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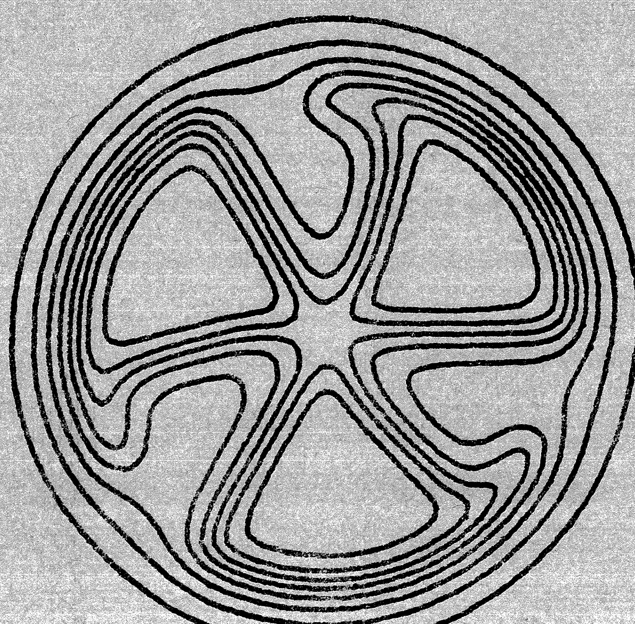

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Mass Measurements of ^{19}Na and ^{23}Al using the (^3He,^8Li) Reaction

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ABSTRACT

The mass excesses of ^{19}Na and ^{23}Al have been measured with the (^3He,^8Li) reaction. The values obtained are 12.928 $\pm$ 12 keV and 6767 $\pm$ 25 keV respectively. The first excited state of ^{19}Na was observed to lie at 120 $\pm$ 10 keV and completes a mass quartet which agrees with a quadratic isobaric multiplet mass equation.

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+On leave of absence from Institut de Physique Nucleaire de Lyon-FRANCE.

In this letter we discuss the use of a new reaction (^3He,^8Li) in measurements of atomic mass excesses. The cross section and Q-value are roughly equivalent to those of the (p,^6He) reaction, which accomplishes the same transfer, but its utilization offers several advantages. Since the highest ^3He energy of a cyclotron is always at least 50% higher than the top proton energy, more nuclei are accessible. For example the 4n+3, T_z=-3/2 nuclei are easily reached with the (^3He,^8Li) reaction (Q∼-34 MeV) using the 76 MeV beam from the Michigan State University cyclotron, but studying the same nuclei via the (p,^6He) reaction (Q=-38 MeV) would be much more difficult at the top proton energy, 50 MeV. In the case of the ^{24}Mg target, the cross section for (^3He,^8Li) is 300 nb/sr which is three times larger than the 100 nb/sr given by Cerny _et al_.[1] for ^{24}Mg(p,^6He). In addition the (^3He,^7Li) reaction provides an excellent calibration reaction for (^3He,^8Li) since it produces particles of similar rigidity. The analogous (p,^5He) reaction is, of course, not observable in a spectrograph. A comparison of (p,^4He) to (p,^6He) is very dependent on an accurate knowledge of the beam energy and the spectrograph calibration. The best calibration for (p,^6He) Q-value measurements has been the same reaction on a different target. In this case the target thickness correction becomes important.

The ^{24}Mg(^3He,^8Li)^{19}Na and ^{28}Si(^3He,^8Li)^{23}Al reaction were produced at 76.8 MeV, and the reaction products were detected in a magnetic spectrograph time-of-flight combination described previously.[2] The targets were 80 μg/cm^2 ^{24}Mg on a

20 μg/cm² carbon backing and a 370 μg/cm² self supporting SiO foil. Angles of 7.6° and 10.0° were employed. Spectra of the two reactions at 7.6° are given in Figs. 1 and 2. In the case of ^{19}Na, the spectrum shown is a composite of three runs, and the energy resolution is about 60 keV. In one of the runs at 7.6° a resolution of 40 keV was obtained. The 150 keV resolution of the ^{23}Al spectrum was dominated by target thickness, whereas for ^{19}Na it is mainly due to the spatial resolution of the counter.

The ^{19}Na mass can be determined in two ways. First, the rigidity of the particles from $^{24}Mg(^{3}He,^{6}Li)$ and $^{24}Mg(^{3}He,^{8}Li)$ can be compared. Since the mass of ^{21}Na is accurately known, the dominant error comes from the beam energy determination, which was carried out by comparing $^{12}C(^{3}He,^{3}He)$ to $^{12}C(^{3}He,^{6}He)$. The second method, comparison of $^{24}Mg(^{3}He,^{8}Li)$ to $^{24}Mg(^{3}He,^{7}Li)$ is less sensitive to the beam energy, but there is a 6 keV error from the mass of ^{20}Na. The two measurements gave mass excesses for ^{19}Na which had identical errors (~12 keV) and differed by only 4 keV. This can be viewed as a check on our method or a verification that the mass of ^{20}Na in the compilations[3] (6850 ± 6 keV) is correct. The other sources of errors, target thickness and angle and centroid determination, were kept individually to less than 4 keV. Three determinations of each type were made, and an average value of 12928 ± 12 keV for ^{19}Na was obtained for the mass excess. This corresponds to a Q-value of -32.876 MeV and makes ^{19}Na unbound to proton decay by 320 keV. Excitation energy measurements for the first excited state give a value of 120 ± 10 keV or a mass excess of 13048 ± 15 keV.

The ^{23}Al mass was also determined in two ways. By comparison of $^{28}Si(^{3}He,^{8}Li)$ to $^{24}Mg(^{3}He,^{8}Li)$ a measurement was obtained which included large target thickness corrections and the 12 keV error from ^{19}Na mass. A comparison of $^{28}Si(^{3}He,^{8}Li)$ to $^{28}Si(^{3}He,^{7}Li)$ includes a beam energy error but reduces the target thickness error. However, the main error in both cases comes from centroid determination because of the relatively poor energy resolution. ^{23}Al is the mirror of ^{23}Ne which does not possess a low lying excited state (like ^{19}Na), and therefore the ^{23}Al ground state is assumed to be a single state. The resulting mass excess is 6767 ± 25 keV, which corresponds to a Q-value of -34.274 MeV.

A summary of all the experimental results and a comparison to the previous measurements of Cerny <u>et al.</u>[1] is presented in Table I. They add one more complete mass quartet and improve the error of a second. These quartets are summarized in Table II. Unfortunately the analog of the ground state of ^{19}Na is not known in ^{19}Ne, and therefore the quartet based on it is not complete. The cited d-coefficients are a measure of the deviation from a quadratic isobaric multiplet mass equation since d is the coefficient of a T_z^3 term required for a fit to the four masses.

It is interesting to examine the cross sections for the various multiparticle pickup reactions leading to proton-rich nuclei. For $(^{3}He,^{7}Li)$ and $(^{3}He,^{8}Li)$ the ratio is about 14:1. For targets of ^{24}Mg, ^{28}Si and ^{40}Ca, the ratio of $(^{3}He,^{6}Li)$ to $(^{3}He,^{7}Li)$ varies from 30 to 50:1. These values are only for the cross section to the ground state region and only at one angle and beam energy, but they reveal a surprisingly small decrease in cross section as the transferred isospin increases. In fact, a preliminary run of $^{58}Ni(^{3}He,^{9}Li)$ shows that the cross section is not prohibitively small although definitely in the range where very long runs are necessary (around 10 nb/sr). The next series of $(^{3}He,^{8}Li)$ experiments, however, will be to measure the masses of unknown T_z=-3/2 nuclei in the sd shell, ^{35}K and ^{27}P.

Table I: Comparison to Previous Measurements (keV)

Nucleus	E_x	Present M.E.	Ref. 1
^{19}Na	G.S.	12928 ± 12	12974 ± 70*
	120 ± 10	13048 ± 15	
^{23}Al	G.S.	6767 ± 25	6766 ± 80

*unresolved

Table II: A=19 and 23 Mass Quartets. The coefficients are fit to $M(T_z)=a+bT_z+cT_z^2(+dT_z^3)$ using the present ^{19}Na and ^{23}Al masses and data from compilations.[a)] The coefficients are in keV with the error in parenthesis also in keV.

A	J^π	b	c	d	χ^2
19	$3/2^+$	-3191(18)	234(5)	-7.0(8.5)	-
		-3206(5)	230(3)	-	0.68
23	$5/2^+$	-3955(28)	235(9)	-8.6(13)	-
		-3972(18)	230(4)	-	0.42

a) F. Ajzenberg-Selove, Nucl. Phys. A190, 1(1972); P.M. Endt and C. VanderLeun, Nucl. Phys. A214, 1(1973).

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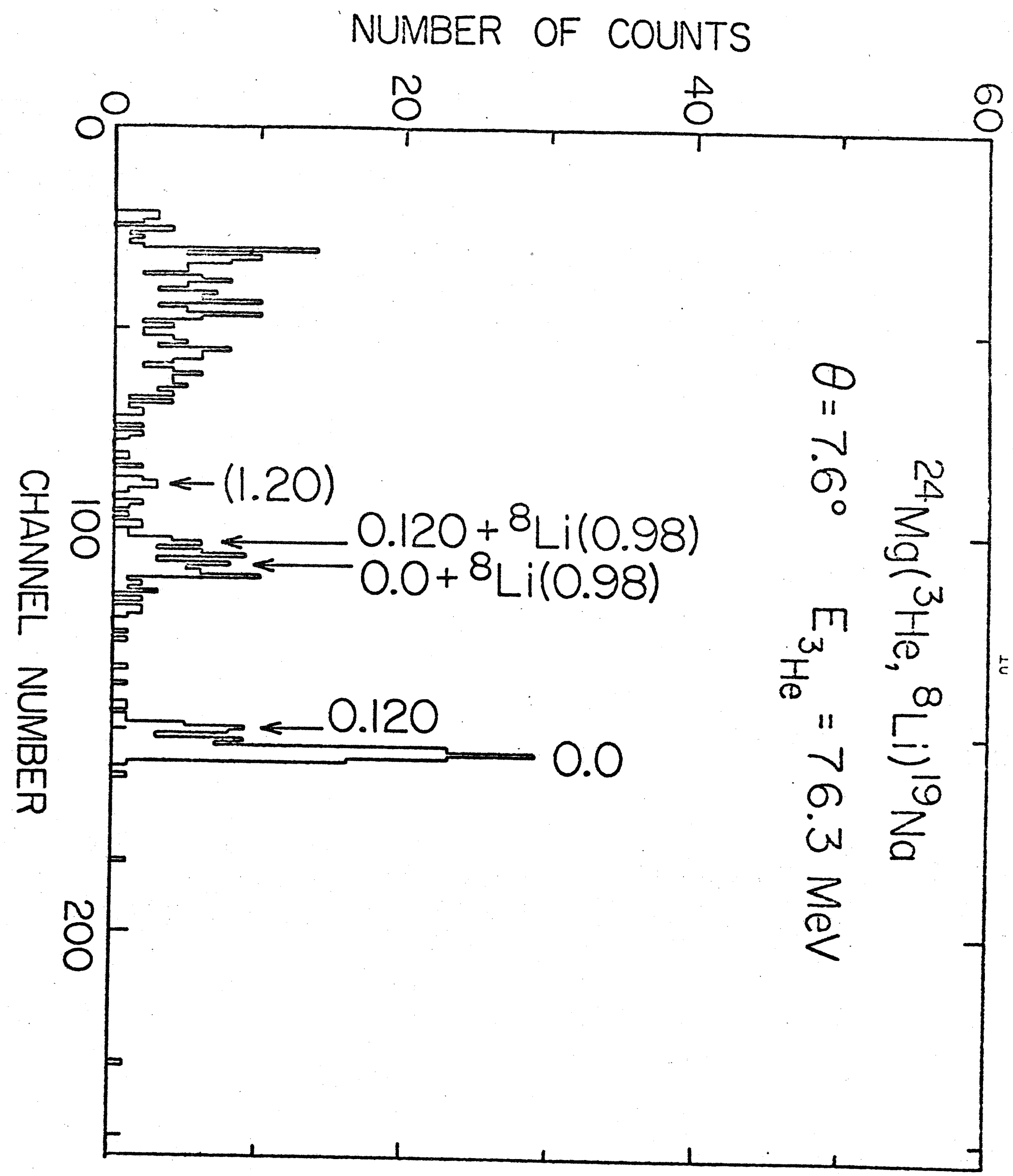
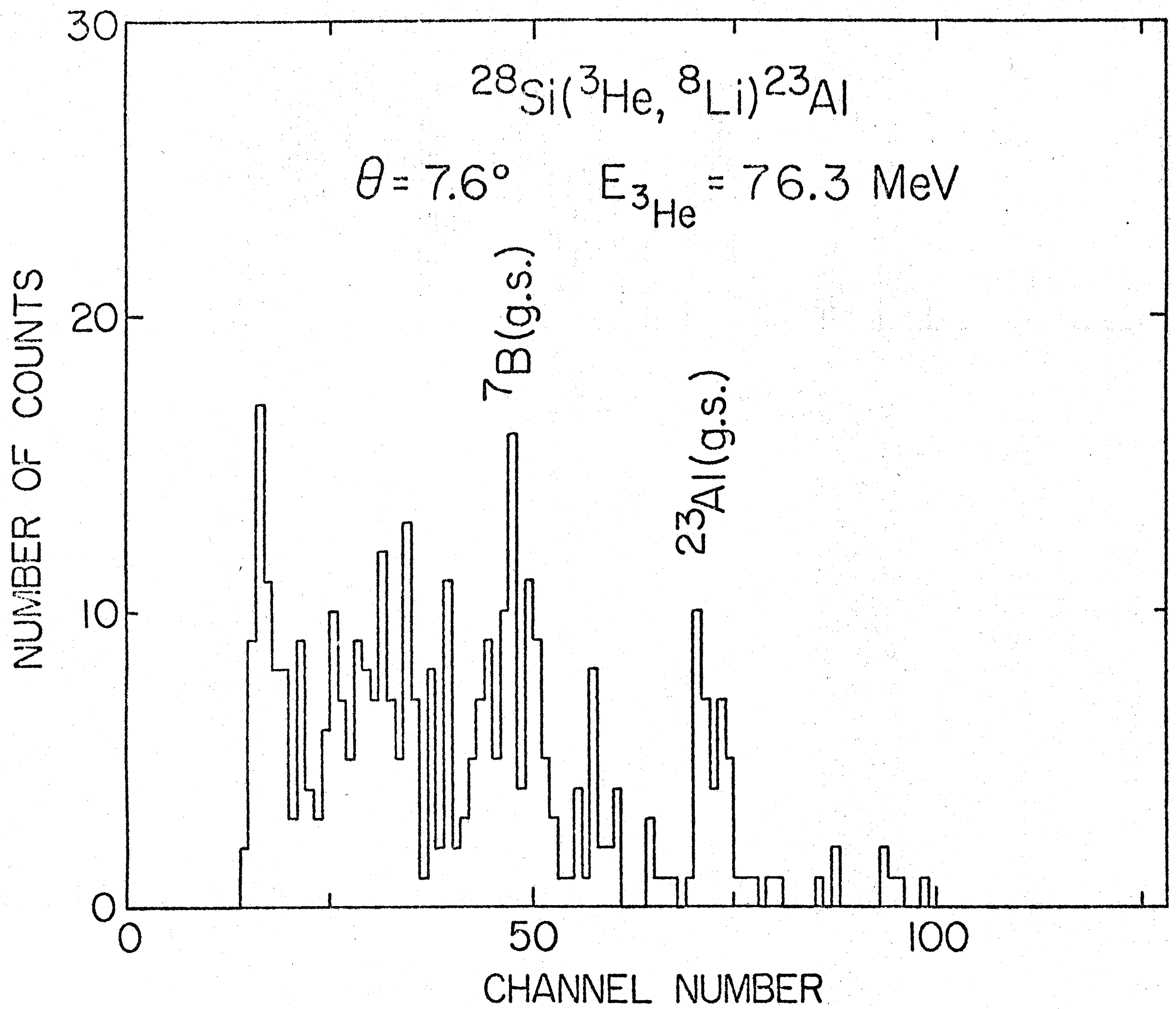
3. F. Ajzenberg-Selove, Nucl. Phys. A190, 1(1972).

FIGURE CAPTIONS

1. A composite spectrum from three runs on the $^{24}Mg(^{3}He,^{8}Li)^{19}N$ reaction at 76.3 MeV and 7.6°.

2. A spectrum from the $^{28}Si(^{3}He,^{8}Li)^{23}Al$ reaction at 76.3 MeV and 7.6°. The energy scale is ~34 keV/channel.




28Si(3He, 8Li)23Al
θ = 7.6°   E3He = 76.3 MeV
7B(g.s.)
23Al(g.s.)
NUMBER OF COUNTS
0
10
20
30
0
50
100
CHANNEL NUMBER