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Fluctuation factors in the EFF-3.0 file for ^{56}Fe

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Abstract

Fluctuation factors extracted from experimental total cross section data for natural Fe are applied to evaluated total *and* inelastic cross sections for ^{56}Fe. The results are stored in the EFF-3.0 file for ^{56}Fe. This approach has a significant impact on shielding calculations with MCNP [1].

CONTENTS

1. INTRODUCTION

Neutron total cross sections for ^{56}Fe display fluctuations up to several MeV, see fig. 1.1, where the data from EFF-2.4 [2] are displayed. In general, inelastic cross sections are not measured as precise as the total cross section. Moreover, the associated data in evaluated files are often based on model calculations, fitted to available experimental data. This entails that these evaluated data display a smooth behaviour. In fig. 1.2, the evaluated inelastic cross section for the first-excited level (2^+ at 0.847 MeV) of ^{56}Fe is displayed. For this level, fluctuations up to about 2 MeV are known from experiment and the corresponding fluctuating cross section is included in the EFF-2.4 file. As a counter-example, the evaluated inelastic cross section for the third excited state (2^+ at 2.658 MeV) of ^{56}Fe is shown in fig. 1.3. Clearly, no fluctuations are included here. From a physical point of view however, there is no reason to assume that this smooth behaviour of inelastic cross sections is realistic. Therefore, it is more appropriate to add fluctuation factors to these partial cross sections as well. We will assume here that we can perform this with the fluctuation factors extracted from the *total* cross section. This approach should be regarded as a reasonable approximation until the true fluctuations of the partial cross sections have been measured with enough accuracy. The method of applying fluctuation factors to the partial cross sections was already suggested by Froehner [3].

The results described here replace those of previous work [8]. The reason is that we obtained evaluated cross sections which are much closer to the experimental data from Geel than the previous evaluated set. As for the evaluated file, the obtained MF3 is combined with the other files to obtain a new EFF-3.0 file for ^{56}Fe.

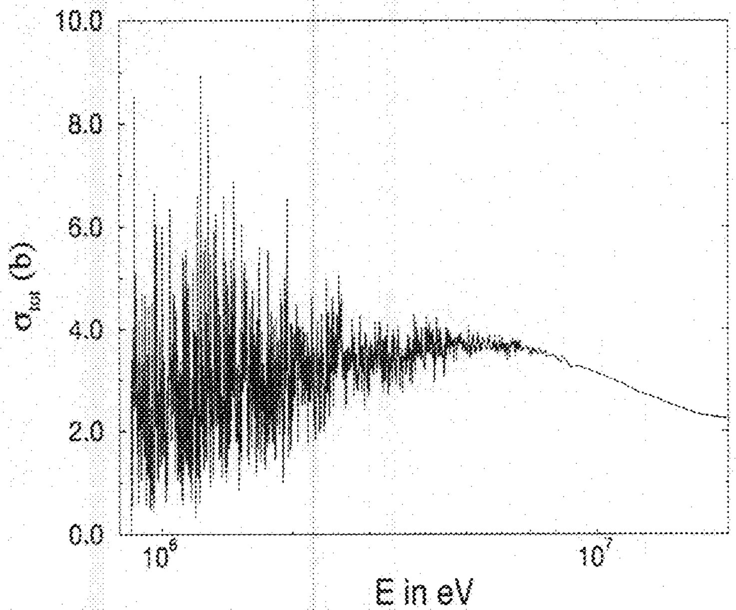

Figure 1.1 *Total cross section for ^{56}Fe from EFF-2.4.*

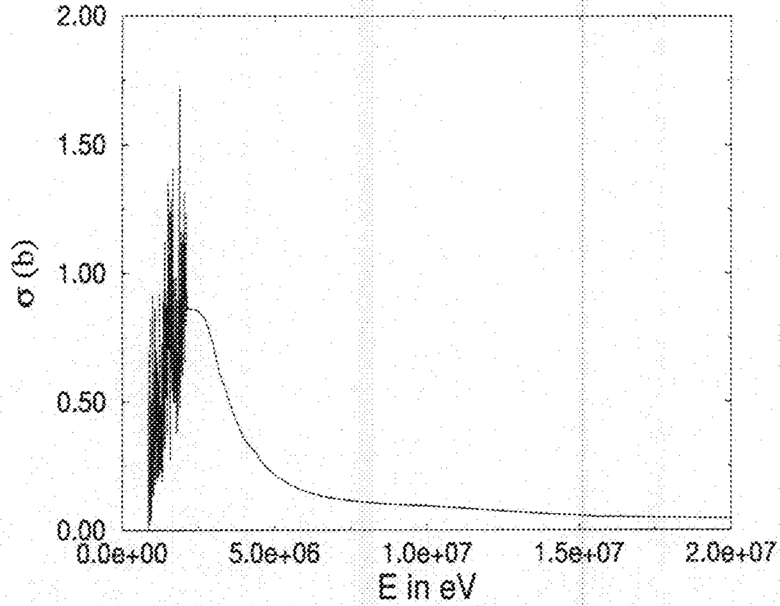

Figure 1.2 *Cross section for the first excited level of ^{56}Fe from EFF-2.4, including measured fluctuations.*

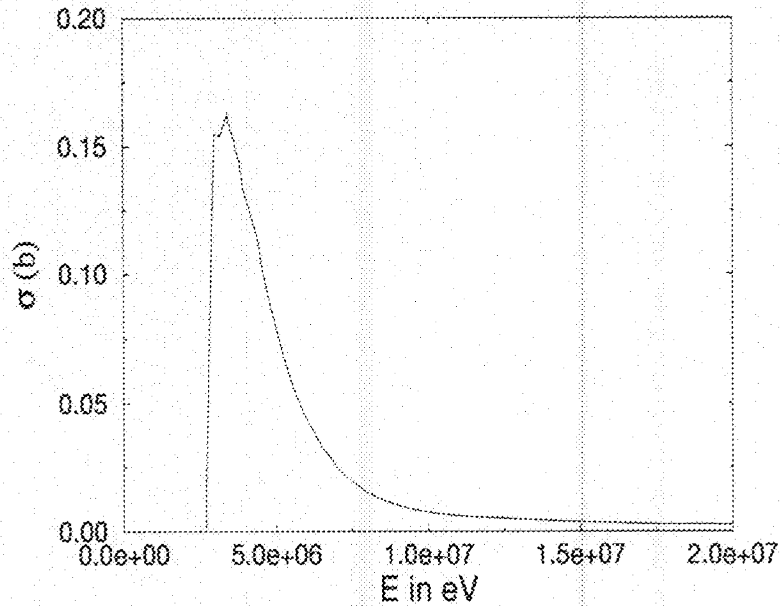

Figure 1.3 *Cross section for the third excited level of ^{56}Fe from EFF-2.4.*

2. FLUCTUATION FACTORS

The starting point of the operation is the ^{56}Fe file of EFF-2.4. In this section, we will give an outline of the method to update the MF3-file.

2.1 Total cross section

In order to determine the fluctuation factors, we consider the total cross sections measured by IRMM, Geel [4, 5], see fig. 2.1. This data set consists of 21490 energy points between 0.85 and 10 MeV.

In the new file for ^{56}Fe, we use evaluated data by Vonach and Tagesen [6] which has group-averaged total cross sections as basis. These cross sections are depicted in fig. 2.2. It is recommended [7] to use these data as point data, which are presented in fig. 2.3. The idea is to combine these total cross sections with the fluctuation information as yielded by the IRMM experiment.

We proceed as follows:

1. We perform a group average with a flat weighting spectrum of the IRMM data using the same 40 energy groups as those of Vonach [7]. Thus, we obtain

$$\langle \sigma_{exp}(E) \rangle^{g.a.} = \sigma_{exp,i}, \tag{2.1}$$

   with $E_{i-1} < E < E_i$ for i=1 to 40. Here, E represents the aforementioned energy grid of 21490 points. The difference with the averaged total cross section of Vonach is depicted in fig. 2.2.

2. We connect the midpoints of the resulting histogram (exactly as was done in Ref. [7]) by straight lines, giving:

$$\sigma_{exp}^{cont}(E) = \sigma_{exp,i-1} + (\sigma_{exp,i} - \sigma_{exp,i-1})\frac{(E - E_{i-1})}{(E_i - E_{i-1})}, \tag{2.2}$$

   with $E_{i-1} < E < E_i$ for i=1 to 40. The resulting curve is depicted in fig. 2.3.

3. We construct new fluctuation factors by relating these averaged cross sections to the measured data:

$$f_{fluc}^{new}(E) = \frac{\sigma_{exp}(E)}{\sigma_{exp}^{cont}(E)}. \tag{2.3}$$

4. We connect the midpoints of Vonach's histogram by a continuous line, as prescribed in Vonach's evaluation (linear interpolation):

$$\sigma_{vonach}^{cont}(E) = \sigma_{vonach,i-1} + (\sigma_{vonach,i} - \sigma_{vonach,i-1})\frac{(E - E_{i-1})}{(E_i - E_{i-1})}, \tag{2.4}$$

   if $E_{i-1} < E < E_i$ for i=1 to 40. This curve is also presented in fig. 2.3.

5. To obtain the new total cross sections, we multiply $\sigma_{vonach}^{cont}(E)$ by the new fluctuation factors:

$$\sigma_{new}(E) = \sigma_{vonach}^{cont}(E) \times f_{fluc}^{new}(E). \tag{2.5}$$

The new total cross sections are shown in fig. 2.4.

In sum, we have applied the fluctuation information of the IRMM experiment on existing evaluated total cross section data. The difference between the IRMM data and Vonach's data has been reduced as compared to the previous difference [8]. The remaining difference is found at the lower energies. We assume here that Vonach's evaluation is the best with respect to smooth total cross sections as it is based on a large set of reliable data.

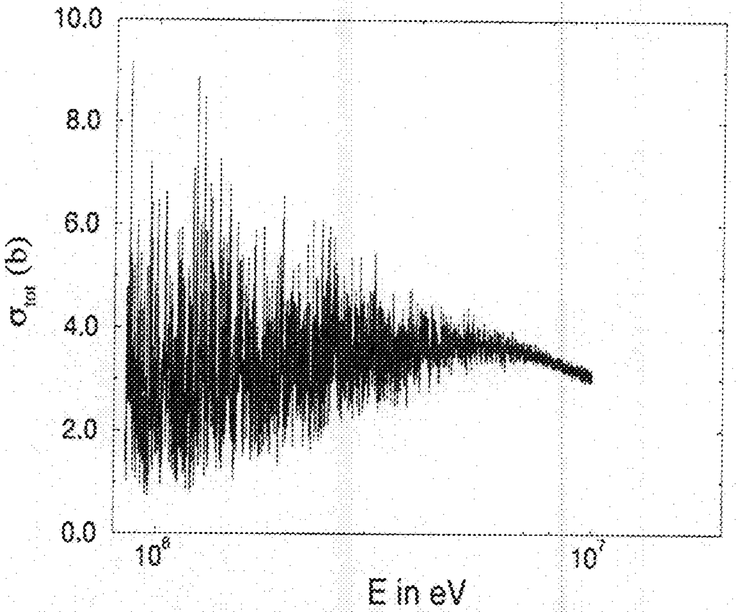

Figure 2.1 *Experimental total cross sections for ^{56}Fe as measured in Geel.*

2.2 Partial cross sections

The fluctuation factors as obtained in Eq. (2.3) could now in principle be applied to all partial cross sections of the MF3-file. In this work, however, we have restricted ourselves to the addition of fluctuations to the *inelastic* cross sections. The reason is that the (n,p) and (n,α) cross sections are small compared to the inelastic scattering cross sections. Moreover, these reactions have a high threshold above which the fluctuations are quite small. Also, we did not apply this method on the (n,γ) cross section, because we are not convinced about the physical justification of this operation for the gamma channel.

As an example of our procedure, the result for inelastic scattering to the first excited level of ^{56}Fe is depicted in fig. 2.5 and that of the third excited level in fig. 2.6. Note that we have chosen to replace the old fluctuation information for the first excited state (from EFF-2.4, see fig. 1.2). In fig. 2.7, the difference is shown.

Finally, internal consistency of the MF3-file is maintained (sum of partials = total) by adjusting the elastic cross section. In figs. 2.8 and 2.9 the difference between the old and the new evaluation for the elastic cross section is displayed.

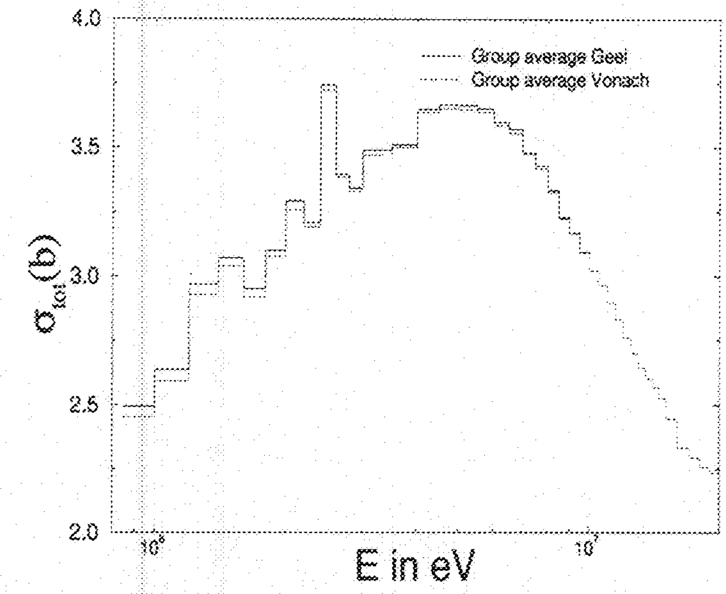

Figure 2.2 *Total cross sections averaged over 40 energy groups for (a) evaluated data from Vonach, (b) experimental data from IRMM, Geel.*

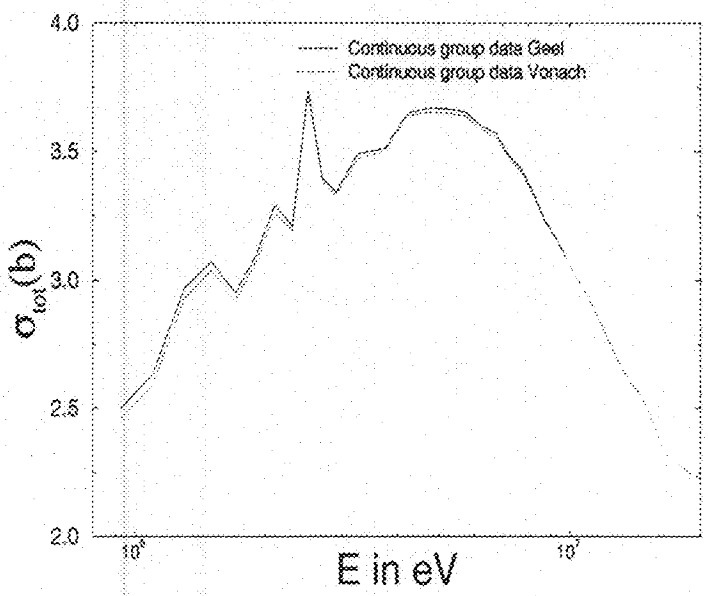

Figure 2.3 *Continuous data, obtained by linear interpolation between the midpoints of the energy groups, derived from (a) evaluated data from Vonach and (b) experimental data from Geel.*

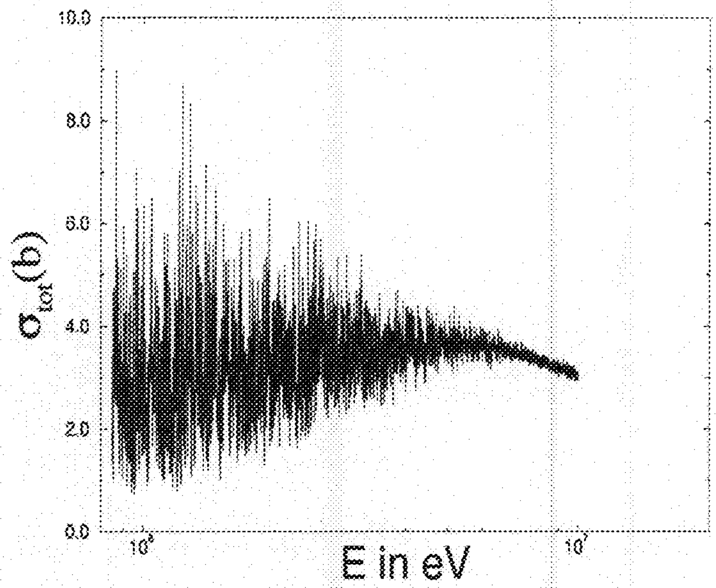

Figure 2.4 *New total cross sections for ^{56}Fe, see text.*

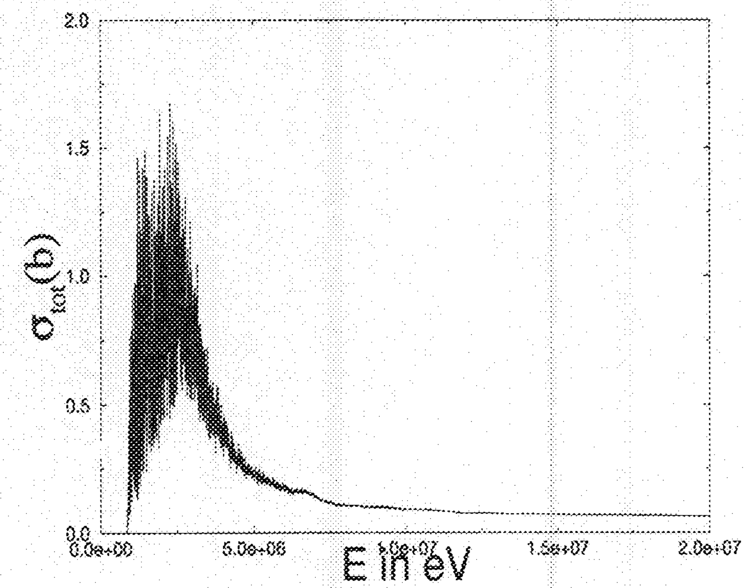

Figure 2.5 *New cross section for the first excited level of ^{56}Fe.*

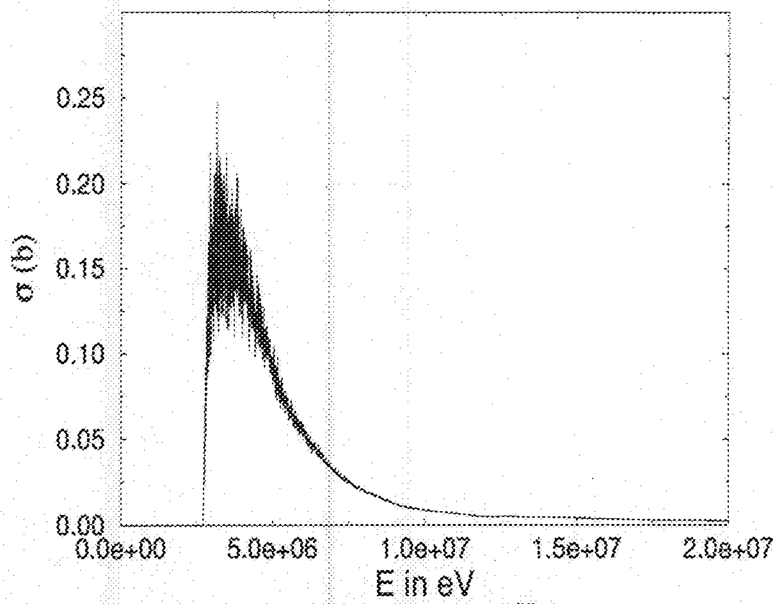

Figure 2.6 *New cross section for the third excited level of* ^{56}Fe.

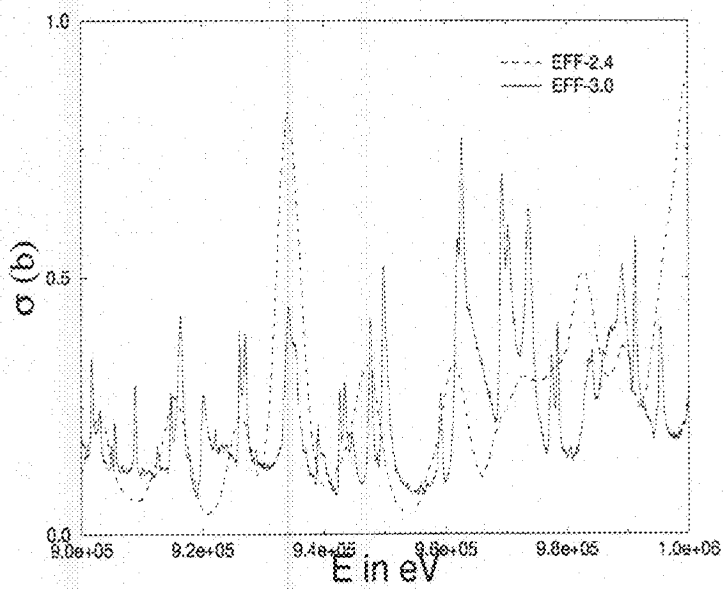

Figure 2.7 *Difference between the EFF-2.4 and EFF-3.0 inelastic cross section for the first excited level of* ^{56}Fe.

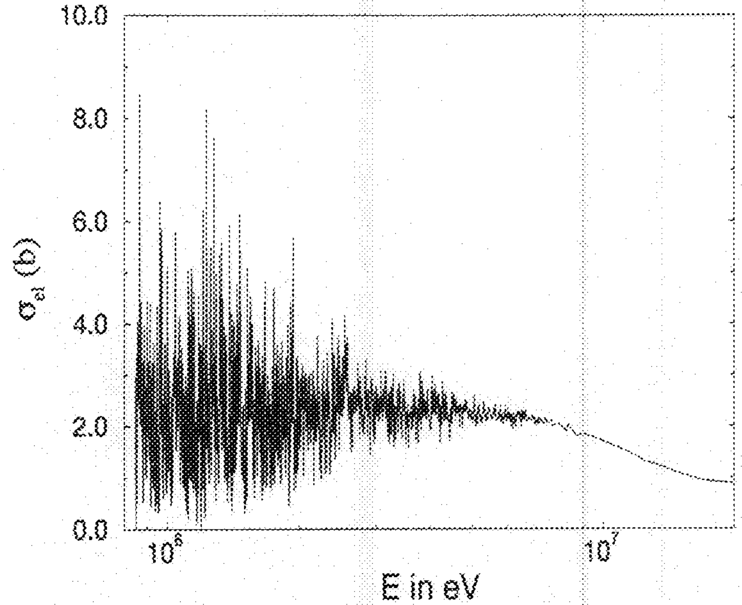

Figure 2.8 *Elastic cross section as extracted from EFF-2.4.*

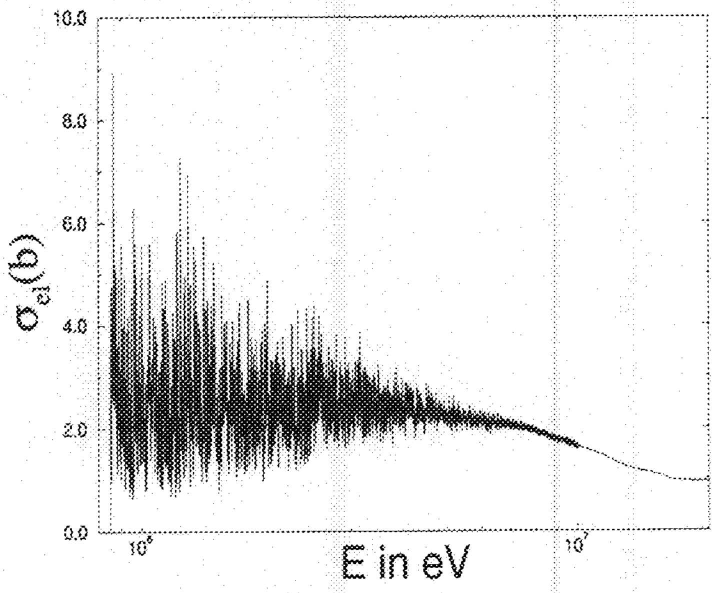

Figure 2.9 *New elastic cross section, see text.*

3. CONCLUSIONS

We have applied fluctuation factors, extracted from accurate experimental data [4], on evaluated [6] total and inelastic cross sections for ^{56}Fe. The results are stored in a new EFF-3.0 file. This EFF-3.0 file also consists of new elastic angular distributions [6] and a new MF6 [9]. These aspects will be discussed in a separate report.

The impact of the added fluctuating inelastic cross sections on shielding calculations with MCNP will be discussed in a future report [1].

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