are seen. Elastically scattered protons from beryllium and the singly charged ground state alphas have energies beyond the range of this plot.

To identify these peaks, their position was observed for three different bombarding energies from 2.35 to 3.29 Mev. At each energy both the singly and doubly charged particles were found at the expected positions. The use of both foil and evaporated targets verified that the alphas came from a reaction in beryllium. Reactions with possible contaminants and elastically scattered protons from contaminants do not give rise to peaks which could be confused with this reaction.

Sufficient counts to fix accurately the alpha-particle edge were taken only at 2.555 Mev bombarding energy. In order to calculate the energy of the alphas, the center of this edge was compared with

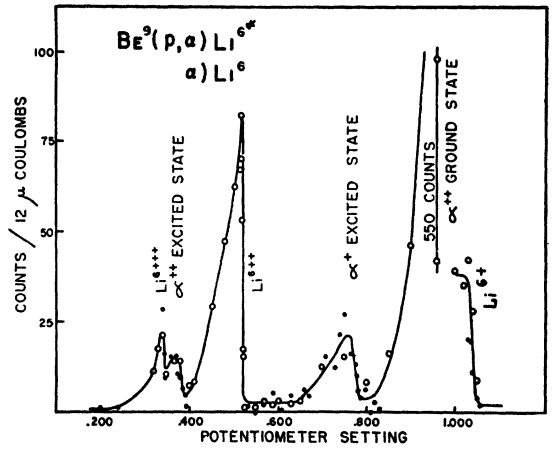

FIG. 1. Alpha and Li^6 counts *vs* potentiometer setting from 10-micro-inch beryllium bombarded with 2.35-Mev protons. Potentiometer setting is approximately energy/charge in Mev. Closed and open circles represent data taken with different amplifier gain settings normalized to equalize background counts. Other data at 2.55-Mev bombarding energy from an evaporated beryllium target were used to determine the position of the alpha-edge.

the center of an edge of protons of known energy scattered from thick platinum. Incident proton energies were obtained by calibrating the cylindrical analyzer against the $Li^7(p, n)Be^7$ threshold.[3]

Relativistic corrections were applied to both analyzers and the relativistic expression used to calculate Q values. The targets were heated during bombardment, and after the data were taken scattered protons from carbon contamination on the target were observed. The amount of carbon present had a negligible effect on the measured Q values. The result obtained is -0.064 ± 0.005 Mev. The 0.1 percent uncertainty in the lithium (p, n) threshold[3] adds an additional uncertainty of 0.06 kev to Q. Table I lists the major errors and their effect on the Q value.

Using our value of 2.123 ± 0.004 Mev[4] for the Q of the ground state reaction, the energy level of Li^6 is 2.187 ± 0.009 Mev. The error of our measurement is 0.007 Mev, while the added error of 0.002 Mev is due to the uncertainty in the $Li(p, n)$ threshold.

The slope of the high energy edge of thick target data is such that an upper limit of 8 kev may be given to the width at half-maximum of the excited level. At 2.34-Mev bombarding energy, the ratio of doubly charged ground-state alphas to the sum of singly and doubly charged excited-state alphas was about 8. The differential cross section at 135° in the laboratory system for the excited state reaction was estimated to be $2.2\pm1\times10^{-27}$ cm²/steradian based on a knowledge of the solid angle and resolution of the spherical analyzer.[2]

TABLE I. Summary of errors.

Quantity	$Be^9(p, \alpha)Li^{6*}$ Error	Effect on Q	$Be^9(p, p')Be^{9*}$ Error	Effect on Q
Bombarding energy	0.7 kev	0.5 kev	1.7 kev	1.5 kev
Emitted energy	2.0 kev	4.0 kev	0.60 kev	0.8 kev
Uncertainty in angle	3 min	0.6 kev	3 min	0.2 kev
Total error of our measurement		5 kev		2.5 kev
Lithium (p, n) threshold uncertainty	0.1%	0.06 kev		2.4 kev

Inelastically scattered protons from an energy level in Be^9 (previously reported at 2.422 ± 0.005 Mev from data on $B^{11}(d, \alpha)Be^{9*}$) were observed at a bombarding energy of 3.46 Mev. Our measurement gives the level at 2.433 ± 0.005 Mev. The differential cross section for inelastic scattering at 135° is $1.4\pm0.4\times10^{-27}$ cm²/steradian at 3.46-Mev incident energy. From this data, an upper limit of 3 kev may be given to the level width. Table I lists the estimated errors of both measurements.

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‡ Work supported by the Wisconsin Alumni Research Foundation and the AEC.
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The Mass-Differences $C^{12}(H^1)_4-O^{16}$, $C^{12}(H^1)_2-N^{14}$, and $C^{12}(H^1)_3-N^{15}$

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THE Bainbridge-Jordan type mass spectrograph which had been installed in the Osaka University was disassembled in the middle of 1943, and its reconstruction and improvement were commenced in 1947 and completed near the end of 1950. Features of its improvement were in the collimating system and in the evacuating system. The collimating system consists of a hole with a diameter of 0.5 mm, and a slit whose width is 0.005–0.008 mm and whose length is 0.2 mm; the distance between them is 45 cm. The energy-selecting slit, which is placed immediately after the energy selector, is 0.08 mm wide. The photographic plate is located nearly along the direction focusing plane through the double-focusing point, because the depth of velocity focusing is deeper than the direction focusing. The evacuating system consists of one 6-in. fractionating oil diffusion pump, two 4.5-in. oil diffusion pumps, and one mercury diffusion pump with liquid air trap, the vacuum being about $7-8\times10^{-6}$ mm Hg at the operating condition. The ions are created by the ordinary gas discharge in a cylindrical glass discharge-tube with a diameter of about 50 mm and a length of about 50 cm; while a stable electric discharge is maintained using a 20-kv transformer with a rectifier and a 2-μf smoothing condenser. The photographic plates used in this experiment are of the Schumann-type prepared in our laboratory.

Under the above-mentioned conditions, the total breadth of a line of medium intensity near the double-focusing point is about 0.01 mm and the dispersion for a one percent mass difference is about 5.82 mm, resulting in an experimental resolving power of about 58,000. The mass-scale calibration is made by using the separation of $Br^{79}-Br^{79}H^1$ and $Br^{81}-Br^{81}H^1$ for each plate, where the masses of Br^{79}, Br^{81}, and H^1 are assumed to be 78.943, 80.941, and 1.0081, respectively; the masses of Br being the mean values of Aston's[1] and ours,[2] while the mass of H^1 is taken from the Mattauch-Flammersfeld table.[3]

With this apparatus, the mass differences of $C^{12}(H^1)_4-O^{16}$, $C^{12}(H^1)_2-N^{14}$, and $C^{12}(H^1)_3-N^{15}$ have been determined. The results are listed in Table I. The table also contains the $(C^{12})_2(H^1)_4-C^{12}O^{16}$ and $(C^{12})_2(H^1)_4-(N^{14})_2$ mass differences, which were measured in order to check whether any discrepancy exists between atomic-molecular doublets and molecular-molecular

TABLE I. Observed mass differences.

Doublet	No. of doublets measured	ΔM 10^{-4} MU
$C^{12}(H^1)_4-O^{16}$	75	364.43 ± 0.05
$(C^{12})_2(H^1)_4-C^{12}O^{16}$	35	364.51 ± 0.06
weighted mean		364.47 ± 0.04
$C^{12}(H^1)_2-N^{14}$	36	125.94 ± 0.02
$(C^{12})_2(H^1)_4-(N^{14})_2$	18	251.99 ± 0.05
weighted mean		125.97 ± 0.03
$C^{12}(H^1)_3-N^{15}$	45	233.95 ± 0.05

doublets, such as Ewald found.[4] The errors given are estimated from the probable errors based on the internal consistency of the data and also from the error that may occur in the mass scale calibration.

These results indicate that the mass differences of molecular-molecular doublets are in good agreement with those of atomic-molecular doublets within the probable error, for both $C^{12}(H^1)_4-O^{16}$ and $C^{12}(H^1)_2-N^{14}$. Consequently, the weighted mean of $C^{12}(H^1)_4-O^{16}$ and $(C^{12})_2(H^1)_4-C^{12}O^{16}$, and that of $C^{12}(H^1)_2-N^{14}$ and $(C^{12})_2(H^1)_4-(N^{14})_2$, are taken to be the mass differences of $C^{12}(H^1)_4-O^{16}$ and $C^{12}(H^1)_2-N^{14}$, respectively. The mass differences obtained in this way are in fair agreement with Nier's recent values[5] of 364.43 ± 0.22 for $(C^{12})_2(H^1)_4-C^{12}O^{16}$, and 125.97 ± 0.21 for $C^{12}(H^1)_2-N^{14}$. However, our values for $C^{12}(H^1)_2-N^{14}$ and $C^{12}(H^1)_3-N^{15}$ are both slightly larger than those of Ewald,[6] 125.23 ± 0.12 and 233.08 ± 0.20, respectively. Also, there is a great discrepancy between our value for $C^{12}(H^1)_4-O^{16}$ and the recent value, 363.67 ± 0.19, calculated from transmutation data.[7]

From values for the $C^{12}(H^1)_2-N^{14}$ and $C^{12}(H^1)_3-N^{15}$ mass differences and $H^1=1.0081297\pm0.032\times10^{-4}$, listed in the Mattauch-Flammersfeld table,[3] the $N^{15}-N^{14}$ mass difference is $0.997332\pm0.06\times10^{-4}$. On the other hand, this mass difference can be obtained from the Q-value of the $N^{14}(d,p)N^{15}$ reaction and the $d-p$ mass difference. Thus, assuming the Q-value to be 8.615 Mev from Malm and Buechner's recent data,[8] and the $d-p$ mass difference to be 1.006582 as calculated by Tollestrup *et al.*,[9] the $N^{15}-N^{14}$ mass difference turns out to be 0.997330. The agreement between the two values is excellent. However, if we use Nier's recent value[10] of 1.008165 ± 4 for H^1, together with our results, the $N^{15}-N^{14}$ mass difference becomes $0.997367\pm0.06\times10^{-4}$, which is slightly larger than that calculated from the transmutation data.

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[8] R. Malm and W. W. Buechner, Phys. Rev. **80**, 771 (1950).
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Angular Correlation of Successive Gamma-Ray Quanta in Cu^{65}

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SIEGBAHN *et al.*[1] have given the disintegration scheme of Ni^{65} (Fig. 1). From their measurements they concluded that the excited levels of 1.12 Mev and 1.49 Mev for Cu^{65} have the angular momenta 7/2 and 5/2, or 9/2 and 5/2. The spin of Cu^{65} in the ground state[2] is known to be 3/2.

An investigation of the angular correlation between the two γ-rays in cascade would give more precise information about the levels. The angular correlation spectrometer used here consisted of two scintillation counters with 1P21 multipliers and anthracene crystals. The coincidence circuit had a resolving time of about 0.19 μsec.

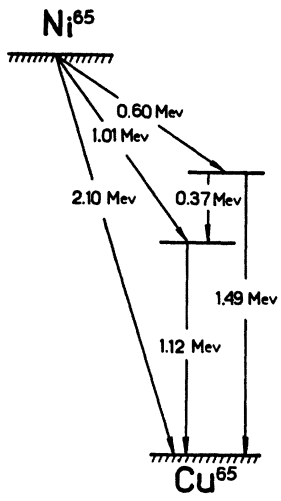

FIG. 1. Disintegration scheme of Ni^{65} (Siegbahn *et al.*).

The Ni^{65} source used was produced by deuteron bombardment of nickel. The deuteron energy was about 7 Mev.

It should be noted that the cascaded energies of 0.37 Mev and 1.12 Mev have rather weak intensities, about 10 and 20 percent, respectively.

The preliminary results of the measurements are given in Fig. 2. If Cu^{65} has a spin of 3/2 in its ground state and it is supposed that the spin of the 1.12-Mev state is 5/2 and that of the 1.49-Mev state is 9/2, one gets, according to Hamilton,[3] for the ratio $f(\pi)/f(\frac{1}{2}\pi)$ between the 180° and 90° directions, a value of 0.90 for a quadrupole-dipole radiation and 1.91 for quadrupole-quadrupole radiation. The first case is in the opposite direction to our experimental value, and the second case is ruled out since this theoretical value is too great and falls far outside the experimental error. Thus we can immediately eliminate a spin of 9/2 for the highest energy state.

If we take a spin of 7/2 for the highest state and if we suppose that we have a quadrupole-quadrupole radiation, we expect

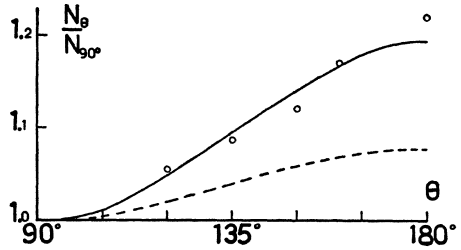

FIG. 2. Angular correlation between the 0.37-Mev and 1.12-Mev gamma-rays. The dashed line represents the calculated angular correlation for dipole-dipole radiation; the solid line represents that for dipole-quadrupole radiation. The circles represent the experimental points.

$f(\pi)/f(\frac{1}{2}\pi)=0.32$, i.e., in the opposite direction to the experimental value.

Finally we may have a dipole-dipole or a dipole-quadrupole radiation. Figure 2 shows, in addition to our experimental points, the angular correlation functions $f(\theta)=1+0.077\cos^2\theta$ (the dashed line) for dipole-dipole radiation and $f(\theta)=1+0.194\cos^2\theta$ (the solid line) for dipole-quadrupole radiation. Our experimental points fit the latter function very well.

A detailed description of the experiment and a discussion of the results will be given in *Arkiv för fysik*.