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Half Life Measurements in ^{155}Gd

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ABSTRACT

In the literature there exists a definite difference for the half life of the 86.5 keV level in ^{155}Gd depending on whether ^{155}Eu or ^{155}Tb sources have been used. Using a good energy resolution electron-electron coincidence spectrometer and a ^{155}Eu source, a half life of 6.48 ± 0.26 nsec was obtained for the 86.5 keV level. This is in agreement with the values previously measured with ^{155}Tb sources. The half life of the 105.4 keV level was measured to be 1.12 ± 0.05 nsec.

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1. INTRODUCTION

During the recent years several groups [1-6] have measured the half life of the 86.5 keV level in ^{155}Gd. The extreme results differ by a factor of 1.5 while each measurement is generally thought to have an error of about 5 %. A closer look at the experimental data, however, shows that they cluster around two values, namely 5 ns and 6.7 ns (table 1). Furthermore all measurements in the 5 ns group are measured with a ^{155}Eu source while the other group of data is measured with a ^{155}Tb source. One explanation of this discrepancy is, of course, that some background radiation is disturbing the measurement, especially as only instruments with poor energy resolution have been used. But, regarding the two distinct groups, it might also be possible that there are actually two close-lying γ-rays which depopulate different levels with different half lives. As the ground state spin in the ^{155}Eu and ^{155}Tb sources differs by one unit these levels could be populated differently. To get a definite answer a remeasurement was performed with a well aged ^{155}Eu source using a good energy resolution electron-electron coincidence spectrometer. During the course of this investigation the half life of the 105.4 keV level in ^{155}Gd was also measured.

2. SOURCE PREPARATION

As the basic material for the source preparations we used 5 mg of spectroscopically pure samarium oxide. To get rid of any contamination of Eu with its high neutron capture cross section, small traces of carrier-free $^{152+154}$Eu and ^{147}Pm activities were added to the non-active samarium solution. This was put onto an ion exchange column with the resin Dowex 50 x 4 (< 400 mesh). The elution was made with α-hydroxy-isobutyric acid. The activity of the eluate was measured and a Sm fraction between the Eu and Pm activities was collected. By this process any Eu content was reduced by at least a factor of one hundred. 4 mg of the purified samarium oxide was irradiated for 6 days at a neutron flux of 2×10^{13} n/cm^2 sec. After the neutron activation the same purification procedure was repeated on the active material, but this time the Eu fraction was collected from which the sources were prepared. They were allowed to decay for about five months, primarily to reduce the content of the 15-day ^{156}Eu activity which is produced by the ^{155}Eu (n, γ) ^{156}Eu reaction (~ 14000 barns). Some preliminary life time measurements were then made (summer 1964) using a coincidence set-up with two plastic scintillators. A half life of ~ 5 nsec for the 87 keV level in ^{155}Gd was obtained and a private communication was given to Löbner [6]. Since that time an electron-electron coincidence spectrometer has been incorporated into our old set-up. With this instrumentation the measurements reported in this paper were performed using ^{155}Eu sources prepared from the stock irradiated in January 1964.

3. INSTRUMENTATION

The basic instrument for these half life measurements have been a long lens electron-electron coincidence spectrometer very similar to the one described by Gerholm and Lindskog [7] together with a time-to-pulse height converter and a multichannel analyser. The detectors consist of specially shaped Naton 136 plastic scintillators [8] optically coupled to the photomultiplier 56 AVP. This combination gives an energy resolution of 10 % for the 662 keV K line in ^{137}Cs and a time resolution of the total electronic system of 450 ps as measured from β-γ coincidences with a ^{60}Co source. Details of the electronic system and the time calibration are given elsewhere [9].

4. EXPERIMENTAL PERFORMANCE

The two lens spectrometers were set to 3 % energy resolution. From the measured electron spectrum it was seen that the 86.5 K line was undisturbed while the 105.4 K line was only partly resolved from the 60 L and M components. In the first experiment we focussed the 86.5 K line into one spectrometer while the other spectrometer detected β-particles of approximately 135 keV. The resulting decay curve, an example of which is shown in Fig. 1, shows a single delayed component. From the slope of this curve the half life was determined. As a mean value from 6 such measurements we obtain a half life for the 86.5 keV level in ^{155}Gd of 6.48 ± 0.26 nsec.

In a second type of experiment we measured the half life of the

105.4 keV level in ^{155}Gd. As the 105.4 K line was only partially resolved from the 60 L and 60 M lines we preferred to use the resolved 105.4 L line which was focussed into one spectrometer. The other channel was unchanged and thus detected β-particles of 135 keV. An example of the resulting decay curve is shown in Fig. 2. From the slope of this decay curve the half life was determined. The corresponding prompt curve is only given for comparison. As a mean value from 5 measurements we obtain 1.12 ± 0.05 nsec for the half life of the 105.4 keV level in ^{155}Gd.

5. DISCUSSION

The result of this investigation together with those from other groups are collected in Table 1. Our new value for the half life of the 86.5 keV level in ^{155}Gd is in agreement with those obtained from measurements in the decay of ^{155}Tb. This rules out the arguments for the idea of two close-lying levels in ^{155}Gd with different half lives. The probable explanation of the discrepancy regarding the measured half life of the 86.5 keV level must be that other cascades than the β^--86.5 keV cascade contributes to the measured decay curve. Such disturbing cascades are difficult to avoid especially with NaI and plastic scintillators when the measured decays are rather complex. In the actual decay of ^{155}Eu, for instance, it is difficult with the mentioned instrumentation to avoid a contribution from the β^--105.4 keV cascade defining a half life of 1.1 nsec. If this is not properly corrected for, such a contribution will give a steeper slope and a shorter half life will result. In the measurements with ^{155}Eu sources the ^{156}Eu contamination must also be handled with care, especially as the first excited state in its decay product ^{156}Gd has an energy of 89 keV and half life of 2.2 nsec. This latter systematical error will be avoided using a ^{155}Tb source. Groups using this source [5, 6] have made a γ-γ coincidence experiment using the 180 keV - 87 keV cascade to determine the half life of the 86.5 keV level in ^{155}Gd. In this case the disturbance from the 105.4 keV level comes in via a 161 keV - 105 keV cascade. Here, however, the possibilities of discriminating against the disturbance from the 105.4 keV level are much better than from a ^{155}Eu source with β^- feeding, as the 161 keV and 180 keV lines are partially resolved in a NaI crystal. With careful settings of the high energy channel the 180 keV - 87 keV coincidence distribution will be rather free from other disturbing cascades and thus give a reliable value for the half life of the 86.5 keV level in ^{155}Gd.

Our value of 1.12 ± 0.05 nsec for the 105.4 keV level is in agreement with earlier investigations (Table 1).

The 86.5 and 105.4 keV levels in ^{155}Gd have been identified with the $\frac{3}{2}$+ (651) and $\frac{5}{2}$+ (642) Nilsson levels respectively. The absolute E1 transition probabilities between these levels and the $\frac{3}{2}$ - (521) ground state have earlier been compared with the Nilsson model estimates. A full account of such a comparison together with the systematic trends for similar E1 transitions is given in a survey by Löbner and Malmskog [10].

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Table 1

References	Source	Method	Level energy	$T_{1/2}$ in ns
M.N. Vergnes[1] [1960]	^{155}Eu	β- γ with plastic and NaI crystals	86.5	5 ± 1
K. Runge et al.[2] [1961]	^{155}Eu	β- γ with NaI crystal	86.5	4.3 ± 0.20
U. Hauser et al.[3] [1961]	^{155}Eu	β- γ with NaI crystal	86.5	5.04 ± 0.25
S.G. Malmskog[4] [1964]	^{155}Eu	β- γ with NE102 plastic scintillator	86.5	~5.0
E. Bozek et al.[5] [1964]	^{155}Tb	γ- γ with NaI crystals	86.5	6.68 ± 0.12
K.E.G. Löbner[6] [1965]	^{155}Tb	γ- γ with plastic and NaI crystals	86.5	6.7 ± 0.3
Present investigation	^{155}Eu	Electron-electron coincidence spectrometer	86.5	6.48 ± 0.26
M.N. Vergnes[1] [1960]	^{155}Eu	β- γ with plastic and NaI crystals	105.4	<1.2
K. Runge et al.[2] [1961]	^{155}Eu	β- γ with NaI crystal	105.4	1.07 ± 0.10
U. Hauser et al.[3] [1961]	^{155}Eu	β- γ with NaI crystal	105.4	1.05 ± 0.05
Present investigation	^{155}Eu	Electron-electron coincidence spectrometer	105.4	1.12 ± 0.05

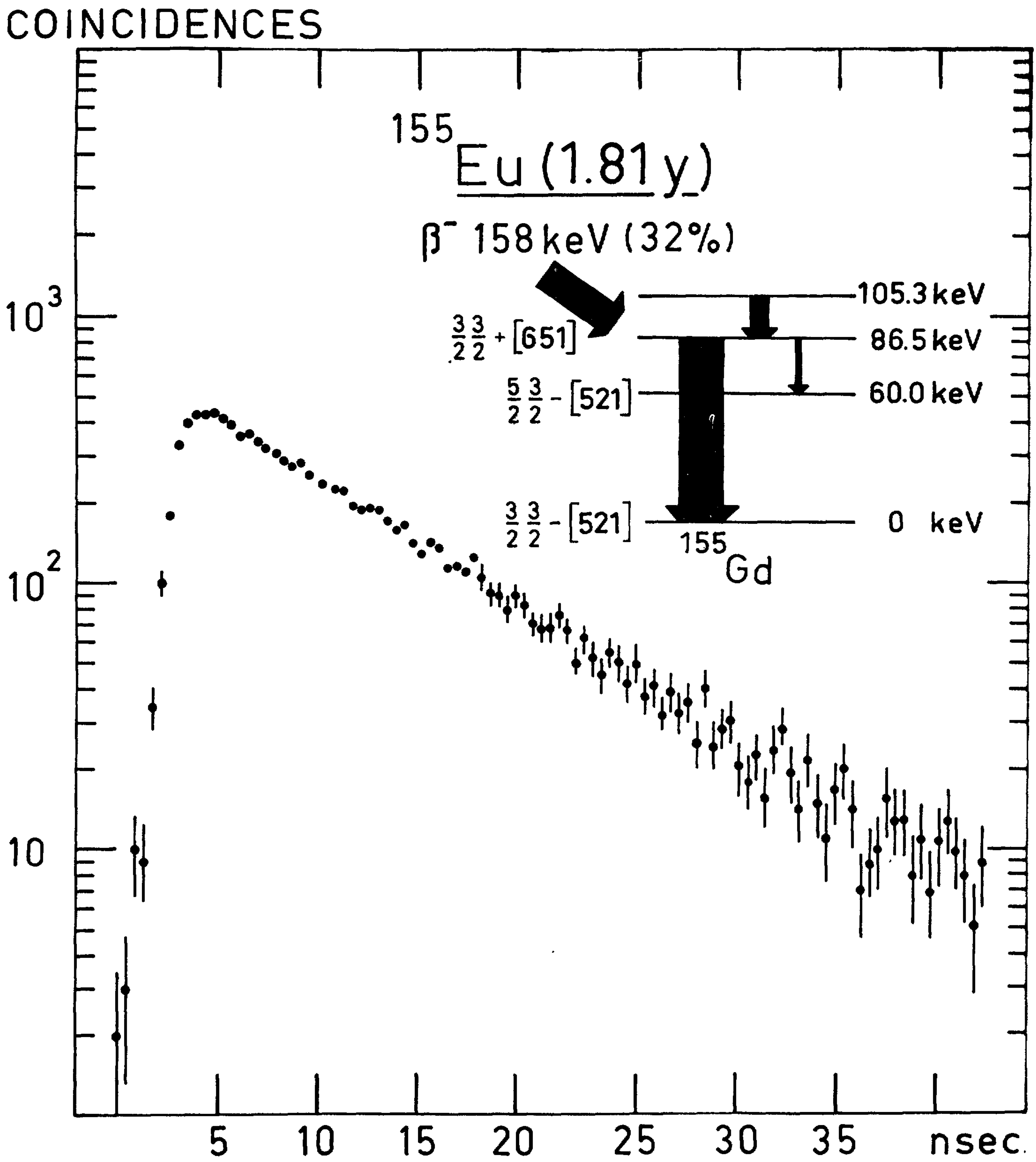

Fig. 1 Delayed coincidence curve taken between the 86.5 K electron line and the β^--continuum at 135 keV giving $T_{1/2} = 6.48 \pm 0.26$ nsec for the 86.5 keV level in ^{155}Gd. The simplified decay scheme shows the principal feeding and deexcitation of the 86.5 keV level.

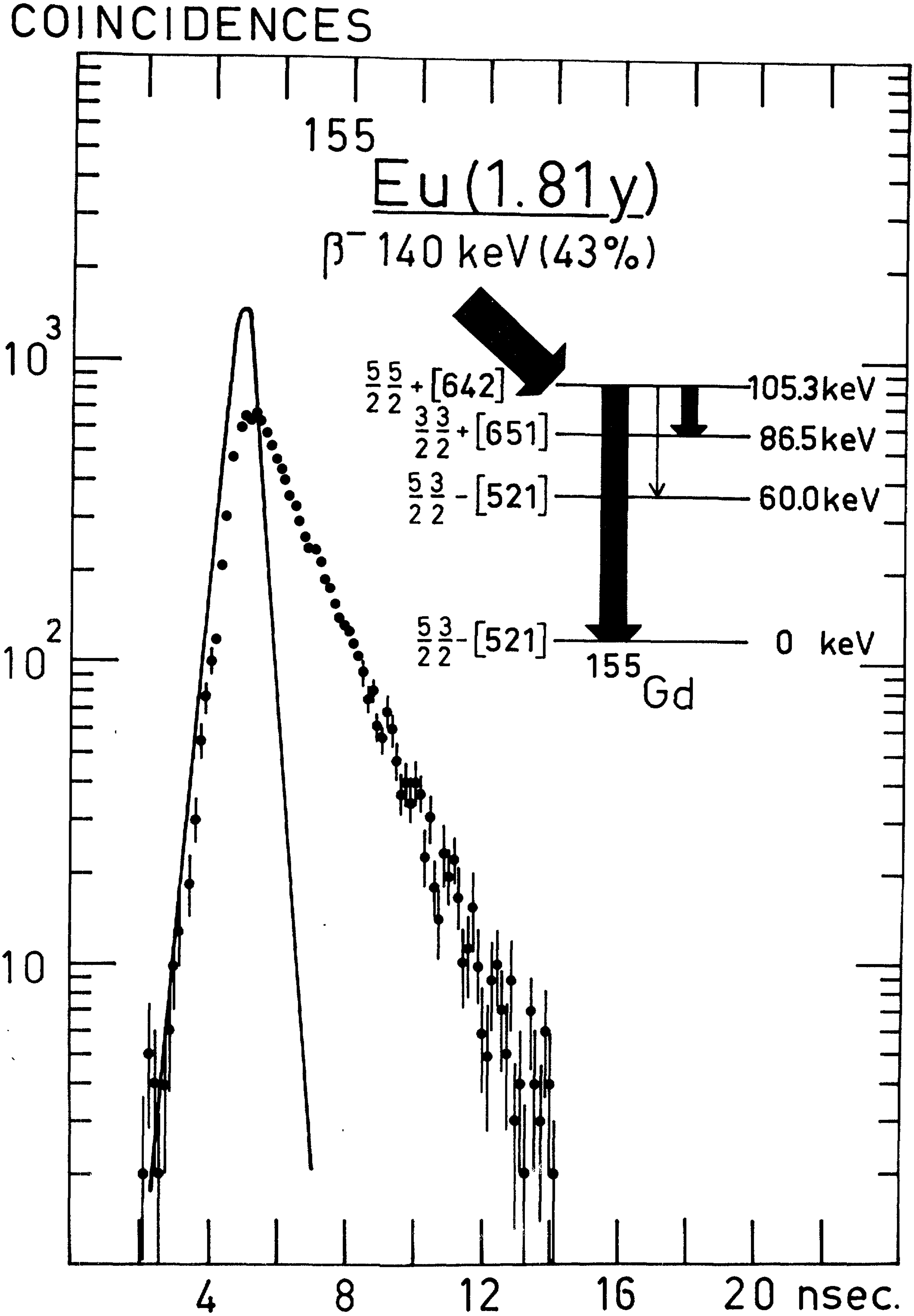

Fig. 2 Delayed coincidence curve taken between the 105.4 L electron line and the β^--continuum at 135 keV giving $T_{1/2} = 1.12 \pm 0.05$ nsec for the 105.4 keV level in ^{155}Gd. The simplified decay scheme shows the principal feeding and deexcitation of the 105.4 keV level.

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