REARRANGEMENT CONTRIBUTION TO THE SYMMETRY ENERGY AND SINGLE PARTICLE POTENTIAL

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(Received in revised form 11. I. 1971)

The G matrix elements are determined as the function of the relative momenta for the N = Z nuclear matter and the Z = 0 neutron gas cases. From this we determine the symmetry energy and its rearrangement part and the single particle potential and its rearrangement part. The saturation condition is fulfilled and the rearrangement terms turn out to be small.

I. The symmetry energy

The total energy of the infinite nuclear matter with different neutron and proton number can be written as

\[ E = -C_1 A + C_2 \left( \frac{N-Z}{A} \right)^2 A = E(\text{pot}) + E(\text{kin}), \]

(1)

where \( C_1 \) is the infinite nuclear matter energy and \( C_2 \) the symmetry energy. Both \( C_1 \) and \( C_2 \) have parts due to the potential and the kinetic energy. The potential energy, according to the Brueckner–Goldstone expansion, can be written as

\[ E(\text{pot}) = \frac{1}{2} \sum_{m=0}^{k_N} \sum_{n=0}^{k_p} (k_m k_n | G_{NN} | k_m k_n) + \]

\[ + \frac{1}{2} \sum_{m=0}^{k_p} \sum_{n=0}^{k_p} (k_m k_n | G_{PP} | k_m k_n) + \sum_{m=0}^{k_N} \sum_{n=0}^{k_p} (k_m k_n | G_{NP} | k_m k_n), \]

(2)

where \( G_{NN} \) is the neutron–neutron, \( G_{NP} \) the neutron–proton and \( G_{PP} \) the proton–proton interaction part of the \( G \) matrix, \( k_N \) the neutron Fermi momenta and \( k_P \) the proton Fermi momenta, and the exchange terms are included in \( G \).

\[ G_{PP}(k_N k_P) = \sum_{s, m_s} G(sm_s, T = 1, T_3 = 1; k_N k_P), \]

\[ G_{NN}(k_N k_P) = \sum_{s, m_s} G(sm_s, T = 1, T_3 = -1; k_N k_P), \]

(3)
\[ G_{NP}(k_N, k_P) = \frac{1}{2} \sum_{s, m_s} [G(sm_s, T=1; T_3=0; k_N, k_P) + \]
\[ + G(sm_s, T=0; T_3=0; k_N, k_P)] , \]

where \( s, m_s \) are the spin and its third component, \( T, T_3 \) the isotopic spin and its third component.

We can express the \( G \) matrix elements as the function of the relative momenta (the total momentum dependence is weak, so we can take an average of it) and the integrals can be written as

\[ \frac{E(\text{pot})}{A} = \frac{c}{k_F^2} \int_0^{k_F} P_1(k_P, k) G_{PP}(k_N, k_P, k) \, dk + \]
\[ + \frac{c}{k_F^2} \int_0^{k_F} P_1(k_N, k) G_{NN}(k_N, k_P, k) \, dk + \frac{2c}{k_F^2} \int_0^{k_F} P_2(k_N, k_P, k) \, dk , \]

where

\[ P_1(K, k) = \frac{2}{3} k^2 \, dk(K-k)^2 (2K+k) , \]

\[ P_2(k_N, k_P, k) = \begin{cases} \frac{4}{3} k_P^2 k^2 \, dk & \text{if } 0 < k < \frac{1}{2} (k_N-k_P) \\ k \, dk \left[ \frac{2}{3} k_N k_P k^3 - \frac{1}{8} (k_N^2-k_P^2)^2 - k^2 (k_N^2+k_P^2) \right] & \text{if } \frac{1}{2} (k_N-k_P) < k < \frac{1}{2} (k_N+k_P) , \end{cases} \]

and

\[ c = \frac{1}{2} \frac{1}{(2\pi)^6} (8\pi)^2 \frac{2}{3\pi^2} , \quad k_F^2 = \frac{2}{3\pi^2} \rho , \]

where \( \rho \) is the density of the system. The \( G \) matrix elements were calculated by SPRUNG et al. [1] for the density domain \( 0.4 \, \text{fm}^{-1} \leq k_F \leq 1.6 \, \text{fm}^{-1} \), using the reference spectrum method [2] in the same way as they had done in an earlier paper [3], only with slight modifications. An explicit calculation of DAHLBLOM [4] based on the three body cluster theory of BETHE [5] has shown that the intermediate state energy is small, so that it is justifiable to make it equal to zero in the calculations. The potentials used for the calculation are the soft core REID potentials [6]. The matrix elements were determined for the \( N = Z \) (nuclear matter) and \( Z = 0 \) (neutron gas) cases. The comparison of them shows [7] that the assumption of BRUECKNER et al. [8], namely that

\[ G_{NN}(k_N, k_P, k) \sim G_{NN}(k_N, k_N, k) \quad (7a) \]

Acta Physica Academiae Scientiarum Hungaricae 30, 1971