HIGH ISOSPIN STATES OF NUCLEI AND MULTINEUTRONS, AND THE SECOND REGION OF NUCLEAR STABILITY

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The question of the existence or non-existence of bound β-active multineutrons reduces to the ratio of the excitation energy of the first nuclear level with isotopic spin T = A/2 (we denote this energy by $\Delta_{A/2,\ T_0}(A)$, where the subscript T_0 characterizes the isospin of the ground state of the nucleus (A, Z), $T_0 = |A/2 - Z|$) to the Coulomb interaction energy $E_{Coul} \approx Q[Z(Z - 1)]/A^{1/3}$ of the proton.

Choosing the isotopically self-conjugated nucleus (A, A/2) as the standard for the comparison of the isobar series, we obtain the obvious relation

$$E_{bind}(A, 0) = E_{bind}(A, A/2) + \frac{Q(A/2)[(A/2)-1]}{A^{1/3}} - \Delta_{A/2,0}(A) \qquad (1)$$

from which we obtain a condition for the existence of a multineutron in the form of the inequality

$$\frac{1}{A}\Delta_{A/2,\,0}(A) < \epsilon(A, A/2) + \frac{Q}{4}A^{2/3}. \qquad (2)$$

The average binding energy per nucleon $\mathcal{E}$ does not exceed, as is well known, 8 - 9 MeV, and Q ≈ 0.6 MeV. As to the left-hand side of (2), it is characterized, within the limits of applicability of the known formulas for the masses of the atomic nuclei (e.g., the Weizsacker-Fermi formula), by the coefficients of the $[(A/2) - Z]^2$ terms.

Using Janecke's most complete and detailed analysis of all the existing experimental data and theoretical concepts [1], we can represent $\Delta_{TT'}(A)$ in the form

$$\Delta_{TT'}(A) \approx \frac{a(A)}{A}[T(T+1) - T'(T'+1)] \pm \delta(A), \qquad (3)$$

where the small correction term δ(A) is equal to zero for all odd A and for even A with even T - T', is added in the case of even (A/2) - T, and is subtracted in the case of odd (A/2) - T.

Since the binding energies (masses) of nuclei for each given A are known at present for not more than six isobars located near the (A, Z) maximum stability line, one can hardly speak of a quantitative applicability of formula (3) at large (T - T') >> 3.

From the qualitative point of view, however, it is important to ascertain whether the following characteristics implied by (3), which are in part contradictory, are retained at large (T - T'): (i) A tendency of the function a(A) to flatten out at large A (like $a(A) \approx 31 - 54/A^{1/3}$ MeV according to [1]). (ii) A decrease of the energies of individual isospin differences $\Delta_{T'+1,T'}(A)$ with increasing A (without allowance for δ(A) oscillations), and their tendency to zero like 1/A in the region of large A. (iii) An increase of the energies of isolated isospin differences $\Delta_{T'+1,T'}(T')$ with increasing T' (without allowance for the δ(T') oscillations), which is proportional to T' up to a(A) at (T' + 1) = A/2, i.e., the presence at large A of a definite upper bound of $\Delta_{T'+1,T'}$, independent of A.

If we assume that the forces acting in the higher-isospin states are the same as in the lower ones and that all other forces are negligible, and extrapolate the laws governing $\Delta_{TT'}(A)$ to the region of large differences $(T - T')$, then

$$\frac{1}{A}\Delta_{A/2,0}(A) \approx \frac{1}{4}a(A),$$

and we can make the following assertion: for any nucleus (A, Z), the excitation energy of the lower of the levels with isospin A/2 exceeds the sum of the total binding energy of the nucleons in this nucleus and the Coulomb-repulsion energy of its protons.

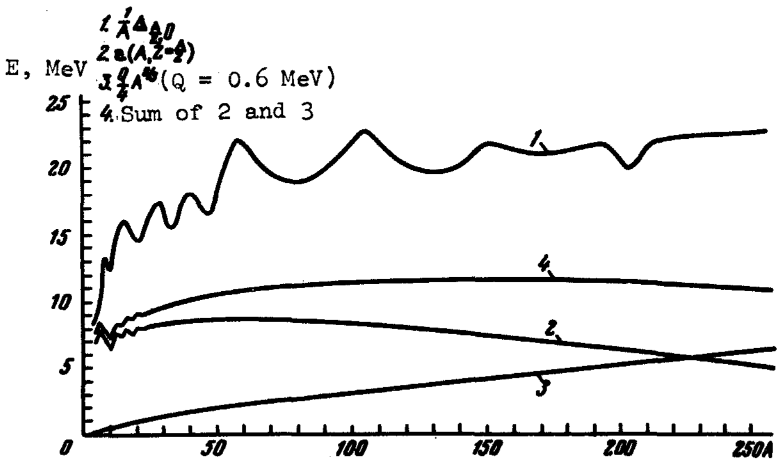
This is illustrated by the figure, which shows the aggregate of the data for $(1/A)\Delta_{A/2,0}(A)$ (curve 1), $\varepsilon(A, A/2)$ (curve 2), $(Q/4)A^{2/3}$ (curve 3), and the sum of curves 2 and 3 (curve 4).

Correctness of the foregoing statement would mean non-existence of any bound multineutrons n^k $(k > 1)$, i.e., the impossibility of formation of neutron nuclei and drops of neutron liquid via purely nuclear forces[1)] (see [2]), and also the absence of isospin-excited nucleon-stable levels of any hydrogen isotope.

According to Baz' and Bragin [3] it is possible to choose from among the published sets of isotopically-invariant nucleon-nucleon interaction potentials some corresponding to the existence of bound multineutrons of sufficiently large masses $(A \gtrsim 100)$, for example n^{112} and n^{168}.

As applied to the energies of high isospin states of nuclei, this would require an extraordinarily rapid decrease of the function a(A) with increasing A in the region where it equals several times ten.

In other words, this would mean an abrupt slowing down of the growth of $\Delta_{T'+1,T'}$, with increasing T' at a given A, even to the extent that the signs of these quantities are reversed, and also a decrease of $\Delta_{T'+1,T}(A)$ much faster



[1)] At $A \gtrsim 10^{56}$ and $R = r_0 A^{1/3} \gtrsim 10$ km the gravitational forces become commensurate with the nuclear forces, and are capable of ensuring the formation of dense neutron matter.

than that of 1/A in the region of large A ($A \gg 2T'$).

The intersection of curves 1 and 4 in the figure would correspond not only to the possible existence of multineutrons in the mass-number region to the right of this intersection, but to the appearance of a second region of stability of atomic nuclei against prompt decay with emission of nucleons (of course, in the presence of radioactive decay). Owing to the rapid decrease of a(A) with increasing A, the replacement of neutrons by protons in this region would result in only a relatively small gain in the isospin component of the binding energy, or even a loss in this component if the sign of the differences of $\Delta_{T'+1,T'}$ is reversed. It follows therefore that even if the second region of the nuclear stability does exist, it cannot be adjacent to the presently known region in any case, and it can form only a larger or smaller "island" of superheavy isotopes of light elements.

It is also of interest to analyze the influence of any specified character of the decrease of the function $(1/A)\Delta_{TT'}(A)$ at large differences $(T - T') \approx A/2$ on the boundary of the hypothetical second region of nuclear stability and on the expected properties of the nuclei in this region.

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[1] J.Janecke, in: "Isospin in Nuclear Physics" (Edited by D.H. Wilkinson) North Holland Publishing Co., Amsterdam, 1969, p. 297.
[2] A.I. Baz', V.I. Gol'danskii, and Ya.B. Zel'dovich, Usp. Fiz. Nauk 72, 211 (1960) [Sov. Phys.-Usp. 3, 729 (1961)].
[3] A.I. Baz' and V.N. Bragin, Phys. Lett. 39(B), 599 (1972).

REMARKS ON UNIFIED GAUGE THEORIES OF WEAK AND ELECTROMAGNETIC INTERACTION[1)]

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Theories of weak and electromagnetic interactions with spontaneously violated gauge invariance have been extensively discussed of late [1 - 7]. In particular, Glashow and Georgi (G-G) [3] proposed a very interesting model without neutral currents and without anomalies connected with the axial current [8, 9].

We show in the present article that the G-G model is unequivocally refuted by the experimental data on $K_L \to 2\mu$ decay. In addition, we discuss a number of problems connected with the duplication of the experimentally observed SU(3) symmetry of strong interactions, which are common to the G-G model as well as to the models of [1, 4 - 6].

In the G-G model, in the most interesting case of decays with $\Delta S = 1$ and with an axial lepton current, only diagrams with exchange of two W bosons contribute to the amplitude (Figs. 1, 2). It turns out that by using current algebra we can calculate exactly the effective neutral-current interaction constant G_0 with strong interactions taken into account

1) Reported at the International Seminar on the μ-e Problem, Moscow, 19 - 21 September 1972.