[4]. Also, until very recently,[5] little has been accurately known about the levels in F^{16}; they can be investigated in the $O^{16}(He^3,t)F^{16}$ reaction.

These reactions were induced by an energy-analyzed, 40.2 MeV He^3 beam from the Berkeley 88-inch, variable-energy cyclotron. Since both the $C^{12},O^{16}(He^3,t)N^{12},F^{16}$ reactions were used for energy calibration, gas targets — Ne^{20} (98% Ne^{20}), O_2 and CH_4 — and a mylar target were used. A 50 mg/cm^2 transmission—360 mg/cm^2 stopping semiconductor counter telescope fed a new type of particle identifier[6]. Complete separation of the tritons from deuterons was obtained. Total energy resolutions (FWHM) of ≈ 200 keV were obtained when the gas target was used but the resolution improved to ≈ 140 keV on the 0.94 mg/cm^2 mylar target.

Figure 1 shows an energy spectrum from the $O^{16}(He^3,t)F^{16}$ reaction, and table 1 lists the observed levels of F^{16} with our tentative J^π assignments. Only those levels that could be easily followed are included in the table, but many additional levels were populated as can be seen in fig. 1. The relative spacings of the first five levels are in excellent agreement with the results of a recent study of the $N^{14}(He^3,n)F^{16}$ reaction[5]. However, we believe that two of their tentative J^π assignments, which are based on level width arguments and are also given in table 1, should be reversed. One way to predict the level ordering of the low-lying quartet in F^{16} is to compare the observed $O^{16}(T=1) - F^{16}$ level shifts with the predicted shift from a Coulomb energy calculation using mirror nuclei and with the systematics of the known $N^{16}-O^{16}(T=1)$ shifts for the quartet. As illustrated in table 2, there is a marked downward shift of the 0^- and $1^-(T=1)$ states in O^{16}, relative to their position in N^{16}, whereas the 2^- and 3^- states are only minorly shifted. Since the first four states in N^{16} are bound, while the corresponding states in both O^{16} and F^{16} are unbound, this shift is probably due to the Thomas-Ehrman effect[7] which would be most pronounced for the s state proton; the 0^- and 1^- states predominantly arise from a $[p_{1/2}{}^{-1}s_{1/2}]$ configuration, while the 2^- and 3^- states arise from a $[p_{1/2}{}^{-1}d_{5/2}]$ configuration[8]. If our J^{π} assignments are correct, the 2^- and 3^- states are again only minorly shifted in F^{16} relative to O^{16}, while the 0^- and 1^- states undergo another downward shift. However, if the $1^- - 2^-$ assignments are reversed[5], the level shifts become generally inconsistent.

The angular distributions of the 0.436- and 0.736-MeV levels closely parallel one another, exhibiting a smooth forward (< 18 deg c.m.) peaking pattern, while the ground state and 0.200-MeV level also parallel one another, but reach a maximum at ≈ 28 deg c.m. A comparison of the observed relative intensities also places the 0.436- and 0.736-MeV levels in one group, and the other two levels in a different group. From this information and the uncontroversial 3^- and 0^- assignments, one is tempted to associate the former group with transitions to $[p_{1/2}{}^{-1}d_{5/2}]$ states, and the latter group with transitions to $[p_{1/2}{}^{-1}s_{1/2}]$ states, which would also be in accord with our J^{π} assignments. It is noteworthy that at forward angles the transitions to individual members of the analogue quartet in O^{16} via the $O^{16}(He^3,He^{3'})O^{16*}$ reaction (simultaneously measured) exhibit similar relative intensities to the above.

The 3.78-MeV level is probably the analogue of either the 3.37- or 3.54-MeV level in N^{16}, and possibly the new T=1 level at 16.47 MeV in O^{16} that is highly populated in the $O^{18}(p,t)O^{16}$ reaction[9]. A comparison of the $O^{18}(p,He^3)N^{16}$, $O^{18}(p,t)O^{16}$, and $O^{16}(He^3,t)F^{16}$ energy spectra (appropriately matched) reveals a high degree of correlation, as would be expected. For every F^{16} level reported here, a potential analogue state in N^{16} is observed.

The energy calibration used to determine the mass of Na^{20} was based on the $C^{12}(He^3,t)N^{12}$ ground state transition and $O^{16}(He^3,t)$ transitions to the 0.436- and 0.736-MeV levels of F^{16} using mass excesses of 17.349[10] and 10.686 MeV[5] for N^{12} and F^{16}, respectively.

Figure 2 shows an energy spectrum from the $Ne^{20}(He^3,t)Na^{20}$ reaction, and the observed levels of Na^{20} are listed in table 1. Since levels above 2 MeV could not be followed easily they have not been included. Our measured Q value for the $Ne^{20}(He^3,t)Na^{20}$ reaction is 14.04 ± 0.05 MeV (±0.08 MeV including N^{12},F^{16} errors) which corresponds to a mass excess for Na^{20} of 6.98 MeV. This is 1.30 MeV less than the currently accepted value[1], and in excellent agreement with the predicted Na^{20} mass[2,3].

Measurement of the Na^{20} mass, and the observation that the 2^- and 3^- levels of F^{16} do not undergo a large Thomas-Ehrman shift, enables us to check some of the assumptions expressed by Wilkinson[11] in regard to the isobaric mass equation

$$M = a + b\,T_z + c\,T_z^2 .$$

As shown in table 3 the coefficients <u>b</u> and <u>c</u> for the same A are independent of T, at least within the present error limits, although the coefficients for the T=2 multiplets consistently tend to be larger. After correcting for pairing energy, the discrepancy between the <u>c</u> coefficients becomes considerably greater; the "corrected" coefficients are also listed in table 3. Possibly the pairing corrections one obtains using the simplest pairing model are not appropriate or there could be other corrections[11], not considered here, that would compensate for the pairing corrections. Additional work, both theoretical and experimental, is needed to clarify the picture.

We are indebted to Dr. Gerald T. Garvey for several valuable discussions.

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Table 1
F^{16} and Na^{20} levels observed

F^{16} Energy (MeV)[a]	J^{π}	J^{π}[b]	Na^{20} Energy (MeV)[a]	J^{π}
0	0-	0-	0	2+
0.200	1-	2-	0.65[c]	
0.436	2-	1-	0.75[c]	
0.736	3-	3-	0.85[c]	
3.78			0.95[c]	
4.25			1.27	
5.45			1.85	
5.9				
6.4				

[a]All excitations accurate to ± 50 keV.

[b]Tentative assignments given in Reference 5.

[c]There are four levels in this region, approximately equally spaced apart.

Table 2
Comparison of the mass excesses (in MeV) of the low lying levels of the mass 16 triad[a]

J	N^{16}	Difference	O^{16}	Difference	F^{16} This Paper	F^{16} [b]
3-	5.97	(2.55)	8.52	(2.90)	11.42	11.42
2-	5.67	(2.56)	8.23	(2.89) (2.66[b])	11.12	10.89
1-	6.07	(2.29)	8.36	(2.53) (2.76[b])	10.89	11.12
0-	5.79	(2.26)	8.05	(2.64)	10.69	10.69
Coul. pred.		(2.68)		(2.83)		

[a]The mass table of Konig et al [1]) has been used.

[b]Reference 5.

Table 3
Comparison of the mass equation coefficients

	T	b	b (after correction for pairing energy)	c	c (after correction for pairing energy)
A = 16	2	-2.92 ± 0.36 MeV	-2.83 ± 0.36 MeV	0.34 ± 0.16 MeV	0.31 ± 0.16 MeV
	1[a]	-2.73 ± 0.06 MeV	-2.65 ± 0.06 MeV	0.17 ± 0.06 MeV	0.09 ± 0.06 MeV
A = 20	2	-3.69 ± 0.36 MeV	-3.59 ± 0.36 MeV	0.35 ± 0.16 MeV	0.32 ± 0.16 MeV
	1	-3.50 ± 0.04 MeV	-3.40 ± 0.04 MeV	0.25 ± 0.08 MeV	0.15 ± 0.08 MeV

[a]Calculation based on the 3- level.

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FIGURE CAPTIONS

Fig. 1. Triton energy spectra from the $O^{16}(He^3,t)F^{16}$ reaction. A gas target was used to obtain the more complete spectrum on the left while a mylar target was used to improve the resolution of the low lying levels shown on the right.

Fig. 2. Triton energy spectrum at 15 degrees from the $Ne^{20}(He^3,t)Na^{20}$ reaction.

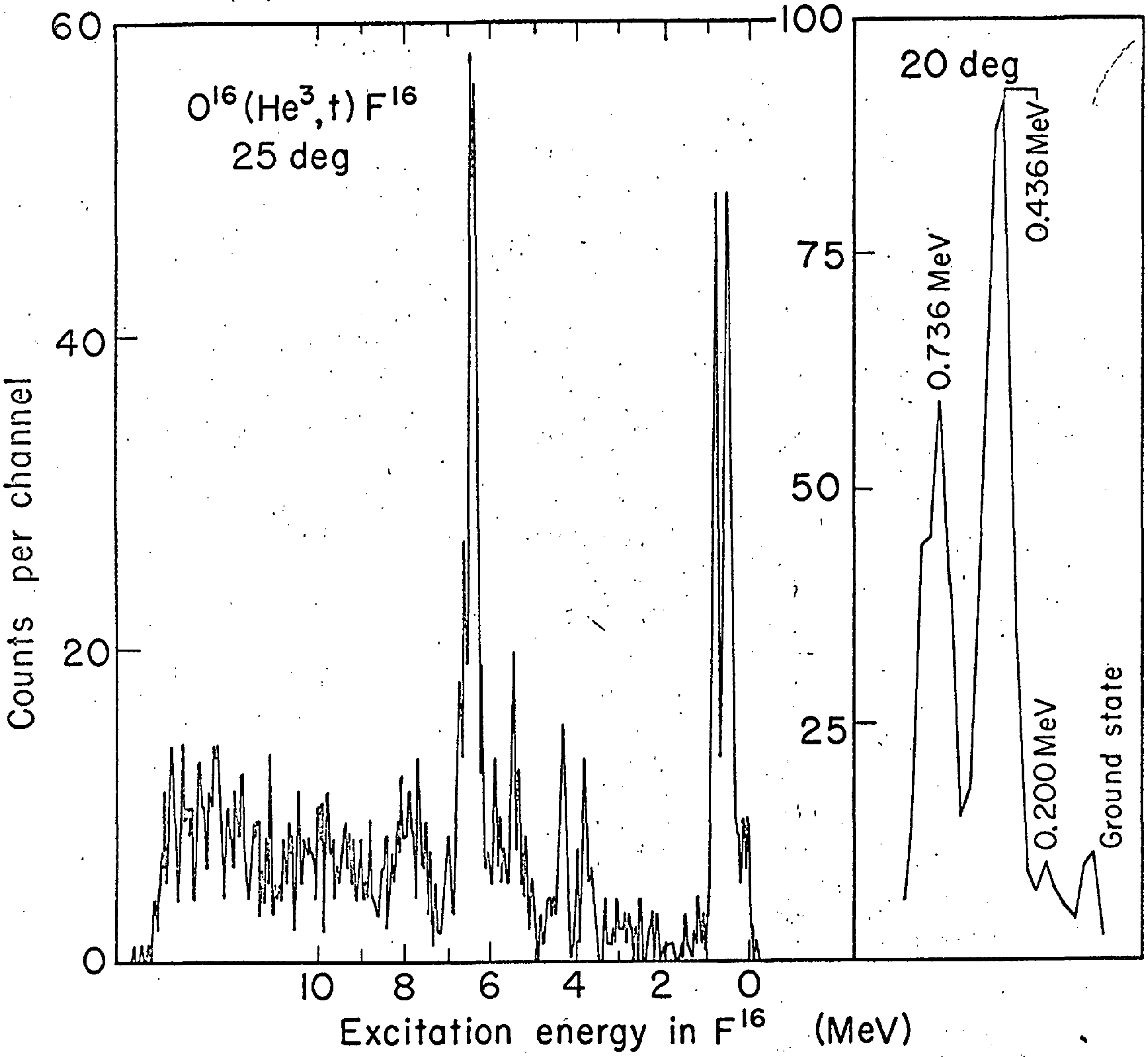

Fig. 1

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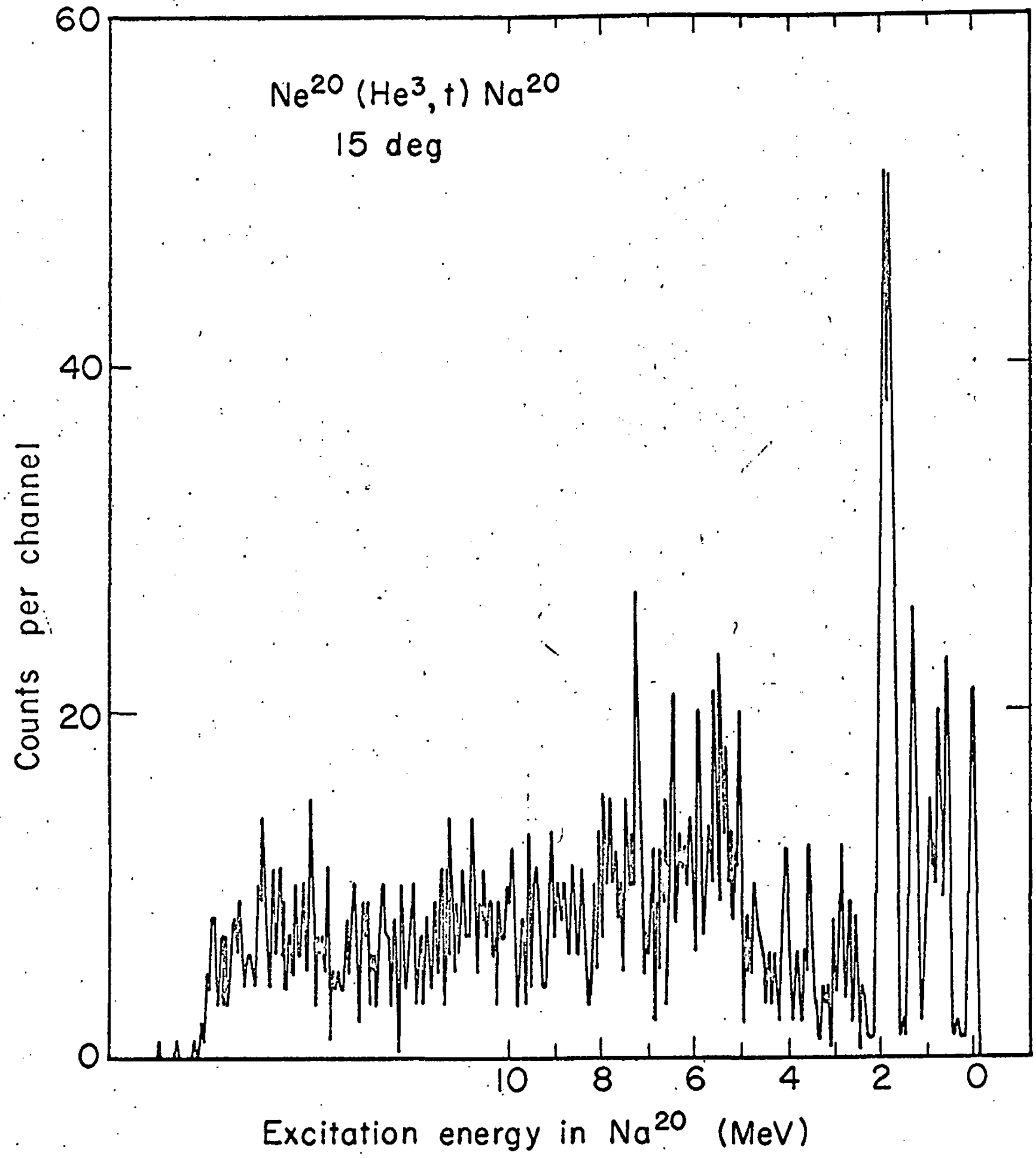

Fig. 2

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