LIMITS ON ASYMMETRIC ORTHOPOSITRONIUM FORMATION IN HIGH Z OPTICALLY ACTIVE MOLECULES

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Abstract. The proposed connection between the parity violating handedness of beta particles in radioactive decay and the sign (L) of biological chirality (the Vester-Ulbricht [V-U] hypothesis) is experimentally tested. The theoretically predicted asymmetry in triplet positronium formation ($A_{Ps}$) is measured in several high $Z$ optically active molecules using low energy positrons with a net helicity. We find $A_{Ps} < 3 \times 10^{-4}$ in selenocystine ($Z = 34$) and thyroxine ($Z = 53$), excluding part of the theoretically predicted range of $4 \times 10^{-3} > A_{Ps} > 2 \times 10^{-6}$ in these molecules. The connection between these limits and limits on asymmetric radiolysis ($A_{R}$) is made, with a new limit of $A_{R} > 10^{-9}$ being placed. This limit on $A_{R}$, which is thirty times lower than a previous measurement in the amino acid leucine ($Z = 6$), is still not small enough to rule out the V-U hypothesis.

1. Introduction

We report new experimental results concerning the Vester-Ulbricht hypothesis which states that asymmetric radiolysis by electrons from beta decay caused the observed sign of biological chirality (L amino acids, D sugars). If the chirality of biological molecules has a causal origin, it must be a result of the weak interaction, the only parity-violating fundamental interaction (see reference [1] for a complete discussion of this point). Two manifestations of the weak interaction, asymmetric radiolysis from longitudinally polarized electrons produced in beta decay [2, 3] and molecular energy differences due to weak neutral currents [4] have been suggested as sources of a chiral polarization $\eta$ induced in a near equilibrium system. Here $\eta$ is defined as $\eta = (\eta_{L} - \eta_{D})/(\eta_{L} + \eta_{D})$, where $\eta_{L}$ and $\eta_{D}$ are the numbers of L and D molecules present and a system is defined to be the population of $N = \eta_{L} + \eta_{D}$ chiral molecules subject to the effects of the weak interaction prior to subsequent processing by any amplification mechanism.

Stochastic fluctuations in the number of molecules present in a system also produce a chiral polarization, $\eta_{F}$. In systems near equilibrium or in static systems, $\eta_{F}$ must be less than $\eta$ to produce a causal origin for the present biological chirality. Since $\eta_{F} \propto N^{-\frac{1}{2}}$, the parameters of a system where the condition $\eta_{F} < \eta$ obtains will be determined by the magnitude of $\eta$. In the subsequent discussion we ignore the effects of random causal mechanisms such as circularly polarized light. The chiral polarization due to weak neutral currents, $\eta_{nc}$ has a value $|\eta_{nc}| \sim 10^{-17}$, and in fact $\eta_{nc}$ has been calculated to be positive for L alanine and the L peptides in the $\alpha$-helix and $\beta$ sheet conformation [4]. By comparison the chiral polarization due to asymmetric radiolysis, $\eta_{R}$, can range (at
The near equilibrium systems referred to above must be operated on by some type of amplification mechanism in order to produce the present biological homochirality. Recently, a simple model of one such amplification mechanism, spontaneous symmetry breaking in autocatalytic systems due to the energy difference between enantiomers caused by weak neutral currents, has been considered [6, 7]. In this model, two systems of achiral reactants combine to form a chiral product, and it has been shown that, under certain plausible prebiotic conditions, when the initial system passes through a nonequilibrium state, a homochiral system, whose sign is determined by the sign of \( \eta_{nc} \), can result even for \( \eta_{nc} \) as small as \( 10^{-17} \). More recently it has been shown that two chiral systems with an initial chiral polarization \( \eta_R \) or \( \eta_{nc} \) can serve as the starting systems for the spontaneous symmetry breaking mechanism [8]. Because the effects of asymmetric radiolysis can be as much as six orders of magnitude larger than \( \eta_{nc} \), \( \eta_R \) can supplant weak neutral currents as the generator of this spontaneous symmetry breaking. Consequently, if autocatalytic systems played an important role in determining the homochirality of life, asymmetric radiolysis is likely to have been the dominant weak interaction effect.

As a result of the above recent theoretical progress in the study of \( \eta_R \) and \( \eta_{nc} \) in systems of monomers under various prebiotic scenarios and of the subsequent amplification, it has become of immediate importance to perform experimental tests of the theories from which \( A_R \) is calculated. These tests would help in (i) the determination of the relative importance of \( \eta_R \) and \( \eta_{nc} \) (ii) the determination of whether the D or L isomer is favored by radiolysis, and (iii) the determination of the value of \( A_R \), or limits on its size, which would in turn establish limits on the smallest number of chiral molecules needed in a static system for the condition \( \eta_R > \eta_F \) to obtain. We discuss in the succeeding sections the results of such an experiment which has established a new upper limit on \( A_R \).

Although the magnitude of \( A_R \) is too small to be directly observed experimentally,