

New Determination of the Half-Life of ^{60}Fe - Measurement of the Activity

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The radionuclide ^{60}Fe is a key nuclide in nuclear astrophysics. The intensity of the recent finding of ^{60}Fe in gamma ray astronomy (e.g. [1]) is an important test for nucleosynthesis models. However a prerequisite is an accurate knowledge of the half-life. The presently accepted value for the half-life of ^{60}Fe ($T_{1/2} = (1.49 \pm 0.27) \text{ Ma}$) originates only from one measurement [2], where an absolute AMS measurement was performed to deduce the ratio of $^{60}\text{Fe}/\text{Fe}$. This motivated us for a new determination of the half-life.

Half-life Measurement in General

For a long half-life in comparison to the measurement time a direct determination via decrease in activity A or number of nuclei N_{rad} with time is not feasible. Therefore one has to determine both A and N_{rad} , or more realistically three quantities, A , N_{stable} and $\frac{N_{rad}}{N_{stable}}$.

$$A = \lambda \cdot N_{rad} = \frac{\ln(2)}{T_{1/2}} \cdot \frac{N_{rad}}{N_{stable}} \cdot N_{stable}$$

This article describes the status of the measurement of A . ^{60}Fe is a beta emitter with a low energy γ -ray (58.6 keV) which is highly converted. The activity of ^{60}Fe can be measured via the grow-in of its daughter, ^{60}Co ($T_{1/2}(^{60}\text{Co}) = 5.27 a$).

$A_{60\text{Co}} = N_{60\text{Fe}} \lambda_{60\text{Fe}} \cdot (1 - e^{-\lambda_{60\text{Co}} \cdot t}) = A_{60\text{Fe}} \cdot (1 - e^{-\lambda_{60\text{Co}} \cdot t})$ for $t \ll T_{1/2}(^{60}\text{Co})$, this corresponds to a linear increase of the activity: $A_{60\text{Co}} \approx N_{60\text{Fe}} \cdot \lambda_{60\text{Fe}} \cdot \lambda_{60\text{Co}} \cdot t$.

If the activity of ^{60}Co is very low at the beginning, the grow in of the daughter activity can be measured via its γ -rays.

Production of ^{60}Fe Nuclei

The first difficulty is to have ^{60}Fe nuclei in a sufficient amount. In cooperation with the PSI (Paul Scherrer Institut) a copper beamdump was selected, which has been irradiated with about $3.6 \cdot 10^{21}$ protons with an energy of 590 MeV. The end of the irradiation was September 1st 1992. The short lived radioactivities have already decayed.

Extraction of the ^{60}Fe Nuclei

The iron had to be separated chemically from the bulk material of copper. One of the remaining nuclei with a half-life in the range of years and a high activity is ^{60}Co , which is in addition the daughter of ^{60}Fe and has to be separated to be able to measure the grow-in. A copper piece of 3.86 g was dissolved in 7 M HNO_3 . Then the solution was evaporated to dryness and again dissolved in 7 M HCl . 5 mg iron as Fe^{3+} and 5 mg of cobalt as Co^{2+} were added as carrier. Then iron is extracted with diisopropylether, were iron goes into the organic phase and other metals like Ni, Co and Cu go into the aqueous phase. The iron was then back extracted with 0.1 M HCl and again extracted with diisopropylether. The last step for the purification was the precipitation of $\text{Fe}(\text{OH})_3$ from the solution. The precip-

itate was again dissolved and given to a precise volume of 5 ml. From this bottle all the subsamples were taken. The sample for the determination of A contains $4000 \mu\text{l}$ of the dissolved initial sample, corresponding to 80% of the total sample. Aliquots will be used to determine N_{rad} . The numbers N_{stable} and $\frac{N_{rad}}{N_{stable}}$ will be determined by MC-ICP-MS (Multi-Collector Inductively Coupled Plasma Mass Spectrometry).

Measurement of the Activity

The activity is measured relative to a standard in the same geometry as the sample, a vial with 5 ml of a weak ^{60}Co solution. Figure 1 shows the grow-in of the two well known γ -lines of ^{60}Co . The exponential fits for both lines correspond to a saturation activity of 49.8 Bq (uncertainty $\leq 3\%$).

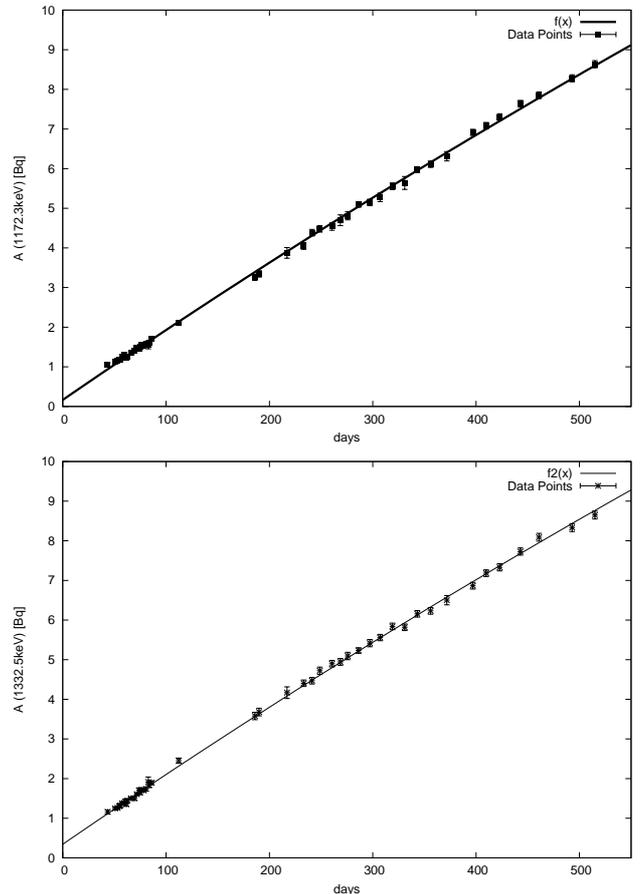


Fig. 1: Grow-in of the ^{60}Co activity measured at the underground lab in Munich/Garching. The exponential fits correspond to a saturation activity of 49.8 Bq.

References

- [1] R. Diehl, *New Astron. Rev.* **50** (2006) 534.
- [2] W. Kutschera *et al.*, *Nucl. Instr. and Meth.* **B5** (1984) 430.