Concerning the possible existence of very heavy neutron nuclei

V. Ya. Antonchenko, V.N. Bragin, and I.V. Simenog

Institute of Theoretical Physics, Ukrainian Academy of Sciences
(Submitted March 29, 1974)
ZhETF Pis. Red. **19**, 606–608 (May 5, 1974)

It is found on the basis of several calculation methods that systems of multineutrons with nonsaturating NN forces form bound states with $N > N_{cr}$ particles, where N_{cr} lies in the approximate range 10^2–10^3 particles, depending on the type of interaction.

The question of bound states of a small number of neutrons has been the subject of very many experimental and theoretical studies (see the review[1]). The dependence of the existence of bound states of a large number of neutrons on the type of *NN* interaction was first investigated in[2]. In[3], the question of multineutrons was solved by phenomenologically extrapolating the binding energies of the existing nuclei. In the present paper we discuss the possible existence of neutron nuclei, on the basis of several calculation methods for different variants of nuclear forces.

We have considered *NN* potentials V_{13} and V_{33} of the following form:

$$V_{13}(r) = \sum_{k=1}^{4} V_k \exp\left\{-\frac{1}{2}(r/a_k)^2\right\},$$

$$V_{33}(r) = \sum_{k=5}^{7} V_k \exp\left\{-\frac{1}{2}(r/a_k)^2\right\}.$$

The parameters V_k and a_k are listed in Table I.

The chosen potentials can be divided into two groups relative to saturation condition:

$$3v_{33}(q) + v_{13}(q) > 0,$$

where $v(q) = \int d\mathbf{r} V(r) \exp(iq \cdot \mathbf{r})$. Potentials II and III satisfy the saturation condition, while potentials I and IV–VII do not.

The chosen potentials were used to calculate the bound states of multineutrons using the K-harmonics method, the oscillator-basis method, and the Thomas-Fermi statistical method.[4] The three methods turned out to yield practically identical results.

Table I.

Interaction variants		k = 1	2	3	4	5	6	7
I	V_k Mev	144.86	–83.34	–	–	–28.97	16.67	–
	a_k, F	0.59	1.13			0.59	1.13	
II	V_k, Mev	144.86	–83.34	–	–	644	–	–
	a_k, F	0.59	1.13			0.46		
III	V_k, Mev	120	–61.3	–	–	65	–	–
	a_k, F	0.68	1.46			1.06		
IV	V_k, Mev	880	–70	–21	–	–	–	–
	a_k, F	0.3045	0.885	1.02				
V	V_k, Mev	560	–390.7	–1.501	–	9.335	–1.37	0.1663
	a_k, F	0.57	0.73	2.27		0.84	1.49	2.27
VI	V_k, Mev	–33.63	–	–	–	–	–	–
	a_k, F	1.25						
VII	V_k, Mev	–705.15	1790.4	–266.97	–1.225	–	–	–
	a_k, F	0.251	0.336	0.695	2.49			

Table II.

Interaction variants	I	IV	V	VI	VII
N_{cr}	2280	1120	910	440	1360

The calculations have shown that the saturating potentials II and III do not lead to formation of bound multineutrons, while the saturating potentials I, IV—VII do produce them, starting with a certain minimal number of neutrons N_{cr}. Table II gives the values of N_{cr} for each of the non-saturating potentials. We note that the results of[2], which were obtained within the framework of the K-harmonic methods, contain a numerical error, but this does not change the qualitative conclusions drawn in[2]. We note also that the N_{cr} calculated here are overestimated in the sense that allowance for the next higher approximations in the considered methods would decrease N_{cr}.

The authors thank A.I. Baz' and G.F. Filippov for valuable discussions of the questions considered here.

[1]A.I. Baz', V.I. Gol'danskiĭ, and Ya. B. Zel'dovich, Usp. Fiz. Nauk **72**, 211 (1960) [Sov. Phys.-Usp. **3**, 729 (1961)].

[2]A.I. Baz and V.N. Bragin, Phys. Lett. **39B**, 599 (1972).

[3]V.I. Gol'danskiĭ, ZhETF Pis. Red. **17**, 56 (1973) [JETP Lett. **17**, 41 (1973)].

[4]V. Ya Antonchenko and I.V. Simenog, Ukr. Fiz. Zh. **18**, 1354 (1973); **19**, No. 5 (1974).