ELASTIC ELECTRON COLLISION WITH CHIRAL AND ORIENTED MOLECULES

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INTRODUCTION

The interest in electron collisions from chiral molecules has been greatly stimulated by Farago1,2. In a series of papers he discussed experimental possibilities, and described some of the new “chiral effects” to be expected, if a beam of electrons passes through a chiral medium:

i.) the differential cross section for scattering of longitudinally polarised electrons depends on the handedness of electrons and molecules (that is, the spin-asymmetry should be different from zero),

ii.) a beam of unpolarised electrons becomes longitudinally polarised.

It has also been pointed out by Hegstrom3 that chiral effects are to be expected in dissociation and rearrangement collisions. Furthermore, as is well known from optical studies4, chiral phenomena can be produced in reactions with non-chiral but oriented molecules, if a “screw-sense” is defined by the geometry of the experiment5.

A number of theoretical and numerical studies has been performed along these lines. On the experimental side, elastic collisions between electrons and randomly oriented chiral molecules have been performed by Kessler and his group6,7,8.
They confirmed the existence of chiral effects, although the order of magnitude of $10^{-4}$ is very small.

On the theoretical side, a detailed analysis has been performed, classifying the expected chiral effects according to their space-time symmetries, and a series of detailed numerical calculations has been performed. The theoretical and experimental results have been reviewed recently.

A new development started with detailed numerical calculations with oriented molecules. It has been found that the values of chiral observables can be increased by 2 - 3 order of magnitude for particular orientations. These results show that the “stereodynamic” of the collision plays an important role.

In the present paper we will review recent theoretical and numerical results. In section 2 some basic definitions will be given, and chiral observables will be introduced. In section 3 we will present data for chiral observables for $HBR$, $H_2S_2$, and $CHFClBr$ obtained by Smith et al. within the “Continuum Multiple Scattering Method”. In section 4 we will consider the “sterodynamics” of the collision in more detail, concentrating on diatomic molecules. After a brief discussion of how to produce and describe anisotropic molecular ensembles in the gasphase, general formulas will be given for the dependence of chiral observables on the orientation and alignment of the initial molecular sample. Numerical results will be presented which might be useful as a guide for future experiments.

**SOME GENERAL FORMULAS AND DEFINITIONS**

Let us consider elastic collisions from fully oriented (chiral or non-chiral) molecules with axes fixed in space. By this we mean that all molecules in the given target ensemble are pointing in one and the same direction with respect to a given “external” coordinate system. As “external” system we will choose the collision system where the incoming electron beam direction is taken as $z$-axis, and the scattering plane is chosen as $xz$-plane. The molecule-fixed rectangular system will be denoted by $\vec{e}_i = \vec{e}_1, \vec{e}_2, \vec{e}_3$. Throughout this paper we will discuss closed-shell molecules.

Let us consider a transition $\vec{k}_0 \ m_0 \ \vec{e}_i \rightarrow \vec{k}_1 \ m_1 \ \vec{e}_i$ where $\vec{k}_0$ ($\vec{k}_1$) denotes the wave vector of initial (scattered) electrons, and $m_0$ ($m_1$) the $z$-component of initial (final) electrons. The molecular axes $\vec{e}_i$ are assumed to be fixed during the collision. The indicated transition will be described in terms of scattering amplitudes $f(\vec{k}_1 m_1, \vec{k}_0 m_0, \vec{e}_i) \equiv f(m_1 m_0)$, normalised in such a way that its absolute square gives the corresponding differential cross section.

\[ |f(m_1 m_0)|^2 = \sigma(m_1 m_0) \]  \tag{1}

An alternative set of amplitudes, denoted by $g_0, g_1, g_2, g_3$, have been introduced by Johnston et al. This set has definite transformation properties under space