PARITY CONSERVATION IN ATOMS: TESTING LAPORTE'S RULE

R. R. LEWIS
University of Michigan, Ann Arbor, MI

ABSTRACT

There are two independent reasons to expect the existence of a new type of weak interaction, involving elastic scattering of electrons and nucleons, e+N \rightarrow e+N. One is the successful development of unified theories of weak and electromagnetic interactions, based on isospin multiplets of leptons, hadrons and vector mesons. The other is the experimental discovery of the elastic scattering of high energy neutrinos from nucleons, ν+N \rightarrow ν+N. Together, these developments provide strong motivation to the search for weak electron-nucleon interactions in ordinary atoms, through a breakdown of Laporte's rule. I will present a review of recent developments in this field, including a qualitative discussion of this type of weak interaction and a short summary of the experiments in progress. I will also give a more detailed discussion of one particular experiment at Michigan, involving microwave transitions in a metastable hydrogen beam.

At present, there is no experimental evidence of a failure of Laporte's rule. The most recent data from optical activity in bismuth vapor, has probably ruled out the gauge model of Weinberg-Salam.

A. BRIEF HISTORY OF PARITY IN ATOMS

In 1924, Laporte\(^1\) analyzed the atomic spectrum of iron and found, among other conclusions, that the states could be classified as either 'primed' or 'unprimed'. Three years later, Wigner\(^2\) showed that this classification followed from symmetry under spatial inversions, with 'primed' or 'unprimed' states being even or odd under inversion. Only thirty years later was it discovered by Lee and Yang\(^3\) that this symmetry was broken in the weak interaction governing beta decay. Since the classic weak interactions do not influence atomic states, to order \(G\), there was no reason to expect a breakdown of Laporte's rule. Only very recently, through technical advances such as the development of the laser, has it been possible to test parity conservation in atoms to terms of order \(G\). Earlier parity experiments\(^4\) were only sensitive to interactions several orders of magnitude stronger than \(G\). In this article, I will review recent developments concerning this subject. The main conclusion will be that there are good theoretical reasons to expect parity nonconservation in atoms, but still no experimental evidence for this. Thus Laporte's rule, after 53 years, has survived its first test at the level of \(G\). An extensive search for parity nonconservation is underway in several laboratories.

An outline of this paper includes three main topics:

1) a qualitative discussion of the form of the parity nonconserving potential, and its consequences in atoms.
2) a brief summary of current parity experiments.
3) a more detailed discussion of a particular microwave experiment in metastable hydrogen, in progress at the Univ. of Michigan.

Some discussion of the theory is necessary to motivate the design of experiments, and to provide a framework for quoting experimental results. I have decided to limit this discussion to the form predicted for the non-relativistic potential, and to move as quickly as possible into a review of the experimental situation. At present, there are more theoretical models than experimental results, so the important future developments will probably be on the experimental side. To counteract the necessarily superficial review of the experiments, I have chosen to analyse just one in some detail. Since I am directly involved in one of the competing groups, you will have to excuse my choosing an experiment which

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I know well, and which we think holds the most promise for significant results.

The paper will conclude with some very brief remarks on the implications of these experiments and a trick slide giving a do-it-yourself parity experiment.

B. QUALITATIVE DISCUSSION OF WEAK INTERACTION THEORY

Our understanding of weak interactions has undergone a steady but remarkably slow progress during the 40 years since the theory was first formulated by Fermi. He described them as a local interaction between pairs of spin 1/2 particles,

\[ H = G \int dx \langle \psi_1 \psi_2 \rangle \langle \bar{\psi}_3 \bar{\psi}_4 \rangle + h.c. \]  

characterised by a single constant

\[ G = 1.4 \times 10^{-49} \text{ erg cm}^3 = 2.2 \times 10^{-14} \text{ eV}^2. \]  

This constant appears universally in interactions of this form; its very small value accounts for the slow progress.

We have learned to think of such interactions in terms of currents of spin 1/2 particles, interacting with intermediate vector mesons (Fig. 1). The small

![Diagram](image)

Figure 1 (a) Charged Currents coupled to $W^\pm$ vector mesons.  
(b) Neutral Currents coupled to $\gamma, Z^0$ vector mesons.