Some Remarks on Parity Violating Effects of Intramolecular Interactions

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Summary. The role of the parity violating weak interaction in atomic and molecular physics is pursued. Parity violating forces do in fact distinguish between molecular configurations which are identical up to a space reflection as is assumed to be the case for optical isomers. The corrections to the binding energies of such molecules are, however, tiny. In conventional weak interaction theory this is due to the gauge invariance of the photon mediating electromagnetic forces between electrons and electrons and between electrons and nucleons. The constraint of gauge invariance does not allow for long range parity violating forces of first order in the weak coupling constant G. This implies that parity violating effects in atoms or molecules are suppressed not only by a factor of \( \lessapprox 10^{-5} \) due to the smallness of the weak coupling constant but also by the ratio of the range of parity violating forces divided by the average extension of the electron cloud which is in addition at most of order \( \lessapprox 10^{-5} \). Therefore no appreciable energy difference between optical isomers is expected within the framework of conventional weak interaction.

Key words: Optical Isomers - Parity Violation - Effective Potential

1. Introduction

It is generally believed that the formation of optically active macromolecules was a necessary step of chemical evolution towards the origin of life. Optically active molecules usually exist in two stereoisomeric forms, the L-form and the D-form which may be viewed as mirror images of each other. Synthetizing them in the laboratory normally leads to a racemic mixture of both forms. In living organisms, however, only one of the possible isomeric forms is realized and then perpetuated (living cells contain L-amino acids

but no D-amino acids). Hence it may be asked whether there is an intrinsic (static) difference between chemical properties of such optical isomers which could give rise to a preference of one particular form in chemical reactions. If there is such a difference, not too small in magnitude, one can imagine accumulation mechanisms in chemical reactions, as e.g. suggested by Yamagata (1966), which acting over geological periods could account for the complete selection of one mode during the time of prebiotic evolution.

Since optical isomers are considered to be space reflected (parity transformed) images of each other only parity violating intramolecular forces can be responsible for different intrinsic properties like molecular binding energies for instance.

There is in fact parity violation in intramolecular interaction due to the existence of weak interaction. Let me first remark that almost all elementary particles (among them the constituents of molecules) do interact weakly. But since they take part also in electromagnetic and/or strong interactions the effect of weak interaction provides only for small correction terms which are difficult to observe unless the stronger interactions are absent (as in neutrino scattering) or paralyzed by selection rules (as in beta decay). Nevertheless such weak correction terms causing parity impurities in wave functions have been observed (Lobashov et al., 1967) in nuclear transitions. Here we intend to discuss the influence of the weak parity violating interaction on molecular binding energy in a semiquantitative way. Let us first see how in principle parity violating interactions could discriminate between optical isomers.

2. Parity Violating Forces as a Source of Optical Asymmetry

The binding energy of a molecule may be viewed as the expectation value of the total Hamiltonian $H$ (depending in general on all coordinates of the multiparticle problem under consideration) in the bound state $\psi$ of the molecule (in the L-form, say)

$$E_B^L = \langle \psi^L | H | \psi^L \rangle$$

If the Hamiltonian is even under space reflection $U_p$, as in the case of

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1 For a review of the subject see for instance the comprehensive articles by: Henley (1969), Fishbach & Tadic (1973), and Gari (1973).