Energy Levels of ^{53}Mn from the β-Decay of ^{53}Fe

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The γ rays following the β-decay of ^{53}Fe were investigated with high resolution detectors. Two unreported weak transitions were detected at the energies 1177 ± 1 keV and 2305 ± 1 keV. Log ft values were determined and spin and parity assignments made. On the basis of the results attained, a new decay scheme was proposed. Comparison with theoretical calculations are made.

I. Introduction

The study of the levels of ^{53}Mn (magic number of neutrons $N = 28$) is of a considerable theoretical interest. Investigations[1,2] on the levels of ^{53}Mn from the β-decay of ^{53}Fe lead to different conclusions about the existence of an allowed β group feeding a level between $\sim$ 1000 and 1500 keV, which was not observed in other experiments[3–5] with nuclear reactions.

The aim of the present work was to explore the above mentioned inconsistency and also to search for new β groups in the decay of ^{53}Fe. The existence of these groups is suggested by values of spin and parity assigned to some levels of ^{53}Mn in nuclear reaction measurements[3–5]. γ-ray spectroscopy techniques allowing high resolution and great statistics are employed.

II. Experimental Procedure

The source of ^{53}Fe was obtained from the reaction ^{54}Fe(γ, n)^{53}Fe, resulting from the irradiation of 286 mg of Fe_2O_3 (enriched to 75 — 90% in ^{54}Fe) with the Bremsstrahlung beam produced in a linear accelerator of electrons, operating with 21 MeV and 50 μA.

Measurements were performed with a 30 cm^3 Ge-Li detector (resolution 3,4 keV FWHM for 1332 keV) and the information obtained was coded and memorized in 4096 channels. A double stabilizer of zero and peak was introduced in the chain with the aim of allowing for the sum of spectra without deterioration of the resolution.

Twenty irradiations were performed; each one was followed by two consecutive measurements of an equal duration (15 minutes). The spectra of the first measurements for each irradiation and those of the second measurements were summed separately.

In order to identify the transitions proceeding from ^{53}Mn, relative intensities to the γ ray or 380 keV were determined for each period of observation and compared with one another, fof each transition.

With the purpose of finding weak transitions possibly existing in the region of 511 keV, two detectors were placed symmetrically to the source and an anticoincidence with 511 keV was performed.

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III. Discussion of Results

The spectrum resulting from 20 irradiations appears in Figure 1. Two unreported weak transitions presenting the same period as the γ-ray of 380 keV were observed at 1177 keV and 2305 keV. The energy and relative intensities of these transitions are shown in Table 1. A third γ ray observed at the energy 890 keV was proved to be a sum effect by measurements with different geometries.

Table 1.

Energy (keV)	Relative intensity to 380 ke$V$ (%)
380 ± 1	100
1177 ± 1	$1{,}0 \pm 0{,}1$
2305 ± 1	$0{,}15 \pm 0{,}03$

The anticoincidence revealed no further transition. The possibility of the γ ray of 1177 keV being the second scape peak of a transition of 2199 keV (between the levels 2571 keV and 380 keV) would be compatible with the levels of ^{53}Mn previously known[3]. That possibility was discarded because the non occurence of a peak of 2199 keV in the spectrum obtained was in disagreement with the ratio peak/second scape (about 5) determined for the detector amployed, in this energy region.

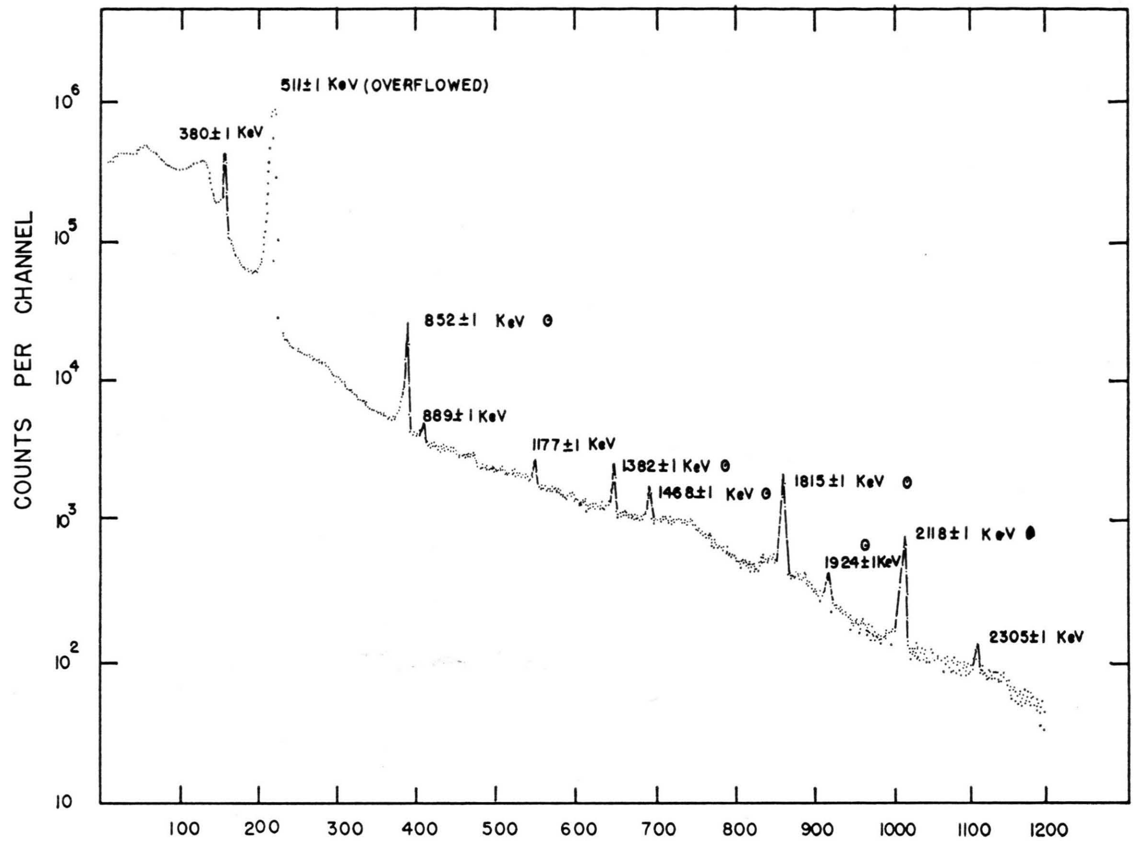

Fig. 1. γ-ray spectrum from ^{53}Mn. ⊙ long livied transition.

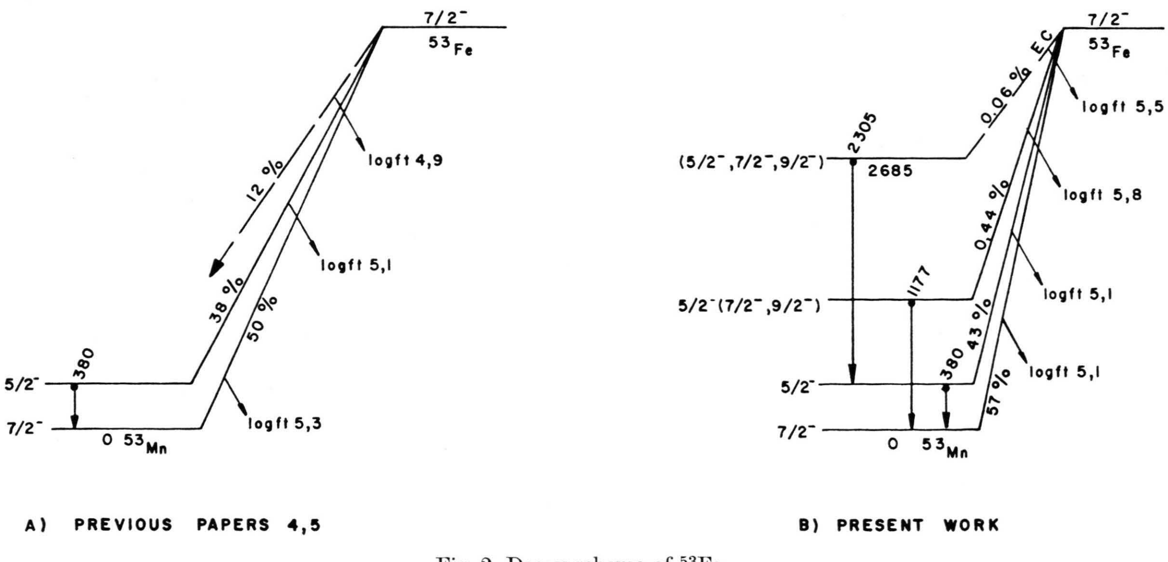

Fig. 2. Decay scheme of ^{53}Fe.

Thus an energy level at 1177 keV was proposed and the log ft of the β group feeding it was determined to be 5.8. This interpretation and the log ft value found are in agreement with experimental results [4], stating the existence of an allowed β group of end point energy $\sim$ 1570 keV.

The Gamma ray of 2305 keV was identified as the transition from the level 2685 keV ($7/2^-$) to the level 380 keV ($5/2^-$).

All the γ rays following the β-decay of ^{53}Fe were positioned in the decay scheme proposed in the present work. Log ft values were determined from the relative intensities of the γ transitions obtained in this paper and also from data indicated in reference [5], concerning the relative abundance of the β groups feeding the ground state and the level of 380 keV.

In Fig. 2 the decay scheme of ^{53}Fe previously proposed [4, 5] (a), and the one we propose (b) are shown.

IV. Comparison with Theories

From Fig. 3 the accuracy attained in shell model calculations is apparent. Even some very simple models based on $(f_{7/2})^n$ pure configuration describe very successfully the first excited levels 380 keV ($5/2^-$), 1230 keV ($3/2^-$), 1440 keV ($11/2^-$) and 1620 keV ($9/2^-$). The importance of configuration mixing is, however, evidenced in the levels 1177 keV ($5/2^-$, $7/2^-$ or $9/2^-$), 2272 keV ($7/2^-$), 2405 keV ($3/2^-$), and 2571 keV ($5/2^-$ or $7/2^-$). As a whole the model which best reproduces the experimental levels up to 2500 keV is the one presented by Lips-McEllistrem [6] in calculations a*, b**, and c*** of their paper. The comparison among these calculations favours calculation c which reproduces the experimental levels with greater accuracy, and predicts the first levels ($11/2^-$) and ($9/2^-$) in the right sequence. It is also noticeable that the calculation c produces a level $\sim$ 1150 keV ($5/2^-$),

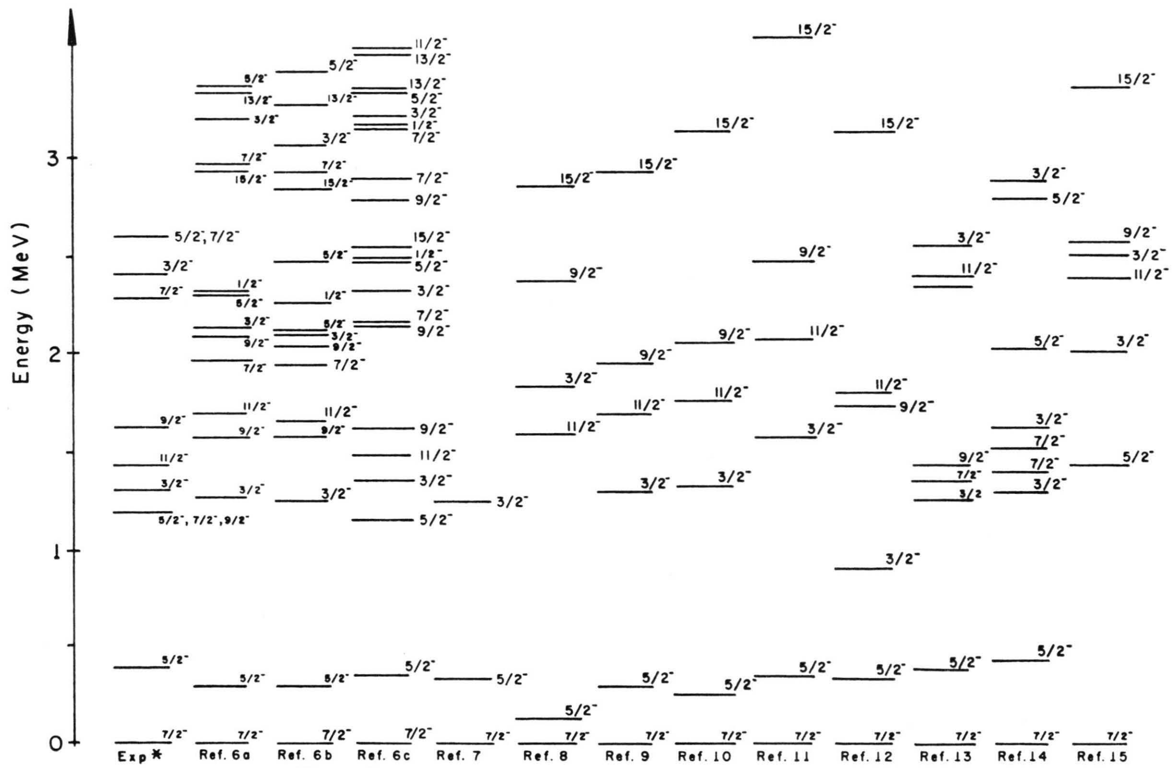

Fig. 3. Experimental and theoretical energy levels of ^{53}Mn (*Ref. [6] and present work).

* The matrix elements of the residual interaction are taken as free parameters and fitted to experimental data.

** The residual interaction is a surface δ interaction.

*** The residual interaction is expressed with the matrix elements of Kuo-Brown [7].

with a strong preponderance of the configuration $(f_{7/2})^4 f_{5/2}$, corresponding to the level 1177 keV ($5/2^-$, $7/2^-$ or $9/2^-$) proposed in the present work. This level cannot be antecipated by most of the calculations available, which, with a few exceptions, do not consider such a configuration.

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