tion to make β-emission possible. The β-emission $H^4 \rightarrow He^4 + \beta^-$ would give rise to high energy (~15 Mev) β-rays with a likelihood of short half-life. A search for these was made using a NaI (Tl) scintillation detector.

To study the region of half-lives of about 1 second, the same technique was used in the Li^8 half-life determination described in the previous letter.[1] The discriminator in the circuit was set so that only high energy electrons would be counted. The observation of Li^8 produced by the $Li^7(d, p)Li^8$ reaction was used as an indicator of the sensitivity of the apparatus and made it possible to relate the expected ratio of β-intensities from H^4 and Li^8 to the ratio of cross sections of the reactions $H^3(d, p)H^4$ and $Li^7(d, p)Li^8$. For a bombarding energy of 3.82 Mev there were 2000 counts observed from Li^8 after bombardment for 3 seconds. There were no counts attributable to H^4 after bombardment of the H^3 target with the same current and energy in the interval extending from 0.006 to 3 seconds after shutting off the cyclotron beam. This experiment was repeated 8 times, and not a single H^4 β-ray was observed.

For half-life investigations in the region of 100 seconds, H^3 was irradiated for 3 minutes and counts were simply looked for on the scaler after cutting the beam. Again, no counts were recorded, though as before, while the beam was on, neutrons from the $H^3(d, n)He^4$ reaction gave many counts.

The β-ray experiments were repeated with 4.1-Mev deuterons and 1/20 of the current of the first set of runs, and again no β-rays were detected. The combined evidence of absence of protons for Q values which would make their detection feasible, together with the absence of β-rays, decreases the probability of the existence of a stable H^4, as is more fully discussed in the following note.[2]

We wish to thank Professor Breit for many helpful discussions and Professor Pollard for his continued interest in the problem.

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[*] Dill-Overlander-Loomis Post Doctorate Fellow. Now at Glasgow University, Glasgow, Scotland.

[†] Assisted by the joint program of the ONR and AEC.

[1] Waldo Rall and Kenneth G. McNeill, Phys. Rev. **83**, 1244 (1951).

[2] G. Breit and J. S. McIntosh, Phys. Rev. **83**, 1245 (1951).

Evidence Regarding Instability of H^4

G. BREIT AND J. S. MCINTOSH
Yale University, New Haven, Connecticut[*]

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McNeill and Rall's attempts[1] to find protons or β-rays from $H^3(d, p)H^4$ failed to detect these particles, decreasing the probability of there being a stable H^4. The mass of a mechanically stable H^4 must be greater than 4.0211, for otherwise $Li^8 \rightarrow He^4 + H^4$ would compete with β-decay of Li^8. It must be less than 4.0259, for otherwise $H^4 \rightarrow H^3 + n$ could take place. The lower limit agrees with the value 4.019 obtained experimentally;[1] E_β for $H^4 \rightarrow He^4 + \beta^-$ is accordingly between 22.0 and 17.3 mMU, and the corresponding values of Q for $H^3(d, p)He^3$ are -2.23 and $+2.23$ Mev. The first of these is directly $H^2 - H^1 - n^1$. Calculations give half-lives as in Table I.

Under "Notes," *N.C.* is a normalization correction for a p neutron taking account of overlap probability with a He^4 proton. The notation is as in the paper by Konopinski.[5] The "forbid." factors give lengthening of the half-life. Uncertainties in Table I are: (a) the *N.C.* may be different for ${}^1D$; (b) just below dissociation into $H^3 + n$ the *N.C.* (${}^1S$) is large and $t_{\frac{1}{2}}$ unobservably long; (c) an uncertainty of a factor of 2 is possible on account of variability of ft values, (d) vector coupling effects in the ${}^3P$ states are neglected. A trace of Fermi interaction would seriously shorten $t_{\frac{1}{2}}$ for ${}^1S_0$.

From data on β-counts, estimates have been made regarding the lower limit of Y_H/Y_L, where Y_H and Y_L are yields of $(\ , p)H^4$ and of $(\ , p)Li^8$. Factors considered are: (1) ratios of barrier penetrations for first stage as in OBJ,[6] (2) ratio of velocities for second stage, (3) ratio of geometric cross sections. Effects of Zr in target and of stopping powers are as in the following note.[7] Curve A in Fig. 1 is derived from data.[1] Absence of counts forbids the region below A. Probable regions of t are marked for states of H^4; w, Q are shown at end points of regions. Curves marked $a, \cdots, d'$ show yield ratios *versus* Q. Primed letters refer to lower E_d. Unprimed letters deal with $E_d = 4.1$ Mev. The graphs for these have been displaced up by $\log_{10} 20$ to allow for the smaller current. The 4.1-Mev experiment gives less information but provides more certainty regarding errors in energy scales, because for $Q = -2.23$ Mev the 3.82-Mev experiment would barely make the reaction possible. The ${}^1D_2$, ${}^1S_0$ states are probably[8] unstable to n emission. The ${}^3P_2$ state appears likely to have lowest energy from shell structure spin-orbit coupling theory.[9] The more likely possibility is made improbable by the experiments[1] within the reservations mentioned together with uncertainties in yields of reactions. The writers are grateful to Drs. McNeill and Rall for a helpful discussion of data.

TABLE I. Expected half-lives of H^4.

State of H^4	Type of transition	Limits on $t_{\frac{1}{2}}$ (sec)	Notes
${}^3P_2$ odd	$\Delta I = 2$ (yes)	$4.5 < t < 16$ $w = 41.2$ to 32.5	($w = 41.2$, *N.C.* $= 3$) ($w = 32.5$, *N.C.* $= 2$) Theory as in references 2, 3, and 4.
${}^3P_{1,0}$ odd	$\Delta I = 0, \pm 1$ (yes)	$0.03 < t < 0.12$ $w = 41.2$ to 32.5	
${}^1P_1$ odd (pure)	$\Delta I = 0, \pm 1$ (yes)		
${}^1P_1 + 0.001\ {}^3P_1$	$\Delta I = 0, \pm 1$ (yes)	$30 < t < 120$	
${}^1D_2$, ${}^1S_0$ even		$0.4 < t < 3$ $w = 41.2$ to 32.5	15, 25 = forbid. factor for $w = 41.2$, 32.5

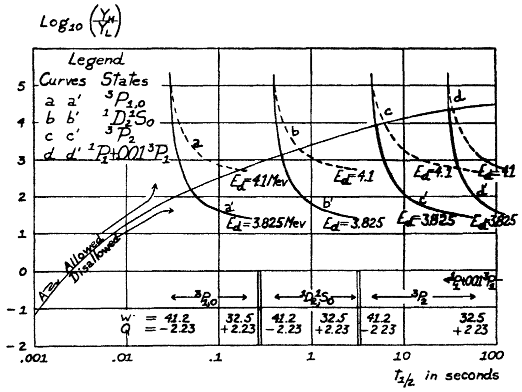

FIG. 1. Allowed and excluded regions. For each state of H^4, parts of curves $a, \cdots d'$ below curve A are excluded.

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[*] Assisted by the joint program of the ONR and AEC.

[1] K. G. McNeill and W. Rall, Phys. Rev. **83**, 1244 (1951).

[2] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).

[3] C. S. Wu, Revs. Modern Phys. **22**, 386 (1950).

[4] F. B. Shull and E. Feenberg, Phys. Rev. **75**, 1768 (1949).

[5] E. J. Konopinski, Revs. Modern Phys. **15**, 209 (1943).

[6] Ostrofsky, Breit, and Johnson, Phys. Rev. **49**, 22 (1936).

[7] J. S. McIntosh, Phys. Rev. **83**, 1246 (1951).

[8] S. S. Share, Phys. Rev. **53**, 875 (1938).

[9] M. G. Mayer, Phys. Rev. **78**, 16 (1950).