reaction is available from the literature;[2] for lead, the bismuth excitation function[3] was used since it has been confirmed that the proton yield as a function of deuteron bombarding energy is very similar for lead and bismuth.[4] The methods of determining the energy and energy distribution of the proton beam, its angle of incidence on the target, and various other experimental details are described in reference 1.

The measured angular distributions are shown in Fig. 1. The closed points were obtained with lead detection, while the open

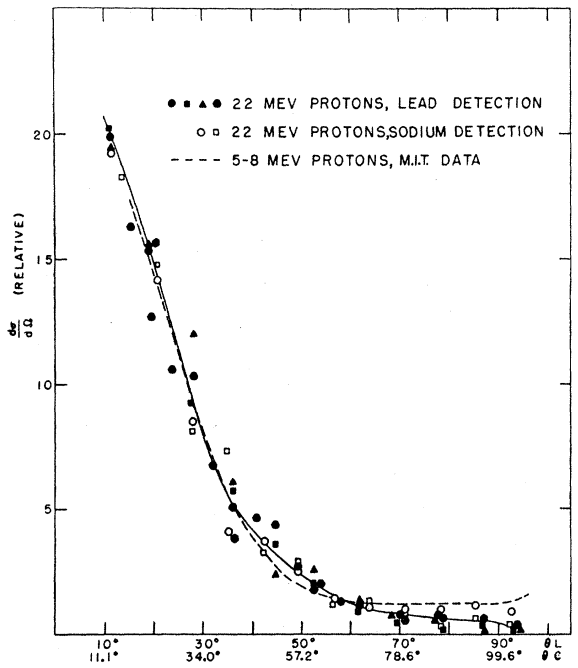

FIG. 1. Angular distribution of deuterons from $Be^9(p,d)Be^8$ (ground state).

ones are the sodium measurements. The dashed line shows the angular distribution for the same reaction obtained in the MIT cyclotron with deuterons of 5, 6, 7, and 8 Mev.[5]

The pronounced forward peak is good evidence that the reaction proceeds almost entirely by neutron pick-up. While no calculations have been made on the basis of the Butler theory,[6] it seems very strange that a calculation characterized by rapidly varying interfering terms—except for the case $l_n=0$—should give such similar results for proton energies of 5, 8, and 22 Mev. The case $l_n=0$ would seem to be excluded because of the relatively gentle rise in the forward direction and also because it would demand $I=\frac{1}{2}$ and even parity for the Be^9 nucleus, in contradiction to the prediction of both the alpha-particle and shell models. In any case, since the parity and spin of Be^8 are known, a theoretical analysis of this angular distribution should determine the parity and spin of Be^9 and thereby, from the published angular distributions[7] for $Be^9(d,p)Be^{10}$ and $Be^9(d,n)B^{10}$ and the known spin of the ground state of B^{10}, the parities and spins of Be^{10} and B^{10}.

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Mass Synchrometer Doublet Measurements at Masses 28 and 30*

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ORIGINALLY designed as a time-of-flight device,[1] the "mass synchrometer" has been converted to an rf mass spectrometer with which masses of ions are measured in terms of high harmonics of their cyclotron frequencies. Its present form is a modification of those previously described.[2] Because intensities are now enormously greater than obtained with a pulsing technique, the magnetic multiplier has been replaced by a Faraday collector connected through a dc feedback preamplifier to the dc input of a Dumont 304A oscilloscope. Band width is such that a single peak may be displayed without distortion 30 times/sec by applying a sawtooth sweep to the frequency (f) of the short rf field wherein the velocity of the (continuous) ion beam is modulated 180° from the source.

To measure the relative mass difference ($\Delta M/M$) between two components of a doublet, f is displaced on alternate sweeps by an amount Δf so adjusted (along with amplifier gain, dc level, and a small fractional increment $\Delta M/M$ in accelerating voltage) that the two peaks appear entirely coincident. A 12-kc square wave applied to the second Y input of the oscilloscope on alternate sweeps considerably augments matching precision by making one peak appear as two parallel traces between which the other is centered. With optimum adjustment $\Delta M/\bar{M}$ is taken as $\Delta f/\bar{f}$ ($\bar{f}$ being the mean frequency for the two peaks). At present this is measured by applying to f the square wave modulation (Δf) alone at about one cycle/sec. A frequency meter is then adjusted to $\bar{f}$ so that the beat between it and f is very nearly constant. The average beat ($=\Delta f/2$) is then measured with scalers over an interval determined by a precision tuning fork. Calibration of the tuning fork and frequency meter are checked with WWV.

Values of ΔM thus obtained for three doublets at mass 28 and one at mass 30 appear in Table I. Each value is the mean of from

TABLE I. Values of ΔM(amu) $\times 10^4$.

	Mass synchrometer	Disintegration energies[a]	Other mass spectrometers
$(N^{14})_2-C^{12}O^{16}$	112.372 ±0.021	112.27 ±0.11	112.54 ±0.09[b] 112.80 ±0.13[c]
$(C^{12})_2(H^1)_4-(N^{14})_2$	251.493 ±0.041		251.61 ±0.11[b] 251.70 ±0.25[c]
$2[C^{12}(H^1)_2-N^{14}]$		251.46 ±0.24	251.68 ±0.10[b] 251.72 ±0.26[c] 251.28 ±0.20[d]
$(C^{12})_2(H^1)_4-C^{12}O^{16}$	363.877 ±0.041		364.23 ±0.08[b] 364.43 ±0.22[c]
$[(C^{12})_2(H^1)_4-(N^{14})_2]$ $+[(N^{14})_2-C^{12}O^{16}]$	363.865 ±0.046		364.15 ±0.14[b] 364.50 ±0.28[c]
$C^{12}(H^1)_4-O^{16}$		363.72 ±0.19	364.15 ±0.08[b] 364.78 ±0.22[c] 363.71 ±0.12[d]
$\frac{1}{2}[(C^{12})_3(H^1)_8-C^{12}(O^{16})_2]$			364.84 ±0.20[c]
$(C^{12})_2(H^1)_6-N^{14}O^{16}$	489.623 ±0.055		
$[(C^{12})_2(H^1)_4-C^{12}O^{16}]$ $+\frac{1}{2}[(C^{12})_2(H^1)_4-(N^{14})_2]$	489.624 ±0.046		

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10 to 21 readings obtained with ion energies of about 1000 volts at various harmonics of the cyclotron frequency between the 140th and 160th (frequencies between 13 and 16 Mc/sec) under

various conditions over a period of one month. Each error is the probable error of a single reading rather than of the mean. Present indications are that in the case of the close doublet N_2-CO this error is quite conservative. In other cases the observation of a slight dependence of peak match on instrument parameters indicates the possibility of systematic errors of the order shown. Half-width resolution in all cases was about 15 000. It is thus evident that our technique of peak matching is astonishingly precise.

Table I shows a self-consistency of our results which is most gratifying. It shows further that values obtained from nuclear disintegration studies and those obtained by Ewald are in essential agreement with ours, while most other recent mass spectrometric measurements are not.

Further measurements and a more complete report will be presented soon.

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Decay Scheme of Magnesium 28†

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MAGNESIUM 28[1,2] is a recently discovered 21.3-hour β^- emitter with a complex gamma-ray spectrum. With the purpose in mind of producing Mg^{28} in order to study its decay scheme, a disk of magnesium metal of ordinary isotopic composition was bombarded in an external beam of 39-Mev alpha-particles for 9.2 hours in the University of California 60-inch cyclotron. The nuclear reaction is $Mg^{26}(\alpha,2p)Mg^{28}$. The Mg^{28} was separated as magnesium ammonium phosphate, as described in the previous publication.[1] Gamma-ray spectra of this chemically separated Mg^{28} were obtained using a sweep-type differential and integral discriminator similar to the one already described by Fairstein.[3] The gamma-rays are listed in Table I with their

TABLE I. Gamma-rays observed from Mg^{28} and Al^{28} in secular equilibrium with each other.

Gamma-rays	Energy (Mev)	Relative intensity
1	~0.03	undetermined
2	0.40±0.02	0.30±0.03
3	0.95±0.02	0.28±0.03
4	1.35±0.02	0.71±0.05
5	1.78±0.02	1.00±0.05

various energies and relative intensities. Gamma-ray 5 is to be associated with the decay of Al^{28}, which is a 2.3-min β^- emitter in secular equilibrium with Mg^{28}. Our value of 1.78±0.02 Mev is within our experimental error of the value of 1.782±0.010 Mev obtained by Motz and Alburger.[4] The relative intensities were obtained by correcting the areas in the photopeaks to account for the Compton distributions and for the geometry and efficiency of the sodium iodide crystal. It was not possible to determine accurately the energy or the relative intensity of the approximately 30-kev gamma-ray. However, there were indications of this gamma-ray both in the absorption measurements and in the gamma-ray spectra.

Absorption measurements on Mg^{28} and Al^{28} show the approximately 3-Mev β^- of Al^{28} together with a 0.40±0.06-Mev β^- of Mg^{28}. The actual absorption measurements on the Mg^{28} β^- do not in themselves indicate as large an experimental error as that quoted. However, the inaccuracy in subtracting the Al^{28} 3-Mev β^- from the Mg^{28} β^- necessitates the setting of such a high error. The data on maximum β^- energy, half-life, logft, and degree of forbiddenness are shown in Table II. The logft value was determined from the graphs given by Moszkowski.[5]

TABLE II. Log ft values for $-$ electrons from Mg^{28} and Al^{28}.

Isotope	Max energy of β^- (Mev)	Half-life (min)	log ft	Degree of forbiddenness
Mg^{28}	0.40	1278	4.0	allowed
Al^{28}	2.865	2.3	4.92	allowed[a]

[a] See reference 4.

These data determine the decay scheme shown in Fig. 1. Thus, for example, the β^- of Mg^{28} is shown by its ft value to be allowed.

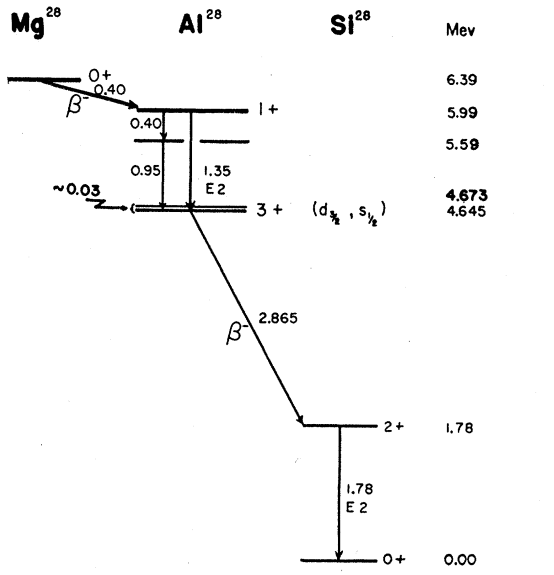

FIG. 1. The decay scheme for the isobaric triplet $Mg^{28}-Al^{28}-Si^{28}$.

Since Mg^{28} is an even-even nuclide, the beta-decay of Mg^{28}, being allowed, must enter a 0+ or 1+ state of Al^{28}. By the composition rules of Nordheim[6] for odd-odd nuclei only the 1+ state is a possibility. The gamma-ray intensities indicate that the β^- of Mg^{28} populates only the upper state of Al^{28}. Furthermore, both the gamma-ray intensities and energies indicate the energy level scheme for Al^{28} as shown. The gamma-ray spectrometer does not have the resolution necessary to distinguish easily a gamma-ray between the 1.35-Mev level of Al^{28} and the ground state, from a gamma-ray between the 1.35-Mev level and the ~30-kev level. A similar arbitrariness arises in the case of the 0.95-Mev level. Probably, unless the two components of the doublets to be expected in each of these two cases were almost equal in intensity, the gamma-ray spectrometer would lump them together as single gamma-rays. The ground state of Al^{28}, according to the rules of Nordheim,[6] must be 3+ since the spins of the odd neutron and odd proton groups will couple to larger than the minimum resultant which is 2. The first excited state of Si^{28} would be expected to be 2+.[7] This is also consistent with the fact that the β^- of Al^{28} is allowed as expected in a transition from the 3+ ground state of Al^{28} to the 2+ first excited state of Si^{28}.

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