Letters to the Editor

SUPER-HEAVY ISOTOPES OF HYDROGEN AND HELIUM

V. I. GOL'DANSKIĬ

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor January 16, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 1637-1639 (May, 1960)

To estimate the stability of many isotopes (in particular H^5, H^7, and He^8) relative to the emission of neutrons, it is advantageous to use data on neutron pairing energy. Figure 1 shows the pairing energy E_p [the difference between the binding energies of the (2m + 2)-nd and (2m + 1)-st neutrons] in the first six neutron layers (from $1s_{1/2}$ to $2s_{1/2}$) for the elements from hydrogen to potassium. It is obvious that the pairing energy is always less for nuclei with an odd number of protons (because the deuteron-like triplet pn bond is disturbed by pairing in an odd-odd nucleus). In the $p_{3/2}$ shell, which is filled in the nuclei H^4–H^7 and He^5–He^8, the pairing of the third and fourth neutrons gives a somewhat smaller energy gain (64 — 90%) than for the first neutron pair. Using these facts, we can present the following estimates.

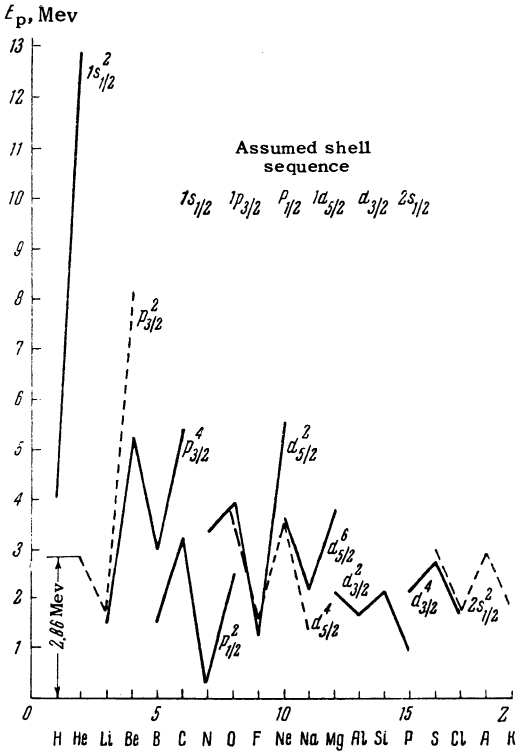

FIG. 1

<u>He^8</u>. The pairing energy does not exceed 2.86 Mev (the value for He^6, in which the first two places in the $p_{3/2}$ shell are filled). On the other hand, this energy is not less than 1.54 Mev (the value for Li^9). The necessary condition for the stability of He^8 is that the energy of the decay He^7 → He^6 + n be less than approximately 1.4 Mev, while the sufficient condition is that this energy not exceed approximately 0.8 Mev.

Comparing the masses of Li^7, He^6, and n and introducing a correction for the Coulomb interaction in He^7 ($1.2\, Z_{He} A^{-1/3}$), we readily find that the isotope He^8 can be stable if the first level T = $^3\!/_2$ for A = 7 is not higher than 12.7 Mev, and is absolutely stable if this level is lower than 12 Mev. We know of a 12.4-Mev level[1] noted in the reaction Li^7(γ n)Li^6 (reference 2), but not observed for the transition Li^7(γ t)He^4. It is therefore natural to assign T = $^3\!/_2$ to this level. If such a level with T = $^3\!/_2$ exists, then the energy of the decay He^7 → He^6 + n is approximately 1.1 Mev, and the condition for the stability of He^8 reduces to having the pairing energy of the last two neutrons not less than approximately 2.2 Mev. Satisfaction of this condition, however, is far from obvious. It should be noted that Zel'dovich's conclusion[3] regarding the stability of He^8 was based on the assumption that the decay energies of He^5 and He^7 and the pairing energies of the first and second pair of neutrons in the $p_{3/2}$ shell are equal. Actually He^7 is not as strong as He^5, and pairing is less feasible in He^8 than in He^6. The problem of the stability of He^8 still remains open and should be resolved by experiment.

A possible method for finding He^8 is to observe the (n, 2p) reactions or the capture (π⁻, p) of slow negative pions in emulsions doped with Be^9 nuclei (the characteristic decay is He $\xrightarrow{8\beta^-}$ Li $\xrightarrow{8\beta^-}$ Be^{8*} → 2α).

We note, however, that in the β^- decay of He^8(0^+) the more probable is not the production of the ground state (2^+) of Li^8, but of the excited state (1^+; 3.22 Mev), with subsequent emission of delayed neutrons (Li^{8*} → Li^7 + n).

<u>H^5</u>. In this case the pairing energy also does not exceed 2.86 Mev (the value for He^6, an even nucleus with the same number of neutrons). It is therefore obvious that for stability of H^5 the energy of the decay H^4 → H^3 + n must not exceed approximately 1.4 Mev. Comparing the masses of He^4, H^3, and n and introducing a correction for the Coulomb interaction in He^4 (~ 0.7 Mev),

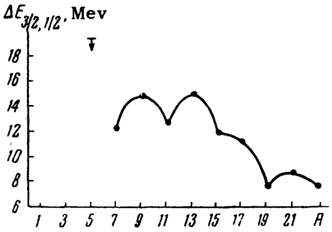

FIG. 2

we conclude that H^5 can be stable only if for the α particle the level with $T = 1$ lies below approximately 22 Mev. As is known, no such levels of He^4 have been observed in the energy range below 22 Mev, and this refutes the assumed[4] stability of H^5. We note that if the decay $H^5 \rightarrow H^4 + n$ requires (because of the pairing effects) the consumption of energy, the decay energy of H^4 cannot exceed 2.86 Mev. In this case the level with $T = 1$ should not be higher than approximately 23.4 Mev for He^4. However, extrapolation to hydrogen of the difference in the binding energy of the first and third neutrons leads to the conclusion that the energy of the decay $H^4 \rightarrow H^3 + n$ is so large, that the decay $H^5 \rightarrow H^4 + n$ becomes energetically feasible (to approximately 1.8 Mev). Then the upper limit of the $T = 1$ level for He^4 rises to approximately 25.2 Mev. These estimates (23.4 — 25.2 Mev) confirm the value of approximately 24 Mev given for the energy of this level in reference 5.

Stability of H^5 relative to the decay into H^3 and 2n agrees also with the energy of the first $T = 3/2$ level at $A = 5$: $\Delta E_{3/2\ 1/2} \leqslant 19.4$ Mev (arrow on Fig. 2). Blanchard and Winter[4] estimated this energy at 19.1 Mev. As is seen from Fig. 2, however, the data regarding $\Delta E_{3/2\ 1/2}$ cannot serve as a proof of the stability of H^5, for the case H–He–Li (transition from $A = 5$ to $A = 7$), which is magic in the number of protons, has an analogue in the case N-O-F (transition from $A = 19$ to $A = 17$) in which a sharper increase is observed in the energy of the first $T = 3/2$ level than in the other cases.

The collective data on the binding energies of neutrons and protons are also evidence in favor of the instability of H^5.

$\underline{H^7}$. If, however, H^5 is nevertheless stable, one would expect also the presence of a stable "superheavy" isotope of hydrogen H^7 (just as the presence of He^6 is proof of the existence of He^8).

In addition to searching for delayed neutrons in the reactions $Li^7(\gamma, 2p)^6$ or $H^3(H^3p)$, a possible method of verifying the existence of H^5 is to observe the reactions (n, 2p) or (π^-, p) in emulsions doped with Li^6. If H^7 is stable, these nuclei could be observed in the reactions $Be^9(\pi^-, 2p)$ in the emulsions.

The author is grateful to Ya. B. Zel'dovich and A. A. Ogloblin for a discussion of this problem.

---

[1] F. Ajzenberg-Selove, and T. Lauritsen, Nucl. Phys. **11**, No. 1, 1959.

[2] J. Goldenberg and L. Katz, Phys. Rev. **95**, 471 (1954).

[3] Ya. B. Zel'dovich, JETP **38**, 1123 (1960), Soviet Phys. JETP **11**, 812 (1960).

[4] C. Blanchard and R. Winter, Phys. Rev. **107**, 774 (1957).

[5] Bogdanov, Vlasov, Kalinin, Rybakov, Samoĭlov, and Sidorov, Ядерные реакции при малых и средних энергиях (Nuclear Reactions at Small and Medium Energies), Acad. Sci. Press, 1958, pp. 7-15.

[6] G. Tautfest, Phys. Rev. **111**, 1162 (1958).

Translated by J. G. Adashko
311

CONNECTION BETWEEN OSCILLATION AND RATE OF LOSS OF CHARGED PARTICLES IN A CYLINDRICAL PLASMA OF LOW PRESSURE IN A LONGITUDINAL MAGNETIC FIELD

A. A. ZAĬTSEV and M. Ya. VASIL'EVA

Moscow State University

Submitted to JETP editor January 21, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 1639-1640 (May, 1960)

THE principal purpose of this investigation was to study the plasma oscillations in a longitudinal column in a constant longitudinal magnetic field. In addition, we investigated the diffusion current on the wall of the discharge tube and the effect of the magnetic field on the longitudinal potential gradient in the column. Such investigations have been attracting attention in recent years in connection with the question of the mechanism by which charged particles are displaced transversely to the magnetic flux lines in a magneto-ionic medium and with other problems in plasma dynamics.[1-4]

The discharge was produced in a cylindrical tube with an inside diameter of 2 cm and an interelectrode gap of 90 cm, filled with helium at 0.2 — 0.05 mm Hg. The anode current ranged from 50 to 350 ma. The positive column was homoge-