# $^{57}$Fe Isomer Shift Calibration Experiment

H. Daniel, F. J. Hartmann, and B. Pitesa

Physics Department, Technical University of Munich, Munich

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The 4 s electron contact density was measured on $^{57}$Fe atoms embedded in Au and in graphite. With the help of the isomer shifts measured on the same sources an estimate of the radial difference $\langle \Delta r^2 \rangle$ was obtained which is rather independent of assumptions: $-\langle \Delta r^2 \rangle < 9 \times 10^{-3}$ fm$^2$ at 80 per cent confidence.

The calibration of the $^{57}$Fe isomer shift is certainly the most important task of Mößbauer spectrometry. Despite the many attempts the situation is not at all satisfactory. The reported radial changes $\langle \Delta r^2 \rangle$ vary between $-38.0 \times 10^{-3}$ fm$^2$ and $-8.2 \times 10^{-3}$ fm$^2$; for reviews cf. [1]–[3]. Recently a large value with small error $[(-33 \pm 3) \times 10^{-3}$ fm$^2]$ has been publised [4]. It was the goal of the present work to obtain an upper limit of $|\langle \Delta r^2 \rangle|$ with as little vague assumptions as possible. The method consisted in measuring the conversion ratio $\alpha_{4s}/\alpha_{3s}$ between 4 s and 3 s electrons on $^{57}$Fe in two different environments, evaluating the two spectra in the same way and use the 4 s electron contact density as a lower limit of the induced total electron contact density change because the core "amplification factor" [1] is certainly larger than unity but very uncertain [2].

$^{57}$Co was implanted with the Garching mass separator [5] into either Au (two sources) or C-graphite (one source). The conversion electron spectra from $^{57}$Fe were taken with a $\pi\sqrt{13}/2$ $\beta$-ray spectrometer [6] set to 0.5 per cent momentum resolution (fwhm). Least squares fits including as a block the right half of the $L_1$ conversion line, the other L lines, $M_1$, $M_{2,3}$, and $N_1$ were performed. Other procedures yielded somewhat different single values but almost the same difference between Au and graphite. The absolute value of the 4s contact density was obtained from the experimental ratio $\alpha_{4s}/\alpha_{3s}$ and the calculated 3s value; the error of the calculation is negligible compared to that of the experiment. Mößbauer spectra of the spectrometer sources were taken after the conversion electron runs. Figures 1 and 2 show Mößbauer and conversion electron spectra of one of the sources of $^{57}$Fe in Au. The results are summarized in Table 1, $S$ denoting the isomer shift as obtained in our experiment.

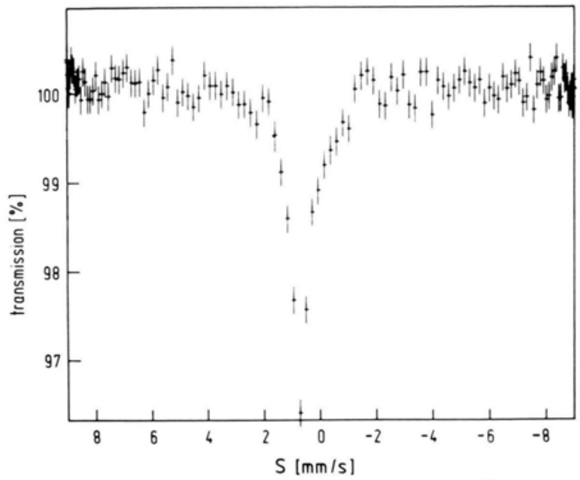


Fig. 1. Mößbauer spectrum of one of the sources $^{57}$Fe in Au.

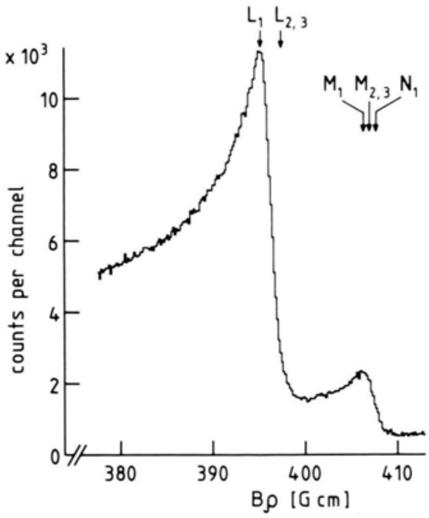


Fig. 2. Conversion electron spectrum of the source of Figure 1. One channel corresponds to 0.17 G cm.

Reprint requests to H. Daniel, Physics Dept., E 18, Technical University of Munich, James-Franck-Straße, D-8046 Garching, Fed. Rep. Germany.

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Table 1. Experimental data; stated errors are standard deviations.

| Source | $\alpha_{4s}/\alpha_{3s}$ | $S$ (mm) |
|---|---|---|
| $^{57}$Fe in Au | $0.061 \pm 0.005$ | 0.65 |
| $^{57}$Fe in graphite | $0.17 \pm 0.10$ | 0.25 |

The final result, $-\langle \Delta r^2 \rangle < 9 \times 10^{-3}\,\mathrm{fm}^2$ at 80 per cent confidence, strongly favors the smaller $|\langle \Delta r^2 \rangle|$ values reported [1, 3] and disagrees with the large ones, in particular with the most recent precise value [4]. The authors of [4], however, did not calculate and hence did not take into account the exchange and overlap corrections necessary in their case of electron capture decay. These corrections were calculated [7] for the neighboring $Z$ decay of Cu to amount to a factor of 1.28; they may very well reduce the final value of $-\langle \Delta r^2 \rangle$ from [4] by an amount of the order of 30 per cent.

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