Charge-Exchange Effect on the Effective Neutron-Proton Interaction in Mirror Nuclei

M. K. Basu and D. Banerjee*

Department of Physics, University College of Science, 92 Acharya Prafulla Chandra Road, Calcutta-9, India

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Systematics of the effective neutron-proton interactions in mirror nuclei are discussed. Magic- and submagic-number effects are clearly indicated. Behavior of the charge-exchange part of the effective neutron-proton interaction is shown.

Once the charge-exchange part of the effective n-p interaction is determined, it is possible to obtain an indication of the ordinary potential that can be tolerated in the presence of charge exchange. This question is of major importance in high-energy n-p scattering. The direct (p, n) reaction connecting ground states of mirror nuclei may be used to study the charge-exchange part of the effective n-p interaction within the nucleus.[1] However, difficulties arise in calculating the correct absolute magnitude of the cross section for a direct-interaction process. Polarization of the nucleons in the target nucleus also causes an increase of the effective interaction. The charge-exchange part can, however, be determined from a comparison of the effective n-p interactions in both nuclei of a mirror pair.

This paper deals with the behavior of the effective n-p interactions in mirror pairs of nuclei. A qualitative explanation of the trends is given. The systematics of the charge-exchange part are also discussed.

The effective n-p interactions I_{np} of the last neutron and proton within the nucleus for all mirror pairs have been calculated with the help of the *1964 Mass Table*.[2] The relation used in the calculation is given below. It was reported in a previous communication[3]:

$$I_{np}(N, Z) = E(N, Z) + E(N-1, Z-1) - E(N-1, Z) - E(N, Z-1), \quad (1)$$

where $E(N, Z)$ is the binding energy of the nucleus (N, Z).

Figure 1 is the plot of I_{np} values of the mirror nuclei versus mass number A. The general pattern of the behavior of n-p interactions in the $Z_<$ and $Z_>$ members of these nuclei is almost the same. n-p interactions of the analog states are usually greater than those for the corresponding neutron-excess states except at $A = 13$, 17, 29, and 41. These four mass numbers are associated with $Z(N) = 6$, 8, 14, and 20, where a subshell or a major-shell closure occurs.

It is clear from the Fig. 1 that I_{np} for $T_z = +\frac{1}{2}$ nuclei is larger when the last neutron is paired than when not paired. The same character is observed also for $T_z = -\frac{1}{2}$ nuclei. This is the effect of nn- and pp-pairing on the n-p interaction. When the last neutron (proton) is paired with the preceding neutron (proton), it comes closer to the preceding neutron (proton) and hence to the last proton (neutron) than when unpaired. Thus a greater I_{np} in the paired case is expected. The analysis by Sherr[4] of the second-order Coulomb differences helps one to better appreciate the above behavior of I_{np}

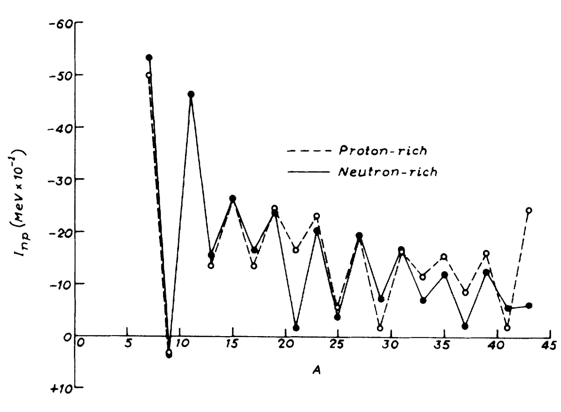

FIG. 1. Plot of effective neutron-proton interaction energies (I_{np}) of mirror nuclei versus mass number.

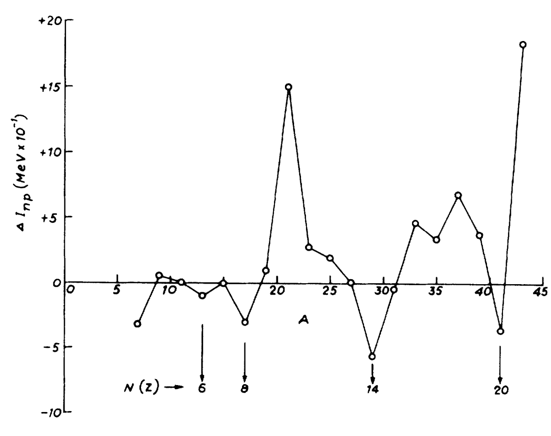

FIG. 2. Difference of I_{np} values (ΔI_{np}) in $Z_<$ and $Z_>$ members of mirror pairs versus mass number.

values in general and the smaller values of I_{np} for $T_z = -\frac{1}{2}$ nuclei at $A = 13$, 17, 29, and 41, in particular.

The difference of I_{np} values in $Z_<$ and $Z_>$ members of mirror pairs of nuclei is plotted in Fig. 2. It is very regular in the sense that it exhibits quite clearly the magic and submagic numbers 6, 8, 14, and 20. The magnitude of I_{np} differences (ΔI_{np}) lies in the range of a few keV to more than one MeV. ΔI_{np} cannot be due to the Coulomb perturbation of the wave function of the last proton in the analog state of the mirror pair. Coulomb perturbation increases the radius of the wave function of the last proton and thereby tends to decrease the effective n-p interaction in the analog state. This is contrary to the findings except at the points of shell or subshell crossings. In order to explain the excess of I_{np} values in the analog state, one must invoke the hypothesis of the "proton-potential anomaly"[5] or one must call this difference the "charge-exchange part of the effective n-p interaction." The presence of a proton-potential anomaly in mirror cases has been ruled out by Sood and Green.[6] Moreover, it would break the charge symmetry, but there is no definite experimental evidence in favor of this, particularly in light nuclei.[7,3]

Under the charge-symmetry hypothesis, which is particularly valid in mirror nuclei, the wave function of the last np pair in the analog state is identical to that of the last np pair in the neutron-excess state, except for the fact that the former is the charge-exchanged wave function of the latter. Now, if the specific n-p force is dependent on charge exchange, the charge-exchange process will affect the effective n-p interactions in the charge-exchanged state. Thus the excess of I_{np} in the analog state over the other state is only due to charge exchange.

The above study shows that the summetry energy, which is proportional to $(N-Z)^2/A$, is not the same for each member of a mirror pair. This asymmetry in the diagonal n-p interactions in mirror nuclei is usually ignored in the study of Coulomb-energy shifts.[7] Such asymmetry will also have some influence on the matrix elements of β^+ decay of mirror nuclei.

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*Present address: Centre de Recherches Nucléaires, Strasbourg, France.

[1]S. D. Bloom, N. K. Glendenning, and S. A. Moszkowski, Phys. Rev. Letters 3, 98 (1959).

[2]J. H. E. Mattauch, W. Thiele, and A. H. Wapstra, Nucl. Phys. 67, 1 (1965).

[3]M. K. Basu and D. Banerjee, Phys. Rev. C 3, 992 (1971).

[4]R. Sherr, in *Lectures in Theoretical Physics*, edited by P. D. Kunz and W. E. Brittin (University of Colorado Press, Boulder, Colorado, 1966), Vol. VIII C, p. 18.

[5]A. E. S. Green, Phys. Rev. 102, 325, (1956); 104, 1617 (1956).

[6]P. C. Sood and A. E. S. Green, Nucl. Phys. 5, 274 (1957).

[7]J. A. Nolen, Jr., and J. P. Schiffer, Ann. Rev. Nucl. Sci. 19, 471 (1969).

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$\frac{1}{2}^+$ Ground States of Cs^{127} and Cs^{129}†

I. V. Goldstein and A. G. de Pinho

Department of Physics, Universidade Católica, Rio de Janeiro (ZC-20), Brazil

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The nature of the $\frac{1}{2}^+$ ground states of the light isotopes of cesium is discussed in the framework of the unified model. These states are well reproduced by the Nilsson model for oblate shapes, as well as by the intermediate-coupling version of the unified model.

I. INTRODUCTION

The total angular momentum of the ground states of Cs^{127} and Cs^{129} has been found[1] to be $\frac{1}{2}$, and the magnetic dipole moments are $\mu = +1.43\mu_N$ and $1.48\mu_N$, respectively. Complementary experimental data[2] lead to the conclusion that the parity of these states is even.