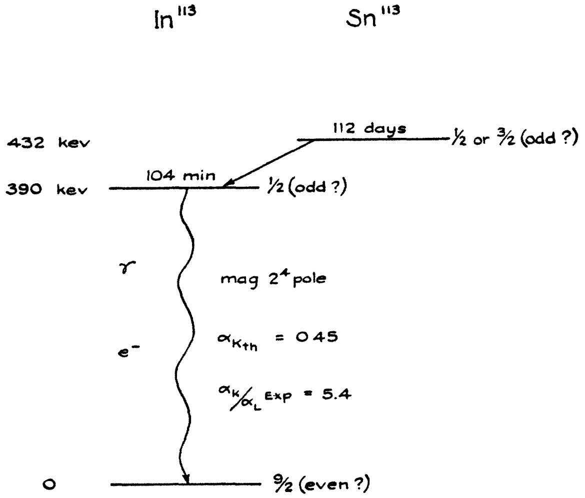

FIG. 1. Proposed decay scheme of Sn^{113}.

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 $\gtrsim 10^{-6}$ 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

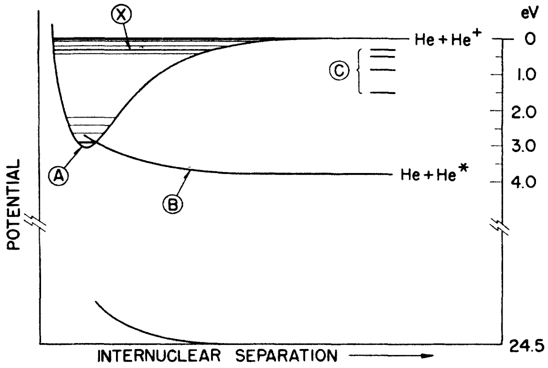

FIG. 1. Dissociative recombination for He_2^+. Some of the vibration levels are omitted.

basis dissociative recombination is still capable of describing our observations.

In order to study the recombination under conditions which rule out the dissociative process, it is necessary to insure the absence of molecular ions during our measurements. Consequently, studies using helium-argon and neon-argon mixtures are planned in which there is sufficient argon to permit rapid ionization of argon atoms by helium or neon metastables, but insufficient concentration to permit formation of molecular argon ions.[11] Since previous work[1] has shown that argon gas also exhibits a large recombination coefficient, the proposed experiments should demonstrate whether atomic or molecular ions are responsible for the large electron capture cross sections.

The authors wish to thank A. O. McCoubrey, who designed the gated photomultiplier circuits.

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The Energy and Angular Distribution of the Gamma-Rays from the Reaction $Li^7(p, \gamma)Be^8$

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During the last years, spectroscopy of high energy gamma-rays has been performed mainly by the use of pair spectrometers.[1] Instead of applying the pair creation process to the determination of quantum energies, one can, in principle, also use suitable (well-known Q-values) photonuclear reactions which give rise to particles of exactly measurable energies. Examples of such reactions are: the photodisintegration of the deuteron, the photofission of C^{12} into three alpha-particles, the (γ, p)-reaction on O^{16}. We have chosen the $C^{12}(\gamma, \alpha)2\alpha$-reaction for analyzing the gamma-rays emitted from the 17.6-Mev state of the Be^8 nucleus. This highly excited state is created by protons of 440-kev energy in a resonance capture process on Li^7. Nuclear track plates (English Kodak NT 1a, emulsion thickness 200 microns) have been irradiated for 60 hours with gamma-rays from a thick target of pure lithium at proton energies of 450–500 kev. The gelatin of the emulsion contains sufficient carbon to give rise to about 40 stars per cm^2 formed by the three emitted alpha-particles, without overly strong background fogging. Since the Q-value of this reaction is -7.35 ± 0.12 Mev, gamma-rays with quantum energies greater than about 12 Mev can be determined by this method. Errors which arise from the microscopic measurement of the alpha-track length may be corrected to some extent by a check of the momentum balance of the reaction. In Fig. 1 the number of stars as a function of the total energy of the three alpha-particles is given. The two groups at 10.3 and 7.4 Mev are those associated with the well-known gamma-lines of 17.6 and 14.7 Mev, which correspond to transitions to the ground state and the first excited state of Be^8, respectively. In addition to these, a very weak third group at about 5.2 Mev appears. It would correspond to a gamma-line of about 12.6 Mev, which in turn relates to a 5-Mev state of Be^8. Since a state at 4.9 Mev in Be^8 is already known, and the gamma-rays leading from it to the ground state have been observed,[2] it seems reasonable that, corresponding to the figure, approximately 10 percent of the transitions from the resonant 17.6-Mev state would lead to the 4.9-Mev state of Be^8. Since the frequency of stars is proportional to the number of the corresponding quanta times the cross section of the $C^{12}(\gamma, \alpha)2\alpha$-reaction, Fig. 1 does not give directly the energy distribution of the gamma-rays. From the work of Walker and McDaniel[1] who give for the resonant radiation a ratio of 2:1 for the number of quanta at 17.6 and 14.7 Mev, respectively, one can estimate a $C^{12}(\gamma, \alpha)2\alpha$ cross-section ratio of 4:1 for 17.6 and 14.7 Mev, respectively.

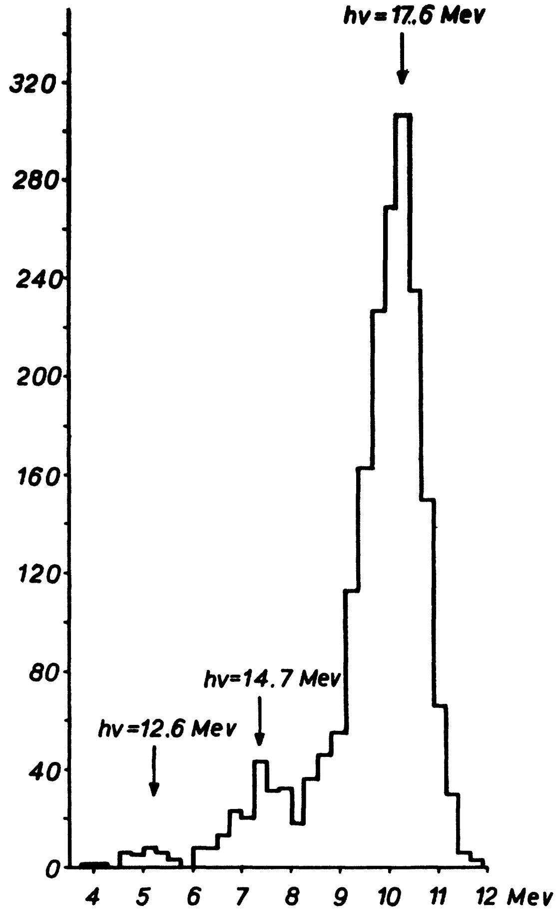

Fig. 1. Energy distribution of carbon stars. Abscissa: total energy of the three alpha-particles. Ordinate: number of stars per 0.25-Mev interval.

By simultaneously irradiating plates which were positioned at various angles with respect to proton beam and the emitted gamma-rays, we were also able to measure their angular distribution. In a preliminary communication, isotropy of the 17.6-Mev line together with a remarkable asymmetry of the 14.7-Mev component were reported.[3,4] Meanwhile, two investigations concerning the angular distribution of the lithium gamma-rays have appeared.[5,6] In both of them the resonant gamma-rays, 17.6 as well as 14.7 Mev, have been found to be isotropic within the limits of error. A thorough reinvestigation of our measurements has shown that the first reported result[3] was erroneous. Our revised measurements give us, from a statistics of 2200 stars, the following intensity ratios:

$$\left[\frac{J(14.7)}{J(17.6)}\right]_{\theta=0°}\Big/\left[\frac{J(14.7)}{J(17.6)}\right]_{\theta=45°}=1.04\pm0.30;$$

$$\left[\frac{J(14.7)}{J(17.6)}\right]_{\theta=0°}\Big/\left[\frac{J(14.7)}{J(17.6)}\right]_{\theta=90°}=1.14\pm0.25;$$

$$\left[\frac{J(14.7)}{J(17.6)}\right]_{\theta=0°}\Big/\left[\frac{J(14.7)}{J(17.6)}\right]_{\theta=135°}=1.02\pm0.25.$$