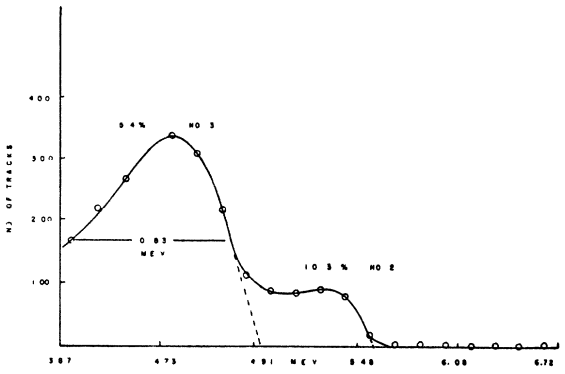

FIG. 1. High energy proton groups. The ratio of peak No. 3 to the background is approximately 170.

In this investigation a semicircular focusing magnetic spectrograph was used to analyze the protons produced by a polonium alpha-particle source. The source and target were $1\frac{13}{32}\times\frac{1}{16}$ in. with a separation of $\frac{1}{8}$ in. between them. This "poor" geometry was necessary to give an appreciable proton intensity and resulted in a broad line for each group (Fig. 1). However, Q may be determined from the value of the high energy cutoff, since, for observation in the direction of the alpha-beam, the most energetic protons are those formed on the surface of the target nearest the source by alphas striking the target normally. Adding the energy loss in the target to the cutoff value gives the total proton energy.

NTA plates, inclined at an angle to the proton beam, were employed as the detector. They were covered with an 8-mg/cm² layer of collodion to screen off stray Po alpha-tracks. This layer was soaked off with a 9 to 1 acetone-water solution before developing. By counting only tracks of the right direction and length, the effect of background radiation and particles scattered in the chamber was eliminated. This enabled one to make long exposures without accumulating appreciable background. The actual exposure times ranged from 37 to 199 hr. The targets were either of pressed boron powder or B_2O_3 evaporated onto a tin foil, and varied in thickness from 1.1 to 2.2 cm of air. This air equivalent was determined by measuring in the spectrometer the energy loss of Po alphas in passing through the target. The magnet used had a maximum usable radius of 26 cm at a field of 18,200 gauss. Current regulation was achieved by a circuit of the type described by Lawson and Tyler.[3]

The energy of each proton group was determined by comparing its radius of curvature with that of the Po 5.300-Mev line. Thus for protons of energy 4–6 Mev (groups 2 and 3 below), the effect of small inhomogeneities in the field are greatly reduced.

Results (See Table I):

$Q\sim3.8$ Mev. Evidence was found for a high energy proton group, but the intensity was too low to give an accurate value.

$Q_2=0.75$ Mev. Using an enriched B^{10} target confirmed the assigning of this group to B^{11}. Five determinations gave a mean deviation of 0.01 Mev. Using mass values from Mattauch's[4] tables, this gives the mass of C^{14} as 14.007824 amu.

$Q_3=0.24$ Mev. Six determinations gave a mean deviation of 0.02 Mev. This larger uncertainty is due to the fact that groups 2 and 3 were not completely resolved, and thus the high energy cutoff of group 3 was partially masked.

TABLE I. Summary of Q values found in this work.

Q Values	
B^{10}	B^{11}
~3.8 Mev	0.75 ± 0.01
0.24 ± 0.02	
-0.22	

$Q_4=-0.22$ Mev. This group was observed only for the run where the protons were observed at 90° to the alpha-beam.

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The L to K Capture Ratio and Disintegration Energy of Sn^{113}

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THE decay scheme of Sn^{113} based on the work of Barnes[1] and of Lawson and Cork[2] is given by the latter to consist of orbital capture to an excited state of In^{113} which then reaches its ground state by successive 85-kev and 390-kev transitions. The properties of the latter transition were found to be: half-life 104 minutes, $\alpha=2.3\pm0.3$ or 0.7 ± 0.1,[3] $\alpha_K/\alpha_L=5.4$. Later Coleman and Poole[4] failed to find the 85-kev gamma-ray.

In order to examine the possibility of direct transitions to the 390-kev state and to the ground state, we have made the following measurements on this activity. (a) With a counter of known beta- and gamma-ray sensitivity, α for the 390-kev transition was found to be 0.35 ± 0.1. The 85-kev gamma-ray, if present, was found to have an intensity of less than one percent of the 390-kev gamma-ray. (b) With a low energy compensated magnetic lens spectrometer,[5] a very thin electroplated source, and two thin Nylon windows (36 and 18 μg/cm²) the intensity of the K Auger electrons relative to the total conversion electrons of the 390-kev transition was found to be 0.61 ± 0.01. The thinness of the source is indicated by the almost complete absence of low energy tail on the 20-kev Auger line. The transparency of the counter window is indicated by the fact that the thinner window increased the 20-kev Auger-line intensity by only 3.8 percent. Correction for window loss is included in the above ratio. The conversion electrons of the 85-kev transition, if present, were found to have an intensity less than one percent of the conversion electrons of the 390-kev transition. All other measurements, where made, were in agreement with previous values.

According to Weisskopf[6] a half-life of 105 minutes for a 390-kev transition is consistent with a magnetic 2^4-pole radiation; therefore the spin of In^{113*} is probably $\frac{1}{2}$. Using a value of $\alpha_K=0.45$, as found in Rose's tables,[7] together with the measured value of α_K/α_L, the theoretical conversion coefficient is 0.53. Although the accuracy of our value is not sufficient to show that the theoretical value is wrong, it is apparent that the previous value was considerably too high. In the following argument the conversion coefficient will be assumed to be 0.53.

From the values of α_K/α_L, α, the Auger coefficient (one minus the fluorescence yield), and the Auger-conversion electron ratio, it can be shown that a negligible number of transitions direct to the ground state can occur and that more than normal L capture occurs. The chief uncertainty in the ratio of L capture to K capture as determined above is the Auger coefficient for indium. The theory of Massey and Burhop[8] gives 0.216, while the experimental results for $Z>40$ almost all give larger values than theory.[8–10] It is therefore assumed that the most probable value of the Auger coefficient for indium is 0.25 and that 0.20 and 0.30 represent outside limits. Using these values the most probable ratio of L capture to K capture is 0.81 with extreme values of 0.31 and 1.43. The ratio normally expected is only 0.115.[11]

Using the theoretical results of Marshak[12] and Rose and Jackson,[11] it can be shown that the orbital capture to the 390-kev

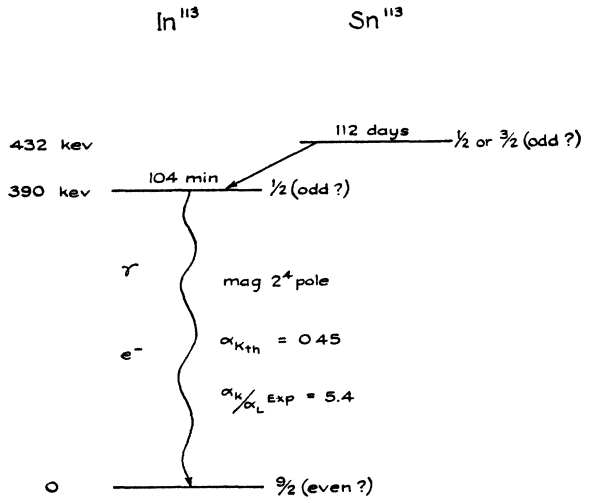

FIG. 1. Proposed decay scheme of Sn^{113}.

state is allowed. By use of these results the most probable value of disintegration energy is computed to be 42 kev with outside limits of 65 kev and 37 kev.

Since the orbital capture transition is allowed, the spin of Sn^{113} is $\frac{1}{2}$ or $\frac{3}{2}$. The transition to the ground state of In^{113} is therefore at least second- and probably third-forbidden. The transition to a state 85 kev above the 390-kev state is energetically forbidden. The proposed decay scheme is shown in Fig. 1. Further measurements on the conversion coefficient of the 390-kev transition and on the Auger coefficient for indium are being made to improve the accuracy of these results.

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Concerning the Mechanism of Electron-Ion Recombination

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MICROWAVE studies of electron-ion recombination[1,2] have yielded recombination coefficients 10^3 to 10^5 times larger than those predicted by quantum theory for radiative capture of electrons by ions. In an effort to determine the capture mechanism occurring in these experiments, we have simultaneously measured the electron density and radiation emitted from the ionized gas. Measurement of the electron density was accomplished by microwave techniques,[3] while a gated photomultiplier and a shuttered spectrograph were used to determine the intensity and spectral distribution of the radiation emitted from the recombination process.

In low pressure helium (1 to 5 mm Hg) the square root of the radiation intensity emitted from the afterglow follows closely the decay of electron density over a considerable range.[4] Spectrographic plates covering the interval from 3700 to 7200A show that the visible radiation consists of line spectra originating from high-lying states ($n=3, 4, 5, 6$) which are all within 1.5 ev of the atomic ionization potential. Absolute intensity measurements indicate that for each electron lost by recombination, roughly one quantum of visible radiation is emitted.

In neon ($p=10$ mm Hg) a similar correlation is observed between the radiation intensity and the square of the electron density. In addition, we again observe roughly one photon for each electron lost by recombination. However, the spectral lines observed all originate from levels more than 0.85 ev below ionization potential.

Recently Bates[5] has suggested that dissociative recombination between electrons and molecular ions is responsible for the large capture cross sections. The process is illustrated for helium in Fig. 1. Thermal electrons are captured by molecular ions in electronic state A; the system then attains a nearby electronic state B, which is presumed repulsive, leading to the dissociation of the unstable excited helium molecule into a normal and an excited atom. If the molecular ion is assumed to be in its ground vibrational state,[6] the energy of the final excited atom can be at most equal to the atomic ionization potential, V_I, minus the dissociation energy, D, of the molecular ion.

For the case of Ne_2^+, this energy limitation might well explain the absence of lines originating from higher states (within 0.85 ev of V_I); unfortunately lack of knowledge of $D(Ne_2^+)$ does not permit a quantitative check.

In the case of helium, however, $D(He_2^+)$ has been computed[7,8] and experimentally estimated[9] to lie between 2.2 and 3.1 ev. Hence our observation of lines originating from atomic levels which are only 0.3 to 1.5 ev below V_I (see C of Fig. 1) presents difficulties for the dissociation hypothesis which, it appears, can be resolved only by the presumption that He_2^+ ions are present in sufficiently high vibrational states. At the pressures employed in our experiments (1–5 mm Hg) the collision frequency of He_2^+ ions with helium atoms is $\sim 10^7$–10^8 sec^{-1}. In order that He_2^+ ions remain in high vibration states for ~ 5 milliseconds (the duration of observations) it is necessary that the probability of vibrational de-excitation be $\lesssim 10^{-6}$ per collision.

A discussion of the lifetime of vibration states is contained in a recent review article by Massey.[10] Experimental results vary greatly from gas to gas; however there are cases reported in which the vibration excitation persists for $\sim 10^5$ collisions. A theoretical estimate for helium (from formulas in reference 10) indicates that the probability of de-excitation of vibration for a molecular ion in a vibration state 0.3 ev below V_I (state X of Fig. 1) is of the order of 10^{-5} per collision. Thus the metastability of high vibration states, while a somewhat extreme hypothesis, must be considered; on this

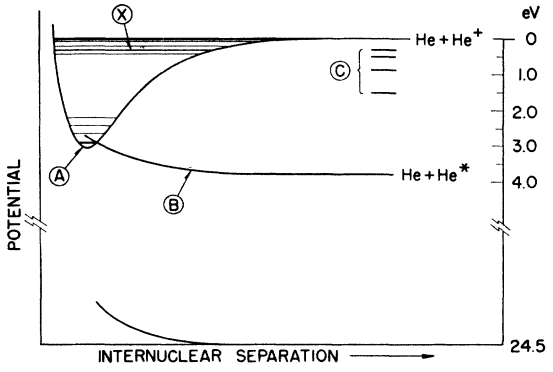

FIG. 1. Dissociative recombination for He_2^+. Some of the vibration levels are omitted.