A SET OF NUCLEAR STOPPING CORRECTION FACTORS

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ABSTRACT

A set of nuclear Stopping correction factors to be used in the analysis of D.S.A. experiments by means of the LSS theory is presented. The results are derived from experimental determinations of the slowing down of ^{28}Si ions in several backings, ranging from carbon to uranium.

1 — INTRODUCTION

The problem of extracting nuclear lifetimes from Doppler shifted γ-rays has been haunting experimentalists for more than a decade, especially when no measured stopping powers are avaiable and in consequence (some) theoretical estimates have to be used in the analysis. The question assumes further importance at low recoil energies due to: (i) the difficulty of measuring stopping powers in this range, and (ii) the complexity of the energy transfer mechanism which leads to the stopping of the recoiling ions.

Usually this has been handled by means of a distinction between two different stopping processes, namely a nuclear (or atomic)

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process and an electronic process, both concurring to the actual stopping. Nuclear (or atomic) stopping contributes appreciably to the total energy loss at low recoil velocities ($v/c < 0.5\%$), whereas for recoils of higher energy electronic stopping is the dominant slowing down mechanism. The stopping cross sections employed in the analysis are usually taken from the theory of Lindhard, Scharff and Schiøtt (LSS) [1] which is based upon the Thomas-Fermi statistical model of the atom. The mathematical treatment developed by Blaugrund [2] has also been widely used, as a straightforward means of deducing lifetime values from experimentally measured energy shifts.

However, the reliability of this method has been questioned practically since its inception [3]. To overcome this situation, which assumed particular relevance when no measured stopping powers were available for the actual experimental conditions, different approaches have been introduced [4].

Neither of them can be said to have been successful in the attempt to explain the slowing down process. Da Silva et al. [5] show it clearly at low recoil energies, by means of a careful study of the well-known lifetime of the second excited state of ^{28}Si [6] using different backing materials, ranging from carbon to uranium.

We also chose the low energy region because this is the situation encountered in the experiments performed with the 2MV Van de Graaff accelerator located at Sacavém. Further, atomic (or nuclear) stopping is the dominant process at these recoil energies.

2 — RESULTS AND DISCUSSION

Up to the present, statements expressing that available potentials lead to an overestimate of atomic (or nuclear) stopping are abundant in the literature. More scarce are, however, adequate estimates of that deviation. Nevertheless, one has to be sure that the lifetimes extracted in a D.S.A. experiment are correct, even if no measured stopping powers are at hand. The experimental results obtained by da Silva et al. [5] mentioned above, warrant the adoption of such a coherent set of nuclear stopping correction factors, which enable the use of straightforward methods, such as the Blaugrund one.

The analysis of D.S.A. experiments by this method proceeds usually through the introduction of corrective factors f_e and f_n, for the electronic and atomic (or nuclear) stopping components, respectively. Further, at low recoil energies, as the atomic component is the main contributor to the stopping, f_e can be safely assumed to equal unity without concern.

The data were reanalised by varying f_n from 1.0 down to 0.1 in order to obtain lifetime vulues which were compatible with the adopted value of (63 ± 6) fs [6] for each case selected (the backings used were: C, Al, Cu, Zr, Ta and U), the inital velocity being $v/c = 0.14\,\%$ in all cases.

Fig. 1 shows the nuclear stopping powers for ^{28}Si ions in carbon and uranium in the Thomas-Fermi case and the corresponding curves used in the analysis (after correction by the multiplicative factors f_n).

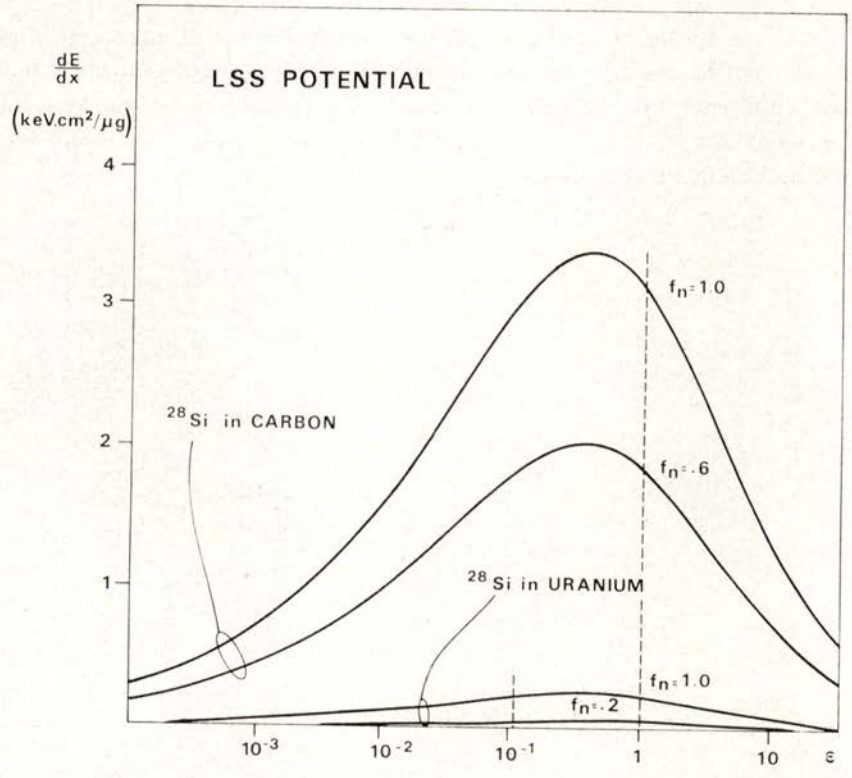

Fig. 1 — Nuclear stopping for ^{28}Si ions recoiling in carbon and uranium. Vertical lines correspond to ε initial in each case (ε as defined in ref. 1).

In Table 1, the whole set of corrective f_n's is presented.

TABLE 1 — Multiplicative correction factors, f_n

Material	Z	τ ($f_n = 1.0$) in fs	f_n for $\tau_{adopted}$ (*)
carbon	6	47 ± 8	$.6 \pm .1$
aluminium	13	44 ± 2	$.5 \pm .1$
copper	29	33 ± 4	$.3 \pm .1$
zirconium	40	42 ± 5	$.4 \pm .1$
tantalum	73	31 ± 8	$.3 \pm .1$
uranium	92	25 ± 7	$.2 \pm .1$

(*) $\tau_{adopted} = (63 \pm 6)$ fs [6]

From these values, a curve that covers the recoil of silicon ions in the entire region encountered in similar experiments can be inferred, thus enabling the selection of a value for the multiplicative f_n to be used in a D.S.A. lifetime analysis employing the Blaugrund method. The curve is shown in fig. 2.

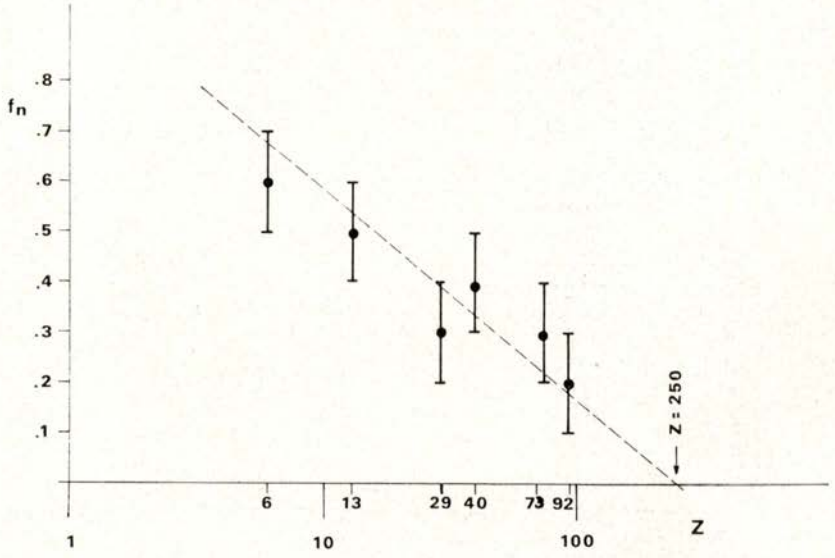

Fig. 2 — Values of the multiplicative factor f_n for silicon ions recoiling in different backings.

The physical meaning of this procedure is possibly hard to perceive [7]. It is however conceivable, at the present state of our investigations, that it conveys solely the indication that a silicon ion recoiling in $Z = 250$ would not loose energy significantly through any other process than an 'electronic' one.

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