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Supplementary Data for Neutron Activation Analysis

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ABSTRACT

In order to facilitate further development and increase the accuracy of the k_0 neutron activation analysis (NAA) an IAEA Co-ordinated Research Project (CRP) was conducted. Relation between microscopic cross section data and constants used in k_0 NAA were derived from first principles. A term that accounts for the fast fission part of the spectrum was introduced. Constants that cannot be measured directly with a high precision like the cadmium correction factor, generalised Westcott factor and the average resonance energy were calculated from selected evaluated data files. In some cases, where the k_0 NAA relies on isotopes with a small abundance, the quality of microscopic data is poor. A selection of "the best evaluation" evaluation was made and plots of the cross sections produced to identify cases, where values derived from evaluated data files should be used with caution. The values for the primary constants like the k_0 and Q_0 factors derived from evaluated data do not supersede the measured constants: agreement between the two merely indicates the degree of consistency and provides a measure of the reliability of the calculated constants. Procedures for the determination of use of the constants are fully backward compatible with the conventional use of the k_0 NAA so that users can implement them in steps as appropriate, considering their internal Quality Assurance procedures. Comments on the algorithms for determining detector efficiency and are included.

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CONTENTS

1. Introduction

Due to its selectivity and sensitivity, neutron activation analysis (NAA) occupies an important place among the various analytical methods. It has proven to be a powerful non-destructive analytical technique for concentrations at or below the µg/g range, while up to 60 elements can be determined performing two irradiations and several gamma-spectrum measurements after different decay periods. The main fields of NAA application are analytical chemistry, geology, biology and the life and environmental science. Its accuracy, the virtual absence of matrix effects and the completely different physical basis when compared to other analytical techniques, make it particularly suitable for the certification of candidate reference materials (RMs), providing e.g. the bulk of the literature data on the standard RMs of the National Institute of Standards and Technology and reference materials of the International Atomic Energy Agency.

The k_0 standardisation method of NAA (k_0-NAA), a concept launched in 1975, can be interpreted as an absolute standardisation method. It relies on k_0 and Q_0 factors and a few other parameters, which are composite constants that can be derived from the basic nuclear data. In practice they are usually determined by direct measurements, partly because equivalent constants derived from the basic data are often discrepant.

The aim of the Co-ordinated Research Project (CRP) on the Reference Database for Neutron Activation Analysis was to improve the status of the database of nuclear constants for k_0-NAA, to contribute to the nuclear structure and decay data and to remove or reduce some of the discrepancies that exist between the integral constants and values derived from differential data.

The INDC Committee, which reviews the programme of the IAEA-NDS has endorsed the CRP at the meeting held in May 2002. A complementary project is in progress at NAPC-Industrial Applications and Chemistry section on "k_0-IAEA Software Development for Neutron Activation Analysis". This software package was chosen as the reference analysis tool for the CRP.

The 1st Research Coordination Meeting (RCM) was held at the IAEA, Vienna, Austria, 3-5 October 2005, and is summarized in IAEA report INDC(NDS)-0477, the 2nd RCM was held at the IAEA, Vienna, Austria, 7-9 May 2007 and is summarized in IAEA report INDC(NDS)-0514 and the 3rd RCM was held at the IAEA, Vienna, Austria, 17-19 November 2008 and is summarized in IAEA report INDC(NDS)-0542.

2. Assessment of Capture Cross Sections from Evaluated Nuclear Data Files for Neutron Activation Analysis (A. Trkov)

The k_0 standardisation method, founded by De Corte [15] in 1987, is still widely used by the NAA community. It relies on a set of integral parameters using certain assumptions on the neutron spectrum. Alternatively, these parameters may be calculated from basic principles relying on energy dependent nuclear data and arbitrary realistic spectrum. In this work the two approaches have been compared systematically for a series of neutron induced reactions, suitable for NAA measurements.

2.1. Definition of basic parameters

The k_0 standardisation method of NAA can be interpreted as an absolute standardisation method. It relies on k_0 and Q_0 factors and a few other parameters, which are composite physical constants that can be derived from the basic nuclear data. The theoretical background is discussed in detail in [15]. The k_0 factor is defined as:

$$k_0 = \frac{M_s \cdot \theta_a \cdot \gamma_a \cdot \sigma_{0,a}}{M_a \cdot \theta_s \cdot \gamma_s \cdot \sigma_{0,s}} \quad , \tag{1}$$

where M is the molar mass of the element, θ the isotopic abundance, γ is the gamma emission probability, σ_0 the thermal (2200 m/s) cross section, and indices a and s refer to the measured nuclide and the standard, respectively. By convention, the (n,γ) reaction on ^{197}Au, is adopted as standard.

Reaction rate A of incident particles with nuclei of the material through which the particles are travelling is parameterised by the reaction cross section $\sigma(v)$, which is the property of the material, and the neutron flux $\phi(v)$, which is related to the density of the particles travelling through the material $n(v)$ and their speed v [15]:

$$\phi(v) = vn(v). \tag{2}$$

Parameterised in terms of the **kinetic energy** E of the incident particles:

$$E = \frac{1}{2} m v^2 , \tag{3}$$

the reaction rate is expressed as:

$$A = K \int_0^\infty \sigma(E) \phi(E) dE . \tag{4}$$

The constant K ensures that the integral of $\phi(E)$ over energy results in the total neutron flux. The integral can be split into the thermal part up to energy E_{cd} (corresponding to neutron speed v_{cd}) and the epithermal part. The energy $\boldsymbol{E_{cd}}$ is often referred to as the **"Cadmium cut-off" energy** and set to 0,55 eV, which corresponds to the effective cut-off energy through a 1 mm thick cadmium filter. Furthermore, the epithermal flux can be decomposed into the resonance part ϕ_r and the suitably normalised fast (fission) spectrum contribution ϕ_h for convenience [15]:

$$\phi(E) = \phi_r(E) + h\phi_h(E). \tag{5}$$

The reaction rate equation becomes:

$$A = K\left[\int_0^{E_{cd}} \sigma(E)\phi(E)dE + \int_{E_{cd}}^{\infty} \sigma(E)\phi_r(E)dE + h\int_{E_{cd}}^{\infty} \sigma(E)\phi_h(E)dE\right]. \tag{6}$$

The cross section σ_h is simply the average capture cross section in the spectrum contributed by fission neutrons $\varphi(E)$.

$$\sigma_h = \int_0^{\infty} \sigma(E)\phi_h(E)dE$$

Since this term represents only a small correction to the total reaction rate in thermal reactor spectra, it is sufficient to use approximations to the fission spectrum shape.

If the fission spectrum fraction h is not known, it can be set to zero and the method reduces to the conventional approximation commonly used in activation analysis.

The reference **resonance integral** I_0 is usually defined by the product of the cross section and the pure $1/E$ spectrum, integrated between some chosen cadmium cut-off energy E_{cd} (in our case 0,55 eV) and an arbitrarily chosen upper limit E_3 (in our case 2 MeV) [15]:

$$I_0 = RI = \int_{E_{cd}}^{E_3} \sigma(E)\psi(E)dE, \quad \psi(E) = \frac{1}{E} \quad . \tag{7}$$

Similarly, the reference Q_0 value is given by:

$$Q_0 = \frac{I_0}{\sigma_0}. \tag{8}$$

In our study, the self shielding effect [14] is neglected.

The **Westcott *g*-factor** is defined as:

$$g = \frac{\int_0^{E_{cd}} \sigma(E)\phi(E)dE}{\sigma_0 \frac{\sqrt{\pi}}{2} \int_0^{E_{cd}} \phi(E)dE} = \frac{2}{\sqrt{\pi}}\frac{\sigma_{th}}{\sigma_0}, \tag{9}$$

where σ_{th} is the average thermal cross section and σ_0 is the cross section for neutrons with speed 2200 m/s. It is easily shown that for a pure 1/*v* absorber the average cross section is $\sqrt{\pi}/2\ \sigma_0$. It is independent of the speed-distribution of the neutron population; it only depends on the average speed v_0. The *g*-factor is a quantitative measure of the deviation of the cross section from 1/*v* behaviour below the cadmium cut-off energy.

For a 1/*v* absorber in a Maxwellian spectrum the average neutron speed depends on the temperature, hence the well-known Westcott *g*-factor relation:

$$g_w = \sqrt{\frac{T_0}{T}} g \ . \tag{10}$$

In the original definition of the *g*-factor the upper integration limit is set to infinity. In the generalised definition of the *g*-factor the upper integration limit E_{cd} is commonly taken as 0.55 eV, but the Maxwellian function falls off above this energy so rapidly, that the contribution to the integral is negligible. The generalised definition of the *g*-factor has an advantage in neutron fields, where the transition from Maxwellian into 1/*E* form begins at relatively low energies [15], where it can be interpreted as an increase in the effective spectrum temperature, while the rest of the formalism remains unchanged.

The **cadmium transmission factor F_{cd}** is introduced to compensate for the non-ideal shape of the cadmium filter, assuming the spectrum closely follows 1/*E* behaviour and ignoring (or subtracting out) the high energy contribution of the fission spectrum [15]. From this it follows:

$$F_{cd} = \frac{\int_0^\infty t(E)\sigma(E)\phi(E)dE}{\int_{E_{cd}}^{E_3} \sigma(E)\phi(E)dE} , \tag{11}$$

where *t(E)* is the cadmium filter transmission function.

Deviation of F_{cd} from unity arises from the cadmium transmission function and from the difference in the upper integration limit. The contribution of the later is small in case of 1/*E* spectrum with a small component of fission neutrons in the spectrum [15].

The **effective resonance energy E_r** was originally defined as a weighted average of the resonance energies, where the contribution of a particular resonance to the resonance integral was used as weight [15]. It is equivalent to replacing the resonances by a single resonance at E_r of width such that it reproduces the resonance integral calculated from the resonance parameters assuming Single Level Breit-Wigner representation. This procedure allows the derivation of an analytical expression relating the Q_0 value in a pure 1/*E* spectrum and the α-dependent $Q(\alpha)$ value.

$$Q(\alpha) = \frac{Q_0 - 2\sqrt{E_0 / E_{cd}}}{(E_r)^\alpha} + \frac{2\sqrt{E_0 / E_{cd}}}{(2\alpha + 1)(E_{cd})^\alpha}$$

The method has severe disadvantages: it is limited to Single Level Breit-Wigner formalism (which is seldom adequate for the most important nuclides) and is valid only over the range of the resolved resonances. A more general method is to use the analytical expression defined above as an interpolation function and to calculate the $Q(\alpha)$ explicitly from the pointwise tabulated cross sections and α-dependent spectrum by direct integration. The method breaks down when the $Q(\alpha)$ value is truly invariant with α, but in such cases the value of E_r is irrelevant anyway. This may happen for example, when there is no resonance structure in the cross sections. Note that in such case the original method of averaging resonance parameters can not be used either, since no parameters are given.

2.2. Analysis of different libraries

In this study, the cross section-related data from different sources have been compared, including the Atlas of Neutron Resonances by Mughabghab [1], Kayzero database [2], and JENDL-4.0 [4], ENDF/B-VII.1 [5], JEFF-3.1 [6], JEFF-3.1/A [7], ROSFOND [8], TENDL [9] evaluated nuclear data libraries.

In most cases, primary attention was given to the JENDL-4.0 and the ENDF/B-VII.1 evaluated data libraries because they are the most recent and usually provided the best match.

Tables with numbers from different sources for each element have been made.

Below, the general methodology is explained and some examples are presented.

The parameters derived from evaluated data libraries were obtained by numerical integration of tabulated cross sections after resonance reconstruction and Doppler broadening to room temperature.

The parameters of "Mughabghab" were taken from the Atlas of Neutron Resonances [1]. Q_0 was calculated using equation (8).

The thermal cross sections σ_0 for Kayzero / Nudat [3] have been calculated from equation (1) assuming ^{197}Au(n,γ) reaction as the standard. Molar mass and natural atomic abundance of the sample were taken from *NIST* [17]. The k_0 factors were taken from De Corte [2]. If an isotope had more than one possible gamma-ray energy, weighted average was made, taking into account each gamma-ray energy with its associated k_0 and gamma emission probability of the measured gamma-ray. The gamma emission probabilities were taken from the Nudat web interface [3]. For each reaction, a graph of the cross section as a function of energy is also plotted using the online tool JANIS [18].

2.3. Treatment of metastable activation products

Sometimes an (n,γ) reaction on an isotope can form an activation product in the ground-state or a long-lived (metastable) isomer. The probability of forming either of them is called the branching ratio, which in general is energy dependent.

When a metastable product is formed, it eventually decays into the ground state with a certain probability. Branching ratios are not always explicitly given, and thus sometimes have to be combined using data from different sources. Below, the treatment of the ground state and metastable activation products is shown through some examples.

Example: ^{109}Ag (n,γ)^{110}Ag

The JENDL-4.0 and the ENDF/B-VII.1 libraries only give total reaction (ground + metastable) σ_0 value. The calculated value for ^{109}Ag(n,γ)^{110}Ag is σ_0 = 90.28 using both libraries, But since the neutron capture in ^{109}Ag can produce either ^{110m}Ag or ^{110g}Ag, branching ratio must be taken into account. The Mughabghab σ_0 values for the metastable and the ground state are:

$^{Mug.}\sigma_0$[g] = 87.1 and $^{Mug.}\sigma_0$[m] = 3.95.

From the Mughabghab values we can determine the branching ratio and calculate the cross section σ_0 for the production of the metastable isomer for other libraries.

$$^{Mug.}\sigma_0[tot] = {}^{Mug.}\sigma_0[g] + {}^{Mug.}\sigma_0[m] \tag{12}$$

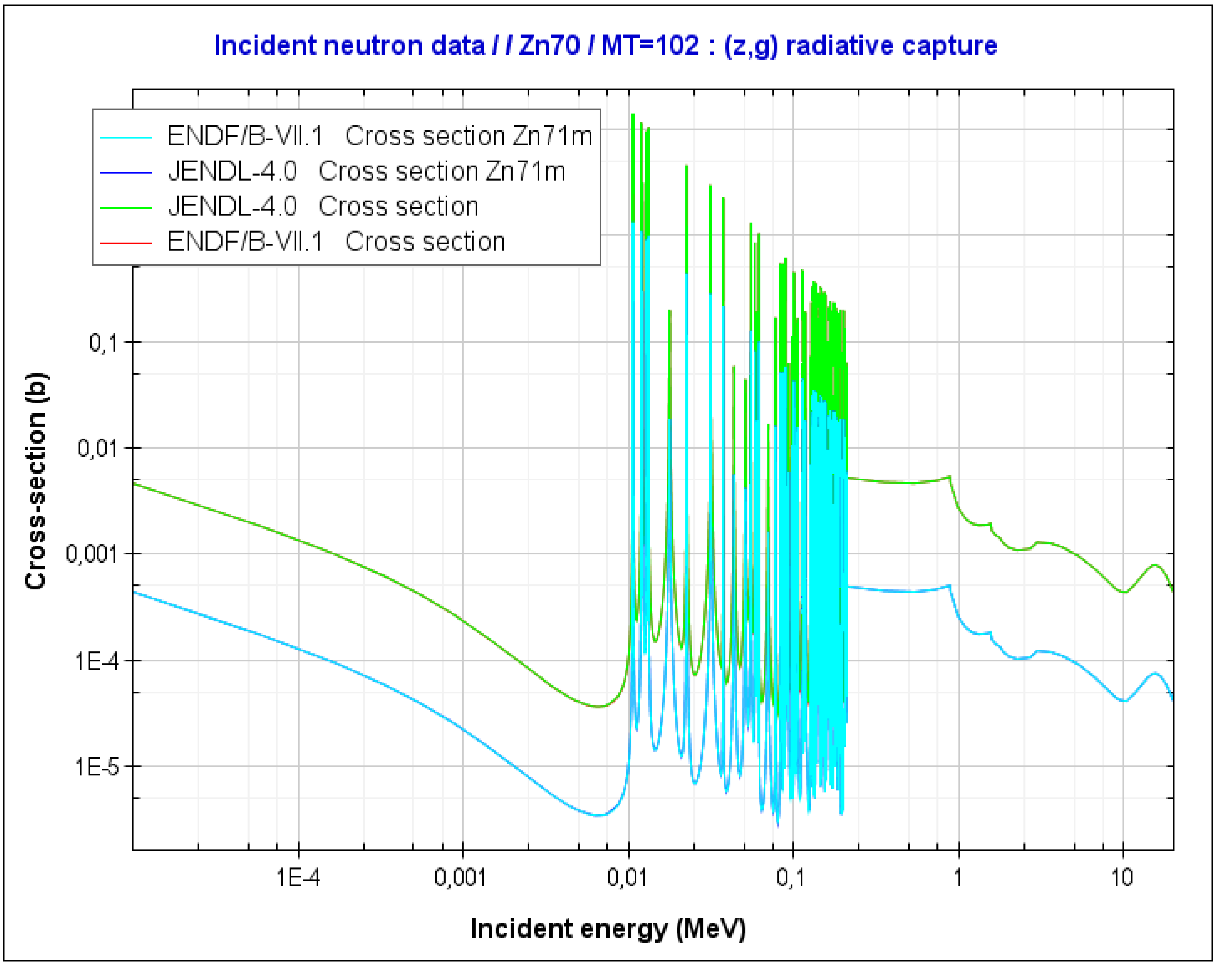
Calculation for other libraries:

$$\begin{aligned} \sigma_0[g] &= \frac{\sigma_0 \cdot {}^{Mug.}\sigma_0[g]}{^{Mug.}\sigma_0[tot]} \\ \sigma_0[m] &= \frac{\sigma_0 \cdot {}^{Mug.}\sigma_0[m]}{^{Mug.}\sigma_0[tot]} \end{aligned} \tag{13}$$

For the resonance integrals the same procedure is applied and then Q_0 can be calculated using equation (8). Generally the branching ratio is not the same in the thermal and the epithermal part.

Special example 1: ^{70}Zn(n,γ)^{71m}Zn

No data are available for the epithermal region, so it is assumed that the branching ratio is the same. A graph is plotted for the cross sections for the excitation of the metastable isomer by multiplying the total production cross section with the branching ratio.



The picture presents the capture cross sections for the production of the metastable product and for total reaction cross section.

Special example 2: ^{93}Nb(n,γ)^{94}Nb

Due to very different half-lives of the ground-state and the metastable activation product, this nuclide is interesting in both states.

Mughabghab, only gives the data for the total capture, but in the Kayzero library, there are data only for the metastable product. Branching ratio has been defined as the ratio between the σ_0 value for the metastable product from the Kayzero database and total σ_0 value from Mughabghab. The branching ratio for the metastable state is 75.0% and is assumed independent of energy.

2.4. Correction of the existing nuclear data libraries

While checking the published data some corrections were made. The k_0 factors by De Corte [2] contained trivial errors:

- ^{87}Rb(n,γ)^{88}Rb: 1.01 × 10^{-1} was corrected to 1.01 × 10^{-4},
- ^{94}Zr(n,γ)^{95}Zr: 1.10 × 10^{-5} was corrected to 1.10 × 10^{-4}.

2.5. Assessment of the capture cross sections by nuclide

The pointwise capture cross sections at 300 K were generated from the major evaluated nuclear data libraries. The thermal values σ_0 were extracted and the Q_0 values were calculated. The values were compared to those in the k_0 database and the values from the Mughabghab evaluation. An assessment of the quality of the data was made. In addition, the generalized Westcott factors, the cadmium filter factors and the effective resonance energies were also calculated from the cross section data that were deemed most accurate. The average capture cross sections in the fission spectrum is approximated by the cross section averaged in a pure ^{235}U prompt fission spectrum taken from the ENDF/B-VII.1 library.

2.5.1. $^{19}F(n,\gamma)^{20}F$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\ \sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.00951	0.9	3.8	0.00916	1.2	0.009571	4.5	0.009580	4.6

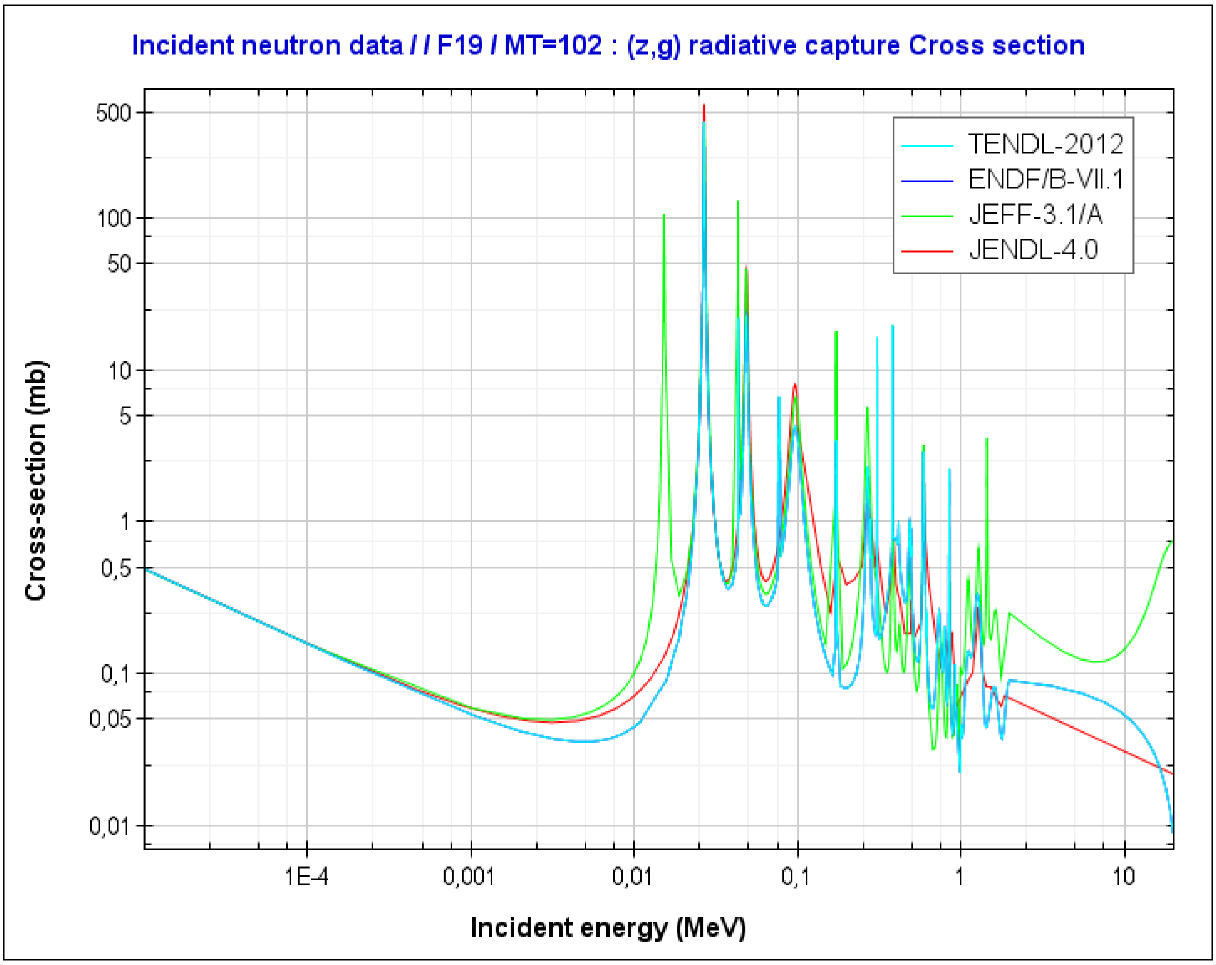
Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
2.103	15.0	-4.4	2.2		2.01	-8.8	1.677	-24

- Thermal cross section by Mughabghab [1] has an uncertainty of 0.9%, but is 3.8% higher than the value derived from Kayzero [2]; the uncertainty of the Kayzero [2] value is 1.2%. ENDF/B-VII.1 [5] and JENDL-4.0 [4] are in good agreement with Mughabghab [1].
- Q_0 value based on Mughabghab [1] data is 2.103 with 15% uncertainty. It is smaller by 4.4% compared to the Kayzero [2] value, which is specified without an uncertainty estimate. The value based on JENDL-4.0 [4] data is 8.8% smaller compared to the Kayzero [2] value. The value derived from the ENDF/B-VII.1 [5] is 1.677, which is about 24% lower. Since the thermal cross section is in good agreement, some further checking was performed.
- Van der Linden [10] reported a Q_0 value of 3.9 with about 3% uncertainty. The same appears in EXFOR [12]. After consultation with De Corte it appears that the alpha-dependence was not taken into account in the measurement.
- Roth [11] reported 2.19 (without uncertainty) as the literature value (probably taken from Mughabghab [1], but the footnote points to the Van der Linden [10] value). In the same table the value 1.5 (without uncertainty) is quoted as the experimental value. The value calculated from the ENDF/B-VII.1 [5] resonance parameters is about 1.7, which is close to the Roth [11] experimental value.
- The JEFF-3.1/A [7] evaluation has a resonance at about 15 keV. Experimental data in EXFOR [12] by Macklin (X4:11380004) would allow the possibility of a resonance at this energy. The total cross section measurements of Hibdon (X4:11122006) show some structure, but the more recent measurements by Larson (X4:10778002) with comparable resolution do not. After consultation with the evaluators L. Leal and C. Guber from ORNL it was concluded that there is no possibility of a strong resonance at 15 keV.
- After consultation with F. De Corte, the Roth [11] measurement is considered to be more reliable, because of a more accurate treatment of the deviation from a 1/*E* spectral shape. If a new measurement is to be performed, special case should be devoted to the spectrum

characterisation, since the first resonance appears at about 27 keV and second-order effects in the spectral shape may influence the results.

The ENDF/B-VII.1 [5] library is recommended for the activation cross section file. The constants derived from this library are:

F_{cd}	=	1.004
g	=	0.999
E_r	=	37353 eV
σ_0	=	0.009580 b
Q_0	=	1.677
σ_h	=	0.000195 b



2.5.2. $^{23}Na(n,\gamma)^{24}Na$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.517	0.8	0.7	0.513	1.2	0.532	3.5	0.528	2.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.587	3.3	-0.5	0.590	4.7	0.563	-4.6	0.575	-2.5

- The uncertainty in the thermal cross section by Mughabghab [1] is 0.8% and is about 0.7% higher than the value derived from the Kayzero [2] database. The uncertainty of the Kayzero [2] value is only 1.2%. ENDF/B-VII.1 [5] and JENDL-4.0 [4] are in good agreement with Mughabghab [1].
- Q_0 value based on Mughabghab [1] data is in very good agreement with the Kayzero [2] value, which has a 4.7% uncertainty assigned to it.
- The Q_0 values derived from JENDL-4.0 [4] and ENDF/B-VII.1 [5] are both within the experimental uncertainty of the Kayzero [2] value.

The new ENDF/B-VII.1 [5] evaluation is recommended because it is the most recent and the resolved resonance range extends to higher energies. The constants derived from this library are:

F_{cd} = 1.018

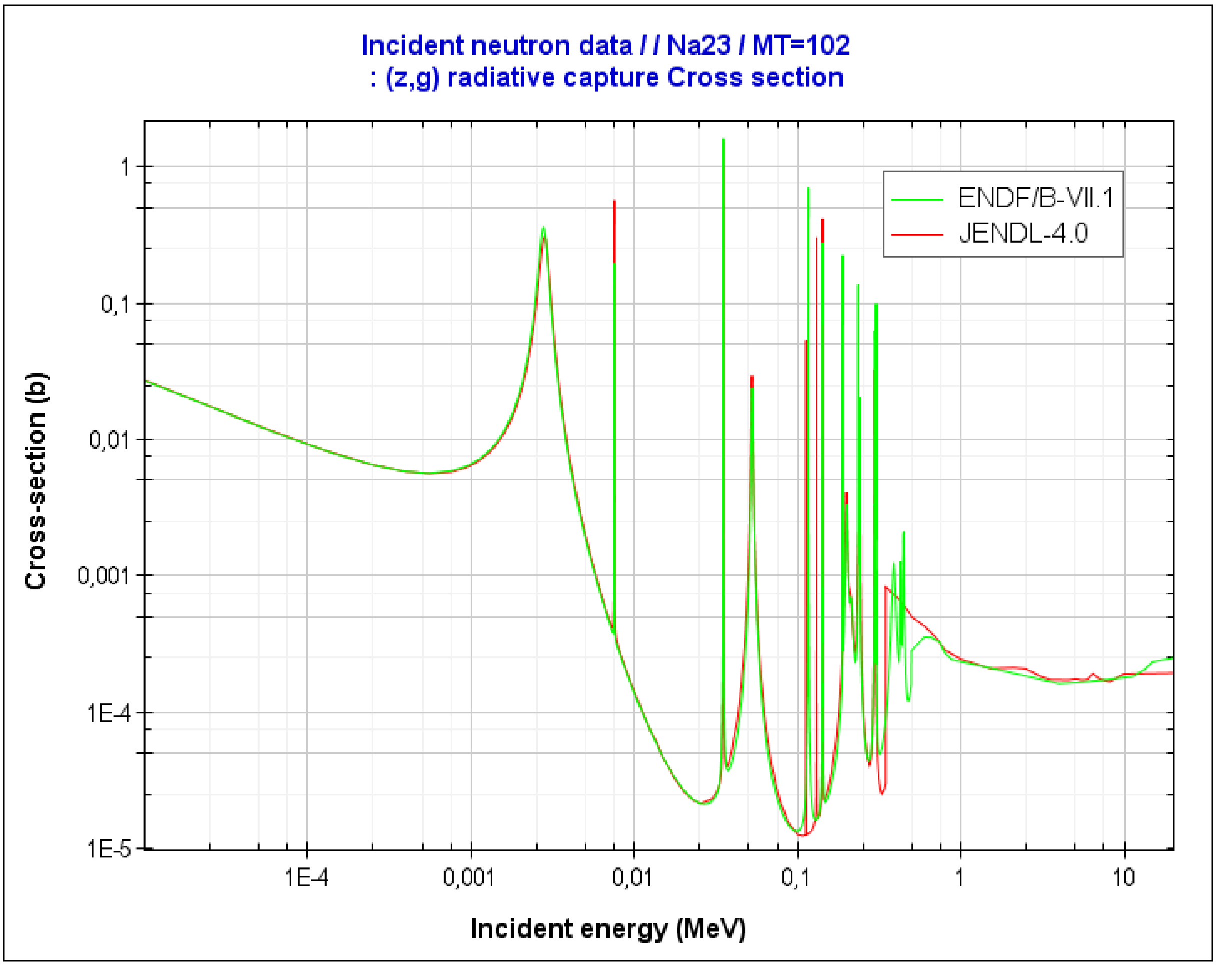
g = 0.999

E_r = 2277 eV

σ_0 = 0.528 b

Q_0 = 0.575

σ_h = 0.000271 b


Incident neutron data / / Na23 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1
0,1
0,01
0,001
1E-4
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.3. $^{26}Mg(n,\gamma)^{27}Mg$

The thermal cross sections σ_0 and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.0384	1.6	4.3	0.0368	0.3	0.03832	4.1	0.03832	4.1

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.625	8.5	-2.3	0.640		0.466	-27	0.467	-27

- The uncertainty in the thermal cross section by Mughabghab [1] is 1.6% and is 4.3% higher than the value derived from Kayzero [2], whereas the uncertainty of the Kayzero [2] value is only 0.3%. ENDF/B-VII.1 [5] and JENDL-4.0 [4] are essentially the same, originating from an earlier JENDL evaluation. They are in good agreement with Mughabghab [1].
- Q_0 value in the Kayzero [2] database has no uncertainty, but is in good agreement with Mughabghab [1], which is claimed to have 8.5% uncertainty. The values derived from the evaluated data files are 27% lower than the Kayzero [2] value. The discrepancy is large and requires an investigation. The adjustment of the resonance parameters to fit the thermal value should be chacked.

Since JENDL evaluations are the basis for the other major libraries, JENDL-4.0 [4] evaluation is selected. The discrepancy in Q_0 would require an investigation. The constants derived from this library are:

F_{cd} = 1.023

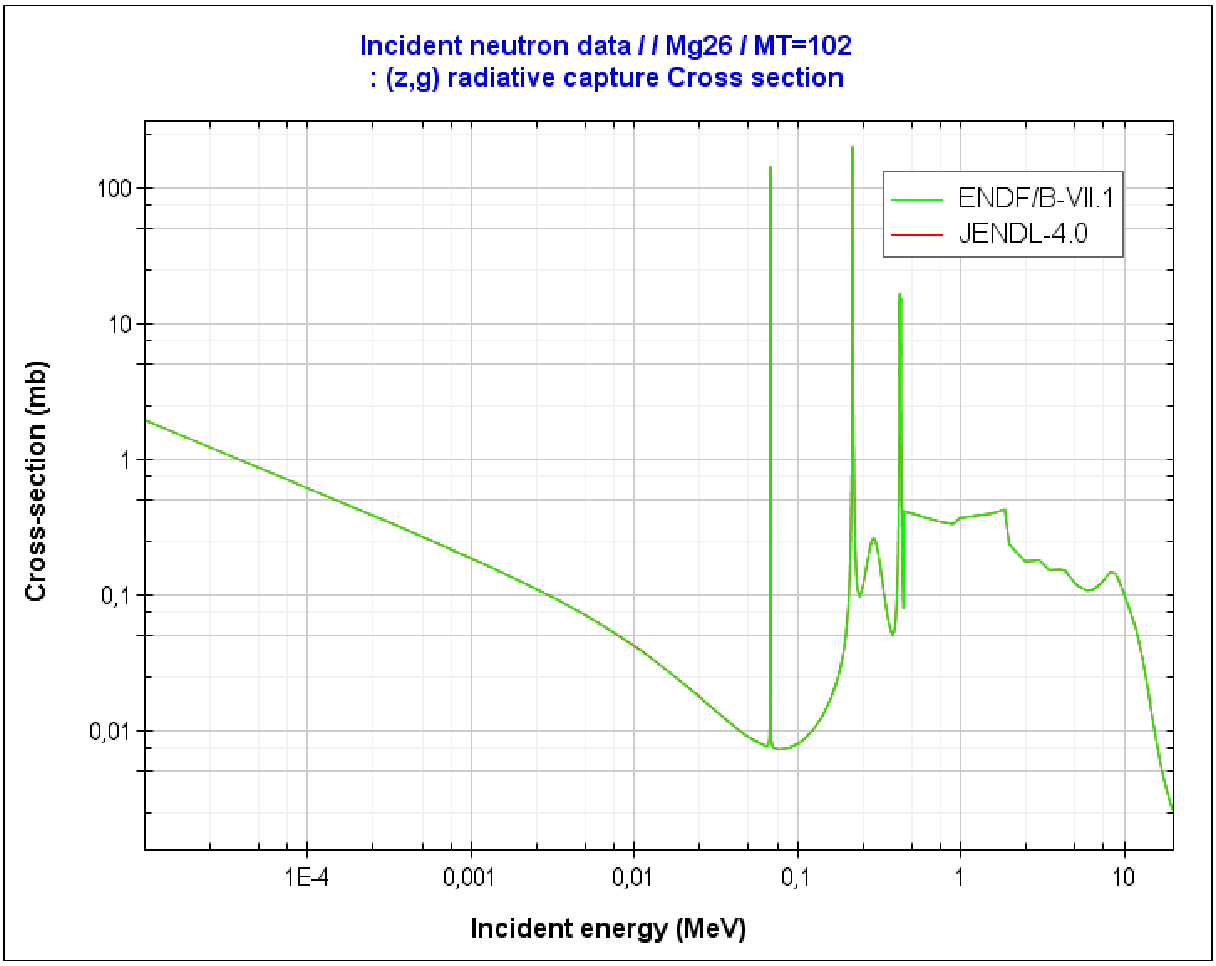
g = 0.999

E_r = 545280 eV

σ_0 = 0.03832 b

Q_0 = 0.466

σ_h = 0.000318 b



Incident neutron data / / Mg26 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (mb)
100
10
1
0,1
0,01
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.4. $^{27}Al(n,\gamma)^{28}Al$

The thermal cross sections σ_0 and the Q_0 values are as follows:

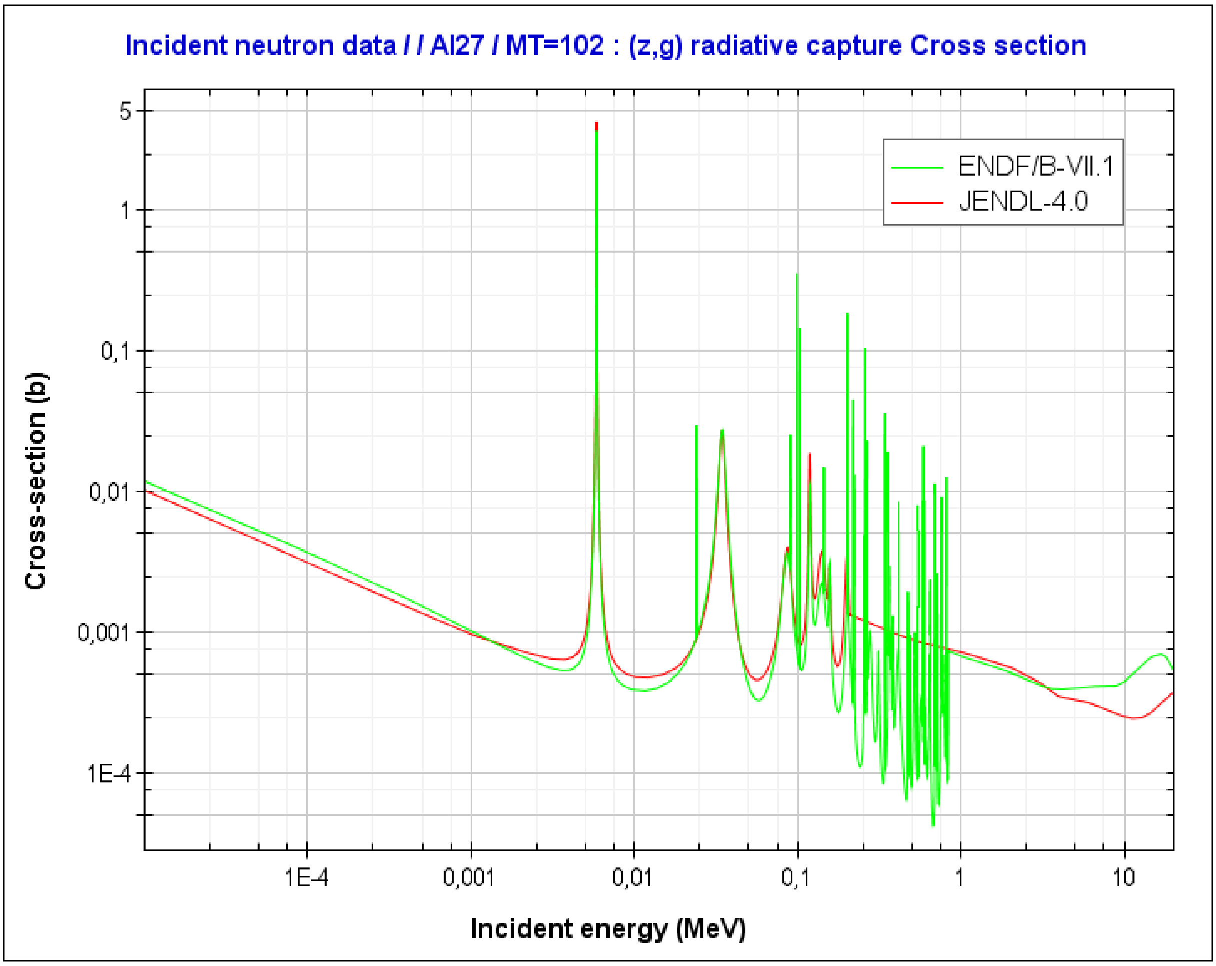
Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.231	1.3	2.2	0.226	0.8	0.230	1.9	0.234	3.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.736	6.0	3.7	0.710		0.514	-28	0.534	-25

- Thermal cross section by Mughabghab [1] with an uncertainty of 1.3% is 2.2% higher than the value derived from Kayzero [2], whereas the uncertainty of the Kayzero [2] value is 0.8%. ENDF/B-VII.1 and JENDL-4.0 [4] are in good agreement with Mughabghab [1]. The data are consistent within two-sigma uncertainties.
- The uncertainty in the Q_0 value according to Mughabghab [1] is 6.0%. There is good consistency between the Q_0 value based on Mughabghab [1] with that in the Kayzero [2] database (which has no assigned uncertainty). It is somewhat surprising that for this important structural material all major libraries differ from the Kayzero [2] Q_0 value by about 25%.
- Several entries for the measurements of the resonance integral can be found in the EXFOR [12] database, but they are discrepant and the original publications should be consulted to identify the sources of discrepancies. In the Kayzero [2] database the Ryves data seem to be adopted.
- A new measurement was reported recently [19], giving the Q_0 value of 0.49 with 3.7 % uncertainty, which strongly supports the values derived from the evaluated data libraries.

The ENDF/B-VII.1 [5] evaluation is the most recent and the resolved resonance range extends to higher energies, therefore this evaluation is selected. The constants derived from this library are:

F_{cd}	=	1.020
g	=	0.999
E_r	=	12308 eV
σ_0	=	0.234 b
Q_0	=	0.534
σ_h	=	0.000537 b



2.5.5. $^{30}Si(n,\gamma)^{31}Si$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		ENDF/B-VII.1 [5]		JEFF-3.1 [6]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.107	1.9	-6.7	0.1147	1.5	0.1071	-6.6	0.1078	-6.0

Mughabghab [1]			Kayzero [2]		ENDF/B-VII.1 [5]		JEFF-3.1 [6]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
5.888	5.1	430	1.11	6.0	5.402	387	6.525	488

- Thermal cross section by Mughabghab [1] with an uncertainty of 1.9% is 6.7% lower than the value derived from the Kayzero [2] database, which has a 1.5% uncertainty. ^{30}Si is a minor isotope with an abundance of 3.092%, so the nuclear data are scarce and difficult to measure. The gamma-emission probability is small and no uncertainty is available, therefore the uncertainty in the thermal cross section can not be estimated. ENDF/B-VII.1 [5] and JENDL-4.0 [4] contain the same resonance parameters and are in good agreement with Mughabghab [1].
- The Q_0 value derived from Mughabghab [1] data is 5.888 with uncertainty of 5.1%. It differs by a factor of five from the value in the Kayzero [2] database, which is 1.11 with 6.0% uncertainty.
- Two measurements related to Q_0 of ^{30}Si appear in EXFOR [12]. Van der Linden [10] reports 6.6, which is very close to the Mughabghab [1] value. Vichai Hayodom from Thailand reports Q_0 of about 1; the EXFOR [12] entry was compiled in 2008, but quoting a report from 1969. Further measured data were published by De Corte [13]. Measurements were performed in four irradiation channels of two different reactors. The results were consistent, the average being 1.11 with 5.8% uncertainty. Since ^{30}Si is a potential dosimetry material, its cross-section data perhaps deserve some attention.

The candidate ENDF/B-VII.1 [5] evaluation is selected, but re-visiting of the evaluation is necessary. The constants derived from this library are:

F_{cd} = 0.998

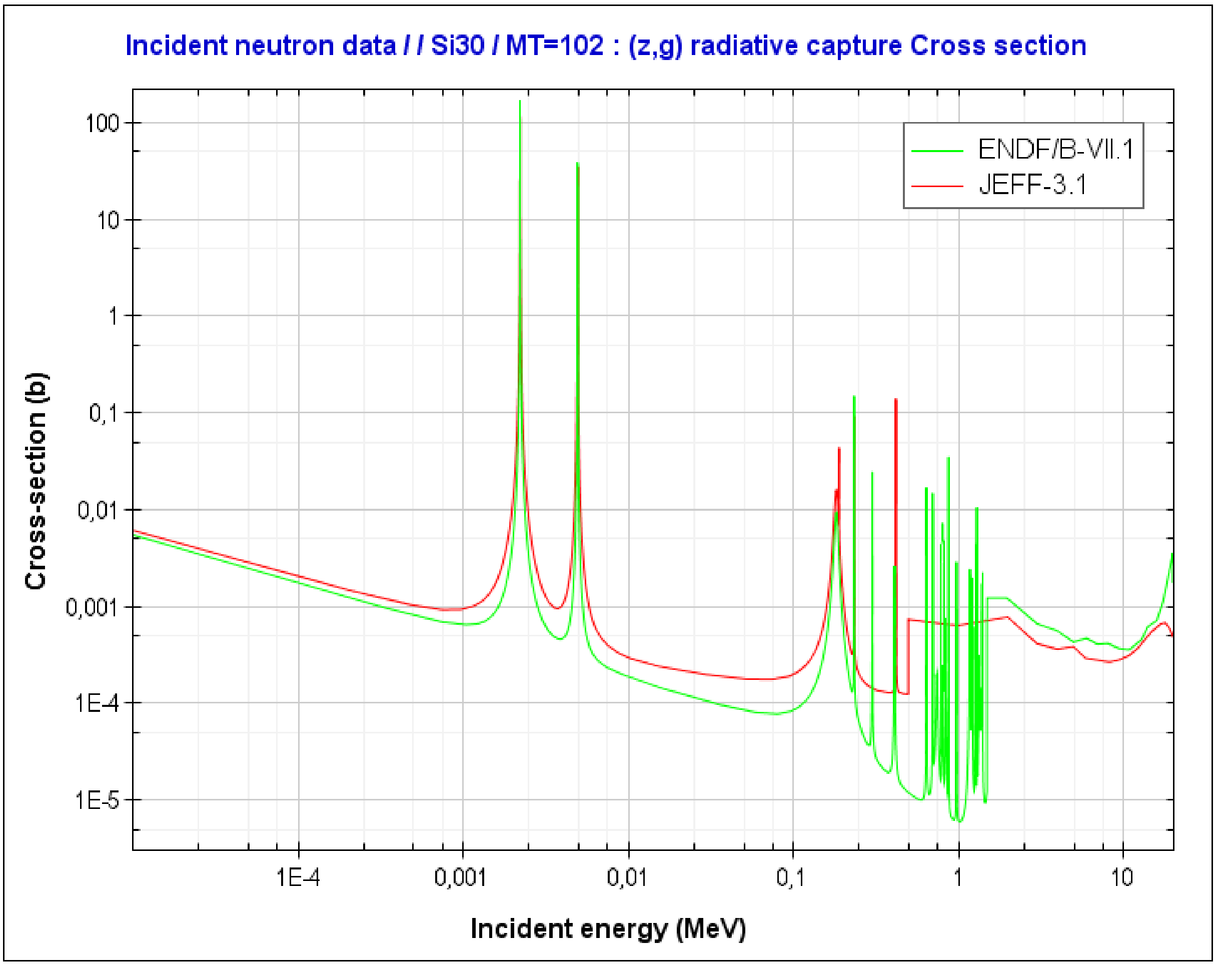
g = 0.999

E_r = 2532 eV

σ_0 = 0.1071 b

Q_0 = 5.402

σ_h = 0.000577 b



2.5.6. $^{36}S(n,\gamma)^{37}S$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
0.236	2.5	-26	0.320	100	0.151	-53

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
0.720	3.5	-36	1.12	7.1	0.7714	-31

- The thermal cross section by Mughabghab [1] has an uncertainty of 2.5%. The uncertainty in the gamma-emission probability is small. Also, the natural abundance of ^{36}S is only 0.01% with 100% uncertainty, so it is difficult to derive a reliable cross section value from the Kayzero [2] database. Being a minor isotope, the nuclear data are difficult to measure. The Mughabghab [1] value is 26% higher than the value derived from the Kayzero [2] database. The uncertainty assigned to the thermal cross section by Mughabghab [1] might be underestimated. The thermal cross-section value in JENDL-4.0 [4] lies within the very large uncertainty to the Kayzero [2] value (mostly due to uncertainty in the isotopic abundance). The ENDF/B-VII.1 [5] library adopted JENDL-4.0 [4] data. The only independent data for this isotope are those in the TENDL-2012 [9] library.
- The Q_0 value in the Kayzero [2] database is 1.12 with uncertainty of 7.1%. In the paper by Van der Linden [10] the same value is reported with 7.1% uncertainty. The value calculated from the JENDL-4.0 [4] data is 31% lower.
- The cross section curves have no resonance structure, most likely because the resonance parameters could not be measured due to the low natural abundance of the isotope.

The JENDL-4.0 [4] evaluation is selected for completeness, but should be used with caution for reasons stated above. Constants for NAA derived from the cross section curves are listed below:

F_{cd} = 1.016

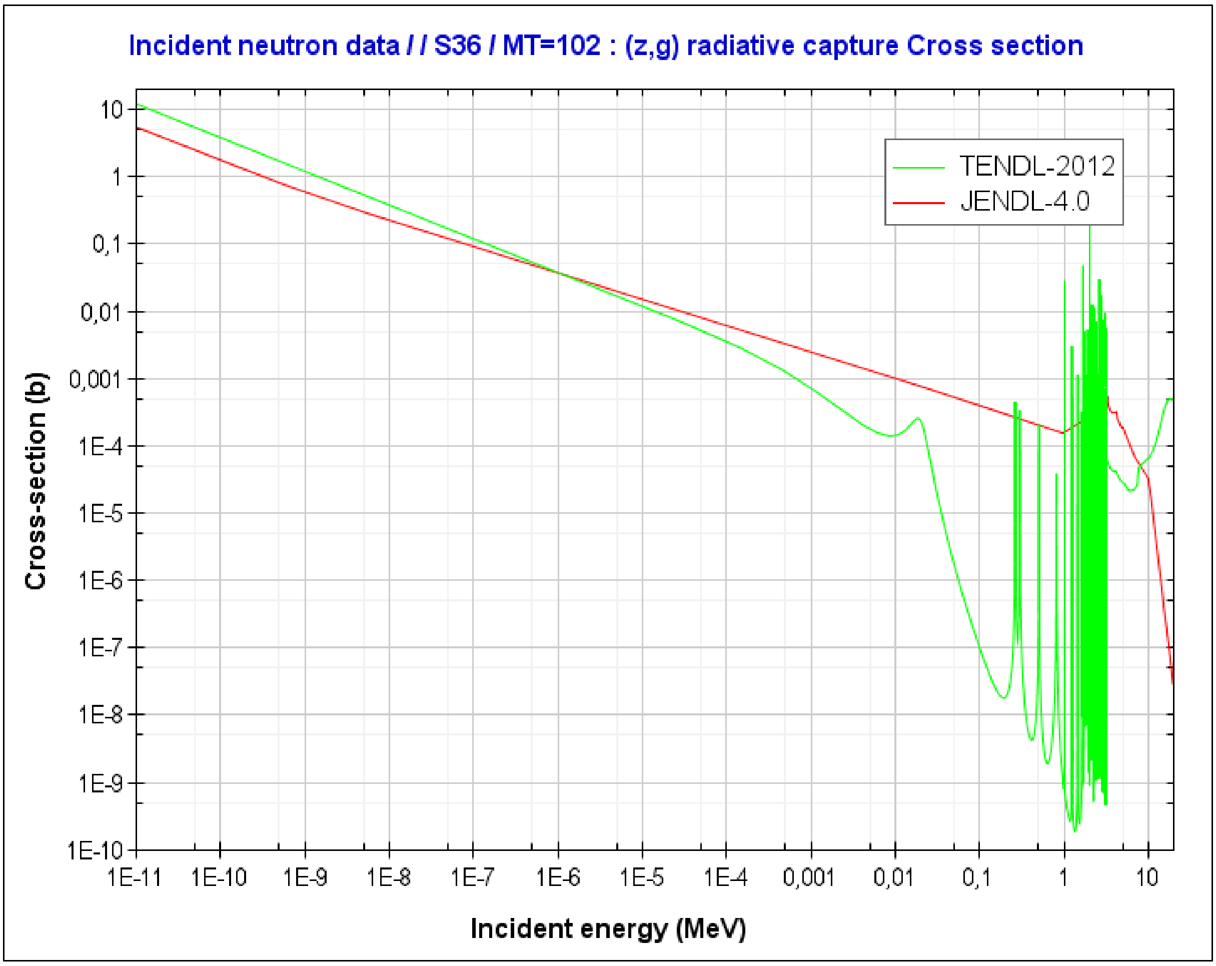
g = 1.013

E_r = 13.67 eV

σ_0 = 0.151 b

Q_0 = 0.7714

σ_h = 0.000251 b



2.5.7. $^{37}Cl(n,\gamma)^{38}Cl$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.433	1.4	3.5	0.418	2.1	0.433	3.5	0.4331	3.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.693	13.4	0.4	0.69	-	0.4460	-35	0.4493	-35

- Thermal cross section by Mughabghab [1] has an uncertainty of 1.4%. The estimated uncertainty of the thermal capture cross section from the Kayzero [2] database is 2.1%. The Mughabghab [1] value is about 3.5% higher, which is within the assigned uncertainties. The thermal cross sections in the evaluated data files are equal to the Mughabghab [1] value.
- The Q_0 value according to Mughabghab [1] has a 13.4% uncertainty. It is in good agreement with the value in the Kayzero [2] database, which has no assigned uncertainty. The Mughabghab [1] value is higher by 0.4%, which is within the uncertainty interval.
- The values calculated from the evaluated nuclear data files all give the same Q_0 value, in spite of the differences in the cross section curves. They are 35% lower than the Kayzero [2] value.

The ENDF/B-VII.1 [5] evaluation is selected because it is the most recent and includes in the analysis all available differential measurements. The thermal capture cross section is consistent with the Mughabghab [1] and the Kayzero [2] value, but the difference in the Q_0 value from the Kayzero [2] database should be investigated. The constants derived from this library are:

F_{cd} = 1.025

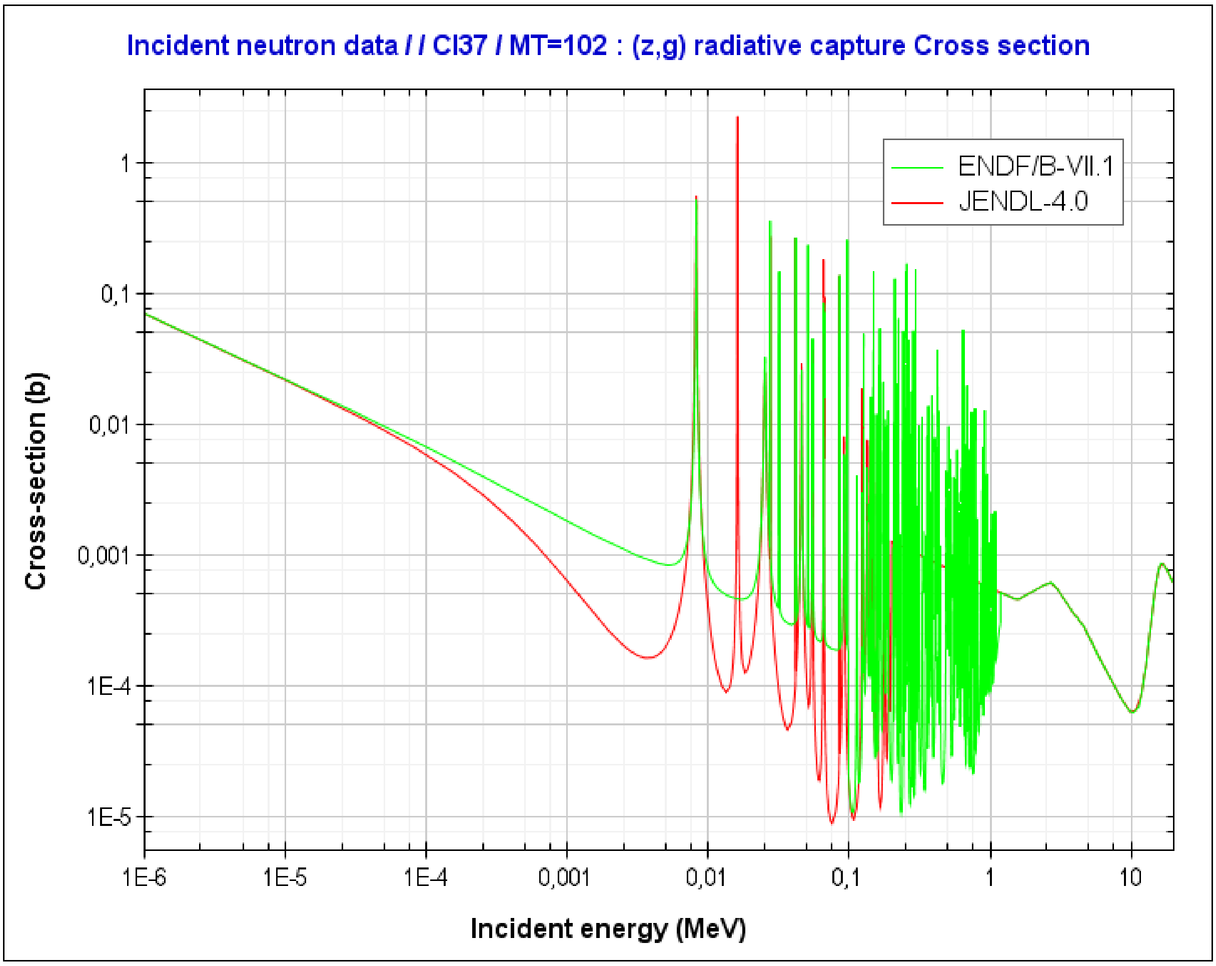
g = 0.999

E_r = 37925 eV

σ_0 = 0.4331 b

Q_0 = 0.4493

σ_h = 0.000479 b


Incident neutron data / / Cl37 / MT=102 : (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.8. $^{40}Ar(n,\gamma)^{41}Ar$

The thermal cross sections and the Q_0 values are as follows:

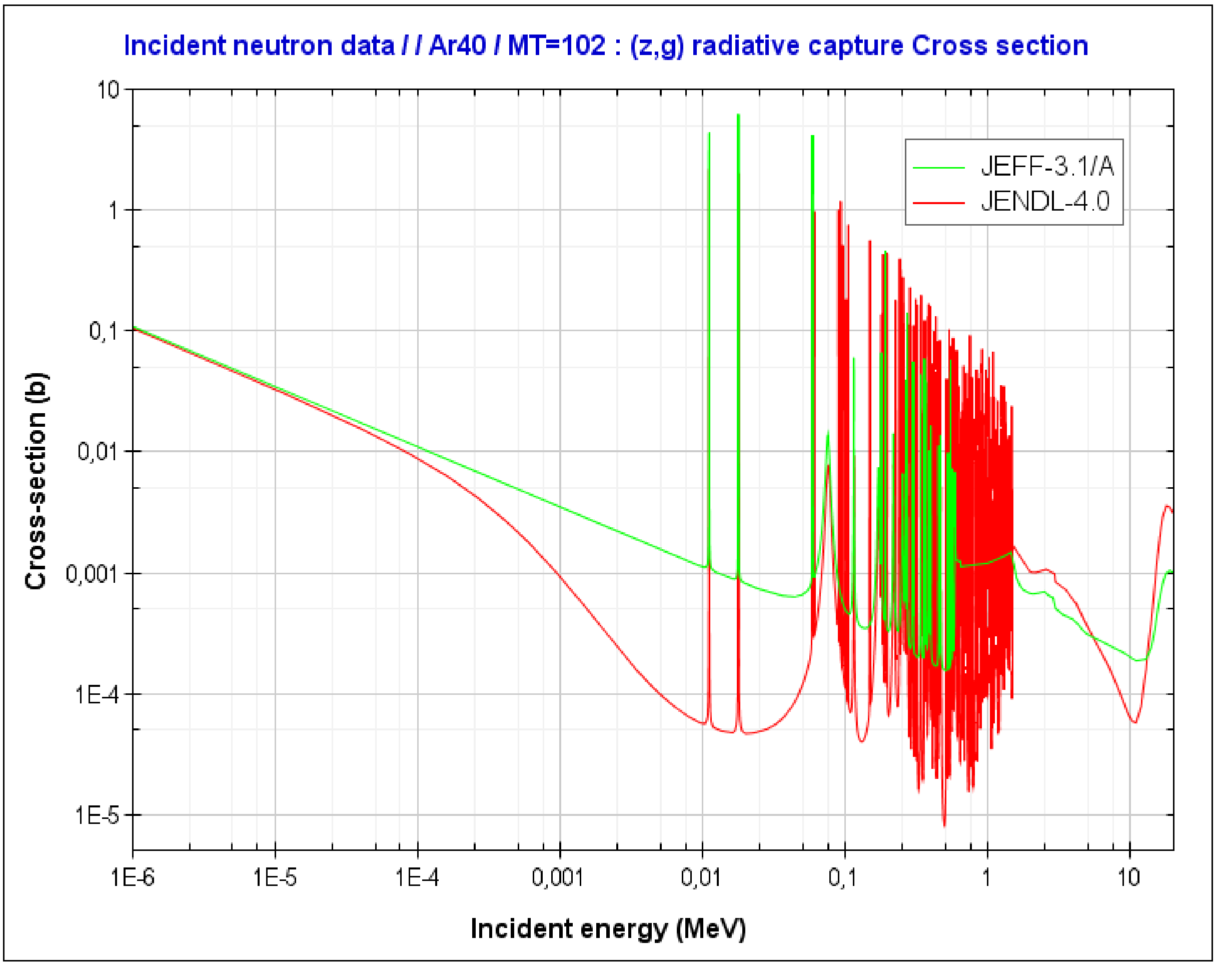
Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		JEFF-3.1/A [7]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.660	1.5	2.6	0.643	0.0	0.660	2.7	0.6805	5.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		JEFF-3.1/A [7]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.621	7.5	-1.4	0.63	-	0.4204	-33	0.451	-28

- All major evaluated data libraries (e.g. ENDF/B-VII.1 [5], JEFF-3.1 [6]) contain the same resonance parameters, originally evaluated for the JENDL libraries, including JENDL-4.0 [4]. Only the evaluation in the European Activation Library JEFF-3.1/A [7] is slightly different, but it is based on older resonance analysis with ad-hoc adjustments.
- The thermal cross section by Mughabghab [1] has an uncertainty of 1.5%. The gamma-emission probability has a very small uncertainty and no uncertainty is specified for the k_0 value in the Kayzero [2] database, therefore the uncertainty of the derived cross section can not be estimated, but it differs from the Mughabghab [1] value by only 2.6%.
- The Q_0 value in the Kayzero [2] library has no assigned uncertainty. It is in good agreement with the value of Mughabghab [1], to which a 7.5% uncertainty is assigned. The values calculated from all major libraries are smaller by 33% and 28%.
- No experimentally measured cross section data are available. It needs to be checked if the dip below the first resonance in the JENDL-4.0 [4] file is realistic. It is not present in the JEFF-3.1/A [7] evaluation. However, the cross section shape of JEFF-3.1/A [7] would not decrease the discrepancy in the Q_0 value significantly.

The JENDL-4.0 [4] evaluation is selected because it is the most recent, but the shape of the resonance curve would require a further investigation. The derived value of E_r is not reliable because the resonance integral is dominated by the $1/v$ part at low energies, which then goes into a dip and the resonances above the dip are not significant. Although the E_r value is suspiciously low, it would reproduce the variation of the resonance integral with alpha, consistent with the shape of the cross section. This nuclide is a case where integral measurements in spectra with different alpha-values could be used to improve the resonance data. The constants derived from the JENDL-4.0 [4] library are:

F_{cd}	=	1.027
g	=	0.998
E_r	=	1.0572 eV
σ_0	=	0.660 b
Q_0	=	0.4204
σ_h	=	0.001010 b



2.5.9. $^{41}K(n,\gamma)^{42}K$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.46	2.1	0.5	1.453	0.8	1.46	0.5	1.461	0.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.973	4.7	11.8	0.87	3.0	1.059	21.7	0.639	-27

- Thermal cross section by Mughabghab [1] has an uncertainty of 2.1% and is in excellent agreement with the value derived from the Kayzero [2] database, which has a 0.8% uncertainty. The thermal cross sections in the major libraries all adopt the JENDL evaluation and are in full agreement.
- The Q_0 value based on Mughabghab [1] data has an uncertainty of 4.7% and is 3.5% higher than the value derived from the Kayzero [2] database, to which a 3.0% uncertainty is assigned.
- The Q_0 values calculated from JENDL-4.0 [4] (and ENDF/B-VII.0) are 21.7% high, but the value from the ENDF/B-VII.1 [5] is 27% low. This is a new evaluation that incorporates all available differential data in the analysis. Further checking is in progress.

Unless additional evidence is found in support of ENDF/B-VII.1 [5], the JENDL-4.0 [4] evaluation is to be selected. The constants derived from the JENDL-4.0 [4] library are:

F_{cd} = 1.008

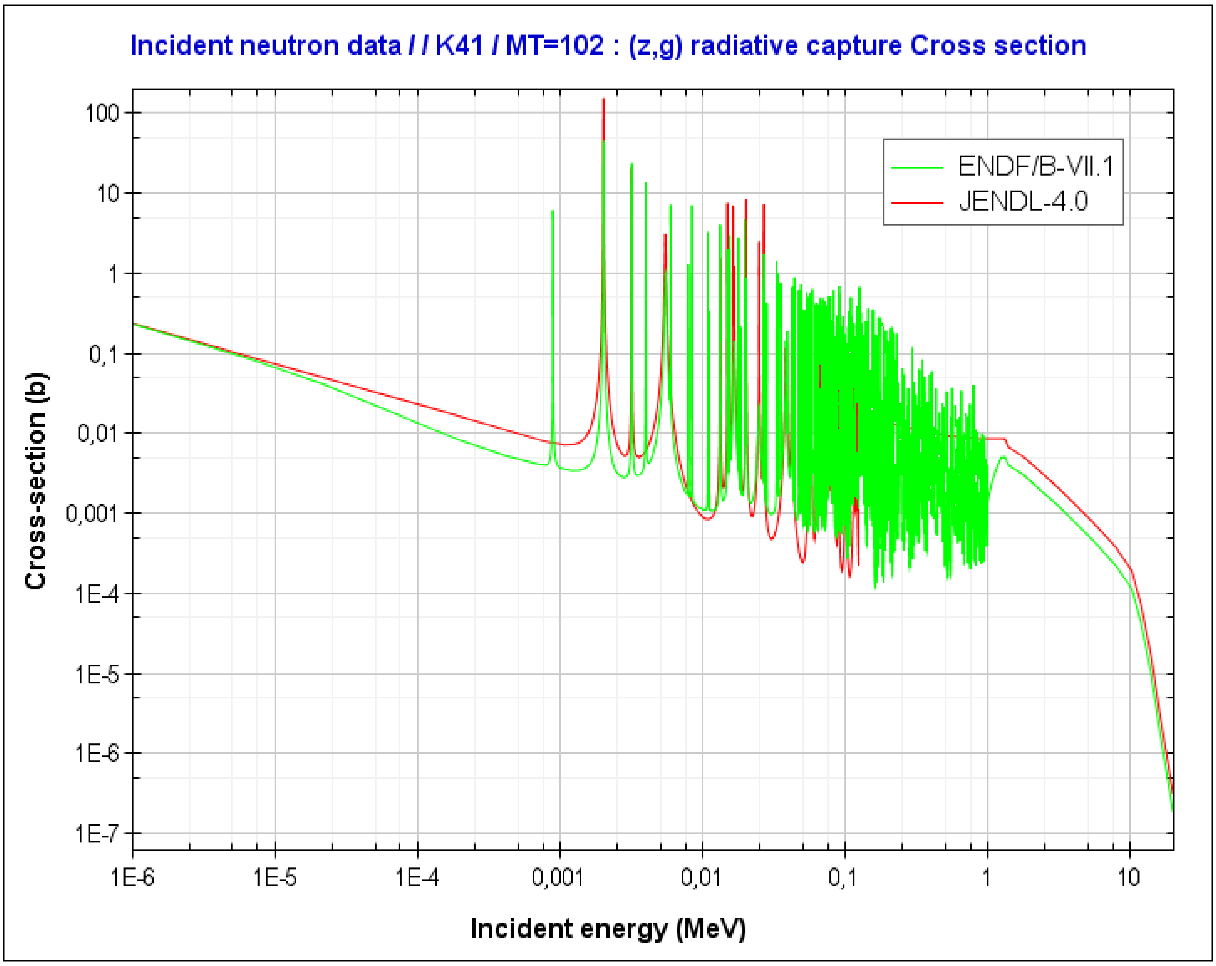
g = 0.999

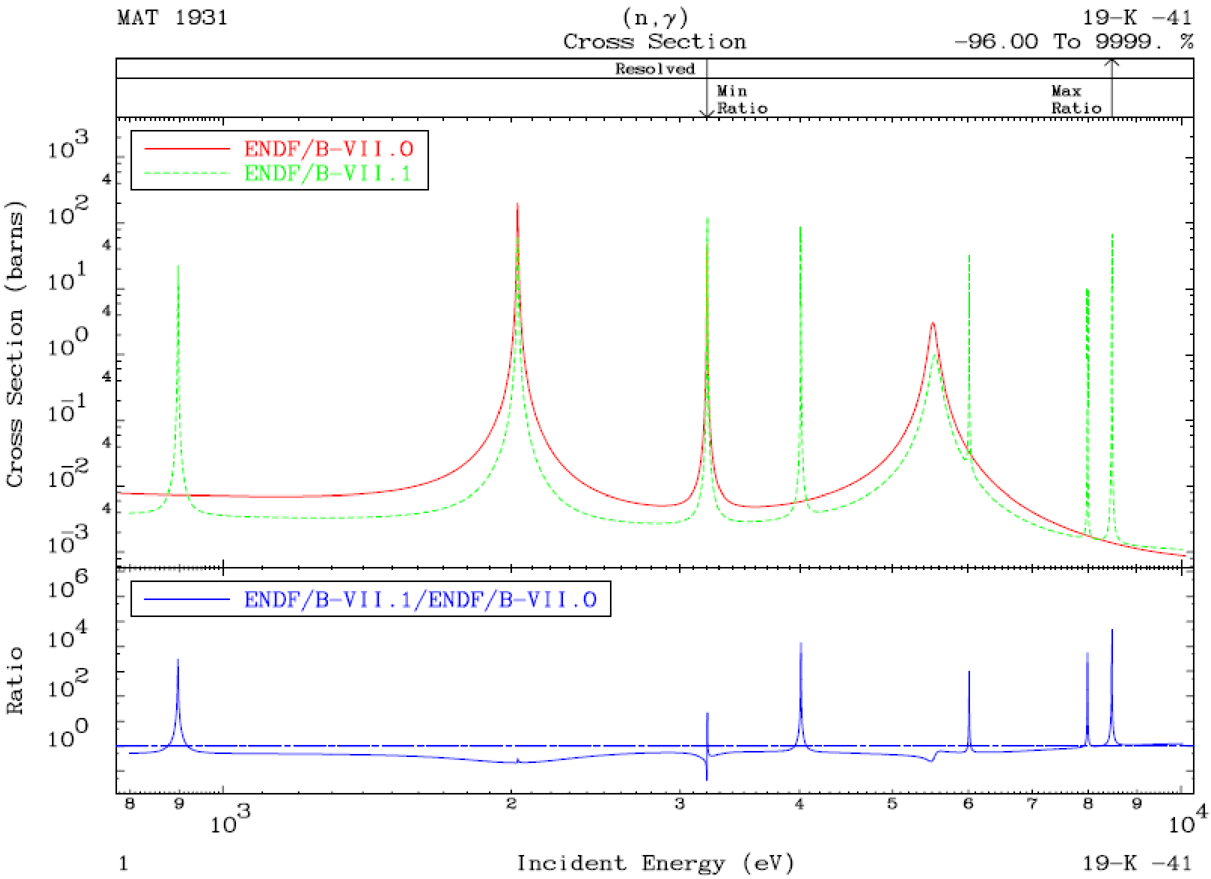
E_r = 3273 eV

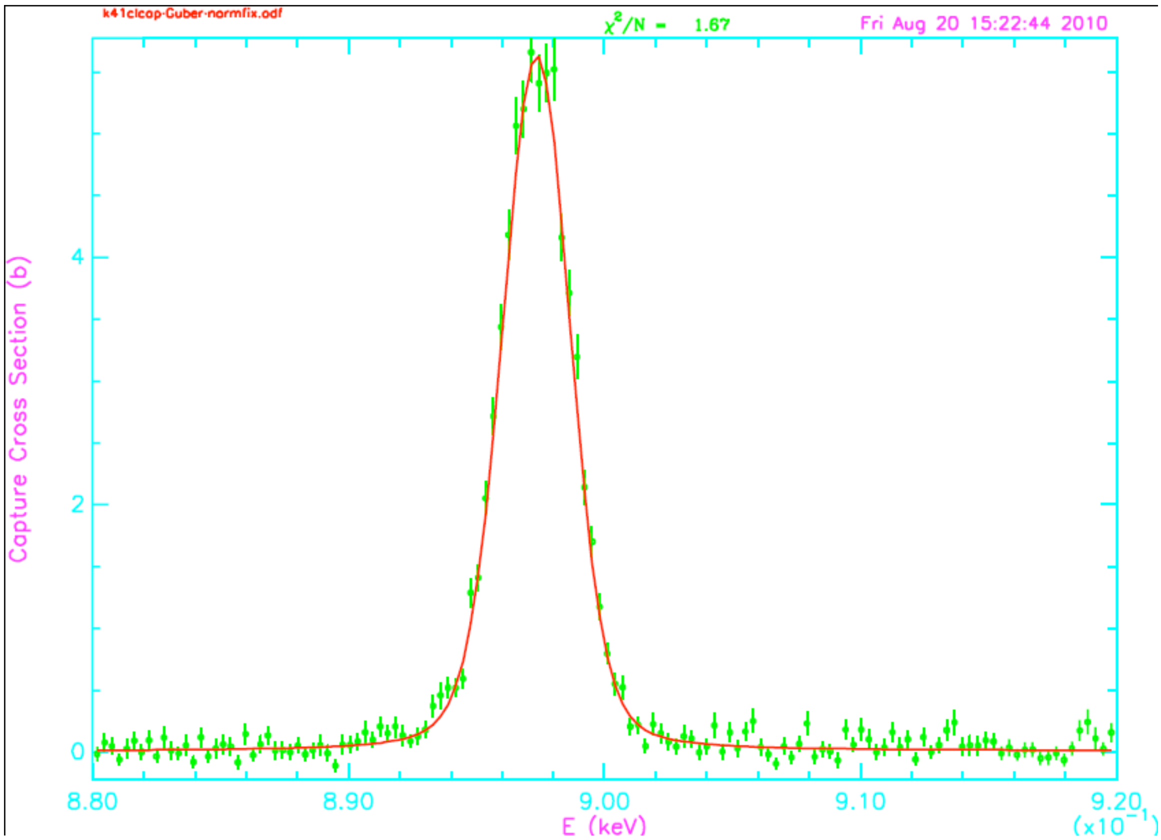
σ_0 = 1.46 b

Q_0 = 1.059

σ_h = 0.00582 b


Incident neutron data / / K41 / MT=102 : (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)


MAT 1931
(n,γ)
Cross Section
19-K -41
-96.00 To 9999. %
Resolved
Min
Ratio
Max
Ratio
ENDF/B-VII.0
ENDF/B-VII.1
Cross Section (barns)
ENDF/B-VII.1/ENDF/B-VII.0
Ratio
Incident Energy (eV)
1
19-K -41


k41clcap-Guber-normfix.odf
χ²/N = 1.67
Fri Aug 20 15:22:44 2010
Capture Cross Section (b)
E (keV)
8.80
8.90
9.00
9.10
9.20
(x10^-1)

2.5.10. $^{46}Ca(n,\gamma)^{47}Ca$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		JEFF-3.1/A [7]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.74	9.5	4.1	0.71	76.2	0.740	4.1	0.7404	4.2

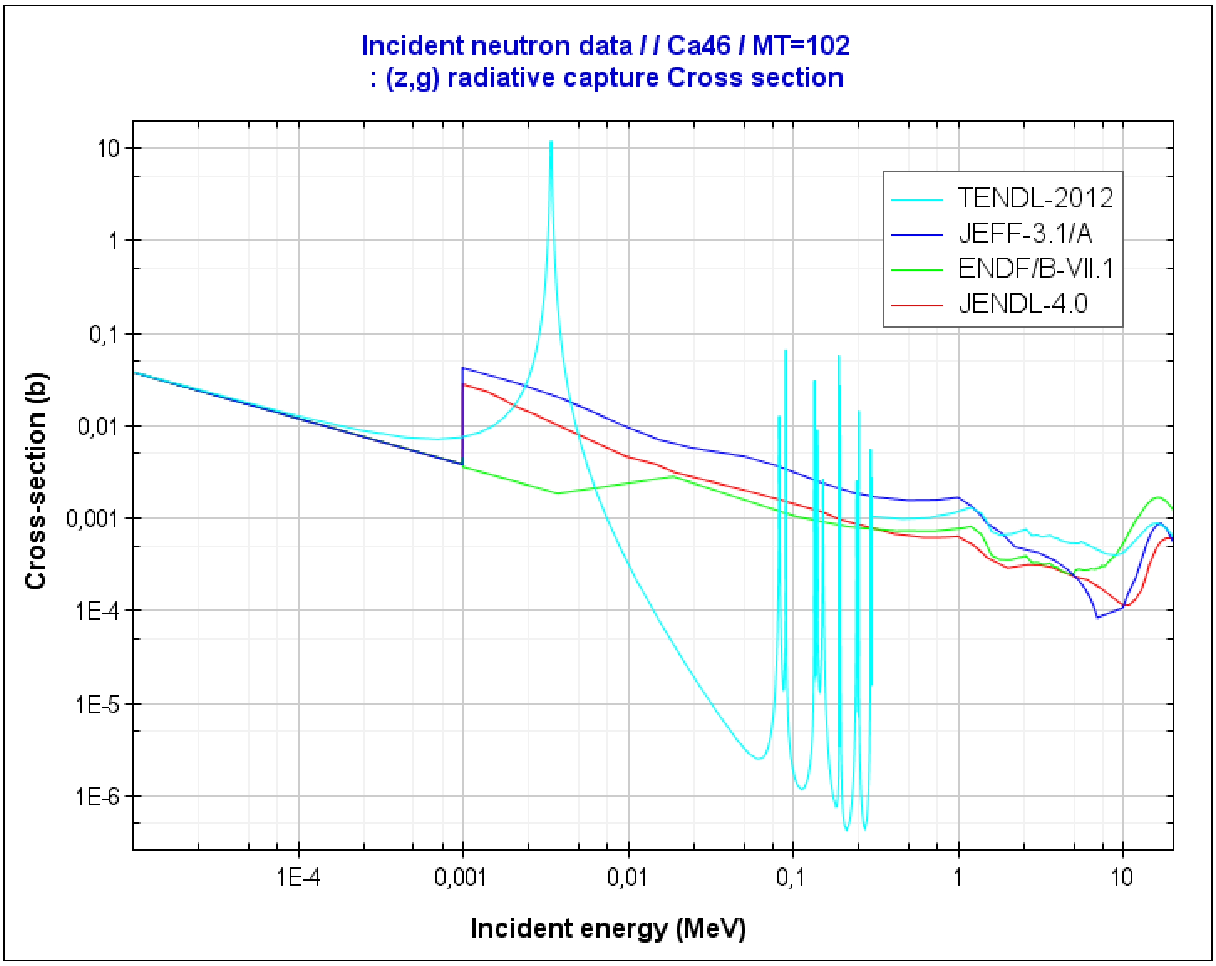
Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		JEFF-3.1/A [7]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.297	14.1	-0.2	1.3	-	0.4695	-64	0.514	-61

- Thermal cross section by Mughabghab [1] has an uncertainty of 9.5% and the difference from the value derived from the Kayzero [2] database is 4.1%, but the uncertainty of this value is 76.2% (20% due to the uncertainty in the gamma emission probability and 75% due to the uncertainty in the natural abundance, which is 0.004%). Good agreement between the two values is probably a coincidence.
- The Q_0 value by Mughabghab [1] has an assigned uncertainty of 14.1% and is in excellent agreement with the value derived from the Kayzero [2] database, for which no uncertainty is given. It is likely that the two are correlated.
- Due to the low abundance of ^{46}Ca, any isotopic measurements are difficult. The Mughabghab [1] compilation includes a single resonance at 28.4 keV, which the TENDL [9] evaluation tries to take into account. All other libraries only give tabulated values, with a jump at 1 keV, below which 1/v behaviour is assumed, normalised to match the thermal point. All evaluations underpredict Q_0 by more than 60%.
- None of the evaluated nuclear data files are suitable for the calculation physical quantities for NAA that can be derived from the cross sections.

A more accurate estimate of the thermal capture cross section and Q_0 could be obtained from Cd-ratio measurements of enriched samples, relative to ^{48}Ca.

The JENDL-4.0 [4] evaluation is selected for completeness, but should be used with caution for reasons stated above. Constants for NAA derived from the cross section curves are not of much value, but are nevertheless listed below:

F_{cd}	=	1.024
g	=	0.999
E_r	=	2925 eV
σ_0	=	0.740 b
Q_0	=	0.4695
σ_h	=	0.000526 b



2.5.11. $^{48}Ca(n,\gamma)^{49}Ca$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		JEFF-3.1 [6]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.09	12.8	-4.6	1.143	11.3	1.093	-4.4	1.093	-4.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		JEFF-3.1 [6]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.817	24.0	81.4	0.45	-	0.4199	-6.7	0.4220	-6.2

- Thermal cross section by Mughabghab [1] has an uncertainty of 12.8%, the difference from the value derived from the Kayzero [2] library is 4.6%, and the quoted uncertainty of this value is 11.3%, mainly due to the uncertainty in the natural abundance. The values in all major libraries are the same and agree with the Mughabghab [1] value, and hence with the Kayzero [2] database within the specified uncertainty.
- The Q_0 value by Mughabghab [1] has an assigned uncertainty of 24.0%, but is larger than the Kayzero [2] value by 81.4%. The Kayzero [2] value has no assigned uncertainty.
- The Q_0 values calculated from evaluated data files agree with the Kayzero [2] value to within 7%.
- The cross sections in the ENDF/B-VII are taken from JEFF-3.1 [6], which in turn differs from the JENDL-4.0 [4] library only in the fast neutron energy region. The resonances in the TENDL [9] library are based on Mughabghab [1] and contain more resonances than the JEFF-3.1 [6] or JENDL-4.0 [4] libraries.

For the time being, the JEFF-3.1 [6] evaluation is selected. The constants derived from the JEFF-3.1 [6] library are:

F_{cd} = 1.027

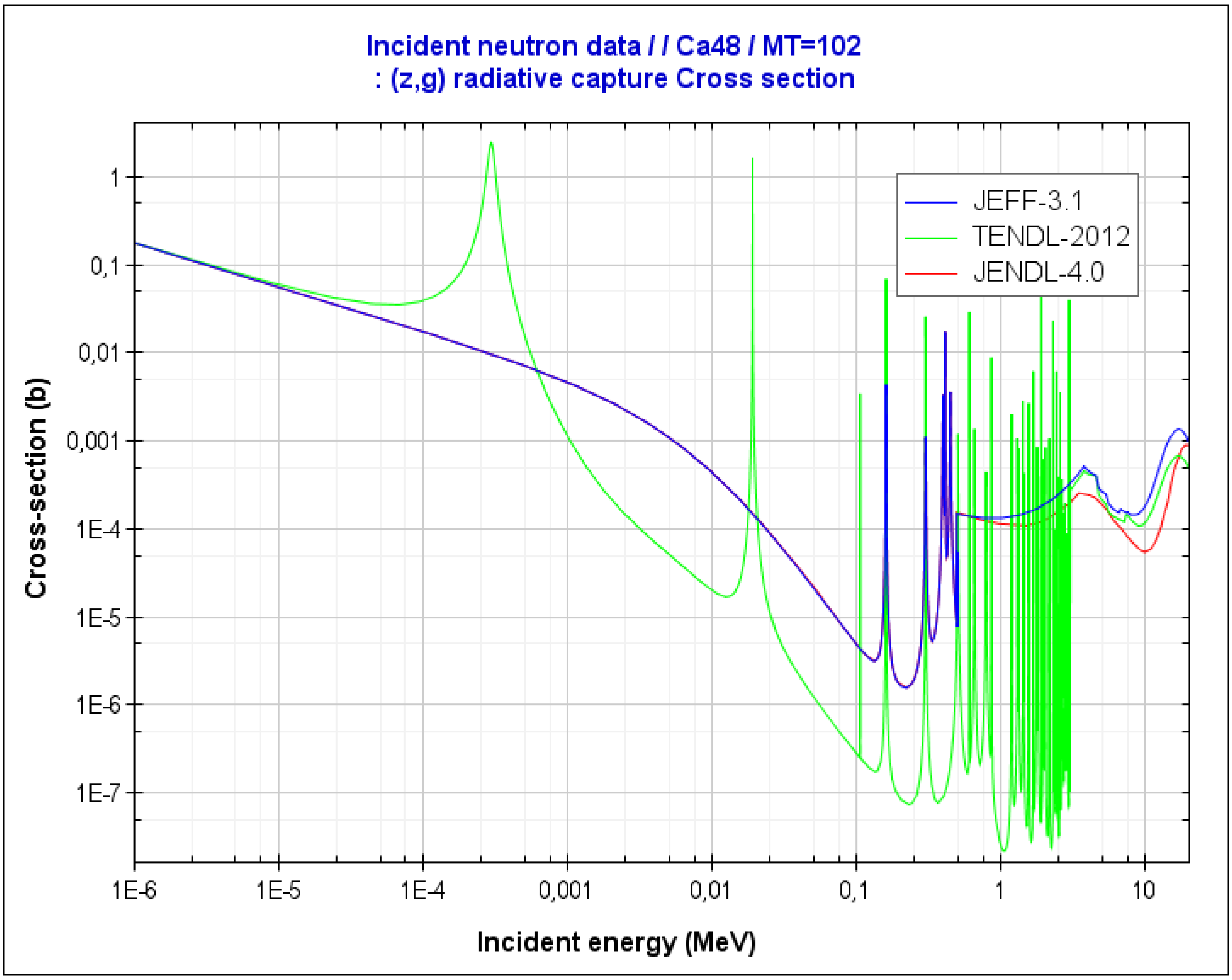
g = 0.999

E_r = 16347 eV

σ_0 = 1.093 b

Q_0 = 0.4220

σ_h = 0.000206 b



2.5.12. $^{45}Sc(n,\gamma)\,^{46}Sc$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
27.2	0.7	3.5	26.27	0.4	27.15	3.3	27.17	3.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.445	4.2	3.5	0.43	-	0.4129	-4.0	0.421	-2.2

- The thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.7%, the difference from the value derived from the Kayzero [2] library is 3.5%, and the quoted uncertainty of this value is 0.4%. It seems likely that the uncertainties are somewhat underestimated. The values in all major libraries are practically the same and lie close to the Mughabghab [1] value.
- The Q_0 value by Mughabghab [1] has an assigned uncertainty of 4.2% and differs from the Kayzero [2] value by 3.5%. The Kayzero [2] value has no assigned uncertainty. The Q_0 values calculated from evaluated data files differ slightly from each other. The closest to the Kayzero [2] value is the ENDF/B-VII.1 [5] library, with Q_0 value smaller by 2.2%.

The ENDF/B-VII.1 [5] library is selected. The constants derived from the ENDF/B-VII.1 [5] library are:

F_{cd} = 1.028

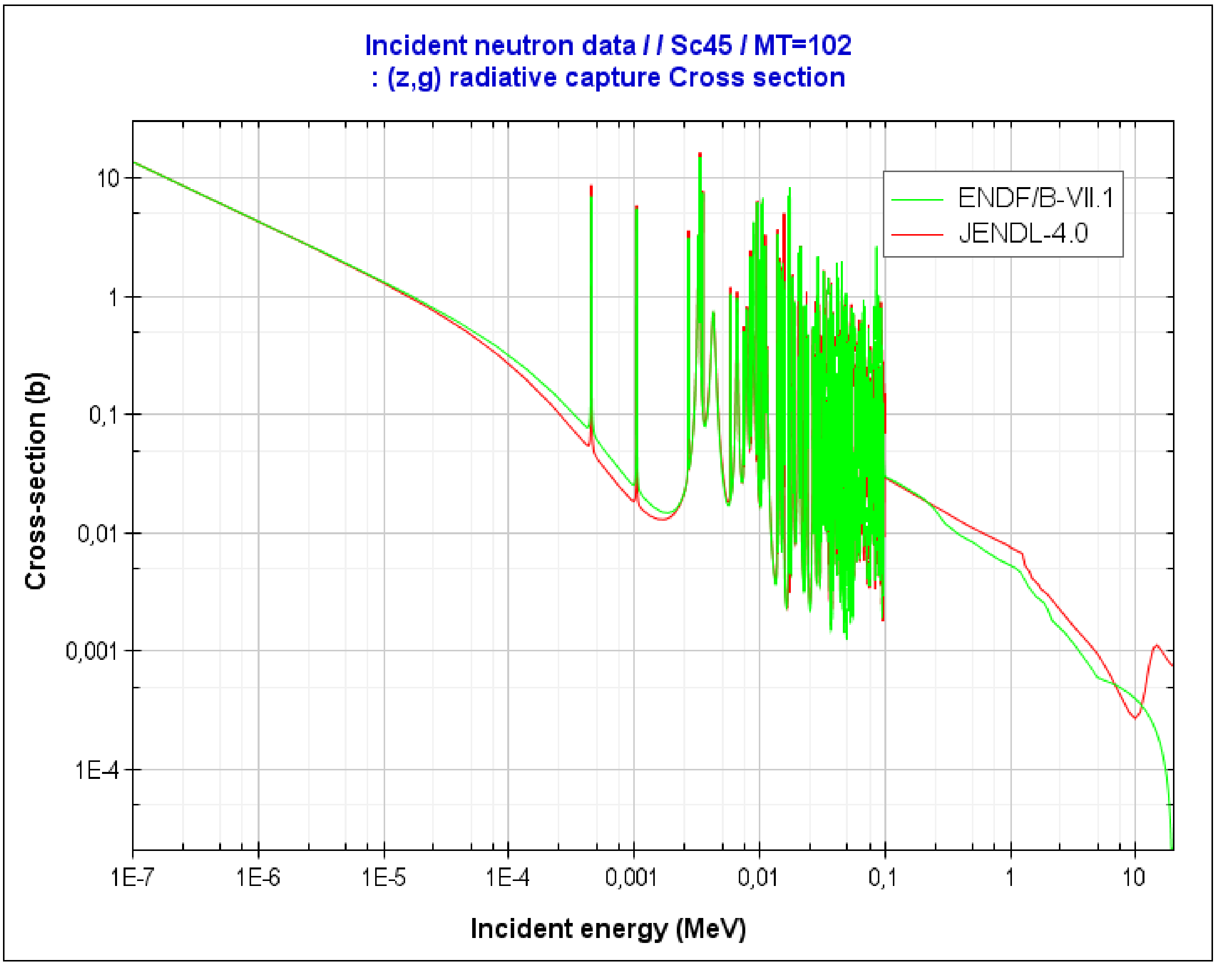
g = 0.999

E_r = 0.798 eV

σ_0 = 27.17 b

Q_0 = 0.421

σ_h = 0.00490 b


Incident neutron data / / Sc45 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
10
1
0,1
0,01
0,001
1E-4
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.13. $^{50}Ti(n,\gamma)^{51}Ti$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.179	1.7	0.8	0.178	1.1	0.1796	1.2	0.1796	1.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.659	9.5	-1.6	0.67	-	0.4678	-30	0.469	-30

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.7%, the difference from the value derived from the Kayzero [2] library is 0.8%, and the quoted uncertainty of this value is 1.1%. It seems likely that the uncertainties are somewhat underestimated. The values calculated from the ENDF/B-VII.1 [5] and the JENDL-4.0 [4] libraries are only 1.2% higher than the value derived from the Kayzero [2] database.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.5% and differs from the Kayzero [2] value by 1.6%. The Kayzero [2] value has no assigned uncertainty. The cross sections in JEFF-3.1 [6] in the resonance range are off by more than an order of magnitude, compared to other evaluations. The Q_0 values calculated from the evaluated data files differ slightly from each other, but they are 30% lower that the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected, but the large discrepancy in the Q_0 values has to be investigated. The constants derived from the ENDF/B-VII.1 [5] library are:

F_{cd} = 1.023

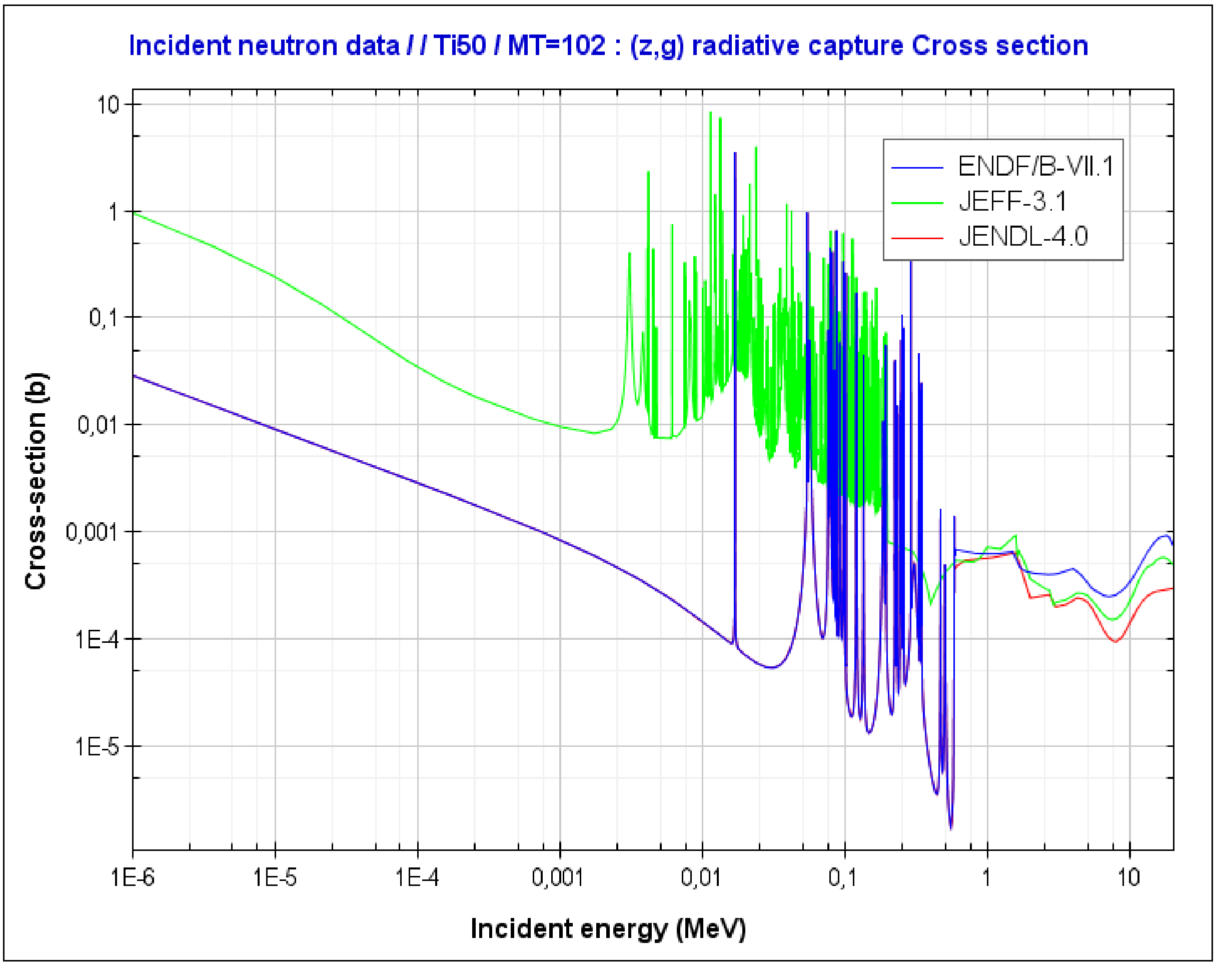
g = 0.999

E_r = 82557 eV

σ_0 = 0.1796 b

Q_0 = 0.469

σ_h = 0.000515 b



Incident neutron data / / Ti50 / MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JEFF-3.1
JENDL-4.0

2.5.14. $^{51}V(n,\gamma)^{52}V$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
4.94	0.8	3.1	4.794	1.6	4.92	2.6	4.92	2.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.547	3.8	-0.6	0.55	-	0.4972	-9.6	0.497	-9.6

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.8%, the difference from the value derived from the Kayzero [2] library is 3.1%, and the quoted uncertainty of this value is 1.6%. This indicates that the uncertainties are somewhat underestimated. The values calculated from the ENDF/B-VII.1 [5] and JENDL-4.0 [4] libraries are practically the same and 2.6% higher than the value derived from the Kayzero [2] database. The JEFF-3.1 [6] library contains data for the natural element.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.8% and is smaller than the Kayzero [2] value by 0.6%. The Kayzero [2] value has no assigned uncertainty. The cross sections in ENDF/B-VII.1 [5] and JENDL-4.0 [4] give the Q_0 value that is 9.6% lower that the Kayzero [2] value.
- The ENDF/B-VII.1 [5] and the JENDL-4.0 [4] libraries are practically the same, while the ROSFOND[8] library contains some additional resonances, possibly belonging to ^{50}V.

The ENDF/B-VII.1 [5] library is selected. The constants derived from this library are:

F_{cd} = 1.022

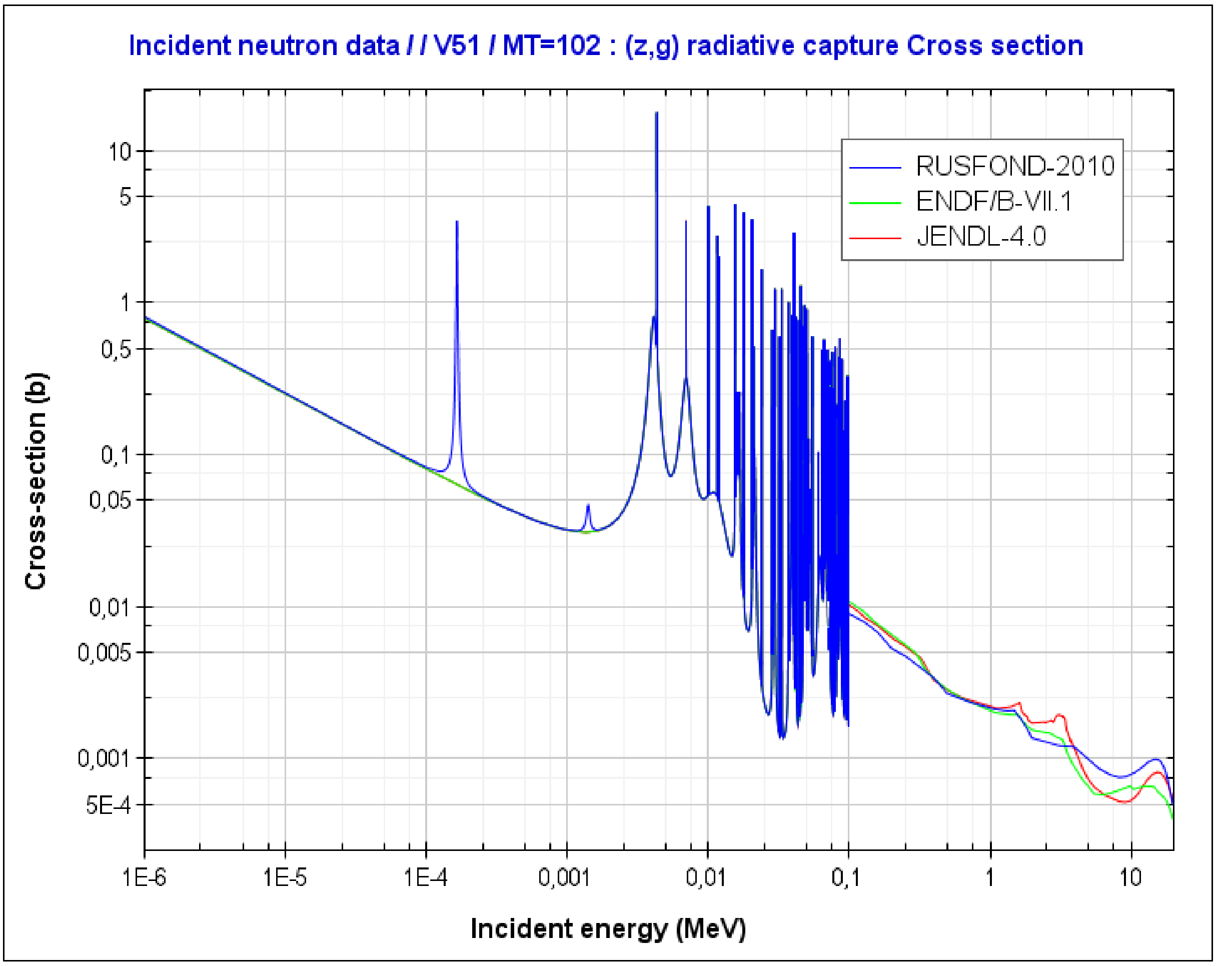
g = 0.998

E_r = 5406 eV

σ_0 = 4.92 b

Q_0 = 0.497

σ_h = 0.00228 b


Incident neutron data / / V51 / MT=102 : (z,g) radiative capture Cross section
RUSFOND-2010
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10
5
1
0,5
0,1
0,05
0,01
0,005
0,001
5E-4
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.15. $^{50}Cr(n,\gamma)^{51}Cr$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
15.4	1.3	1.6	15.15	0.6	15.38	1.5	15.41	1.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.760	2.1	43.3	0.53	2.4	0.4505	-15	0.447	-16

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.3%, the difference from the value derived from the Kayzero [2] library is 1.6%, and the quoted uncertainty of this value is 0.6%. This indicates that the uncertainties are somewhat underestimated. The values calculated from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 1.5% and 1.7% higher than the value derived from the Kayzero [2] database.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 2.1% and is larger by 43.3% in comparison with the Kayzero [2] value, which has an uncertainty of 2.4%. The cross sections in JENDL-4.0 [4] and ENDF/B-VII.1 [5] give Q_0 values that are 15% and 16%lower that the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because it is the most recent, but the discrepancy in the Q_0 value should be investigated. The constants derived from the ENDF/B-VII.1 [5] library are:

F_{cd} = 1.025

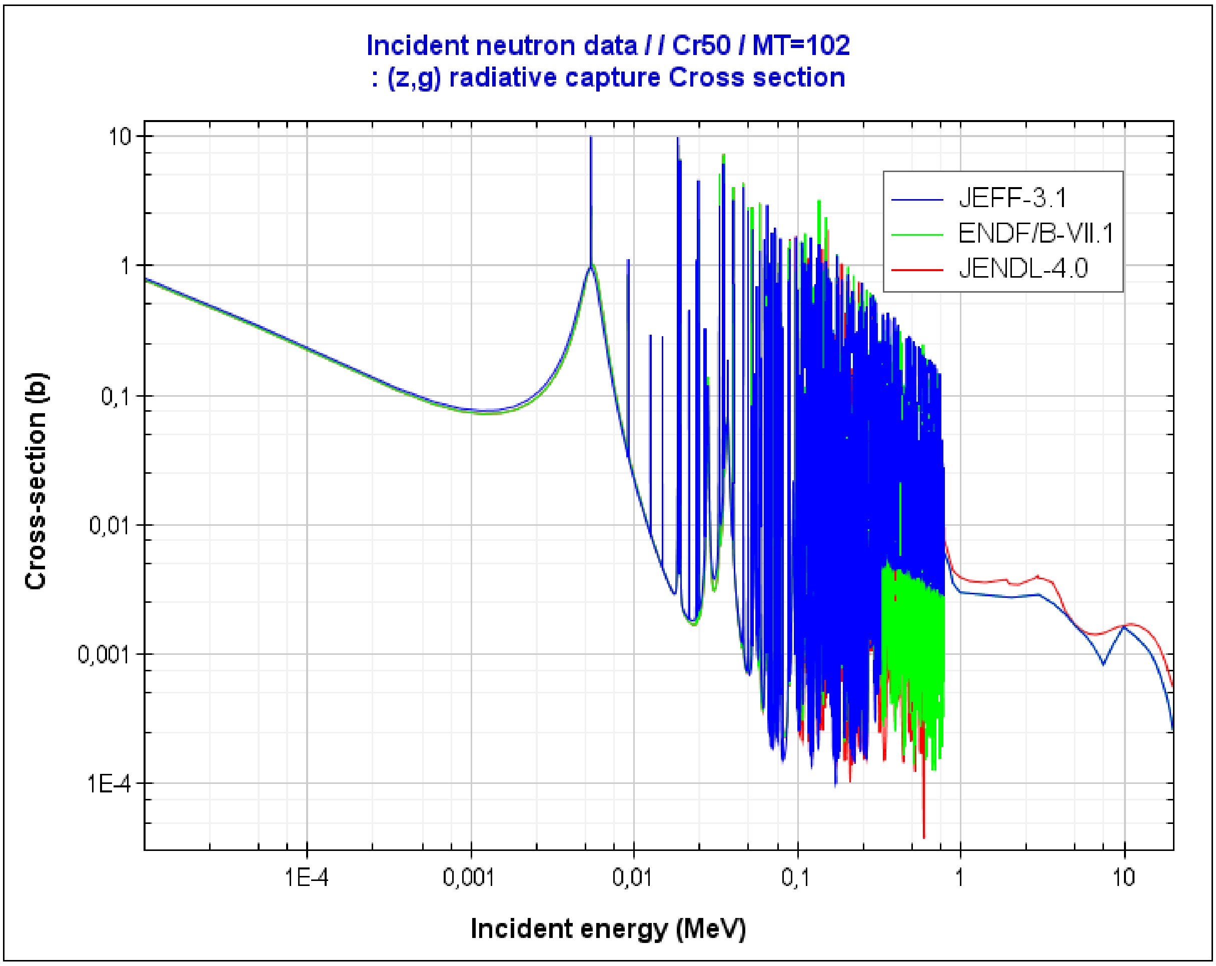
g = 0.998

E_r = 22493 eV

σ_0 = 15.41 b

Q_0 = 0.447

σ_h = 0.00388 b


Incident neutron data / / Cr50 / MT=102
: (z,g) radiative capture Cross section
JEFF-3.1
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
Incident energy (MeV)
10
1
0,1
0,01
0,001
1E-4
1E-4
0,001
0,01
0,1
1
10

2.5.16. $^{55}Mn(n,\gamma)^{56}Mn$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
13.36	0.4	1.2	13.20	0.6	13.28	0.6	13.28	0.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.003	3.8	-4.7	1.053	3.0	0.995	-5.5	0.995	-5.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.4% and is 1.2% higher than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.6%. The values in the ENDF/B-VII.1 [5] and the JENDL-4.0 [4] libraries are the same and differ from the Kayzero [2] value by 0.6%. Overall, the differences are small. It seems likely that the quoted uncertainties are somewhat underestimated.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.8% and is smaller by 4.7% in comparison with the Kayzero [2] value, which has an uncertainty of 3.0%. The values in the ENDF/B-VII.1 [5] and the JENDL-4.0 [4] libraries are the same and differer from the Kayzero [2] value by 5.5%.

The ENDF/B-VII.1 [5] library is selected because it is the most recent. The constants derived from this library are:

F_{cd} = 1.007

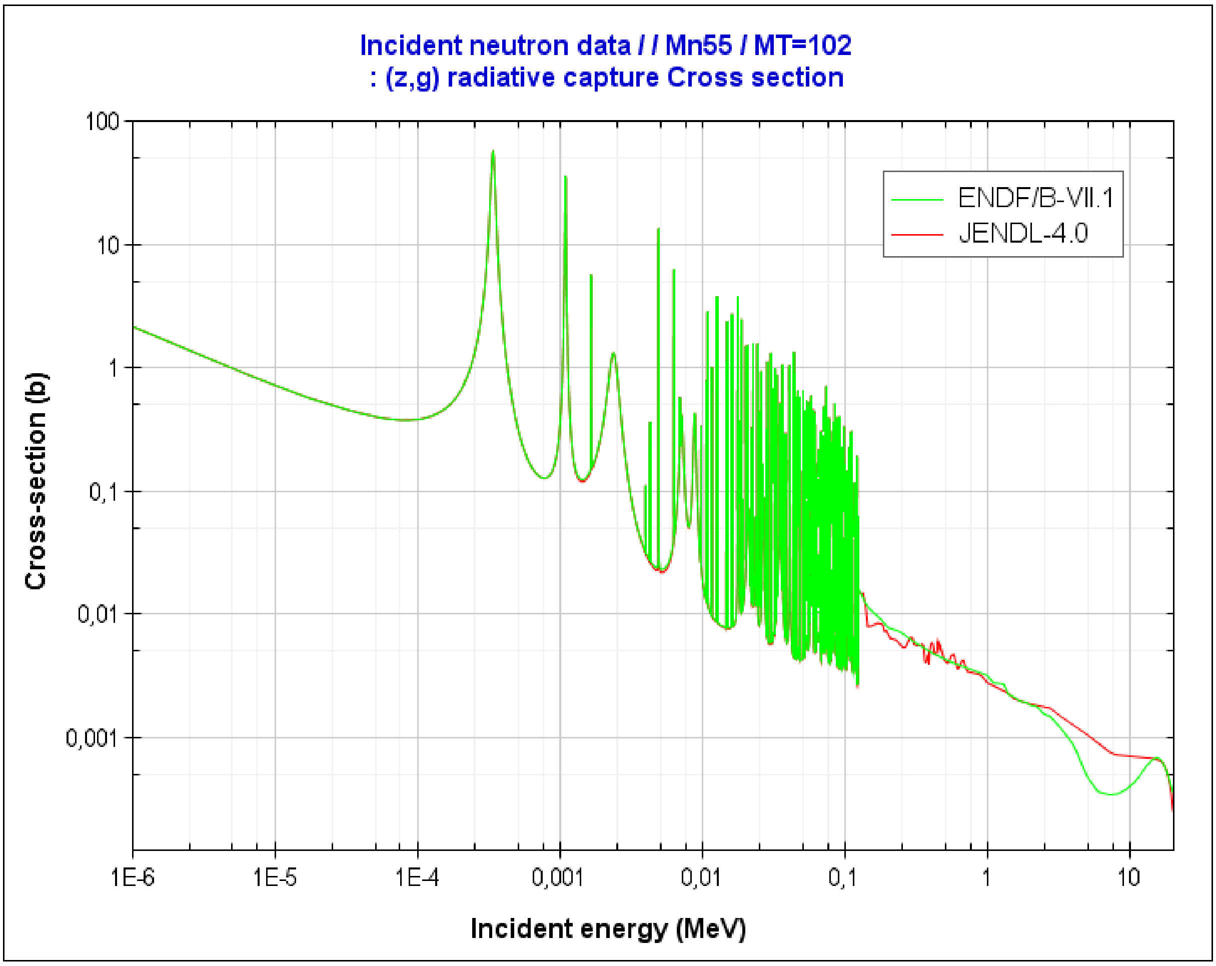
g = 0.999

E_r = 381.3 eV

σ_0 = 13.28 b

Q_0 = 0.995

σ_h = 0.00282 b



Incident neutron data / / Mn55 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
Incident energy (MeV)
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
ENDF/B-VII.1
JENDL-4.0

2.5.17. $^{58}Fe(n,\gamma)^{59}Fe$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		JEFF-3.1 [6]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.32	2.3	5.4	1.253	3.1	1.301	3.8	1.315	5.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		JEFF-3.1 [6]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.136	5.2	16.6	0.975	1.0	1.020	4.6	0.9544	-2.1

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.3% and is 5.4% higher than the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.1%. The cross sections in the JENDL-4.0 [4] file and the JEFF-3.1 [6] file are higher by 3.8% and 5.0%, respectively. In the JEFF-3.1 [6] evaluation an analysis of the abundance values was carried out by M. Moxon, which is relevant because the natural abundance of ^{58}Fe is only 0.282% and the recommended value has changed in recent years, therefore some older measurements of the cross sections were affected. The ENDF/B-VII.1 [5] evaluation was carried over from ENDF/B-VI.8 and is older.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.2% and is larger by 16.6% in comparison with the Kayzero [2] value, which has an uncertainty of 1.0%. The value from the JENDL-4.0 [4] library is 4.6% higher while the JEFF-3.1 [6] value is 2.1% lower.

The JEFF-3.1 [6] library is selected because the issue of the natural abundance of ^{58}Fe was taken into account in the evaluation process. It is a recently revised evaluation for use in dosimetry. The constants derived from this library are:

F_{cd} = 1.002

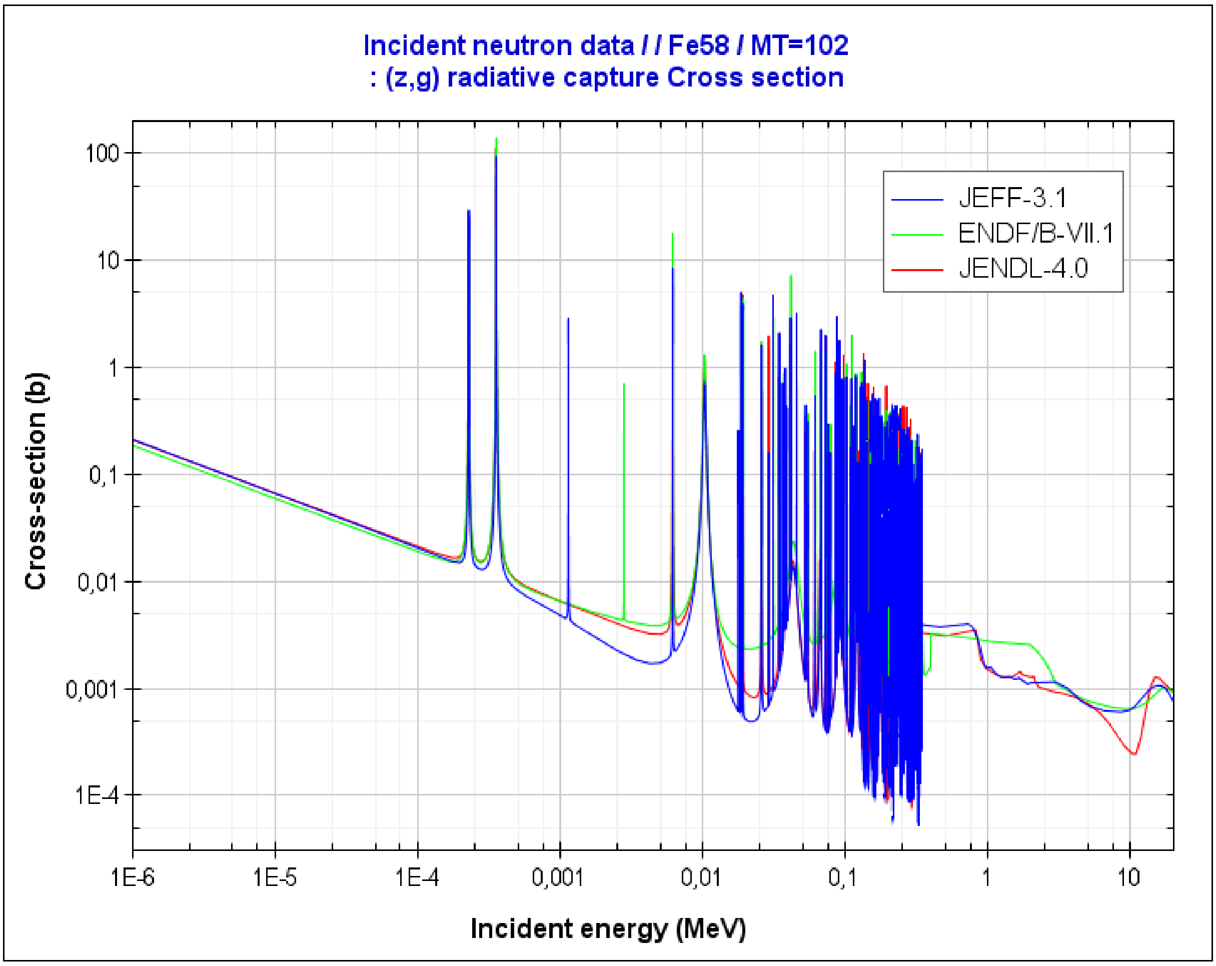
g = 0.998

E_r = 503.6 eV

σ_0 = 1.315 b

Q_0 = 0.9544

σ_h = 0.00202 b


Incident neutron data / / Fe58 / MT=102
: (z,g) radiative capture Cross section
JEFF-3.1
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.18. $^{59}Co(n,\gamma)^{60}Co$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
37.18	0.2	-2.0	37.92	0.3	37.22	-1.9	37.19	-1.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.990	2.7	-0.5	2.0	3.0	2.015	0.7	2.016	0.8

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.2% and is 2.0% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.3%. JENDL-4.0 [4] and ENDF/B-VII.1 [5] values are 1.9% smaller than the Kayzero [2] value. Overall, the agreement is good, but the uncertainties by Mughabghab [1] and Kayzero [2] seem to be underestimated.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 2.7% and is in excellent agreement with the Kayzero [2] value, which has an uncertainty of 3.0%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are almost the same and consistent with the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected, being practically the same as JENDL-4.0 [4]. The constants derived from this library are:

F_{cd} = 0.990

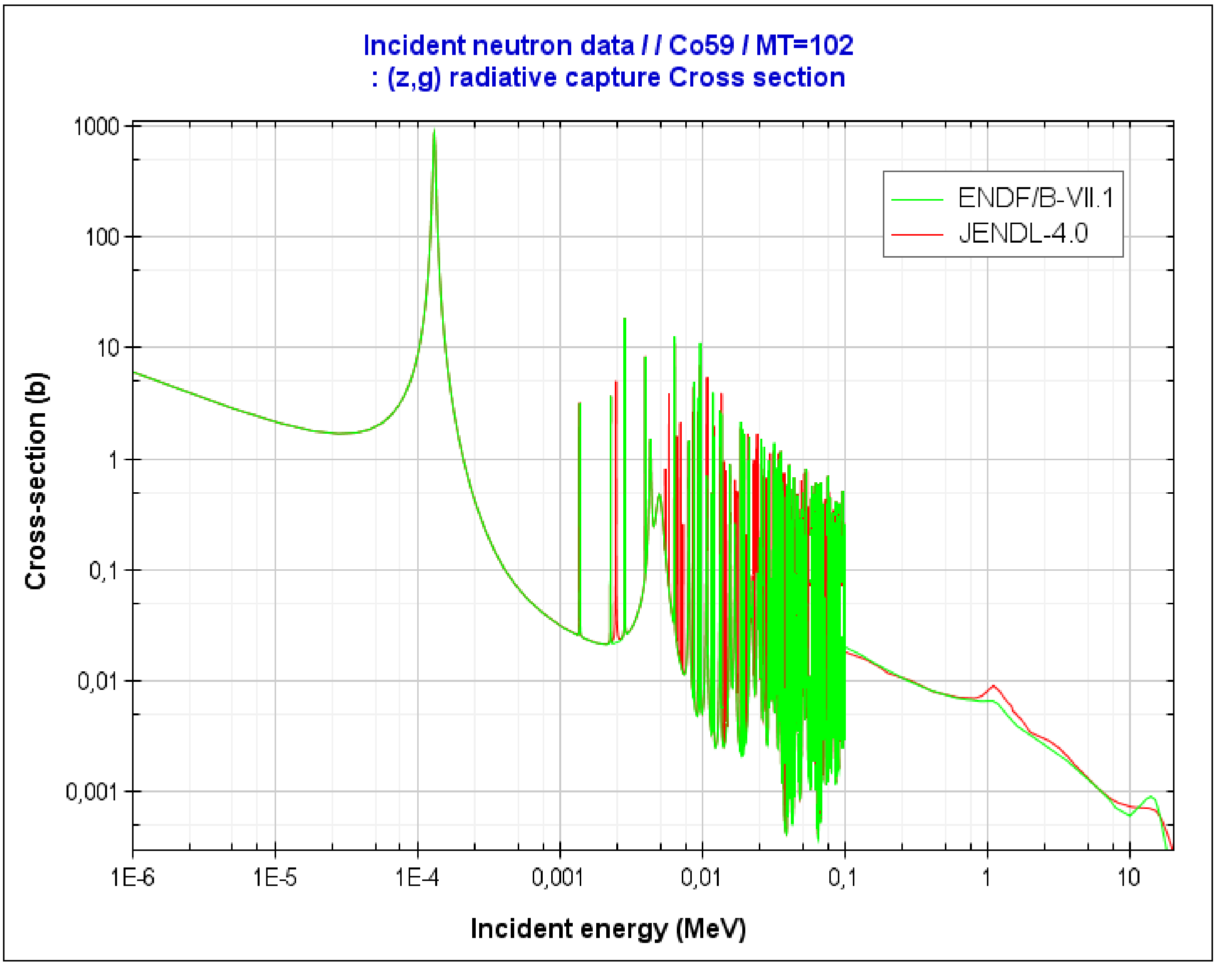
g = 0.999

E_r = 121.9 eV

σ_0 = 37.19 b

Q_0 = 2.016

σ_h = 0.00491 b



Incident neutron data / / Co59 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.19. $^{64}Ni(n,\gamma)^{65}Ni$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.64	2.4	1.1	1.622	0.7	1.481	-8.7	1.481	-8.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.652	14.2	-2.6	0.67	-	0.5283	-21	0.531	-21

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.4% and is 1.1% bigger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.7%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are the same, but 8.7% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 14.2% and is smaller by 2.6% in comparison with the Kayzero [2] value, which has no assigned uncertainty. The values from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 21% smaller.

The ENDF/B-VII.1 [5] library is selected. The constants derived from this library are:

F_{cd} = 1.020

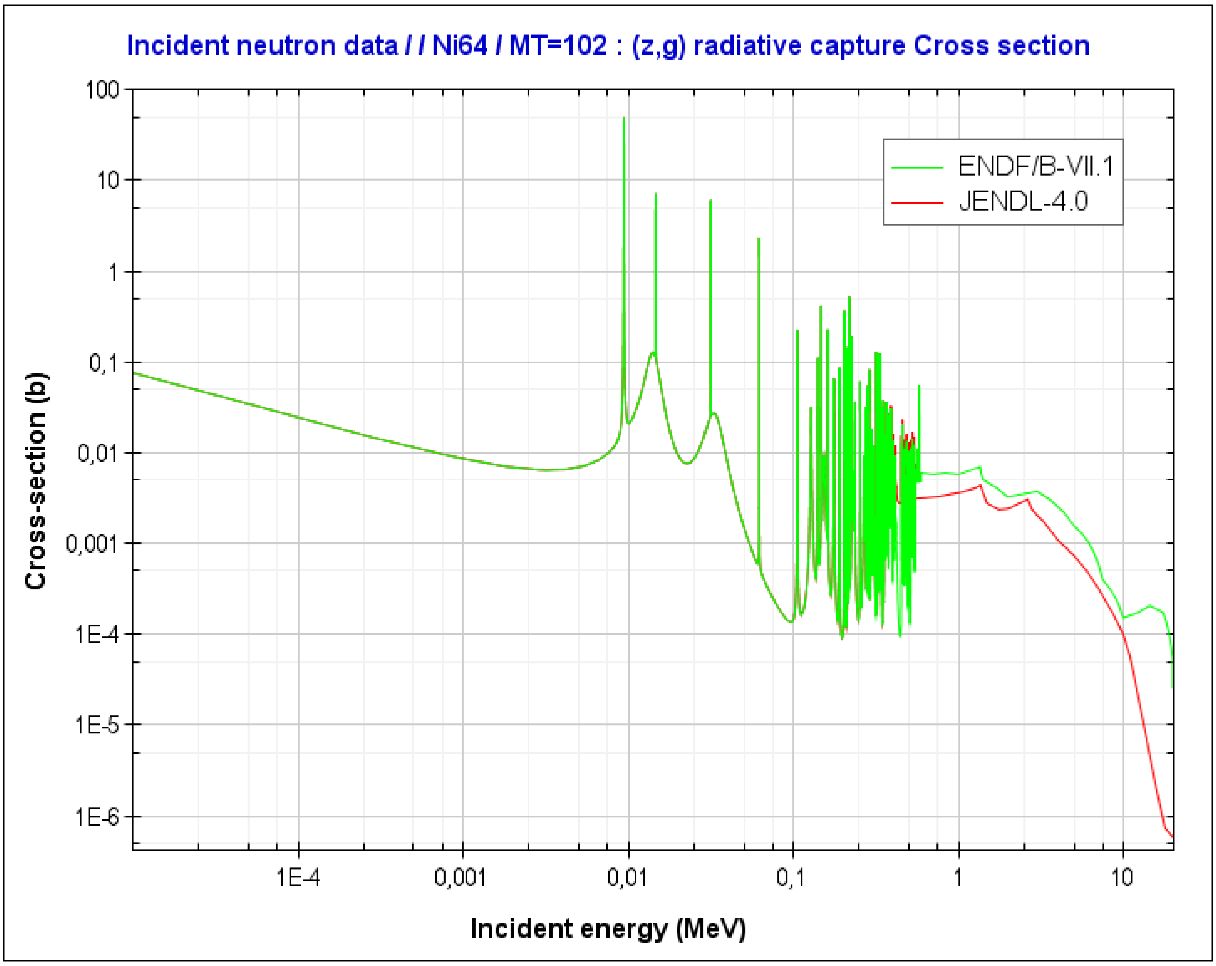
g = 0.998

E_r = 13861 eV

σ_0 = 1.481 b

Q_0 = 0.531

σ_h = 0.00400 b


Incident neutron data / / Ni64 / MT=102 : (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.20. $^{63}Cu(n,\gamma)^{64}Cu$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
4.50	0.4	-2.7	4.624	1.1	4.508	-2.5	4.471	-3.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.104	1.7	-3.1	1.14	-	1.087	-4.6	1.086	-4.7

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.4% and is 2.7% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.1%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the value by Mughabghab [1]. The agreement between values is reasonable, but the assigned uncertainties are likely to be slightly underestimated.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 1.7% and is smaller by 3.1% in comparison with the Kayzero [2] value, which has no uncertainty given. The values from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are closer to the Mughabghab [1] value, but only slightly more than 4.5% higher than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected for consistency with the isotope ^{65}Cu, even though the cross sections in JENDL-4.0 [4] are slightly closer to the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 1.007

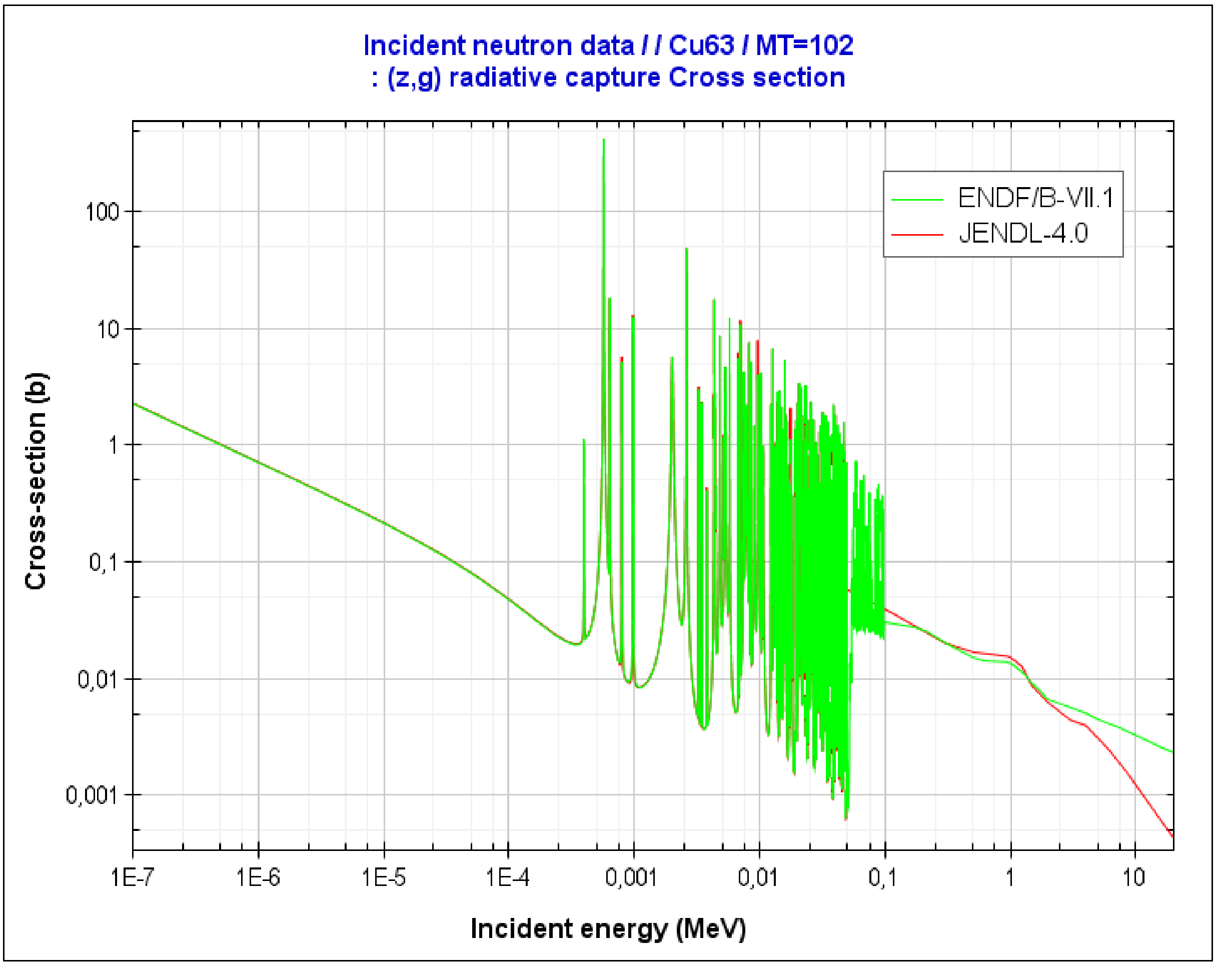
g = 0.998

E_r = 1290 eV

σ_0 = 4.471 b

Q_0 = 1.086

σ_h = 0.0105 b


Incident neutron data / / Cu63 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.21. $^{65}Cu(n,\gamma)^{66}Cu$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
2.17	1.4	9.2	1.988	1.2	2.169	9.1	2.150	8.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.009	3.5	-4.8	1.06	-	1.000	-5.7	1.007	-5.0

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.4% and is 9.2% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.2%. The values in the JENDL.4 and the ENDF/B-VII.1 [5] libraries lie close to the Mughabghab [1] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.5% and is smaller by 4.8% in comparison with the Kayzero [2] value, which has no assigned uncertainty.

The ENDF/B-VII.1 [5] library is selected, although the differences between the evaluations are small. The constants derived from this library are:

F_{cd} = 0.992

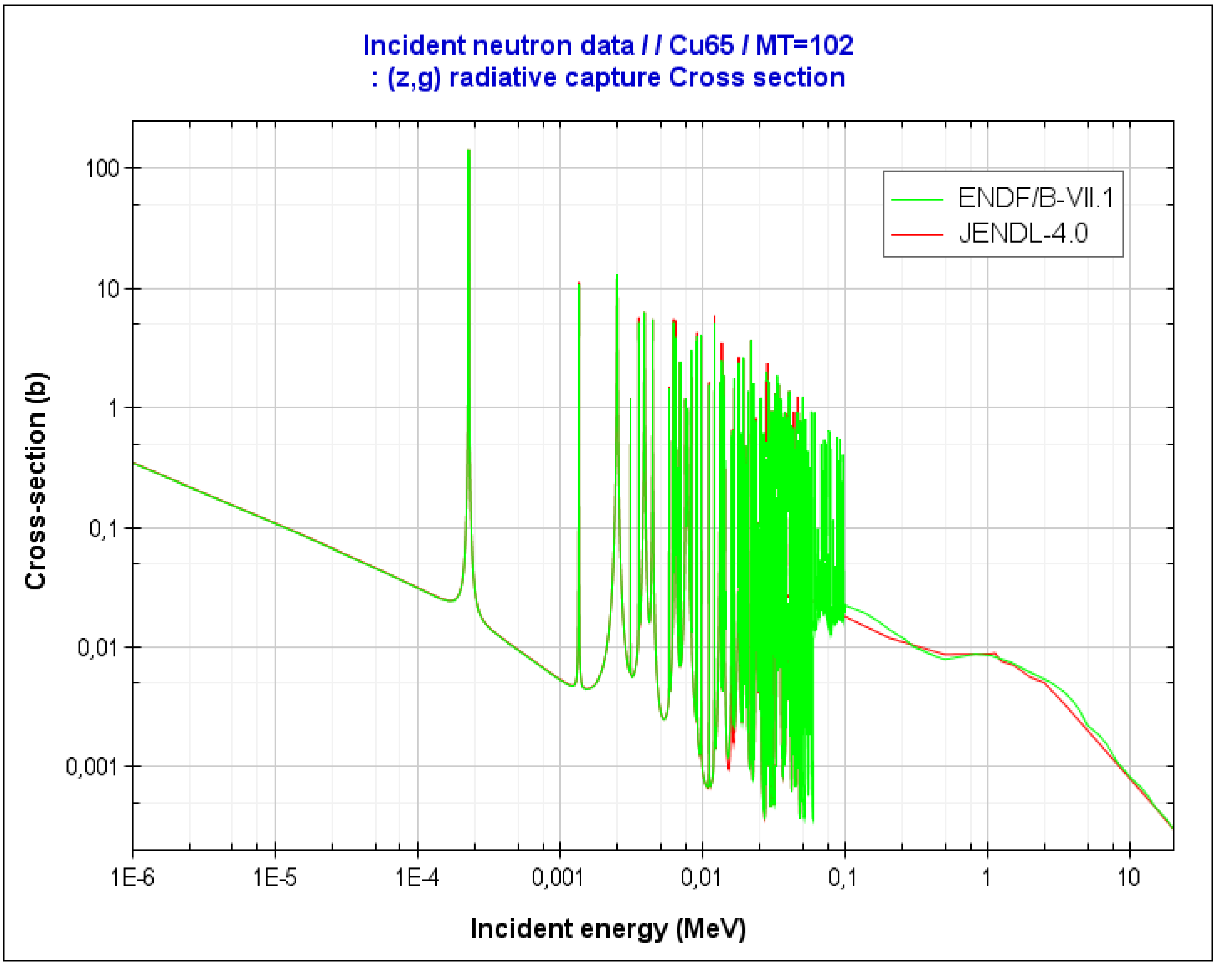
g = 0.998

E_r = 770.7 eV

σ_0 = 2.150 b

Q_0 = 1.007

σ_h = 0.00698 b


Incident neutron data / / Cu65 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.22. $^{64}Zn(n,\gamma)^{65}Zn$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.79	2.5	6.5	0.7415	0.8	0.7876	6.2	0.7876	6.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.734	5.1	-9.1	1.908	5.0	1.780	-6.7	1.772	-7.1

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.5% and is 6.5% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.8%. In the ENDF/B-VII.1 [5] library the JENDL-4.0 [4] evaluation for ^{64}Zn is adopted, therefore the two of them are identical. The thermal cross section in the library is bigger by 6.2%.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.1% and is smaller by 9.1% in comparison with the Kayzero [2] value, which has an uncertainty of 5.0%. The value derived from the JENDL-4.0 [4] library is smaller than the Kayzero [2] value by 6.7%.

The JENDL-4.0 [4] library is selected because it is the root evaluation adopted in the ENDF/B-VII.1 [5] library. The constants derived from this library are:

F_{cd} = 1.003

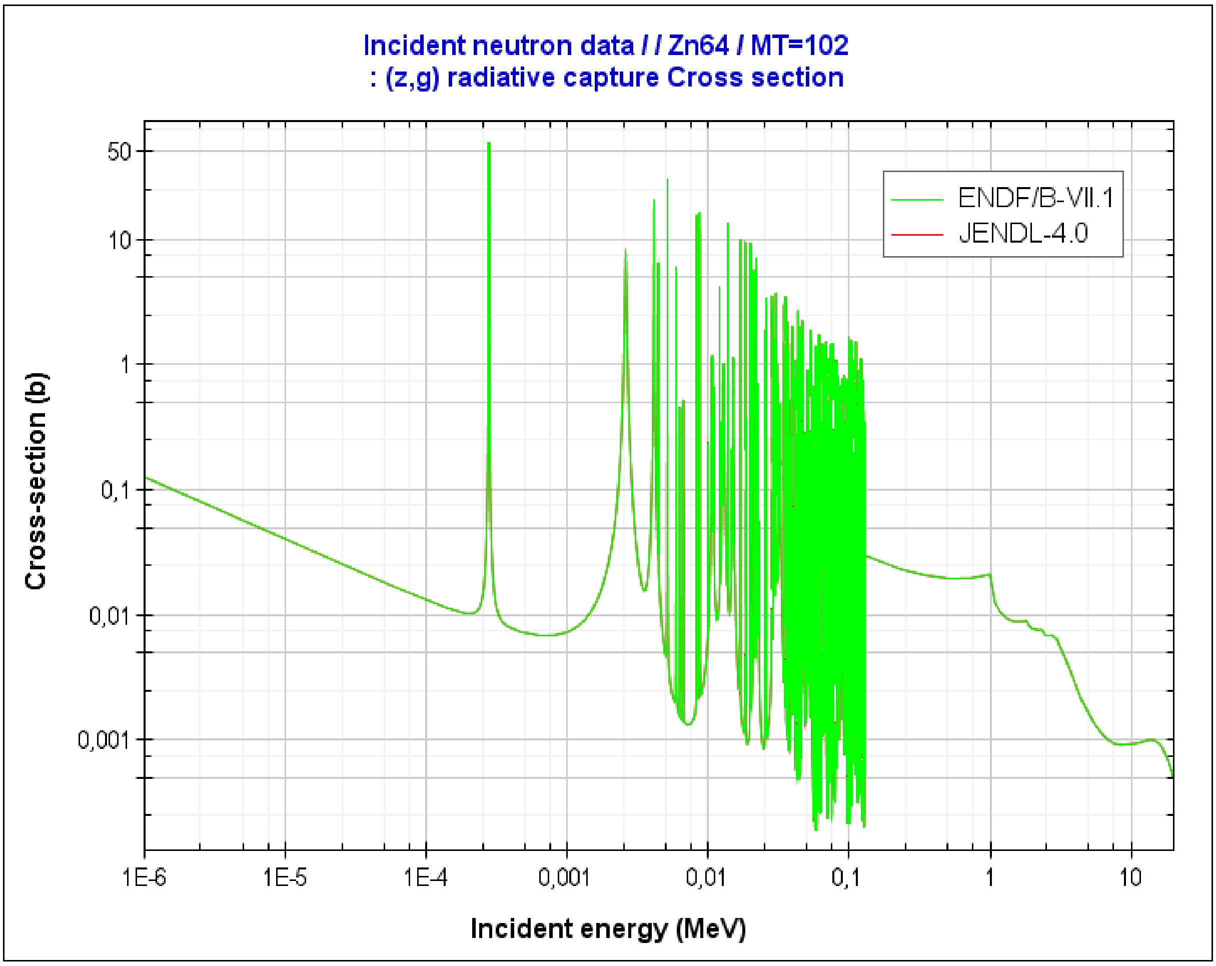
g = 0.998

E_r = 2800 eV

σ_0 = 0.7876 b

Q_0 = 1.780

σ_h = 0.0114 b


Incident neutron data / / Zn64 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
50
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.23. ^{68}Zn(n,γ)^{69m}Zn

The thermal cross sections and the Q_0 values, which refer to the formation of the metastable residual ^{69m}Zn, are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.072	5.6	4.2	0.0691	0.9	0.07173	3.8	0.07033	1.7

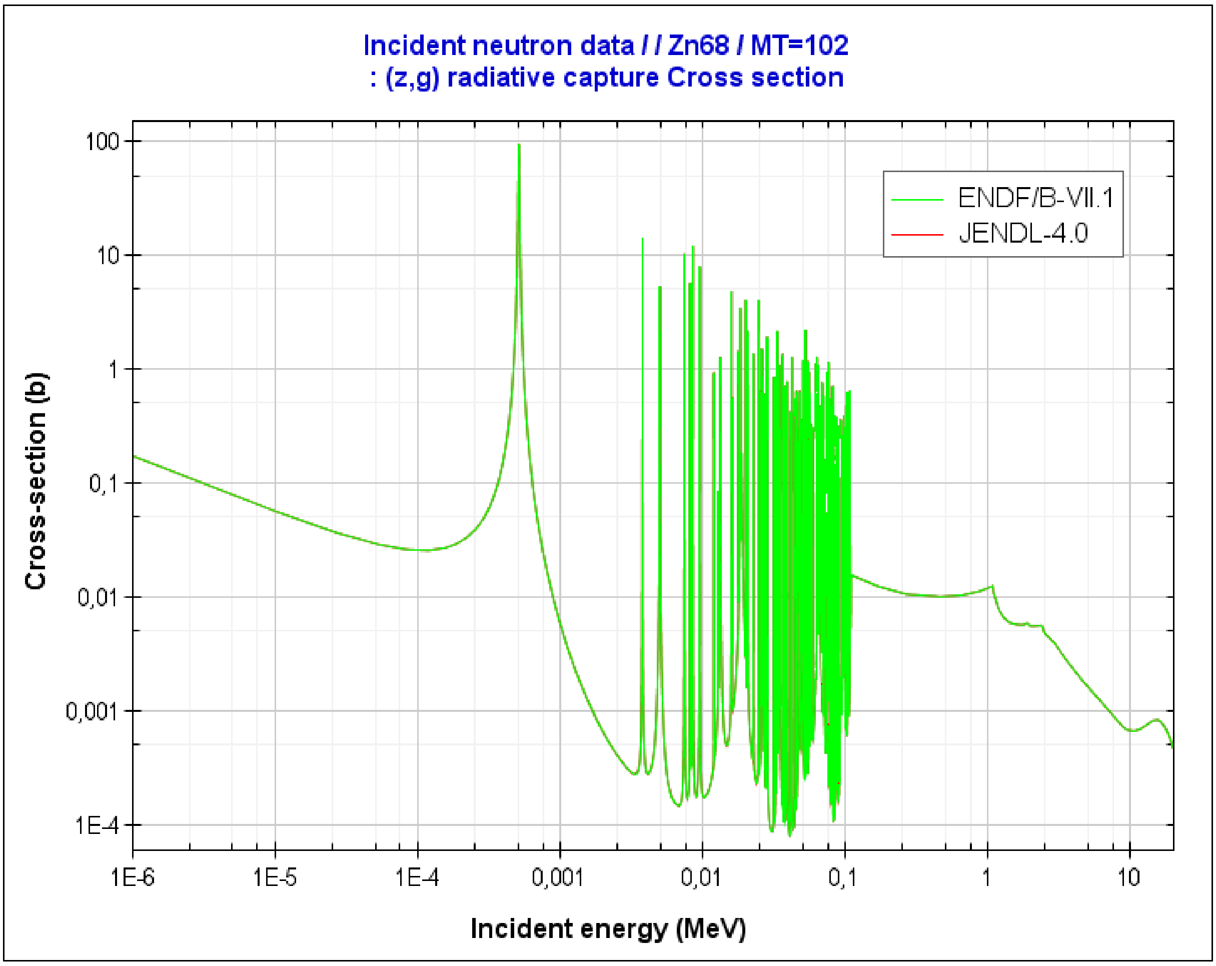
Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
2.861	5.6	-10	3.19	1.4	2.515	-21	3.091	-3.1

- Thermal cross section by Mughabghab [1] that is quoted refers to the production of the metastable product with a half-life of 13.6 hours. It has an uncertainty of 5.6% and is 4.2% bigger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.9%. The JENDL-4.0 [4] library does not contain the branching ratios for the production of the metastable nuclide. Assuming that the branching ratio for thermal incident neutrons of 6.73% (with an uncertainty of 11%) by Mughabghab [1] is correct, the thermal cross section in JENDL-4.0 [4] is 3.8% bigger than the value obtained from the Kayzero [2] database. The value in the ENDF/B-VII.1 [5] library agrees with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.6% and is smaller by 10% in comparison with the Kayzero [2] value, which has an uncertainty of 1.4%. The effective branching ratio in the epithermal range for the production of the metastable nuclide is 5.89% (with an uncertainty of 8.0%) according to Mughabghab [1]. With this ratio the Q_0 value from the JENDL-4.0 [4] file is smaller by 21% compared to the Kayzero [2] database. (Note that the difference would be smaller if a branching ratio at thermal energy was adopted, assuming it was energy-independent). The value derived from the ENDF/B-VII.1 [5] library is 3.1% smaller than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because it has the branching ratios given explicitly and agrees with the Kayzero [2] constants. The constants derived from this library are:

F_{cd}	=	0.998
g	=	0.998
E_r	=	605.4 eV
σ_0	=	0.07033 b
Q_0	=	3.091
σ_h	=	0.000841 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.24. $^{70}Zn(n,\gamma)^{71m}Zn$

The thermal cross sections and the Q_0 values, which refer to the formation of the metastable residual ^{71m}Zn, are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.0087	5.7	-64	0.0239	22.2	0.008676	-64	0.008676	-64

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
9.348	9.0	18.3	7.9	-	1.125	-86	1.126	-86

- Thermal cross section by Mughabghab [1] that is quoted refers to the production of the metastable product with a half-life of 3.9 hours. It has an uncertainty of 5.7%, but it is smaller than the value derived from the Kayzero [2] library by 64%, which is quoted with an uncertainty of 22.2%. The ENDF/B-VII.1 [5] library adopted the JENDL-4.0 [4] evaluation for ^{70}Zn, therefore the two are identical. No branching ratios for the production of long-lived metastable states are given in the evaluated nuclear data libraries. Assuming that the brancing ratio for thermal incident neutrons of 9.5% by Mughabghab [1] is correct, the value in the JENDL-4.0 [4] library is lower by 64% in comparison to the Kayzero [2] value. Note that the natural abundance of ^{70}Zn is only 0.631 %.
- With the assumption that the branching ratio is independent of energy, the Q_0 value for the total capture cross section is the same as that for the production of the metastable product. The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.0% and is larger by 18.3% in comparison with the Kayzero [2] value, which has no quoted uncertainty. The value derived from the JENDL-4.0 [4] library is seven times lower.

The JENDL-4.0 [4] library is arbitrarily selected, but the huge discrepancy in the thermal cross section (and the Q_0 value) should be investigated. The constants derived from this library are:

F_{cd} = 1.008

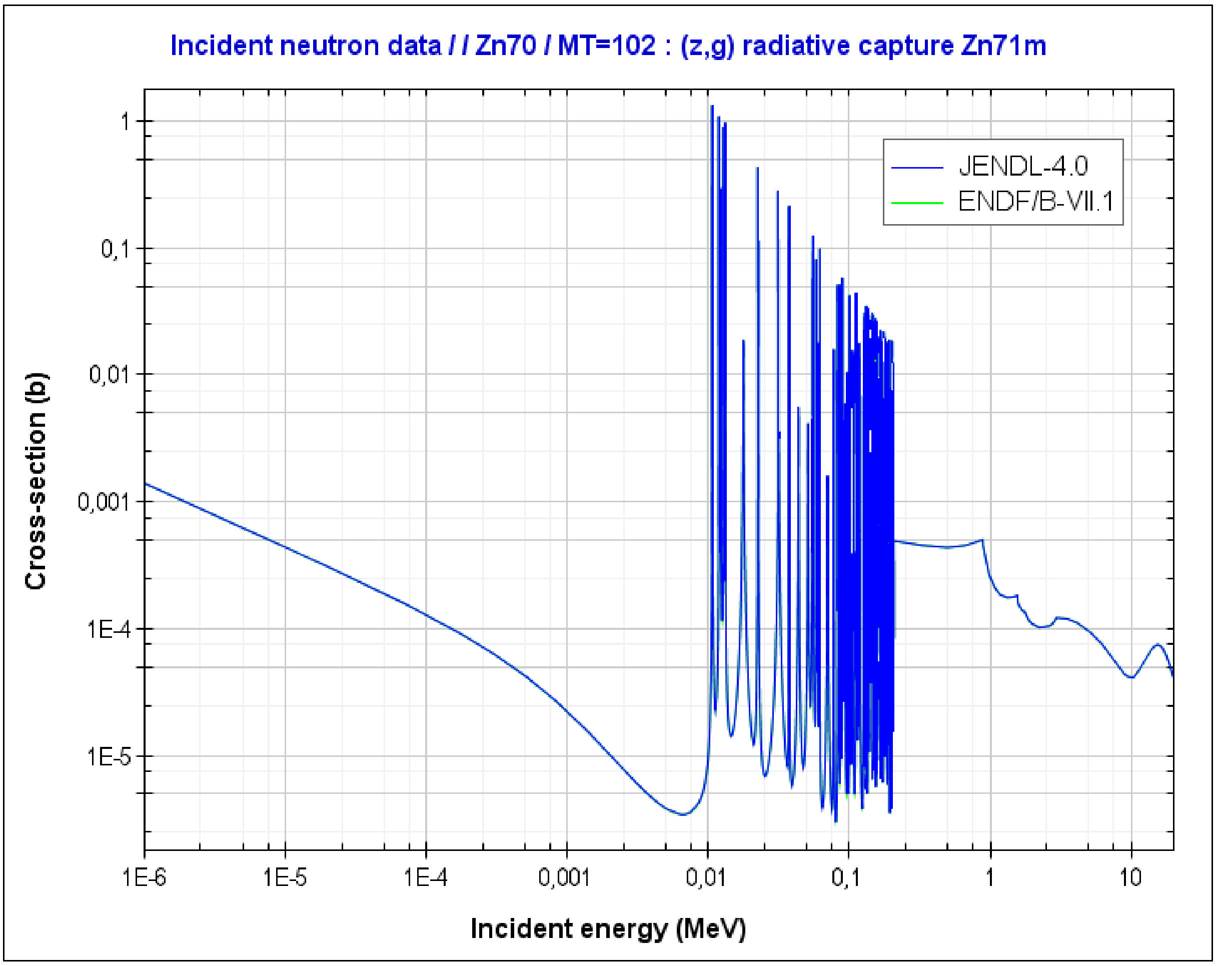
g = 0.998

E_r = 32263 eV

σ_0 = 0.008676 b

Q_0 = 1.125

σ_h = 0.00238 b



Incident neutron data / / Zn70 / MT=102 : (z,g) radiative capture Zn71m
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.25. $^{71}Ga(n,\gamma)^{72}Ga$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
4.61	3.3	0.8	4.572	0.4	3.711	-19	4.732	3.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
6.746	6.9	0.8	6.69	1.2	8.647	29.3	6.925	3.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.3% and is in very good agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.4%. The cross section from the ENDF/B-VII.1 [5] library differs from the Kayzero [2] value by 3.5%, but the cross section from the JENDL-4.0 [4] library is much more discrepant.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.9% and is in excellent agreement with the Kayzero [2] value, which has an uncertainty of 1.2%. Again, the value derived from the ENDF/B-VII.1 [5] library is in much better agreement with the Kayzero [2] value compared to the JENDL-4.0 [4] library.

The ENDF/B-VII.1 [5] library is selected because it agrees better with Mughabghab [1] and Kayzero [2] data. The constants derived from this library are:

F_{cd} = 0.989

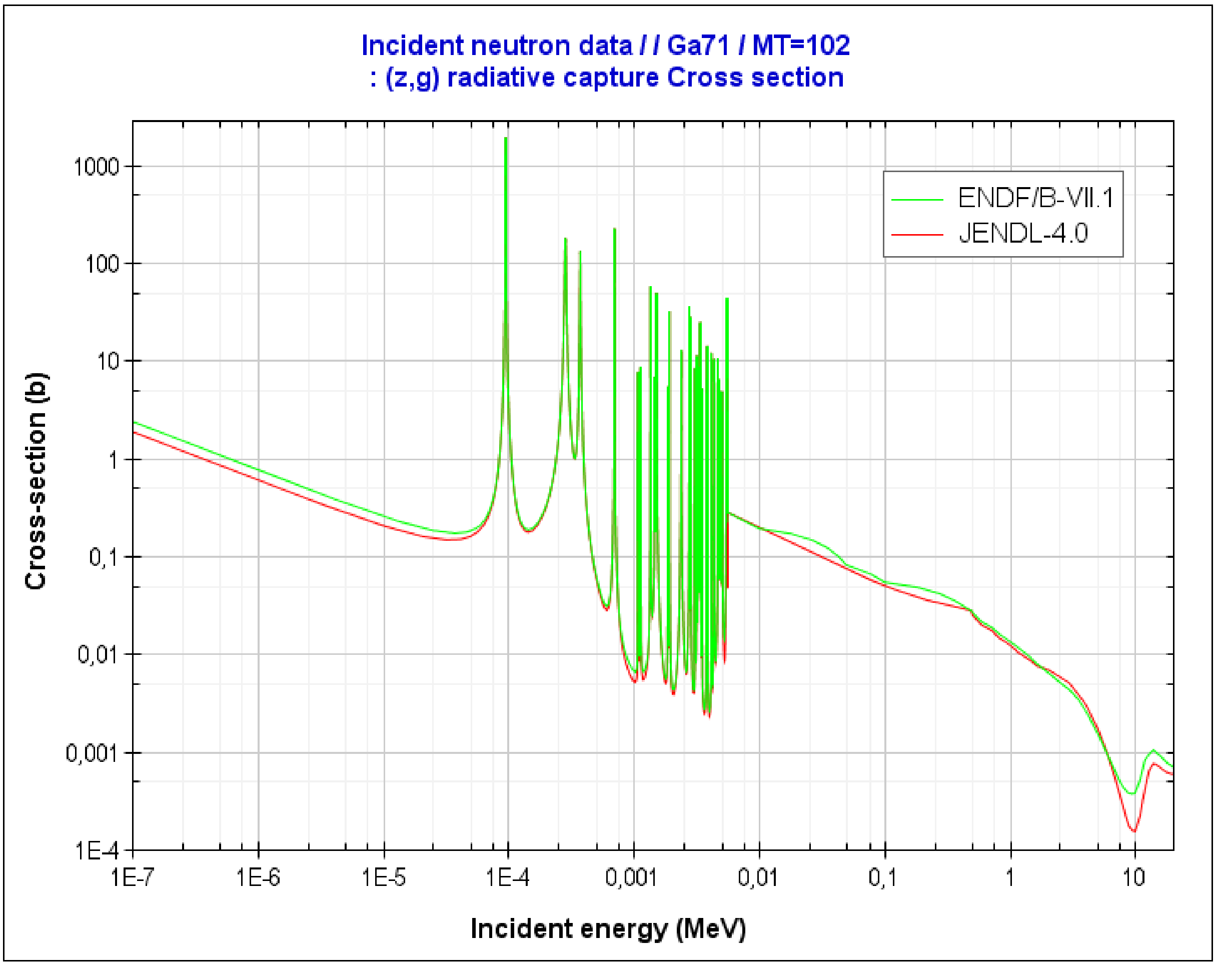
g = 0.999

E_r = 165 eV

σ_0 = 4.732 b

Q_0 = 6.925

σ_h = 0.0130 b


Incident neutron data / / Ga71 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.26. $^{75}As(n,\gamma)^{76}As$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
4.09	2.0	6.1	3.854	2.9	4.153	7.7	4.502	16.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
15.159	3.8	11.5	13.6	-	15.321	12.7	14.267	4.9

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.0% and is 6.1% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.9%. The thermal cross section in the JENDL-4.0 [4] library lies close to the value by Mughabghab [1] and is 7.7% higher than the Kayzero [2] value. The thermal cross section in the ENDF/B-VII.1 [5] library is 16.8% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.8% and is larger by 11.5% in comparison with the Kayzero [2] value, which has no uncertainty given. The Q_0 value calculated from the JENDL-4.0 [4] library agrees well with Mughabghab [1], but is 12.7% higher than the Kayzero [2] value. The value calculated from the ENDF/B-VII.1 [5] library is in better agreement with the Kayzero [2] velue.

The JENDL-4.0 [4] library is selected because the thermal cross section is closer to the Kayzero [2] value, even though there is considerable discrepancy in the Q_0 value. The constants derived from this library are:

F_{cd} = 0.996

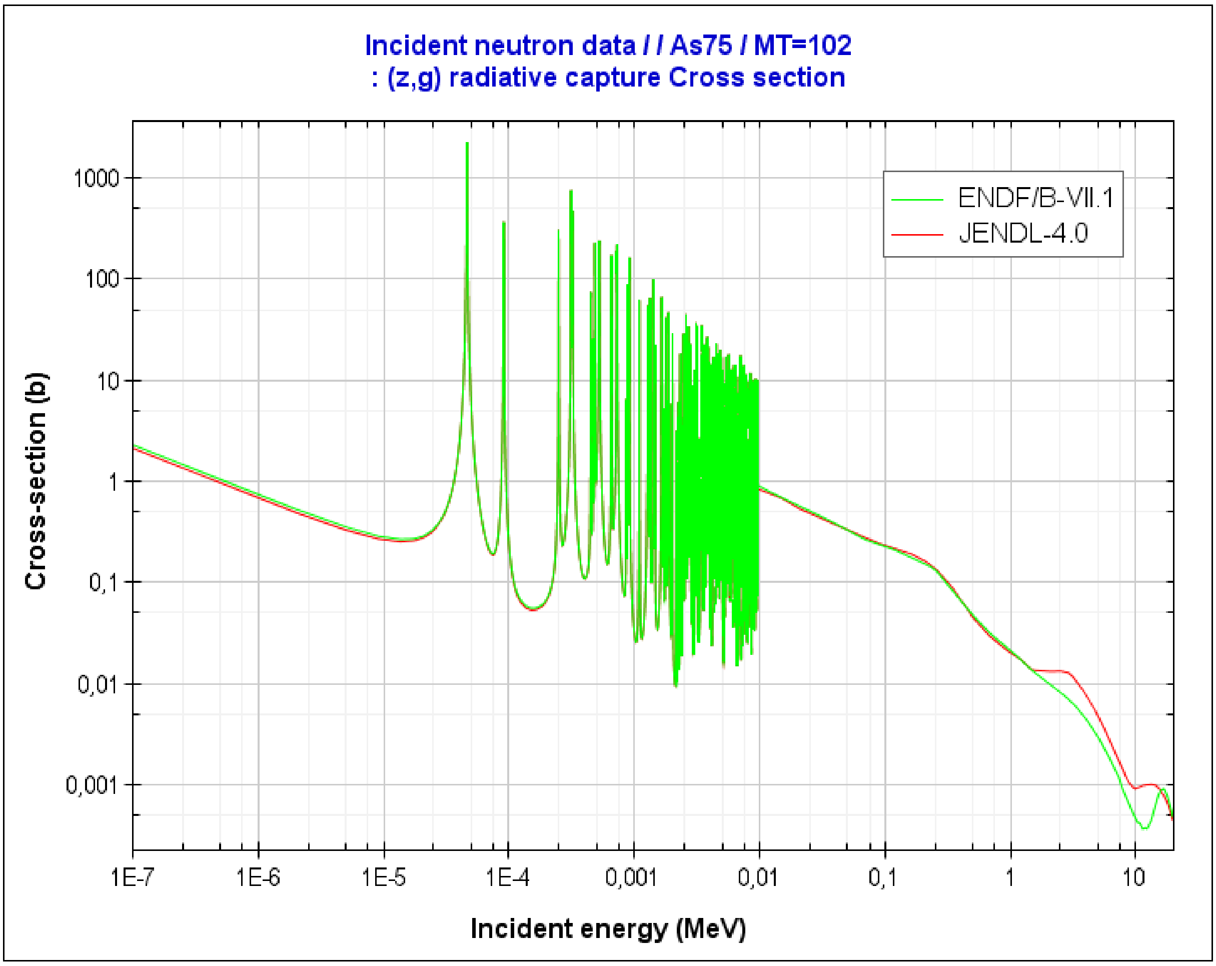
g = 0.999

E_r = 127.4 eV

σ_0 = 4.153 b

Q_0 = 15.321

σ_h = 0.0301 b


Incident neutron data / / As75 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.27. $^{74}Se(n,\gamma)^{75}Se$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
52.2	1.5	2.5	50.94	4.6	51.82	1.7	51.82	1.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
11.034	4.1	2.2	10.8	6.5	11.173	3.5	11.175	3.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.5% and is 2.5% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 4.6%. The resonance data in JENDL-4.0 [4] and ENDF/B-VII.1 [5] are the same, originating from an earlier JENDL evaluation, and agree well with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.1% and is larger by 2.2% in comparison with the Kayzero [2] value, which has an uncertainty of 6.5%. The values from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are fully consistent with the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because it is more recent. The constants derived from this library are:

F_{cd} = 0.872

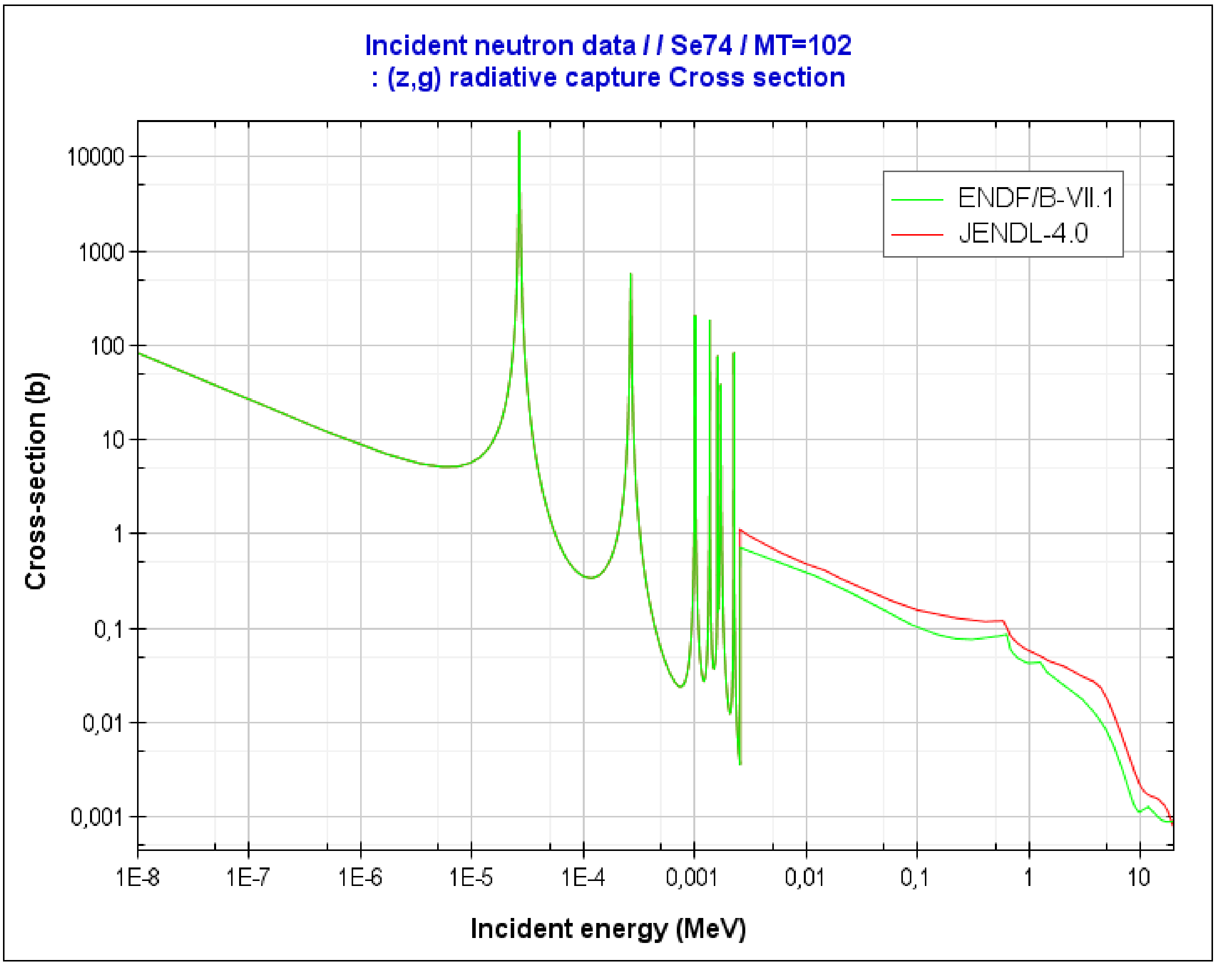
g = 0.999

E_r = 29.04 eV

σ_0 = 51.82 b

Q_0 = 11.175

σ_h = 0.0382 b


Incident neutron data / / Se74 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
10000
1000
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.28. $^{76}Se(n,\gamma)^{77m}Se$

The thermal cross sections and the Q_{00} values for the production of the metastable residual ^{77m}Se are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
20.00	5.0	5.9	18.89	3.4	20.06	6.2	20.06	6.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.850	12.8	10.4	0.77	-	0.8278	7.5	0.8232	6.9

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.0% and is 5.9% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.4%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries do not include the branching ratios for the production of the metastable residual. Assuming the branching ratio for thermal incident neutrons of 23.6% by Mughabghab [1], the values in these libraries lie close to each other and to the Mughabghab [1] value; they are 6.2% higher compared to the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 12.8% and is larger by 10.4% in comparison with the Kayzero [2] value, which has no uncertainty given. Assuming a branching ratio in epithermal range for the production of the metastable nuclide of 42.2% by Mughabghab [1], the values derived from the JENDL-4.0 [4] and ENDF/B-VII.1 [5] libraries lie close to each other and to the Mughabghab [1] value; they are 7.5% and 6.9% higher compared to the Kayzero [2] value, the ENDF/B-VII.1 [5] library being slightly closer.

The ENDF/B-VII.1 [5] library is selected because it agrees marginally better with the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 1.025

g = 0.998

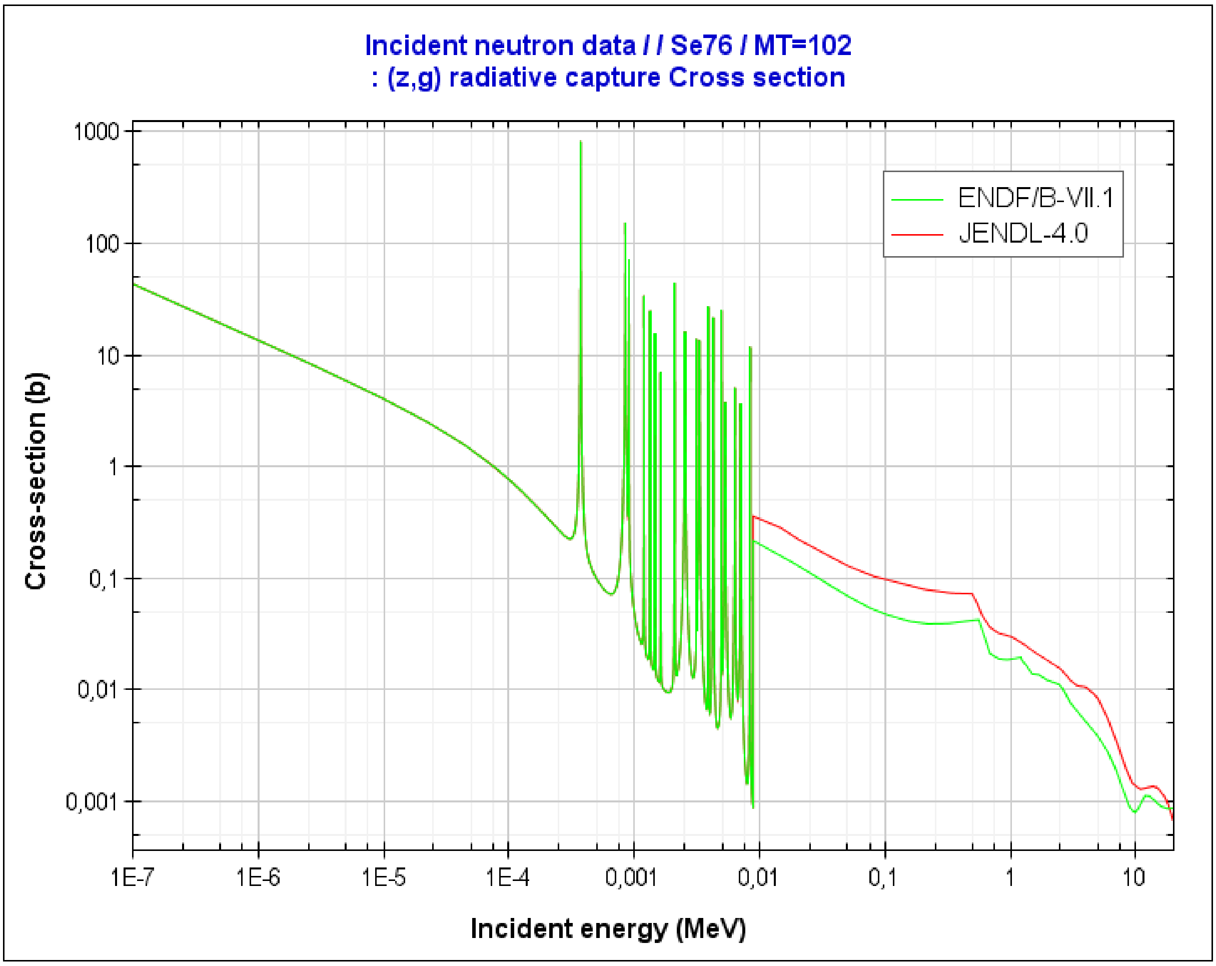
E_r = 2843 eV

σ_0 = 20.06 b

Q_0 = 0.8232

σ_h = 0.00408 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.29. $^{79}Br(n,\gamma)^{80g}Br$

The thermal cross sections and the Q_0 values for the production of the ground state residual ^{80g}Br are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
7.88	3.0	1.1	7.797	0.3	8.407	7.8	8.407	7.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
12.056	12.0	-0.4	12.10	-	11.460	-5.3	11.443	-5.4

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.0% and is 1.1% larger than the value derived from the Kayzero [2] library, which is given without the uncertainty. The branching ratios for the production of the ground state residual are not given in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries. Assuming a branching ratio for thermal incident neutrons of 76.4% by Mughabghab [1], the thermal cross section values lie close to each other and are 7.8% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 12.0% and is smaller by 0.4% in comparison with the Kayzero [2] value, which has no uncertainty given. Assuming a branching ratio in the epithermal range for the production of the metastable nuclide of 74.8% by Mughabghab [1], the values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to each other and are around 5.5% smaller than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because it is more recent, even though the resonance parameters are practically the same and originate from an earlier JENDL evaluated library. The constants derived from this library are:

F_{cd} = 0.997

g = 0.998

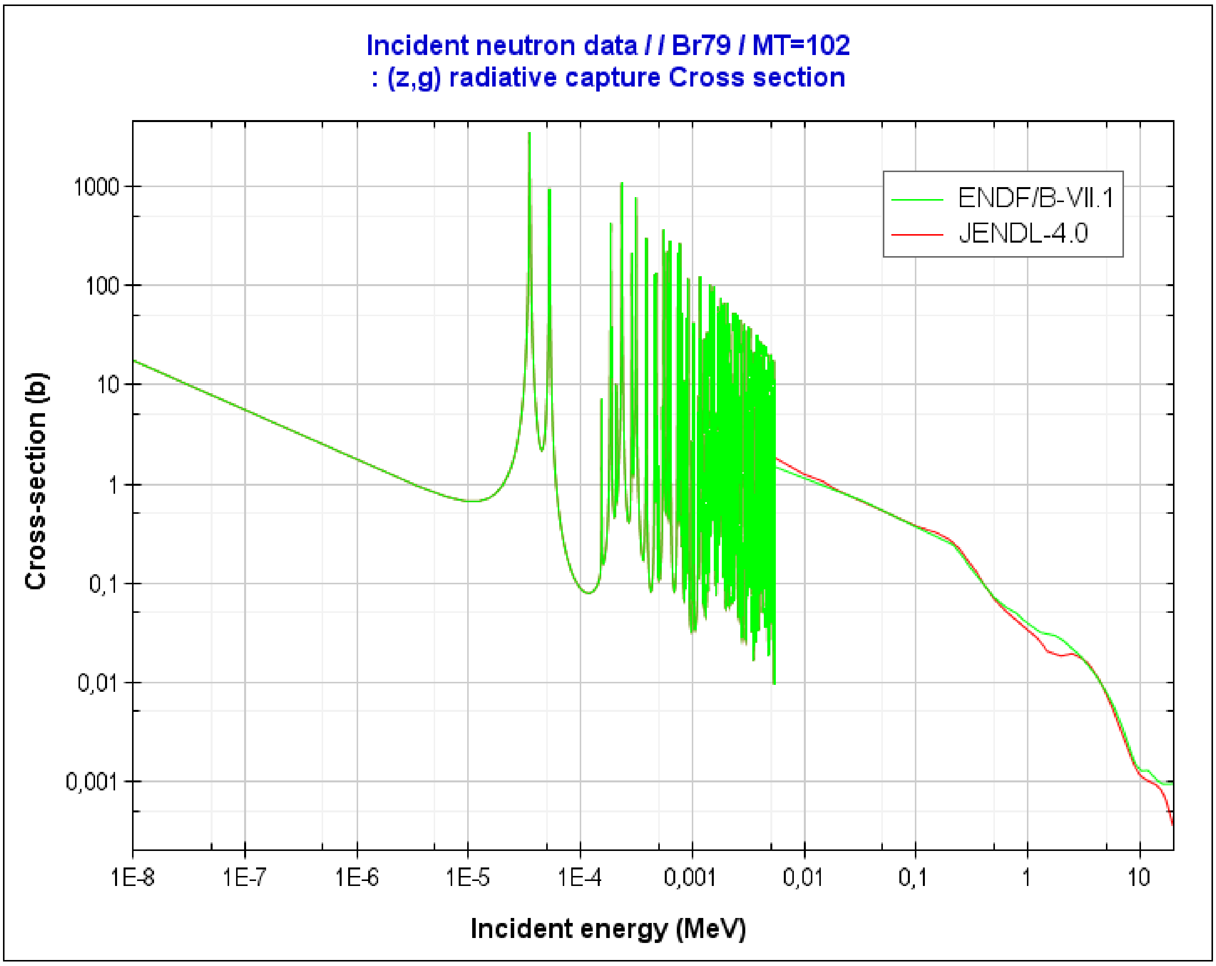
E_r = 83.89 eV

σ_0 = 8.407 b

Q_0 = 11.443

σ_h = 0.0378 b

The plot is for the total capture cross section since the cross sections for the excitation of the ground state residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.30. $^{81}Br(n,\gamma)^{82}Br$

The thermal cross sections and the Q_0 values (for the production of the residual in the ground and the metastable state $^{82g+m}Br$) are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
2.36	2.1	-7.9	2.563	1.7	2.357	-8.0	2.365	-7.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
18.644	11.6	-3.4	19.3	3.0	19.758	2.4	19.383	0.4

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.1% and is 7.9% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.7%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are almost the same. They lie close to the Mughabghab [1] value and are about 8% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 11.6% and is smaller by 3.4% in comparison with the Kayzero [2] value, which has an uncertainty of 3.0%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are consistent with the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected. The constants derived from this library are:

F_{cd} = 0.990

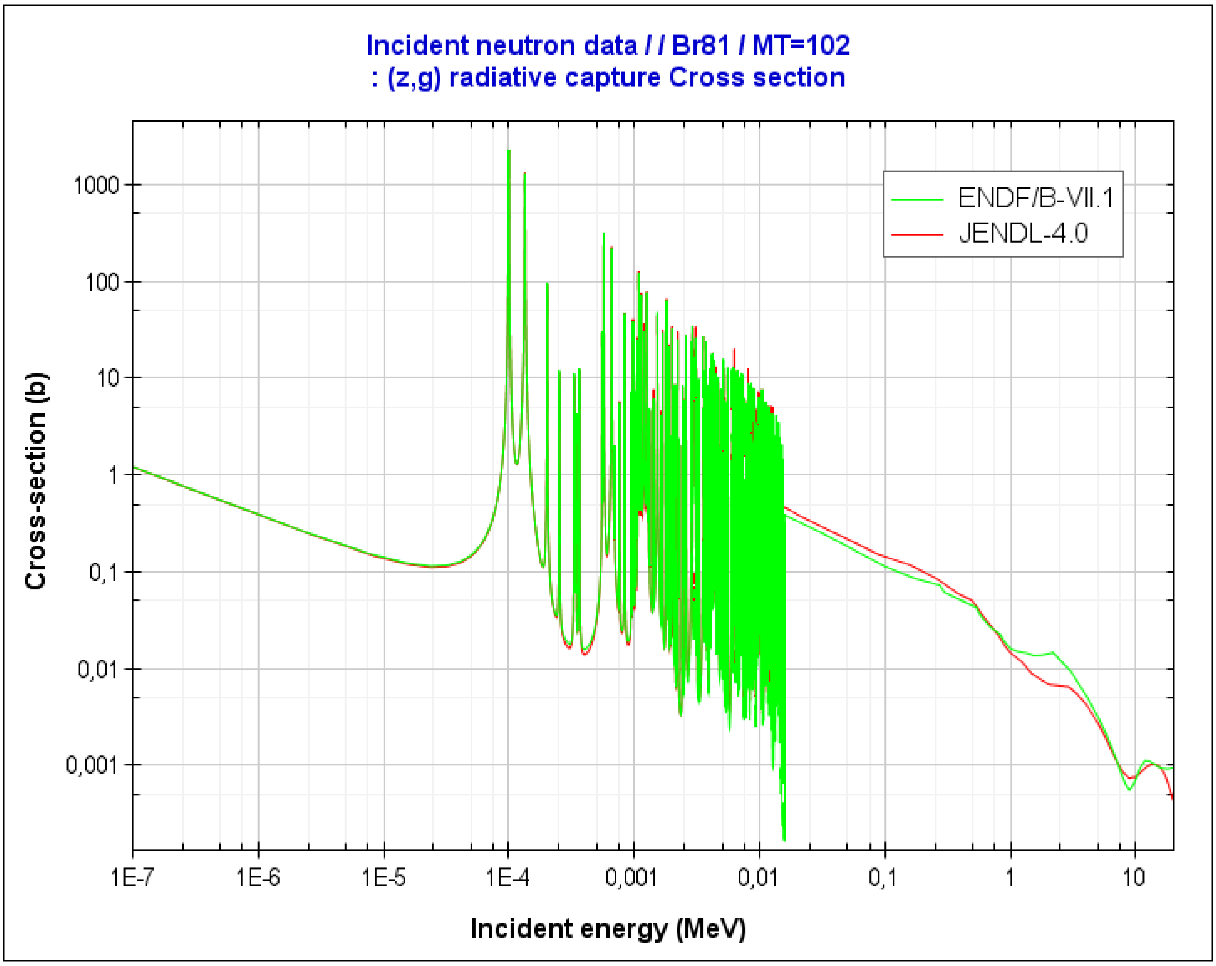
g = 0.999

E_r = 169.0 eV

σ_0 = 2.365 b

Q_0 = 19.383

σ_h = 0.0215 b



Incident neutron data / / Br81 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.31. $^{85}Rb(n,\gamma)^{86}Rb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.494	1.4	-1.6	0.502	1.0	0.4803	-4.4	0.4937	-1.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
13.826	3.5	-6.6	14.8	2.5	18.193	22.9	15.380	3.9

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.4% and is 1.6% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.0%. The value in the ENDF/B-VII.1 [5] library is closer to the Kayzero [2] value (compared to the value in the JENDL-4.0 [4] library), being smaller by only 1.7%.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.5% and is smaller by 6.6% in comparison with the Kayzero [2] value, which has an uncertainty of 2.5%. The value derived from the ENDF/B-VII.1 [5] library is closer to the Kayzero [2] value (compared to the value in the JENDL-4.0 [4] library), being larger by only 3.9%.

The ENDF/B-VII.1 [5] library is selected because it is more consistent with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.994

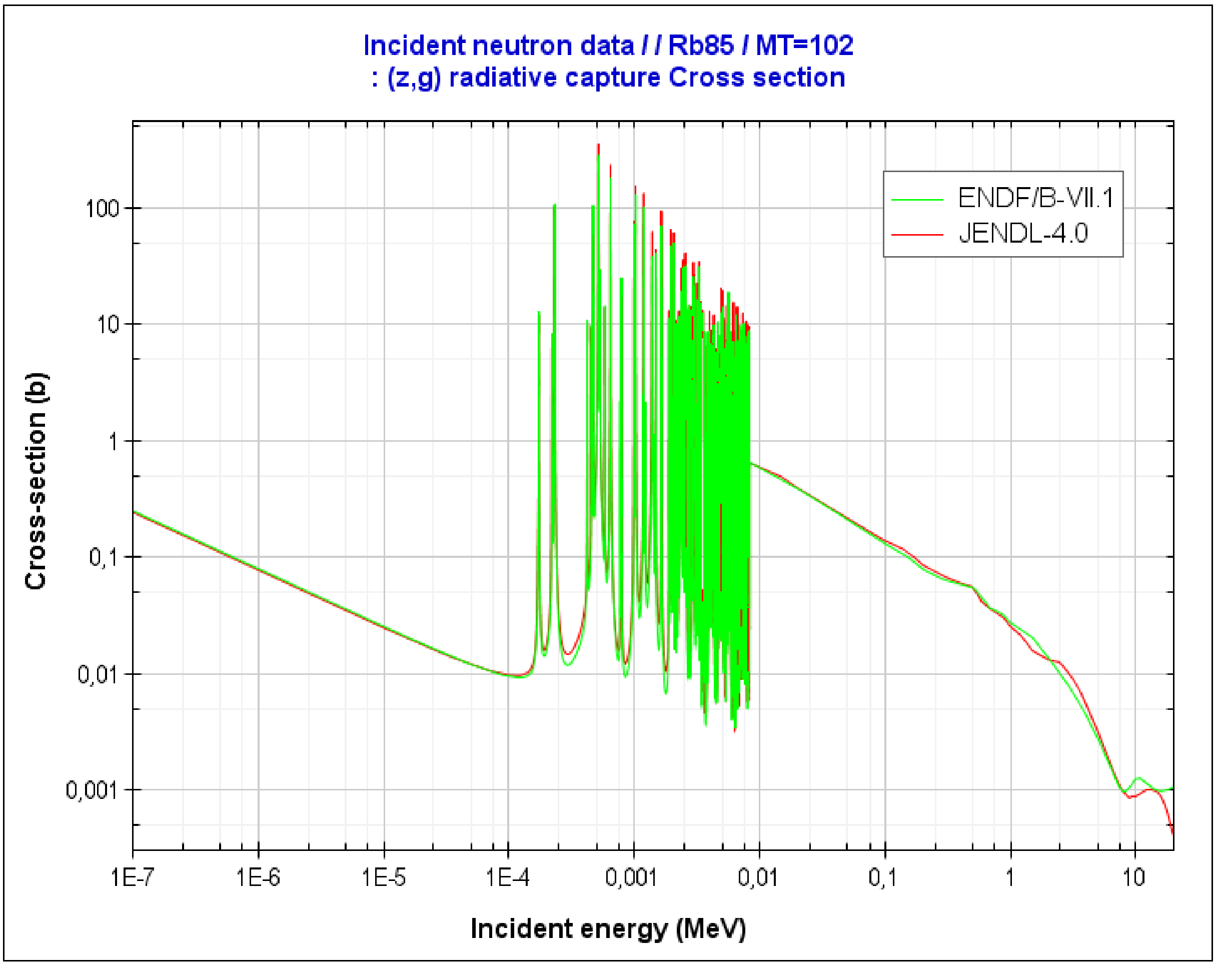
g = 0.998

E_r = 1421 eV

σ_0 = 0.4937 b

Q_0 = 15.380

σ_h = 0.0259 b


Incident neutron data / / Rb85 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.32. $^{87}Rb(n,\gamma)^{88}Rb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.102	3.9	0.3	0.102	1.0	0.1201	18.2	0.1201	18.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
23.33	6.4	0.1	23.3	3.0	22.623	-2.9	22.906	-1.7

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.9% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.0%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are both larger than the Mughabghab [1] and the Kayzero [2] values by 18.2%,
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.4% and is in excellent agreement with the Kayzero [2] value, which has an uncertainty of 3.0%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are also in very good agreement with the Mughabghab [1] and the Kayzero [2] values.

The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.991

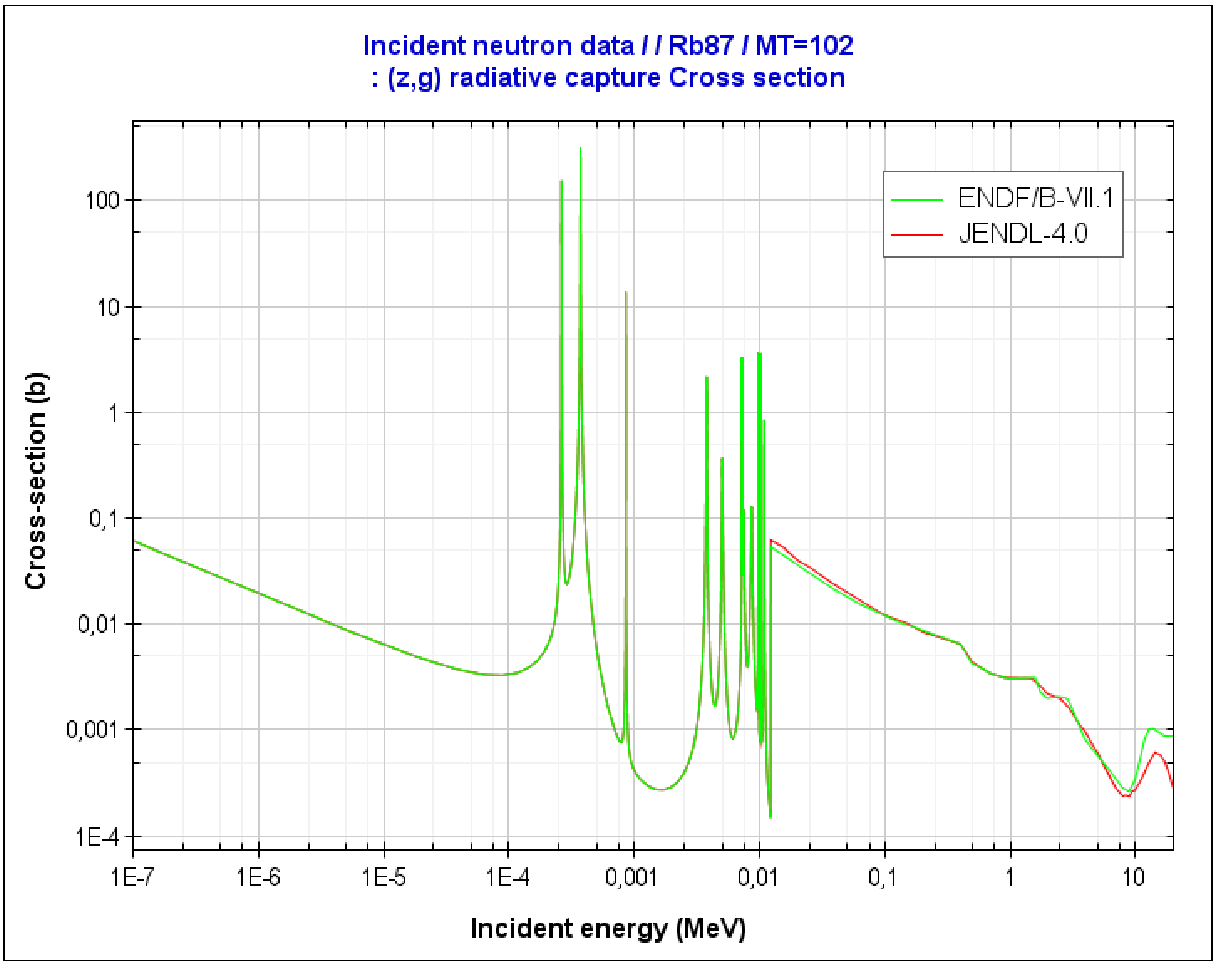
g = 0.999

E_r = 411.0 eV

σ_0 = 0.1201 b

Q_0 = 22.906

σ_h = 0.00301 b



Incident neutron data / / Rb87 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
100
10
1
0,1
0,01
0,001
1E-4
Cross-section (b)
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.33. $^{84}Sr(n,\gamma)^{85}Sr$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.822	14.6	15.1	0.714	2.0	0.8279	15.9	0.8223	15.1

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
11.87	-	-10	13.2	-	13.746	4.1	13.888	5.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 14.6% and is also 15.1% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.0%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the values by Mughabghab [1] and are 15.9% and 15.1% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has no assigned uncertainty and is smaller by 10% in comparison with the Kayzero [2] value, which also does not have an uncertainty given. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries differ from the Kayzero [2] value by 4.1% and 5.2%, respectively.

The ENDF/B-VII.1 [5] library is selected. The differences between the two libraries considered are not significant; the JENDL-4.0 [4] cross sections seem to have some structure in the fast energy range which is hard to justify. The discrepancies in the thermal cross section value require a further investigation. The constants derived from the ENDF/B-VII.1 [5] library are:

F_{cd} = 0.996

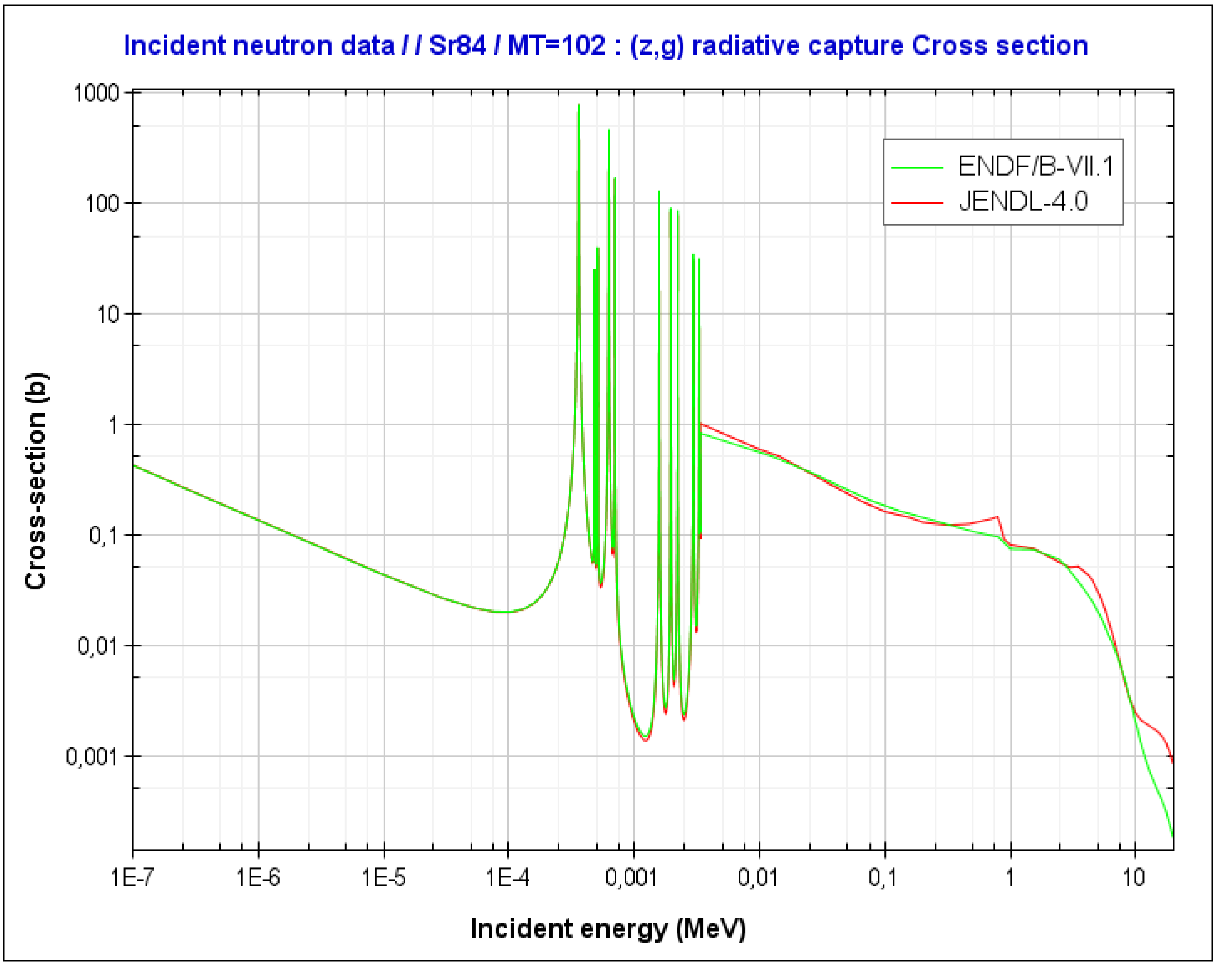
g = 0.999

E_r = 936.2 eV

σ_0 = 0.8223 b

Q_0 = 13.89

σ_h = 0.0709 b



Incident neutron data / / Sr84 / MT=102 : (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.34. $^{86}Sr(n,\gamma)^{87m}Sr$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{87m}Sr are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.77	7.8	0.1	0.7696	0.6	0.7700	0.1	0.7448	-3.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
6.234	9.3	51.7	4.11	1.7	4.588	11.6	4.813	17.1

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 7.8% and is in full agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.6%. The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries do not give any branching ratios for the production of the metastable residual. Assuming the branching ratio for thermal incident neutrons of 74.0% by Mughabghab [1], the value in the JENDL-4.0 [4] library is also in full agreement, while the value in ENDF/B-VII.1 [5] is smaller by 3.2%.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.3%, but is larger by 51.7% in comparison with the Kayzero [2] value, which has an uncertainty of 1.7%. Assuming that the branching ratio is independent of energy and adopting the thermal value of 74.0% by Mughabghab [1], the values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] library both give a higher Q_0, JENDL-4.0 [4] being closer and differing by 11.6%.

The JENDL-4.0 [4] library is selected because it is in better agreement with the Kayzero [2] database. The constants derived from this library are:

F_{cd} = 0.998

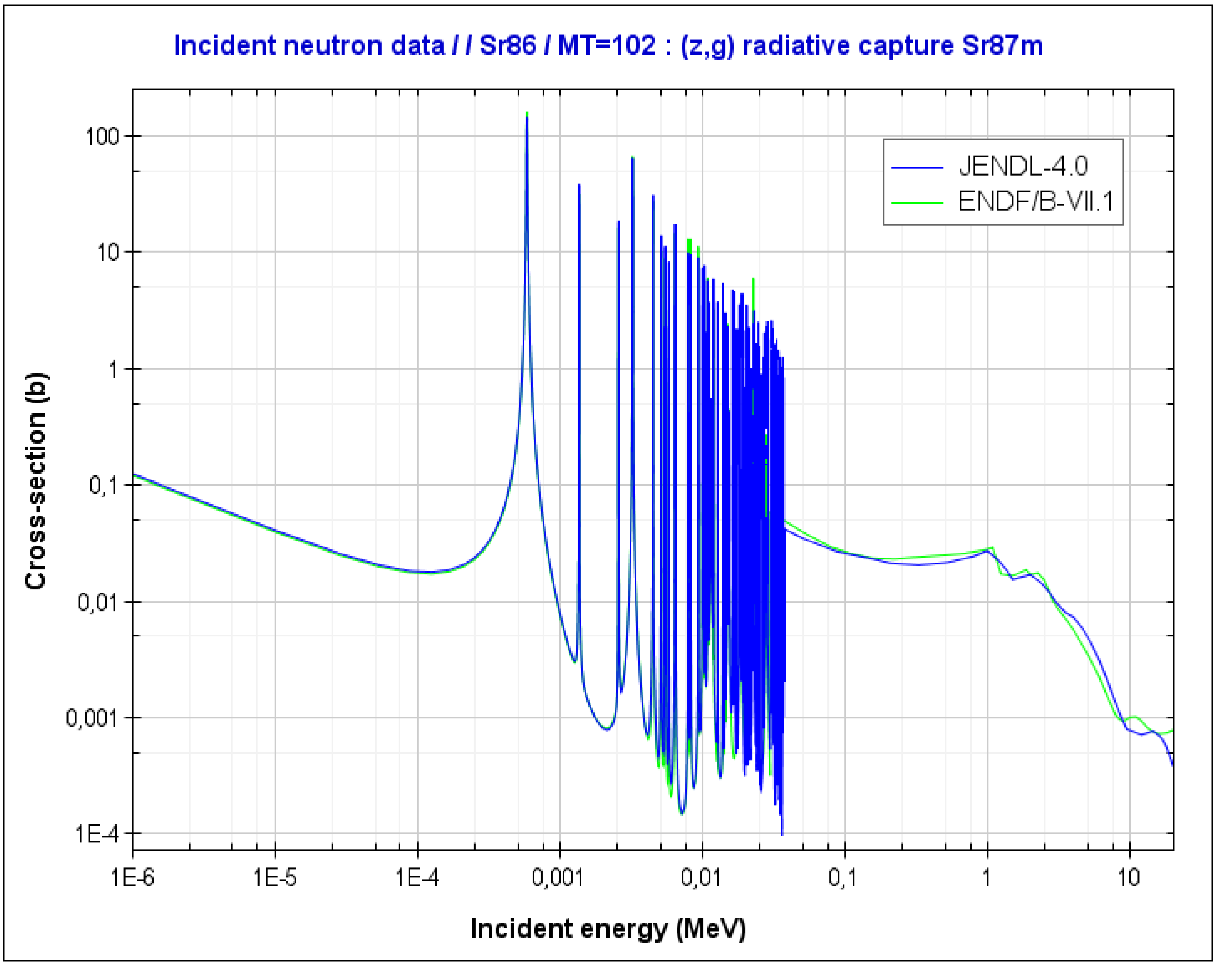
g = 0.999

E_r = 934.0 eV

σ_0 = 0.7700 b

Q_0 = 4.588

σ_h = 0.0164 b



Incident neutron data / / Sr86 / MT=102 : (z,g) radiative capture Sr87m
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.35. $^{89}Y(n,\gamma)^{90m}Y$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{90m}Y are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.0010	20.0	-4.2	0.001043	0.9	0.001003	-3.9	0.000999	-4.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.750	21.0	-87	5.93	2.3	0.6476	-89	0.650	-89

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 20.0% and is 4.2% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.9%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie very close to the value by Mughabghab [1] and are both low by 3.9% and 4.2% compared to the Kayzero [2] value.
- The branching ratio for the production of the metastable residual in the epithermal range is not given by Mughabghab [1] and is assumed energy-independent and equal to the thermal value, which is 0.0781%. The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 21.0% (not including the uncertainty in the branching ratio) but is smaller by 87% in comparison with the Kayzero [2] value, which has an uncertainty of 2.3%. No branching ratios are given in the evaluated nuclear data files either. Using the same assumption for the branching ratios, the Q_0 values lie close to the Mughabghab [1] value, but are 89% lower than the Kayzero [2] value. It seems there is either a typing error in the exponent somewhere or the branching ratio exhibits a very strong energy-dependence.

The ENDF/B-VII.1 [5] library is selected arbitrarily. The constants derived from this library should not be used before the large discrepancies are resolved, but are listed anyway as follows:

F_{cd} = 1.015

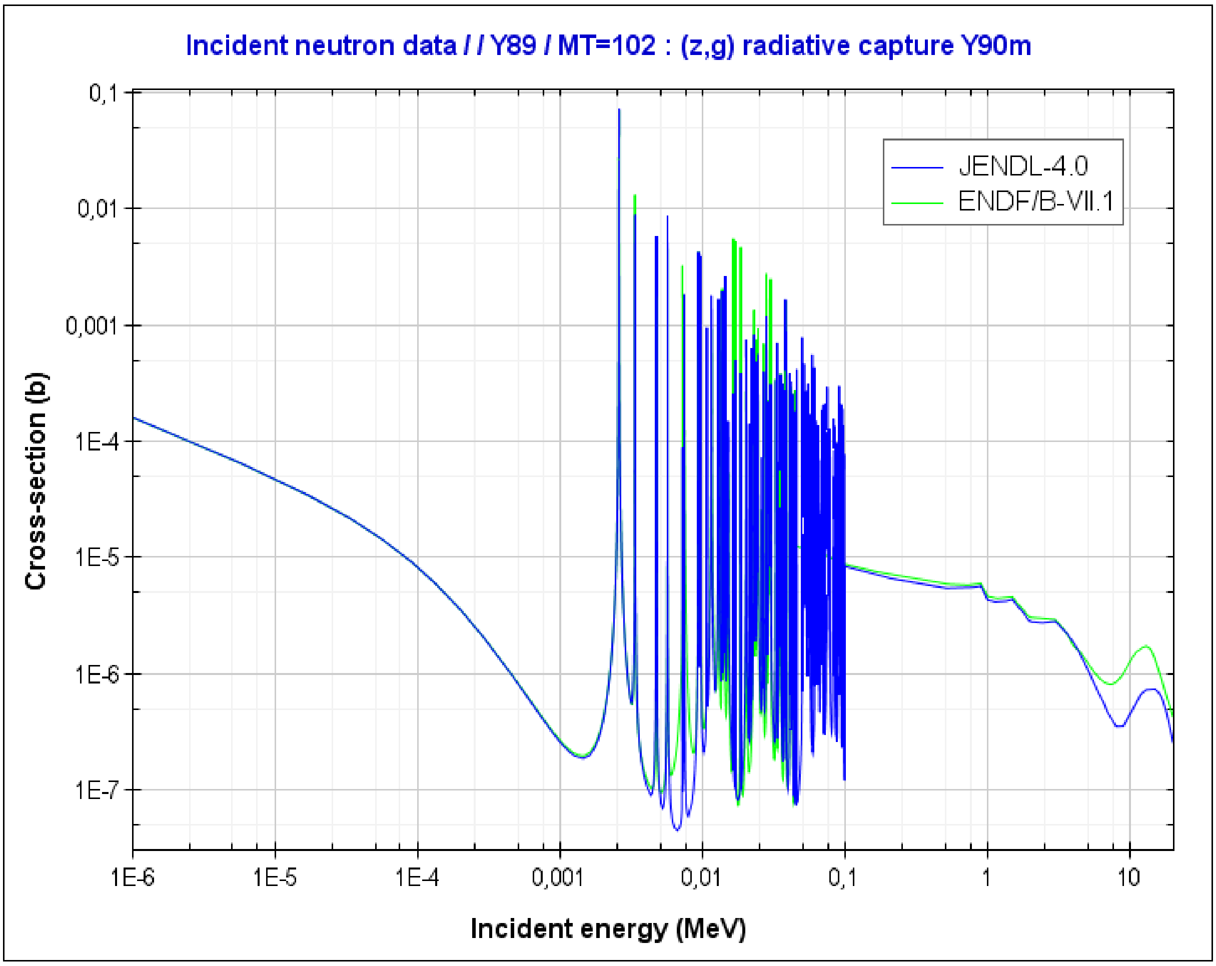
g = 0.998

E_r = 11305 eV

σ_0 = 0.000999 b

Q_0 = 0.650

σ_h = 0.0000404 b



2.5.36. $^{94}Zr(n,\gamma)$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.0494	3.4	-2.7	0.051	1.8	0.05069	-0.2	0.04989	-1.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
5.668	5.0	6.7	5.31	3.3	5.607	5.6	6.358	19.7

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.4% and is 2.7% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.8%. The values from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are in good agreement with the Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.0% and is larger by 6.7% in comparison with the Kayzero [2] value, which has an uncertainty of 3.3%. The value derived from the JENDL-4.0 [4] library agrees with the value by Mughabghab [1], while the ENDF/B-VII.1 [5] value is 19.7% higher.

The JENDL-4.0 [4] library is selected because it is in better agreement with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.999

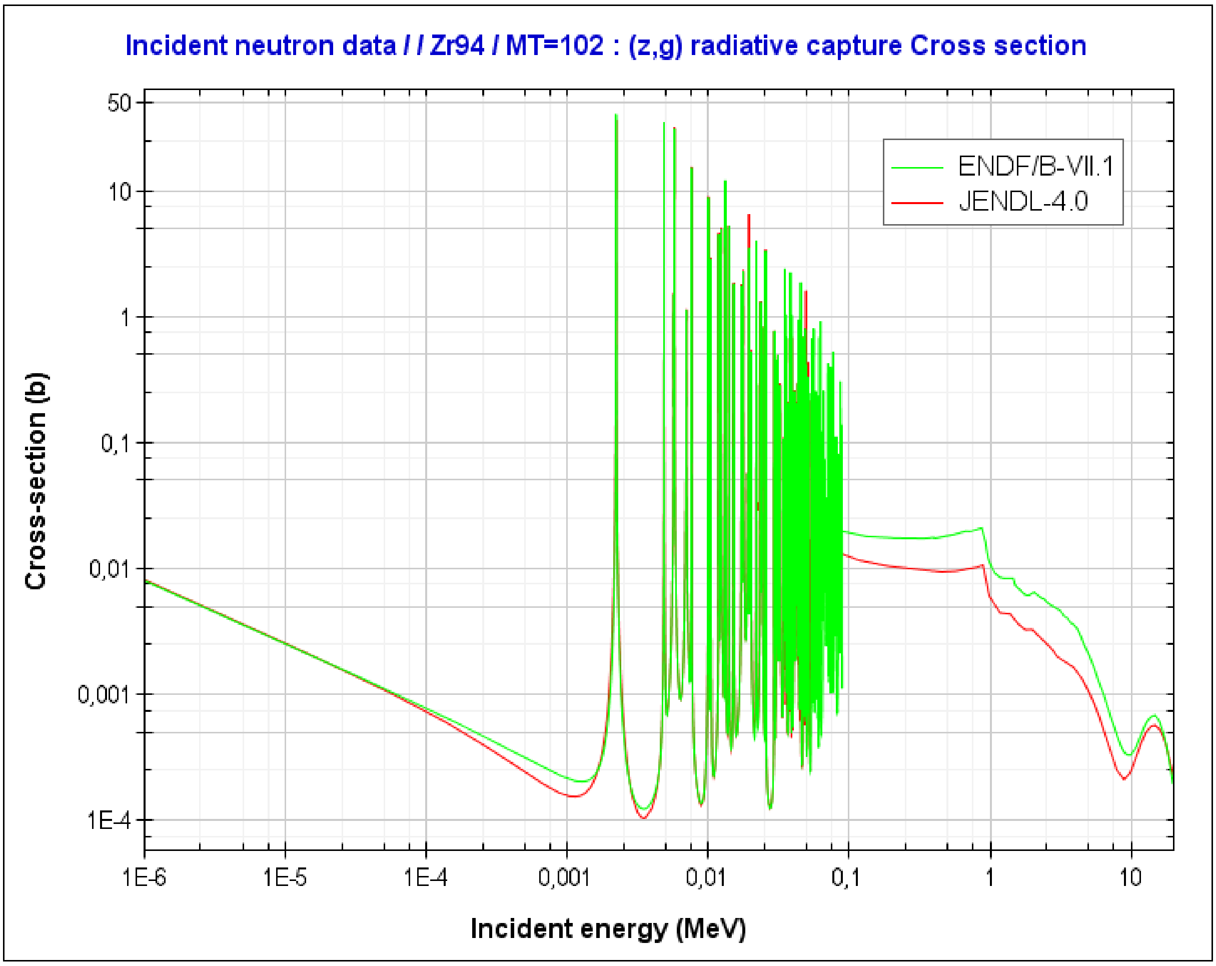
g = 0.999

E_r = 9873 eV

σ_0 = 0.05069 b

Q_0 = 5.607

σ_h = 0.00496 b



Incident neutron data / / Zr94 / MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
50
10
1
0,1
0,01
0,001
1E-4
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.37. $^{96}Zr(n,\gamma)$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.0229	4.4	16.3	0.0197	3.3	0.02032	3.2	0.02286	16.1

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
230.6	4.8	-8.4	251.6	1.0	208.1	-17	221.0	-12

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 4.4% and is 16.3% higher than the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.3%. The value in the JENDL-3.2 library is 3.2% higher while the value in the ENDF/B-VII.1 [5] library is 16.1% higher.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.8% and is smaller by 8.4% in comparison with the Kayzero [2] value, which has an uncertainty of 1.0%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 17% and 12% smaller, respectively.

The JENDL-4.0 [4] library is selected because it agrees better with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.997

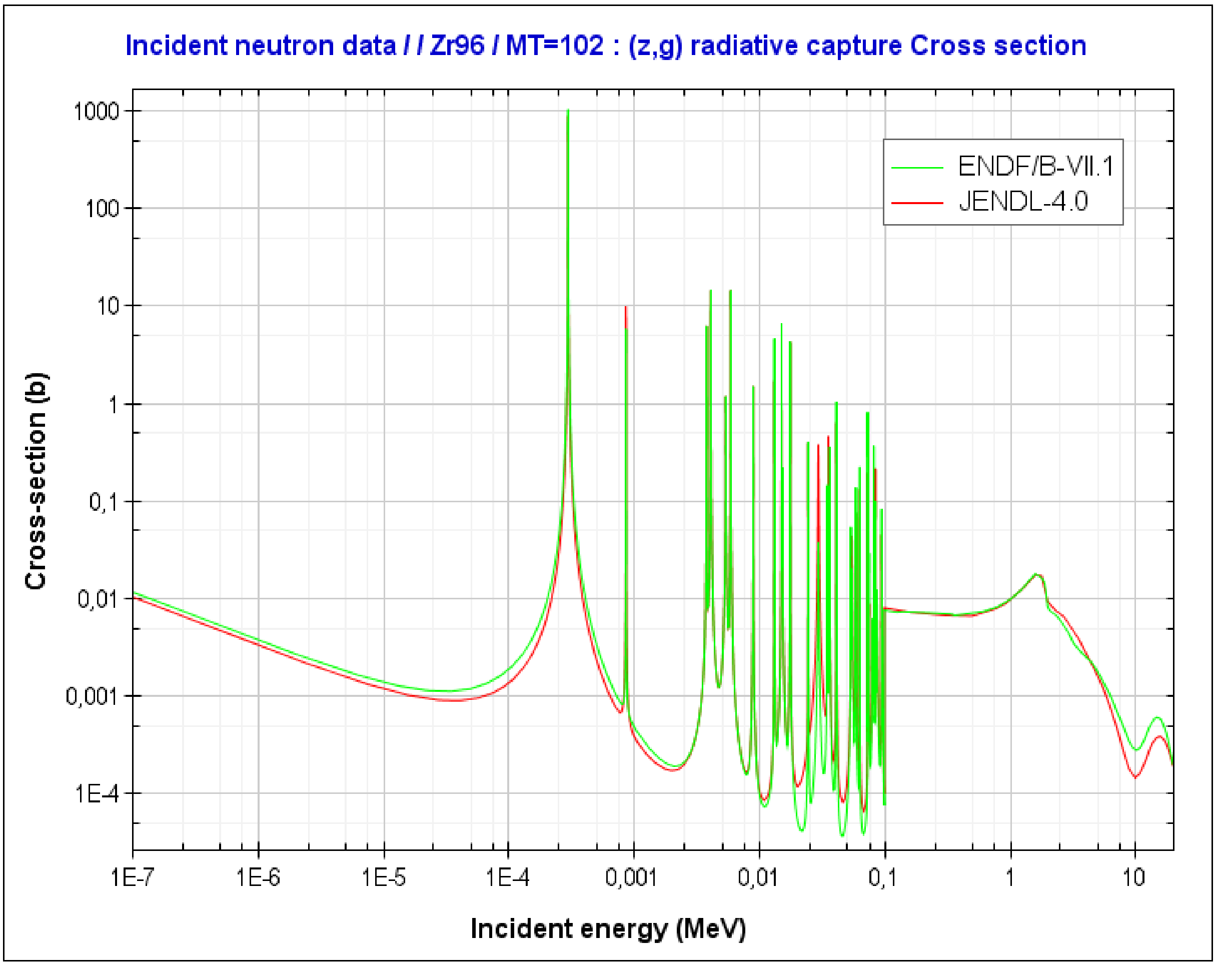
g = 0.999

E_r = 358.0 eV

σ_0 = 0.02032 b

Q_0 = 208.1

σ_h = 0.00820 b


Incident neutron data / / Zr96 / MT=102 : (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.38. $^{93}Nb(n,\gamma)^{94}Nb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.15	4.3	-	1.15	-	1.143	-0.6	1.156	0.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
7.217	6.5	-1.8	7.35	2.7	7.835	6.6	8.565	16.5

- The Kayzero [2] library does not give thermal cross section for total capture, but only for metastable residual. So for comparison we have used Mughabghab [1] value for Kayzero [2] also. Values from other libraries are in good agreement with the Mughabghab [1] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.5% and is smaller by 1.8% in comparison with the Kayzero [2] value, which has an uncertainty of 2.7%. The value derived from the JENDL-4.0 [4] library differs from the Kayzero [2] value by 6.6%, while the value from the ENDF/B-VII.1 [5] differs by 16.5%.

The constants from the JENDL-4.0 [4] library are listed below, but they should not be used for the neutron activation analysis:

F_{cd} = 0.990

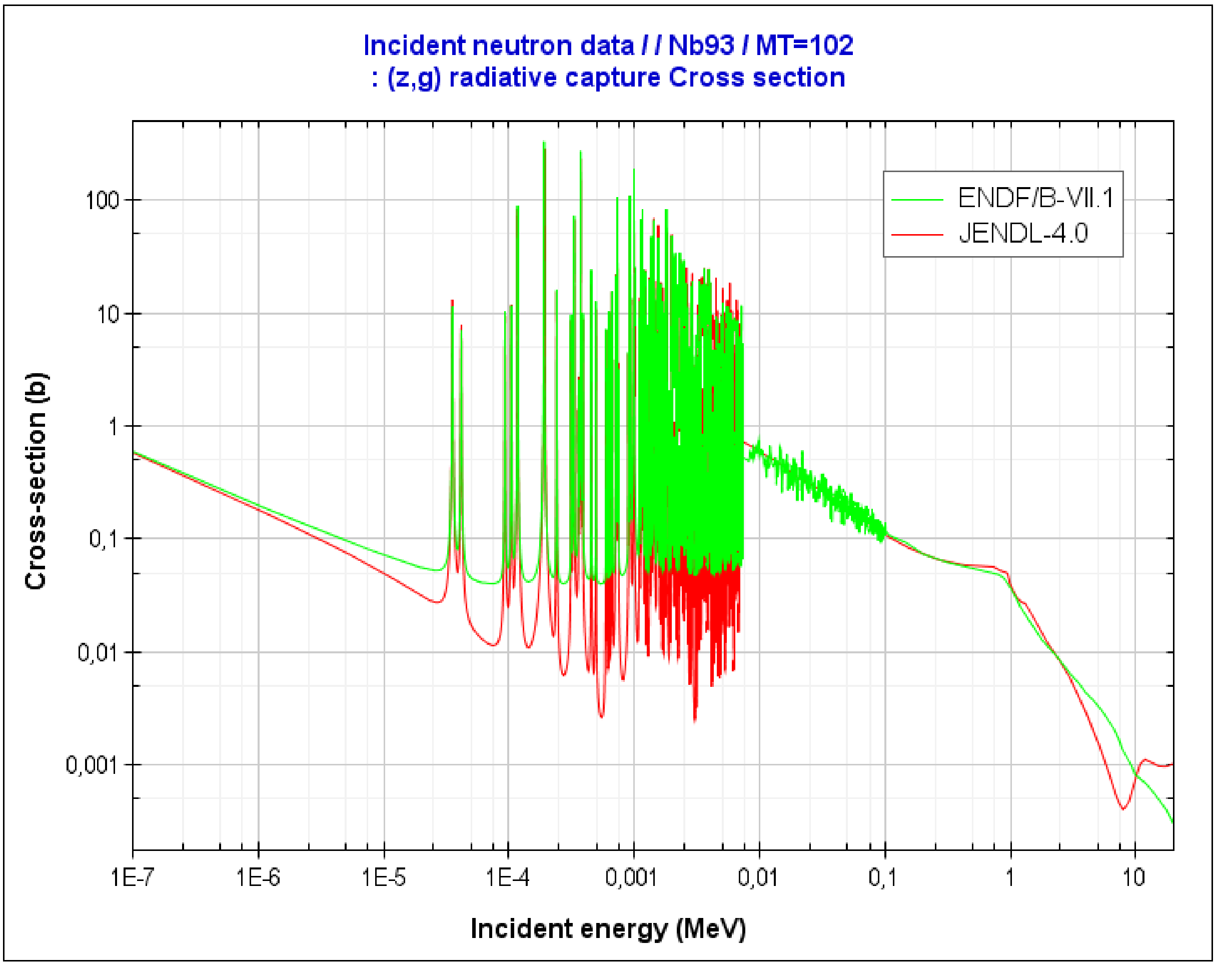
g = 0.998

E_r = 937.9 eV

σ_0 = 1.143 b

Q_0 = 7.835

σ_h = 0.0280 b


Incident neutron data / / Nb93 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.39. $^{93}Nb(n,\gamma)^{94m}Nb$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{94m}Nb are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.863	5.8	-	0.863	-	0.858	-0.6	0.868	0.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
7.217	8.6	-1.8	7.35	2.7	7.835	6.6	8.565	16.5

- Mughabghab [1] does not give the thermal cross section for the production of the metastable residual. Only the total capture is given and so the branching ratio can not be determined. The branching ratio is not given in the evaluated data files either. Because Mughabghab [1] does not give thermal cross section value for metastable residual we have used Kayzero [2] value for Mughabghab [1] also. Branching ratio have been adopted as ratio between metastable value of thermal cross section from Kayzero [2] and total value from Mughabghab [1] being 75.0% and independent of energy. Values from other libraries are in good agreement with Kayzero [2] value.
- Assuming that the branching ratio is energy-independent, the Q_0 value for the production of the metastable residual is the same as the Q_0 for the total capture cross section. The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 8.5% and is smaller by 1.8% in comparison with the Kayzero [2] value, which has an uncertainty of 2.7%. The value derived from the JENDL-4.0 [4] library differs from the Kayzero [2] value by 6.6%, while the value from the ENDF/B-VII.1 [5] differs by 16.5%.

Since the branching ratio for the production of the metastable residual is not given, no recommendation on the best choice of the cross section data can be made. The constants from the JENDL-4.0 [4] library are listed below, but they should not be used for the neutron activation analysis:

F_{cd} = 0.990

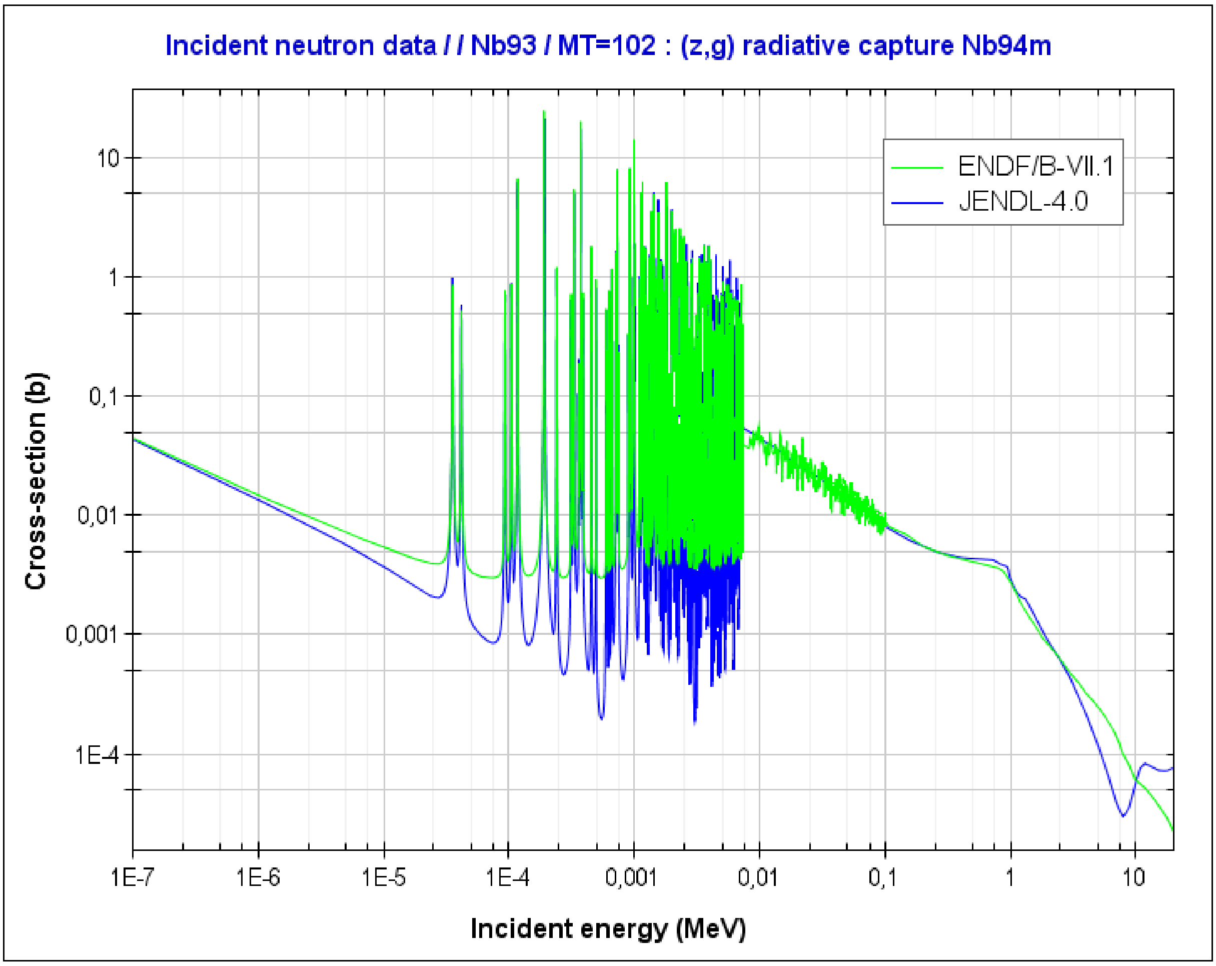
g = 0.998

E_r = 937.9 eV

σ_0 = 0.858 b

Q_0 = 7.835

σ_h = 0.0210 b



2.5.40. $^{98}Mo(n,\gamma)^{99}Mo$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.130	4.6	-0.5	0.1307	1.5	0.1322	1.2	0.1300	-0.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
51.54	6.4	-2.9	53.1	6.3	52.21	-1.7	50.17	-5.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 4.6% and is 0.5% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.5%. The value in the JENDL-4.0 [4] library is in very good agreement with the Kayzero [2] value while the ENDF/B-VII.1 [5] value is 0.5% lower.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.4% and is smaller by 2.9% in comparison with the Kayzero [2] value, which has an uncertainty of 6.3%. The value derived from the JENDL.4 library is in very good agreement with the Kayzero [2] value while the ENDF/B-VII.1 [5] value is 5.5% smaller.

The JENDL-4.0 [4] library is selected because it lies closer to the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.995

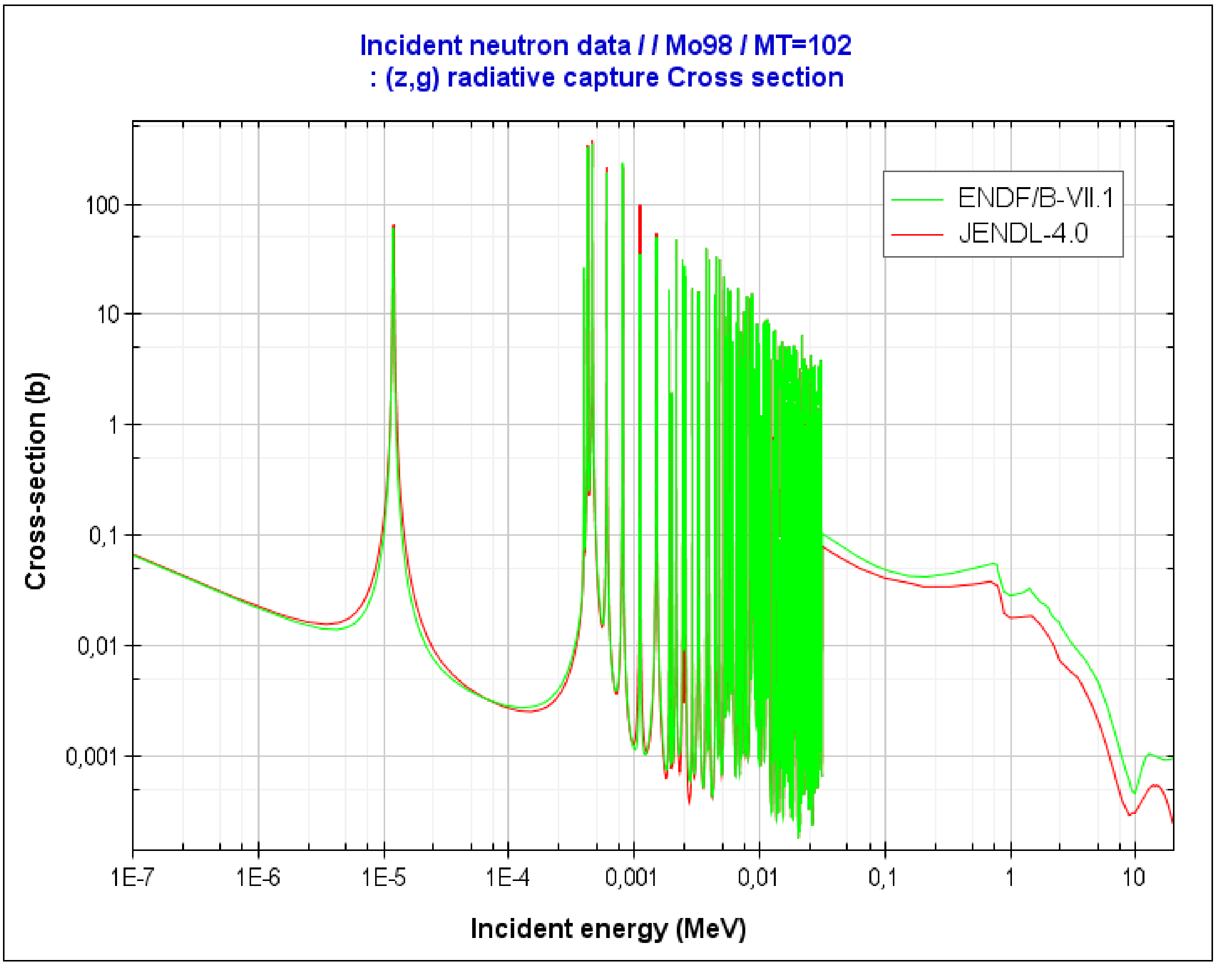
g = 0.999

E_r = 266.3 eV

σ_0 = 0.1322 b

Q_0 = 52.21

σ_h = 0.0174 b



Incident neutron data / / Mo98 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.41. $^{100}Mo(n,\gamma)^{101}Mo$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.199	1.5	3.2	0.193	2.3	0.1938	0.5	0.1991	3.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
18.894	4.3	0.5	18.8	4.0	20.372	8.4	19.247	2.4

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.5% and is 3.2% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.3%. The value in the JENDL-4.0 [4] library is in very good agreement with the Kayzero [2] value while the ENDF/B-VII.1 [5] agrees better with the Mughabghab [1] evaluation and is 3.3% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.3% and is in excellent agreement with the Kayzero [2] value, which has an uncertainty of 4.0%. The value derived from the JENDL-4.0 [4] library is 8.4% higher, while the ENDF/B-VII.1 [5] value agrees with the Kayzero [2] value within the experimental uncertainty.

The ENDF/B-VII.1 [5] library is selected because overall it shows better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.993

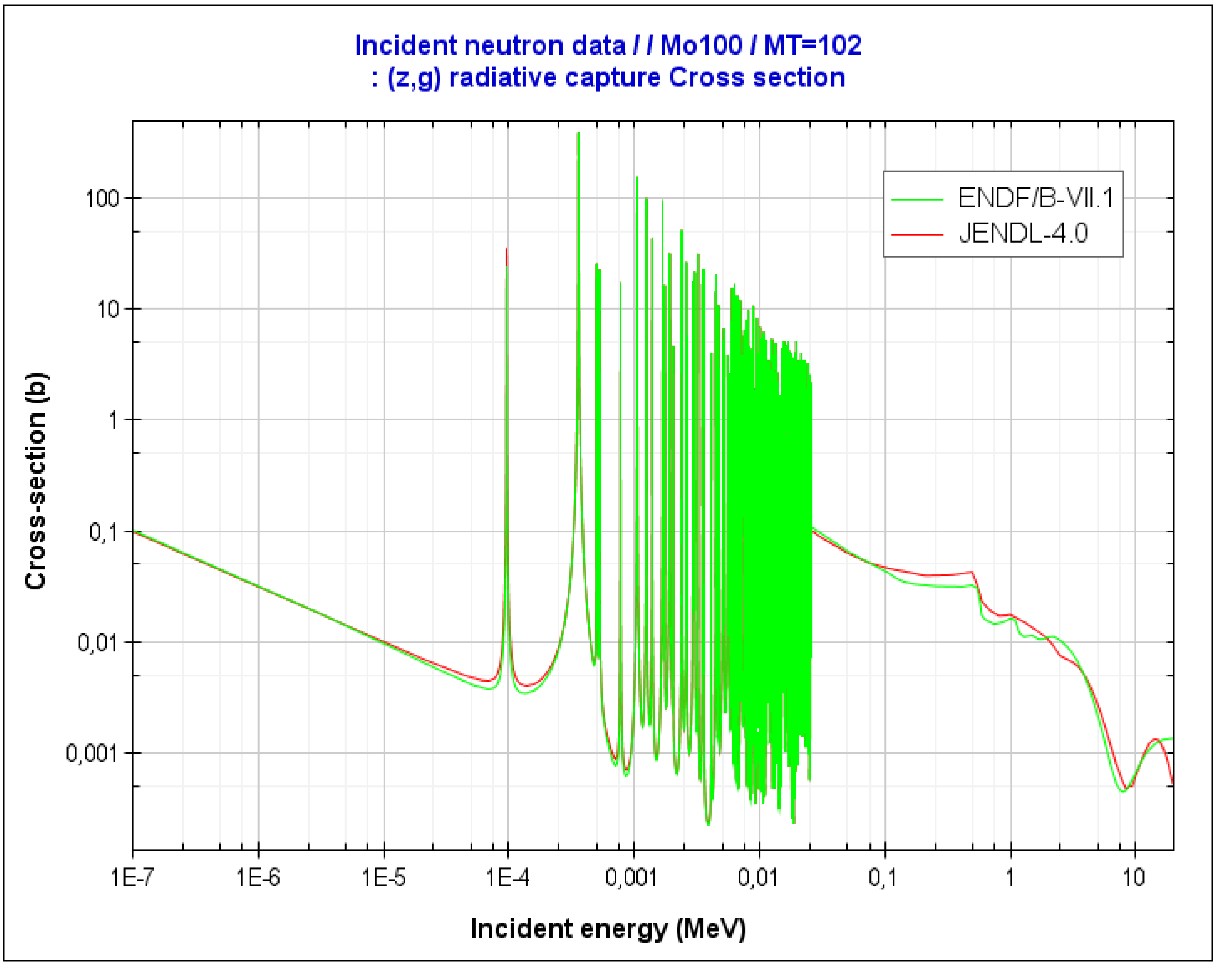
g = 0.999

E_r = 886.8 eV

σ_0 = 0.1991 b

Q_0 = 19.247

σ_h = 0.0138 b



Incident neutron data / / Mo100 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.42. ^{96}Ru(n,γ)^{97}Ru

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.29	6.9	26.3	0.2297	2.6	0.2711	18.0	0.2902	26.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
21.93	7.8	-17	26.5	3.5	23.47	-11	24.94	-5.9

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 6.9% and is 26.3% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.6%. The value in the JENDL-4.0 [4] evaluation is larger by 18.0% while the ENDF/B-VII.1 [5] is larger by 26.4% and consistent with the Mughabghab [1] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 7.8% and is smaller by 17% in comparison with the Kayzero [2] value, which has an uncertainty of 3.5%. The values derived from the evaluated data files are smaller, the ENDF/B-VII.1 [5] value being closer, differing by 5.9%.

No evaluated data library contains any resolved resonance parameters for this nuclide. They differ mainly in the breakpoint from which the unresolved average resonance parameters aplly and these are derived from the systematics. The cross sections from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are presented in the plot. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants are not suitable for use in NAA, but they are listed below:

F_{cd} = 0.993

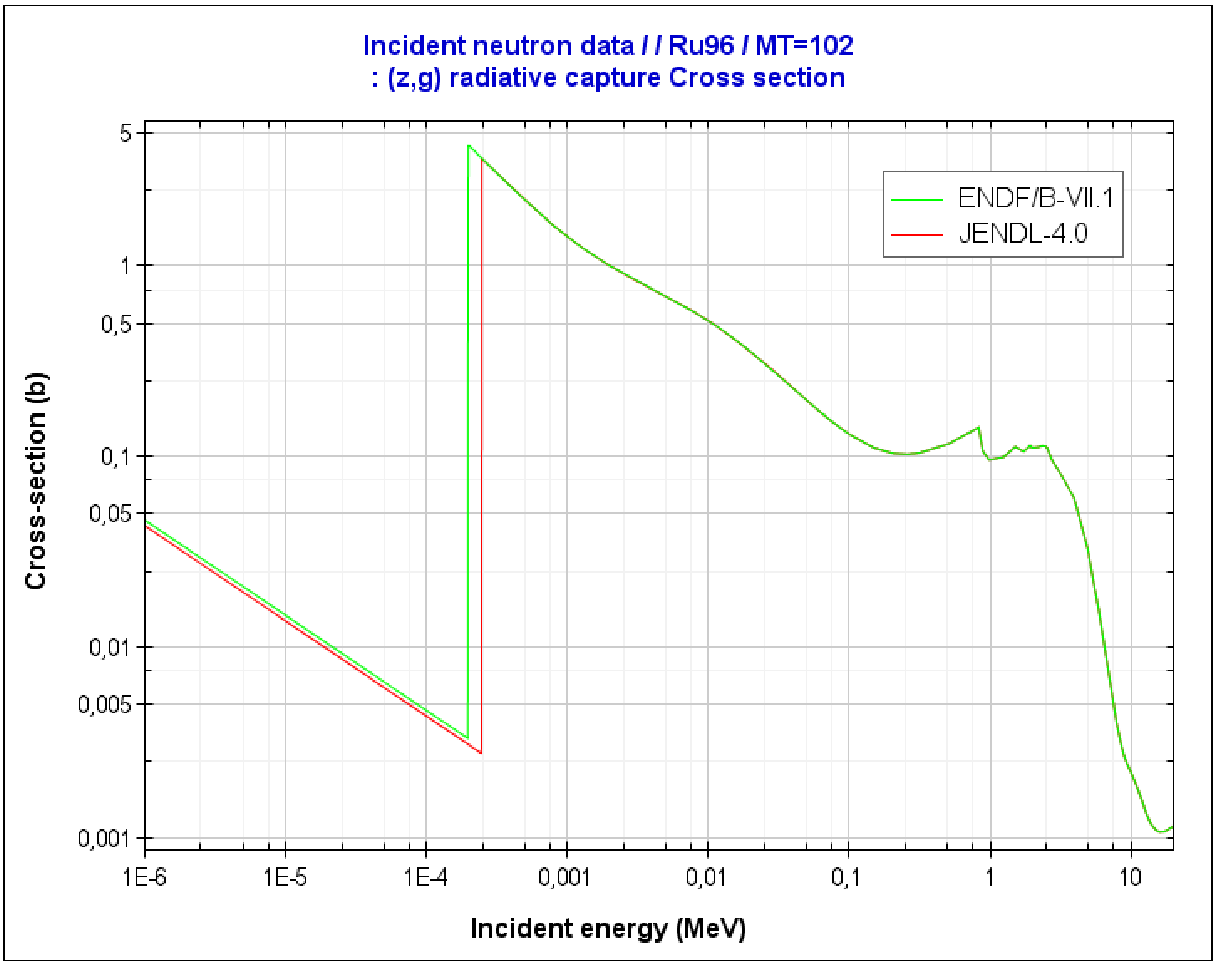
g = 0.998

E_r = 1444 eV

σ_0 = 0.2902 b

Q_0 = 24.94

σ_h = 0.0979 b



Incident neutron data / / Ru96 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
5
1
0,5
0,1
0,05
0,01
0,005
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.43. $^{102}Ru(n,\gamma)^{103}Ru$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.27	3.1	10.3	1.152	1.0	1.476	28.1	1.270	10.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
3.858	6.9	6.3	3.63	-	2.956	-19	4.284	18

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.1%, the difference from the value derived from the Kayzero [2] library is 10.3%, and the quoted uncertainty of this value is 1.0%. The ENDF/B-VII.1 [5] evaluation is consistent with the Mughabghab [1] value, but still 10.3% high compared to the value derived from the Kayzero [2] library.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.9% and is consistent with the Kayzero [2] value, which has no uncertainty given. The value in the JENDL-4.0 [4] library is 19% lower and the value in the ENDF/B-VII.1 [5] library is 18% higher than the value in the Kayzero [2] library.

The ENDF/B-VII.1 [5] library is selected because it agrees better with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.999

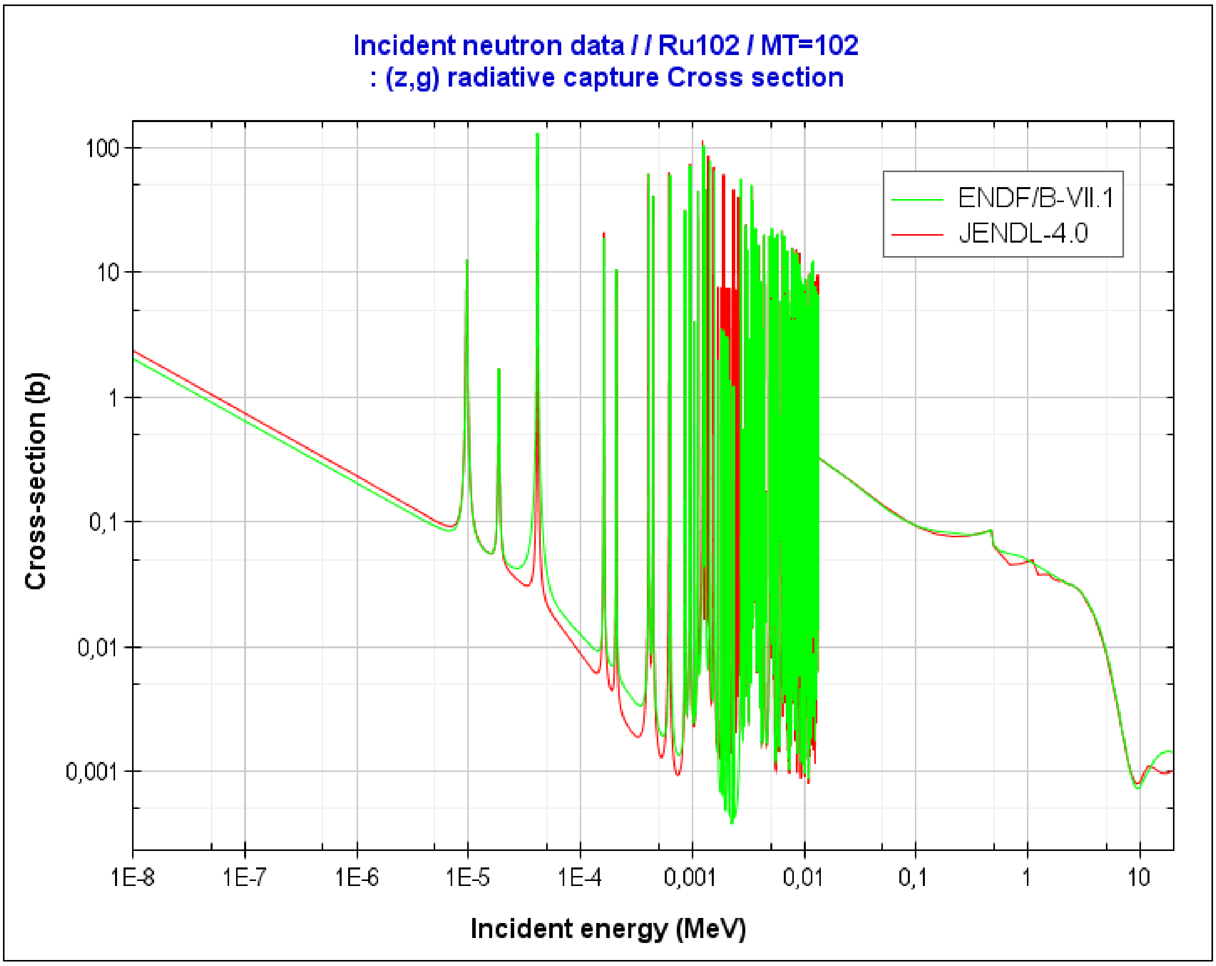
g = 0.998

E_r = 517.6 eV

σ_0 = 1.270 b

Q_0 = 4.284

σ_h = 0.0415 b


Incident neutron data / / Ru102 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.44. $^{104}Ru(n,\gamma)^{105}Ru$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.491	2.0	-0.9	0.496	2.3	0.4692	-5.3	0.4717	-4.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q$_0$	Diff.
	[%]	[%]		[%]		[%]		[%]
12.83	3.8	0.2	12.8	2.7	14.06	9.9	14.00	9.4

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.0% and is 0.9% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.3%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller, differing from the Kayzero [2] value by about 5%.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.8% and is fully consistent with the Kayzero [2] value, which has an uncertainty of 2.7%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are less than 10% higher.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.977

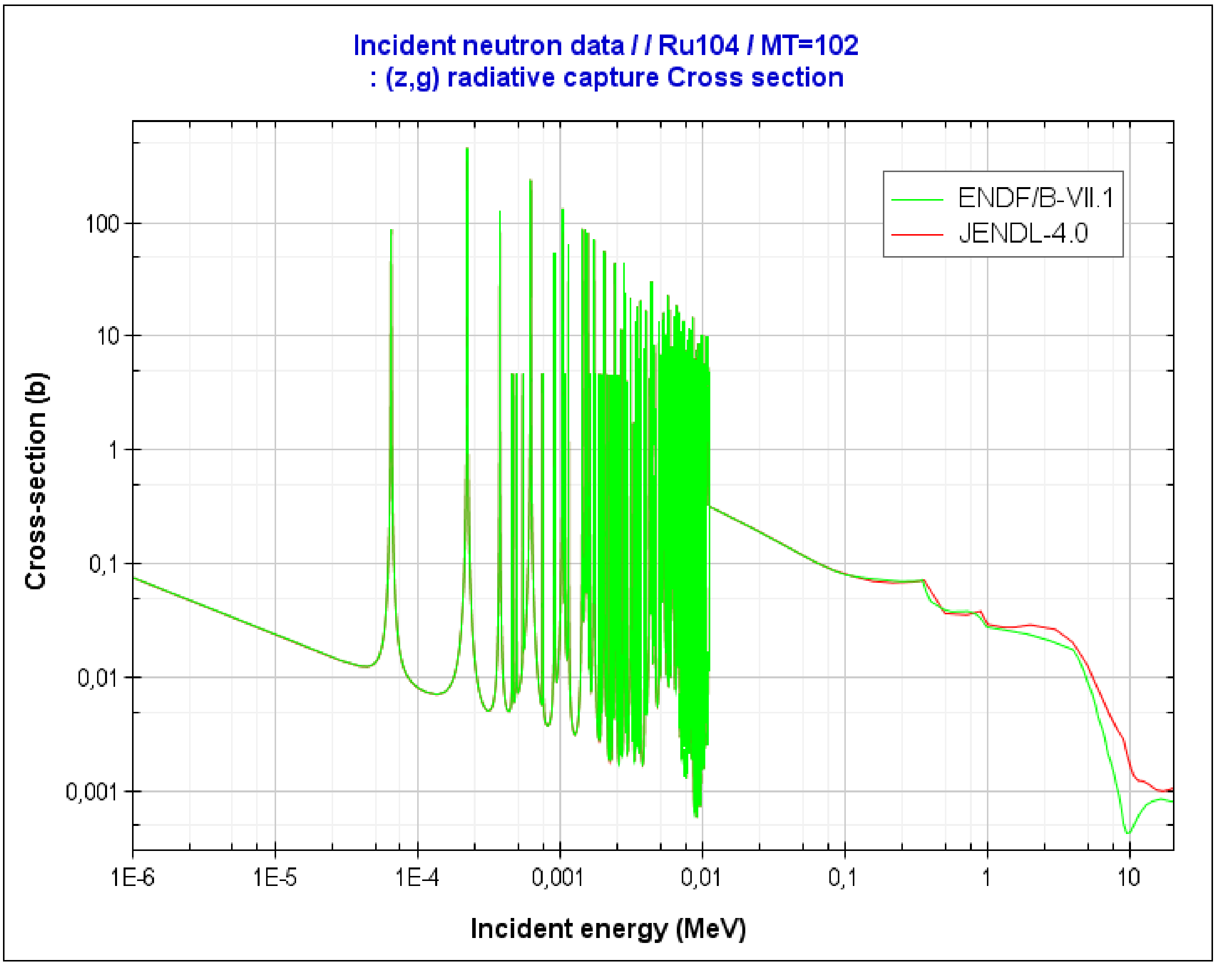
g = 0.999

E_r = 734.7 eV

σ_0 = 0.4717 b

Q_0 = 14.00

σ_h = 0.0291 b


Incident neutron data / / Ru104 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.45. $^{103}Rh(n,\gamma)^{104}Rh$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JEFF-3.1 [6]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
143.5	1.0	-16	170.5	25	142.8	-16	142.1	-17

Mughabghab [1]			Kayzero [2]		JEFF-3.1 [6]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
7.052	5.1	4.5	6.75	4.0	6.724	-0.4	6.754	0.1

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.0% and is 16% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 25% (due to the uncertainty in the gamma emission probability). The values in the JEFF-3.1 [6] and the ENDF/B-VII.1 [5] are in agreement with the Mughabghab [1] value and consistent with Kayzero [2], considering the assigned uncertainty.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.1% and is larger by 4.5% in comparison with the Kayzero [2] value, which has an uncertainty of 4.0%. The value derived from the JEFF-3.1 [6] and the ENDF/B-VII.1 [5] librarias are in excellent agreement with the Kayzero [2] value.

The cross sections in the resonance range in the JENDL-4.0 [4] library look similar to JEFF-3.1 [6], but the integral constants differ from the Kayzero [2] values more than the ENDF/B-VII.1 [5] or JEFF-3.1 [6]. The JEFF-3.1 [6] library is selected. The constants derived from this library are:

F_{cd} = 0.960

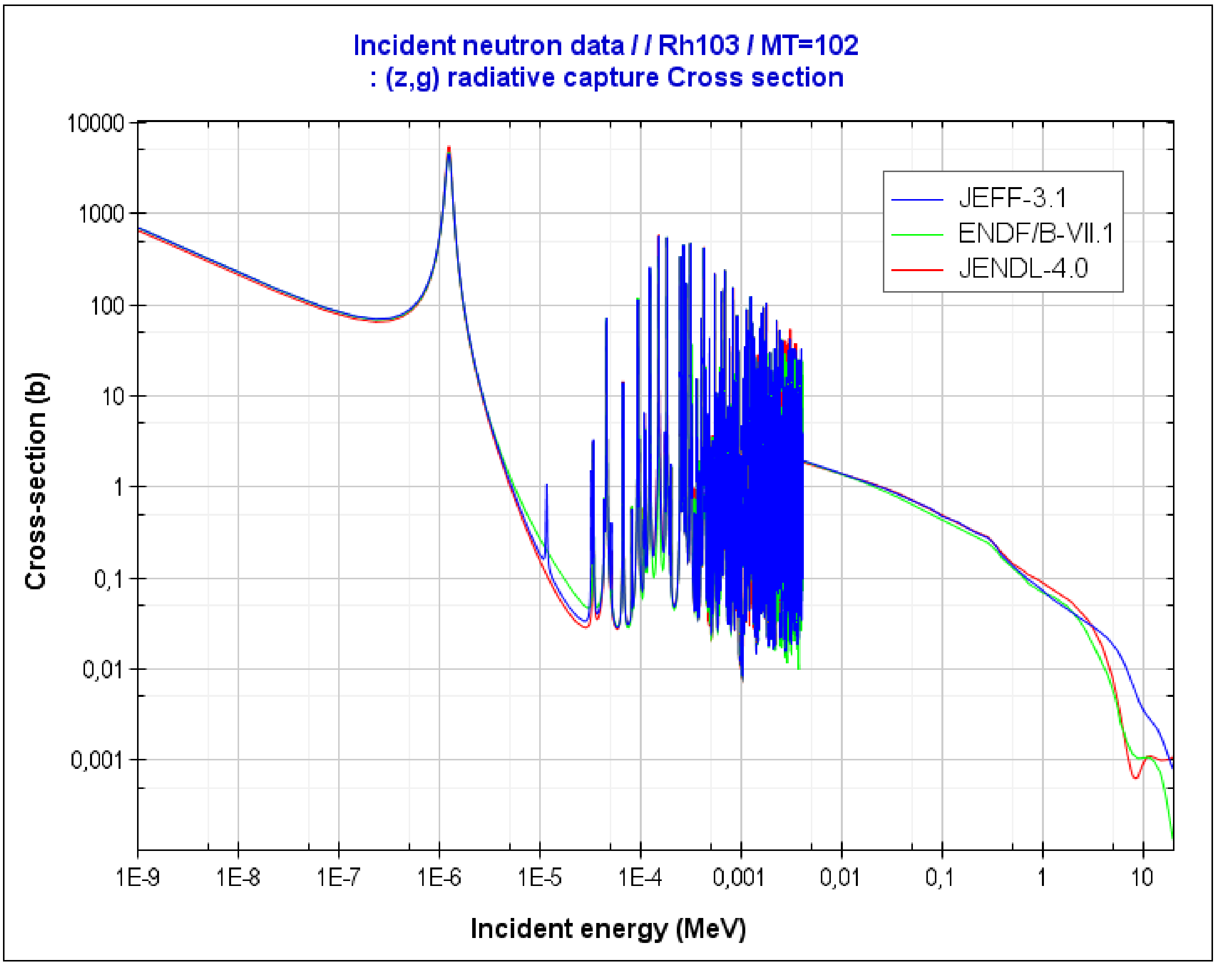
g = 1.022

E_r = 1.356 eV

σ_0 = 142.8 b

Q_0 = 6.724

σ_h = 0.0806 b


Incident neutron data / / Rh103 / MT=102
: (z,g) radiative capture Cross section
JEFF-3.1
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.46. $^{108}Pd(n,\gamma)^{109}Pd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
8.665	5.8	-2.9	8.920	10.7	8.047	-9.8	8.483	-4.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
28.16	6.0	5.9	26.6	1.7	30.19	13.5	28.78	8.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.8% and is 2.9% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 10.7%. The value in the ENDF/B-VII.1 [5] library is closer to the Kayzero [2] value and is smaller by 4.9%.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.0% and is larger by 5.9% in comparison with the Kayzero [2] value, which has an uncertainty of 1.7%. The value derived from the ENDF/B-VII.1 [5] library is closer to the Kayzero [2] value and is larger by 8.2%

The ENDF/B-VII.1 [5] library is selected because it is closer to the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.963

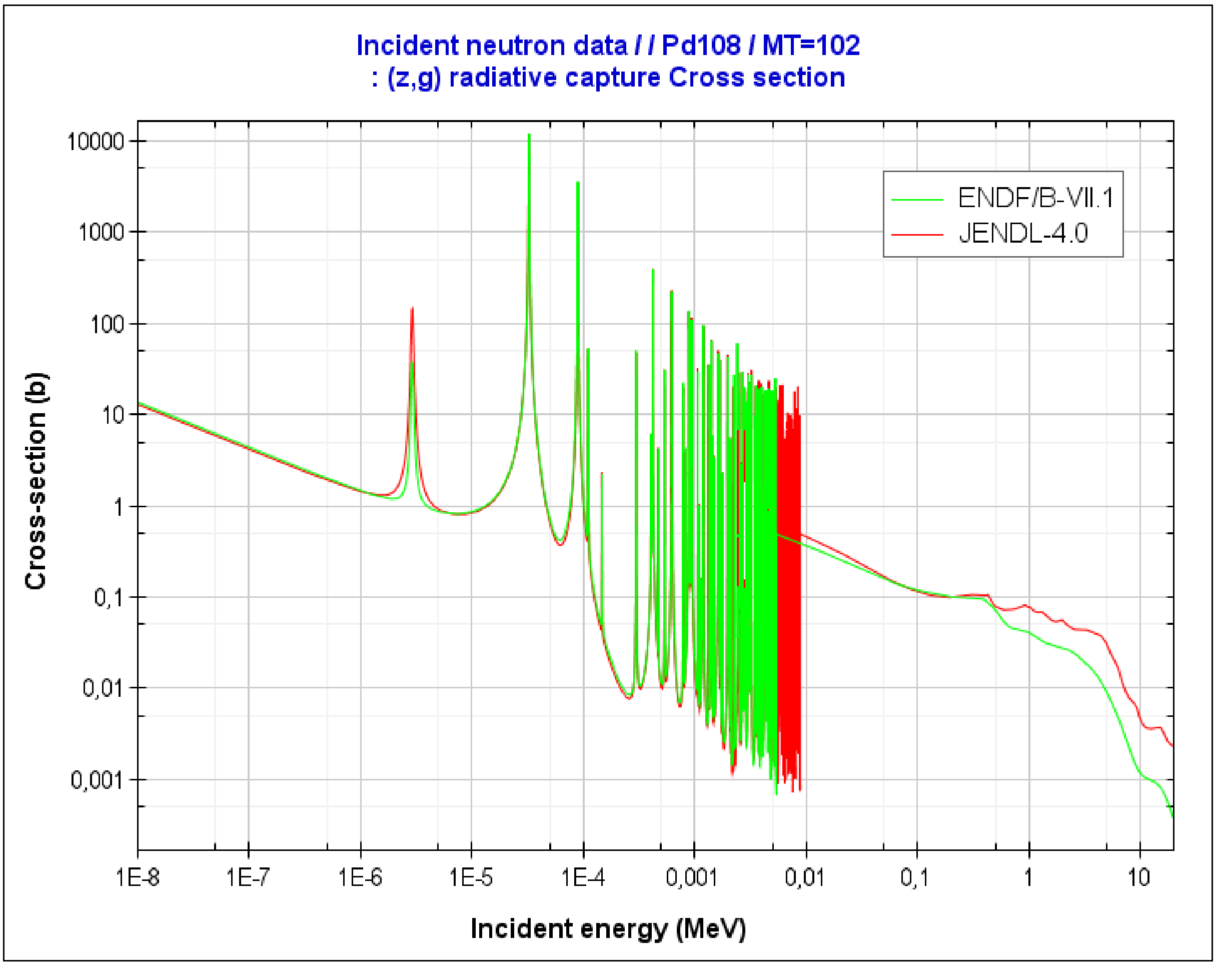
g = 0.999

E_r = 40.18 eV

σ_0 = 8.483 b

Q_0 = 28.78

σ_h = 0.0378 b


Incident neutron data / / Pd108 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.47. $^{108}Pd(n,\gamma)^{109m}Pd$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{109m}Pd are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.185	5.4	8.9	0.170	10.7	0.1718	1.1	0.1811	6.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
28.16	9.7	12.6	25	1.7	30.19	20.7	28.78	15.1

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.4% and is 8.9% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 10.7%. The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries do not contain branching ratios. Assuming the branching ratio for thermal incident neutrons of 2.14% by Mughabghab [1], the JENDL-4.0 [4] value is 1.1% larger than the Kayzero [2] value. The ENDF/B-VII.1 [5] value is in good agreement with Mughabghab [1] and is 6.6% larger than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.7% and is larger by 12.6% in comparison with the Kayzero [2] value, which has an uncertainty of 1.7%. Assuming that the branching ratio in the epithermal range for the production of the metastable nuclide is independent of energy and using the thermal value by Mughabghab [1], the JENDL-4.0 [4] value is 20.7% larger and ENDF/B-VII.1 [5] value is 15.1% larger than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because it agrees slightly better with the Kayzero [2] values on average. The constants derived from this library are:

F_{cd} = 0.963

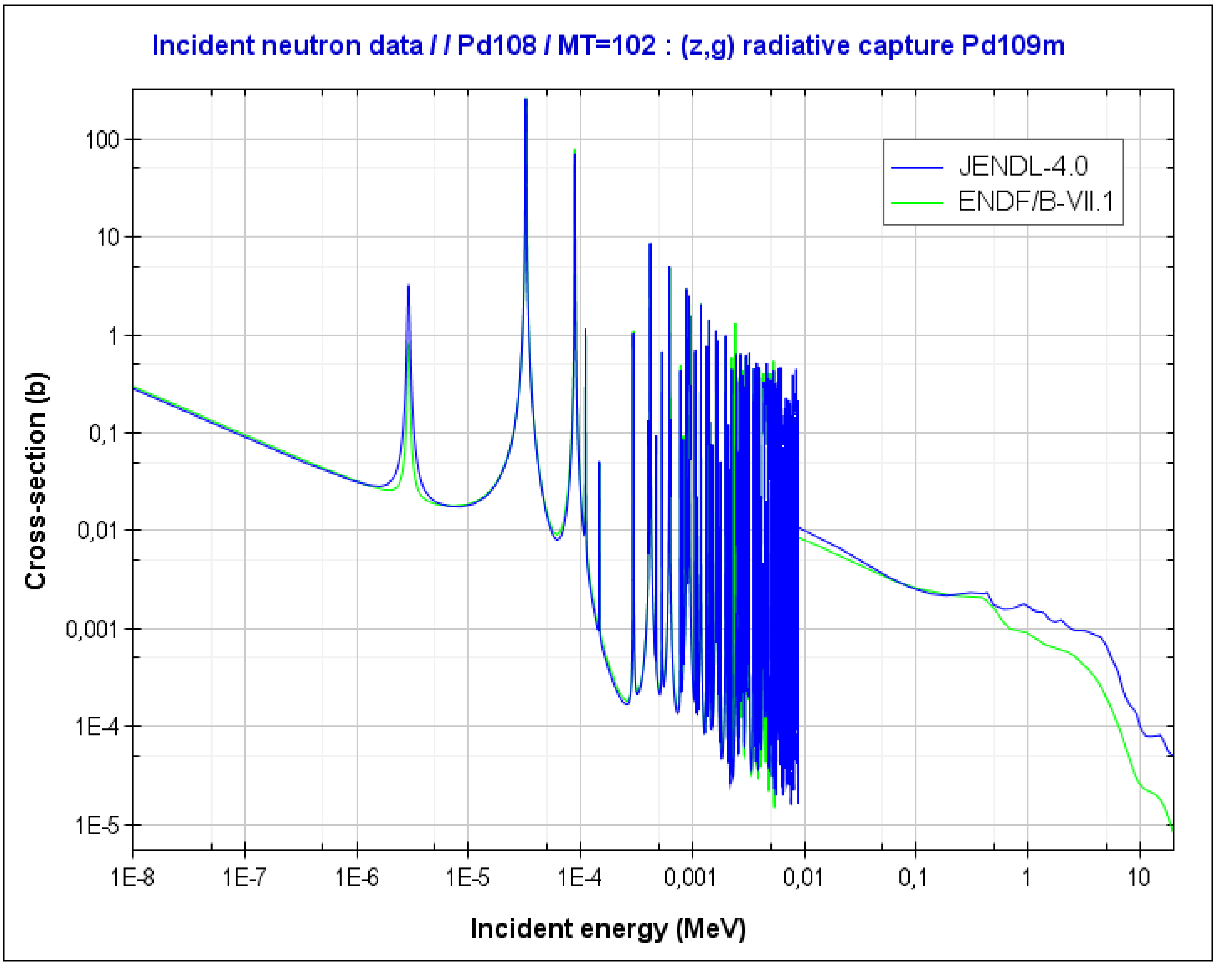
g = 0.999

E_r = 40.18 eV

σ_0 = 0.1811 b

Q_0 = 28.78

σ_h = 0.000809 b


Incident neutron data / / Pd108 / MT=102 : (z,g) radiative capture Pd109m
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.48. ^{110}Pd(n,γ)^{111m}Pd

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{111m}Pd are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.033	9.1	141	0.0137	1.4	0.0102	-26	0.0104	-24

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
20.0	14.0	68.1	11.9	6.7	71.5	500	66.8	461

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 9.1% but is by more than a factor of two larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.4%. No branching ratios are given in the JENDL-4.0 [4] and ENDF/B-VII.1 [5] libraries. Using the branching ratio for the thermal incdent neutrons of 4.52% by Mughabghab [1], the values in the evaluated data files are only 26% and 27% smaller, but this seems more like a coincidence. There must be some misinterpretation of the data somewhere, but it is not possible to track it down.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 14.0% and is larger by 68.1% in comparison with the Kayzero [2] value, which has an uncertainty of 6.7%. Assuming that the brancing ratio in the epithermal range for the production of the metastable nuclide is 22.3% by Mughabghab. The value from the JENDL-4.0 [4] library is 500% larger and the value from the ENDF/B-VII.1 [5] is 461% larger than Kayzero [2] value. The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries give values, which are higher by more than a factor of five. This confirms that there is an error of interpretation of the data somewhere.

The constants derived from the ENDF/B-VII.1 [5] library are given for completeness, but they sould not be used for any NAA analysis before the discrepancy in the data is resolved:

F_{cd} = 0.983

g = 0.998

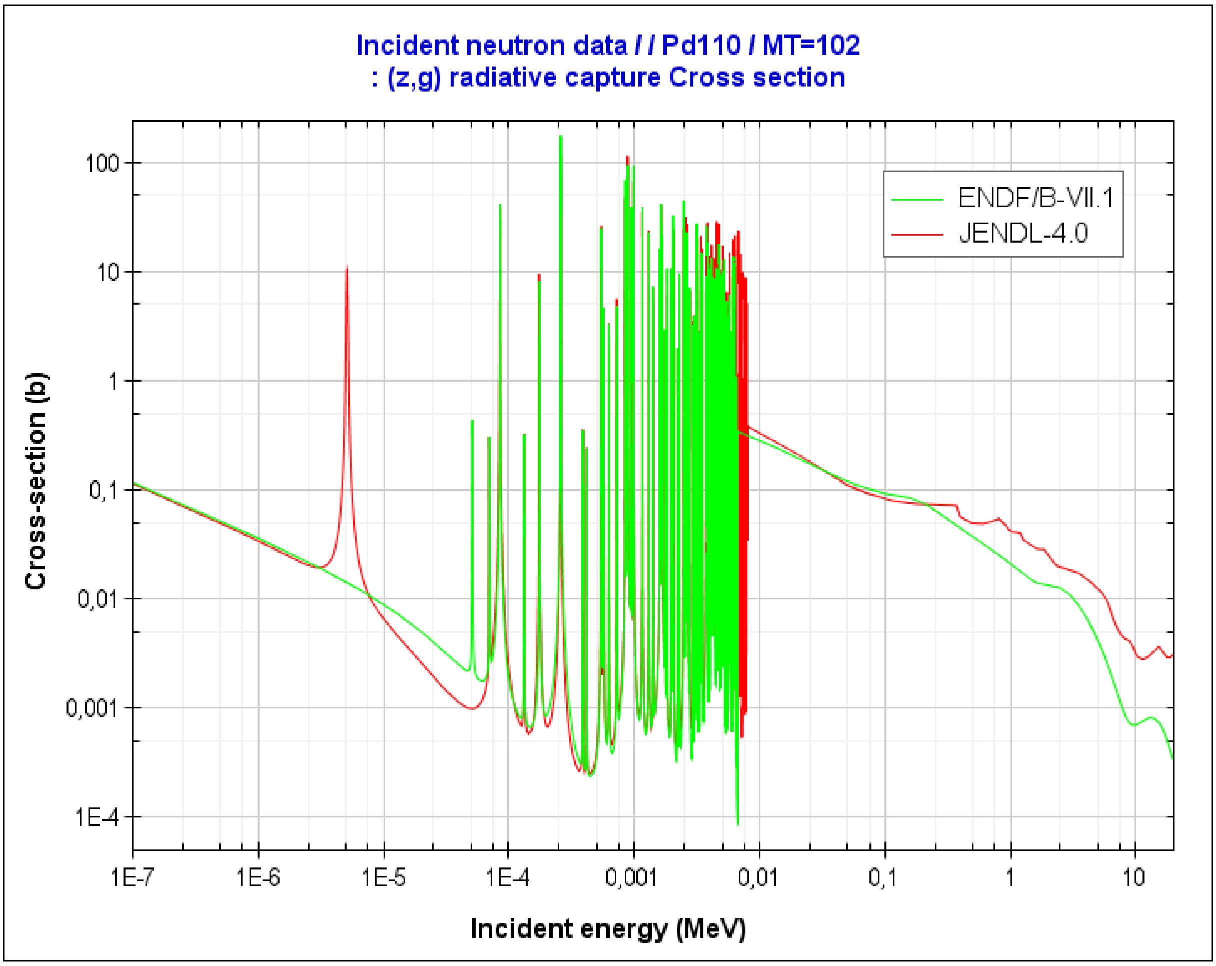
E_r = 1631 eV

σ_h = 0.0104 b

Q_0 = 66.8

σ_f = 0.000949 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.49. $^{107}Ag(n,\gamma)^{108}Ag$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
37.6	3.2	15.9	32.43	6.8	37.65	16.1	37.61	16.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
2.846	5.7	-1.9	2.9	-	2.781	-4.1	2.917	0.6

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.2% and is 15.9% smaller than the value derived from the Kayzero [2] library, which has no uncertainty given. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are fully consistent with the Mughabghab [1] value and are 16.0% larger than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.7% and is smaller by 1.9% in comparison with the Kayzero [2] value, which has no uncertainty given. The velue derived from the JENDL-4.0 [4] library is 4.1% smaller while the value derived from the ENDF/B-VII.1 [5] library is only 0.6% larger than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because of marginally better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 1.003

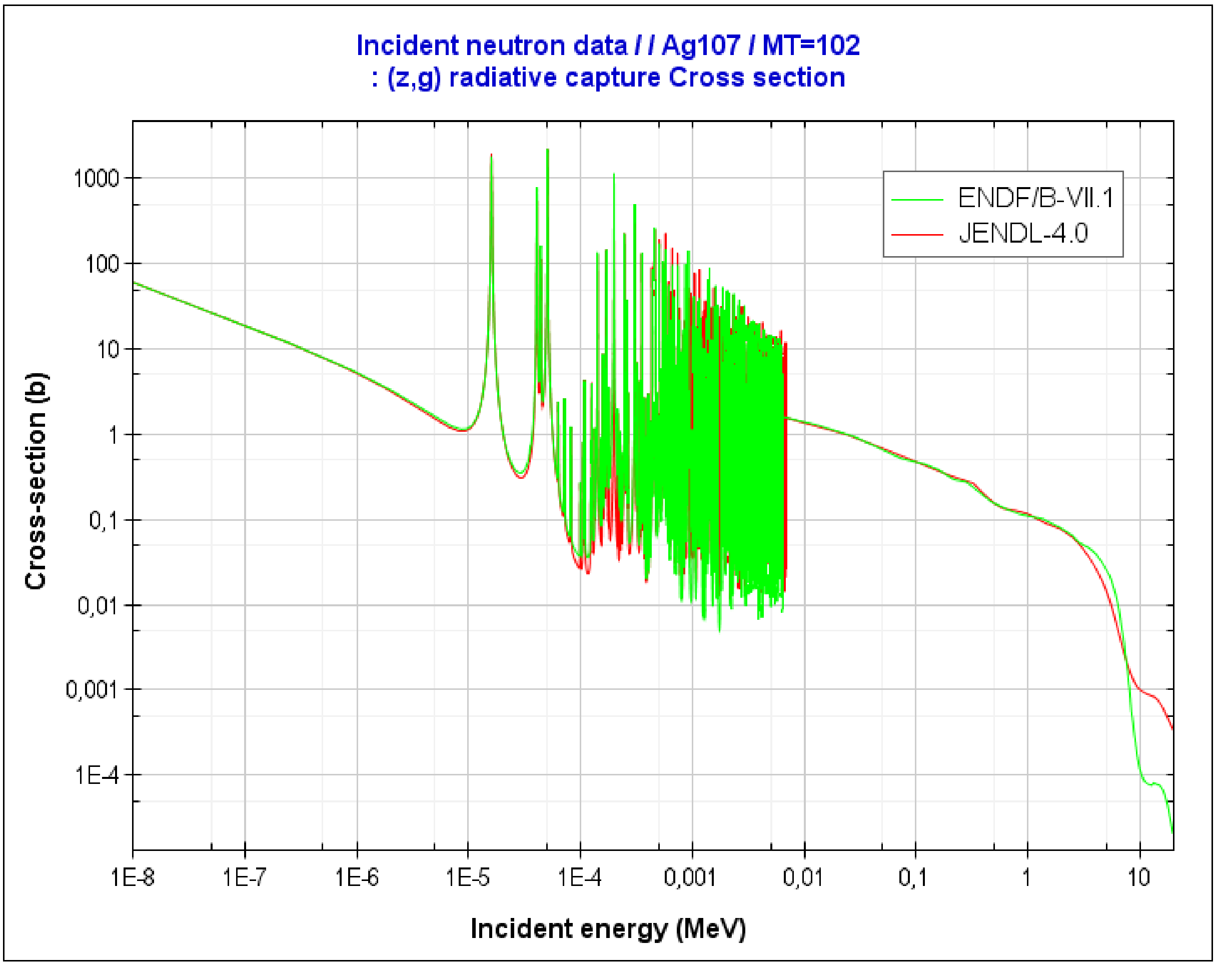
g = 0.997

E_r = 63.13 eV

σ_0 = 37.61 b

Q_0 = 2.917

σ_h = 0.106 b


Incident neutron data / / Ag107 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.50. $^{109}Ag(n,\gamma)^{110g}Ag$

The thermal cross sections and the Q_0 values for the production of the ground state residual ^{110g}Ag are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
87.1	3.4	19.4	72.94	0.4	86.36	18.4	86.36	18.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
16.13	4.9	-12	18.4	-	16.18	-12	16.23	-12

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.4% and is 19.4% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.4%; this value does not include the uncertainty of the gamma emission probability because it is not given in the Nudat [3] database. Assuming that the brancing ratio for thermal incident neutrons of 95.7% by Mughabghab. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 18.4% higher.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.9% and is smaller by 12% in comparison with the Kayzero [2] value, which has no uncertainty given. The effective brancing ratio in the epithermal range for the production of the ground state nuclide is 95.6% by Mughabghab [1]. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 12% smaller.

The two libraries are equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.999

g = 1.003

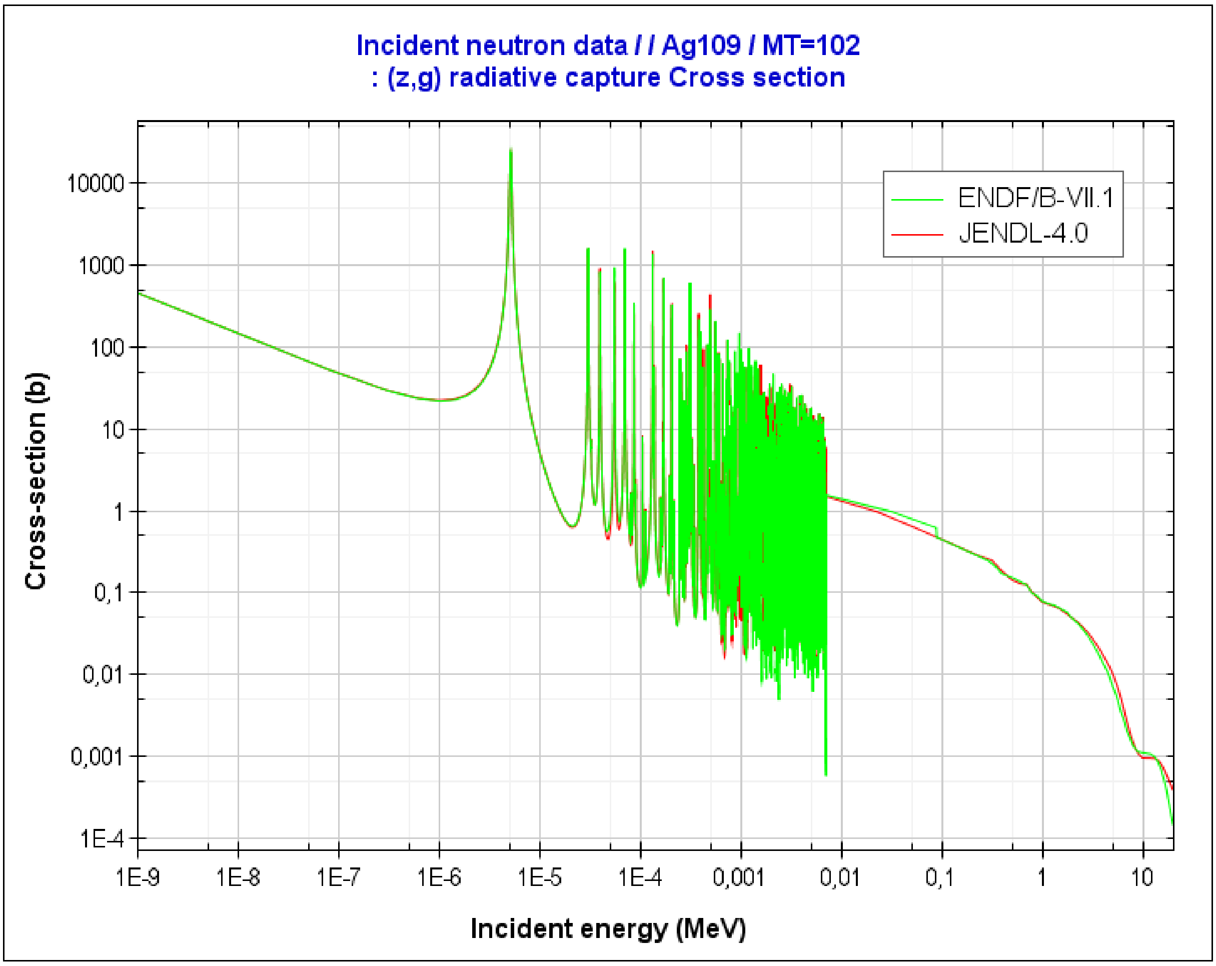
E_r = 6.017 eV

σ_0 = 86.36 b

Q_0 = 16.23

σ_h = 0.0796 b

The plot is for the total capture cross section since the cross sections for the excitation of the ground state residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.51. $^{109}Ag(n,\gamma)^{110m}Ag$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{110m}Ag are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
3.95	1.3	1.1	3.907	1.5	3.917	0.3	3.917	0.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
16.48	4.6	-1.3	16.7	4.2	16.53	-1.0	16.59	-0.7

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.3% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.5%. Assuming that the brancinh ratio for thermal incident neutrons of 4.3% by Mughabghab [1] is correct. The values from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 0.3% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.6% and is lower by 1.3% in comparison with the Kayzero [2] value, which has an uncertainty of 4.2%. The effective brancing ratio in the epithermal range for the production of the metastable nuclide is 4.4% according to Mughabghab [1]. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are about 1% smaller.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.999

g = 1.003

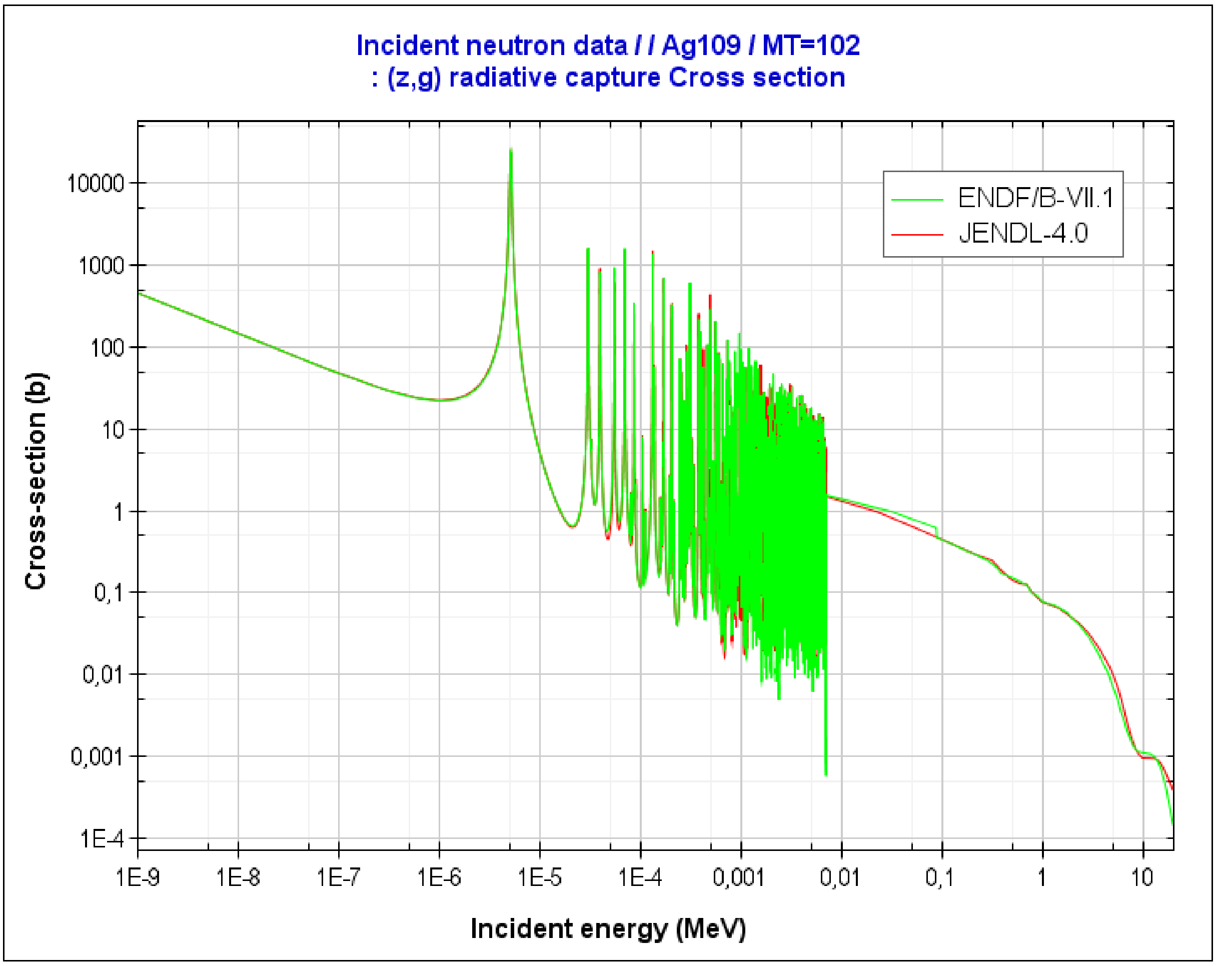
E_r = 6.02 eV

σ_0 = 3.917 b

Q_0 = 16.59

σ_h = 0.00366 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.52. $^{114}Cd(n,\gamma)^{115}Cd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.294	5.4	-9.0	0.323	2.7	0.3406	5.4	0.3055	-5.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
42.86	9.6	32.3	32.4	-	49.47	52.7	40.69	25.6

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.4% and is 9.0% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.7%. The value in the JENDL-4.0 [4] library is higher by 5.4% and the value in the ENDF/B-VII.1 [5] library is 5.5% lower.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.6% and is larger by 32.3% in comparison with the Kayzero [2] value, which has no uncertainty given. The value in the ENDF/B-VII.1 [5] library is closer to the Mughabghab [1] evaluation and the Kayzero [2] value, but note the large Cd correction that ought to be applied.

The ENDF/B-VII.1 [5] library is selected because the Q_0 value derived from it is in better agreement with the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 0.933

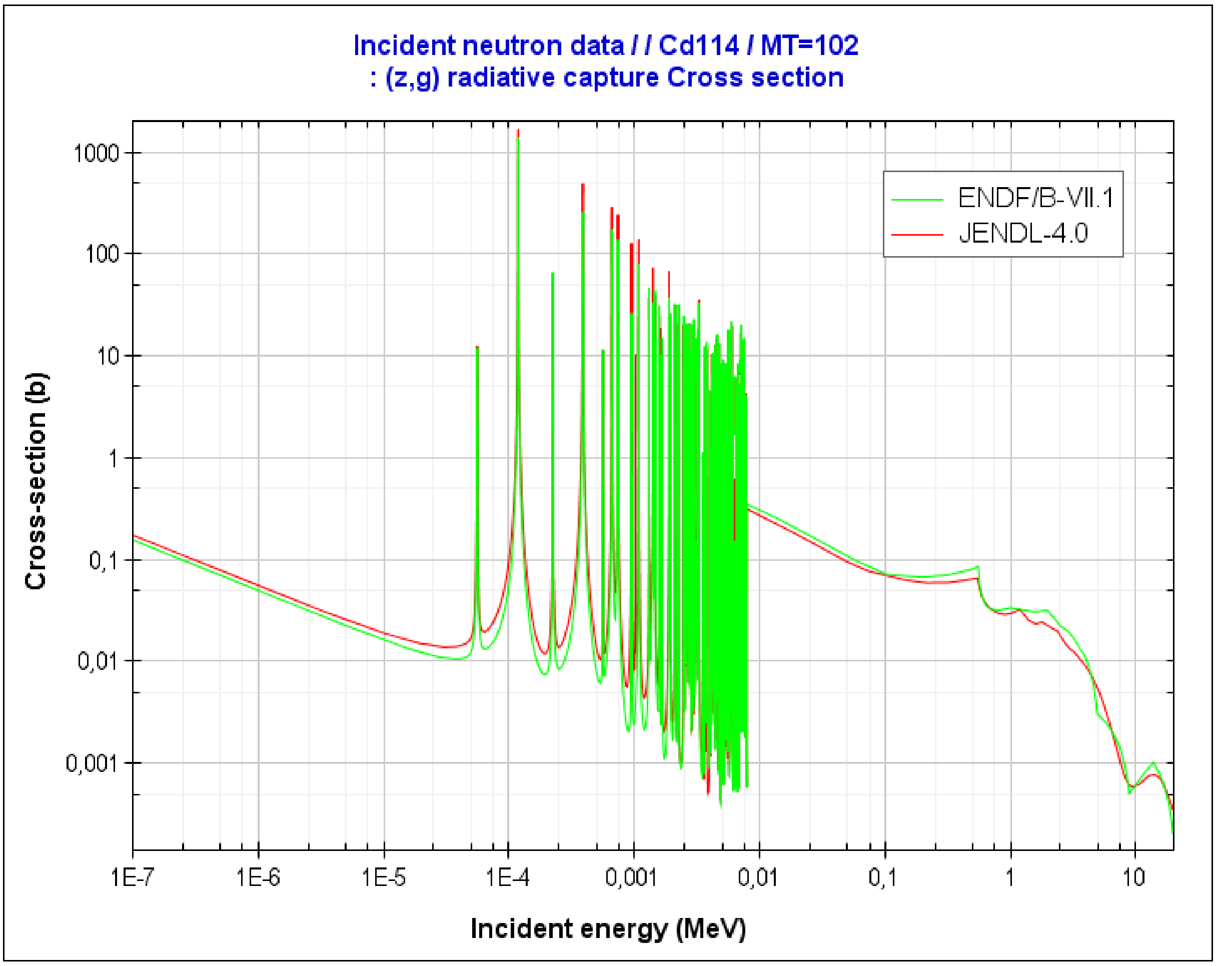
g = 0.999

E_r = 289.1 eV

σ_0 = 0.3055 b

Q_0 = 40.69

σ_h = 0.0323 b


Incident neutron data / / Cd114 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.53. $^{113}In(n,\gamma)^{114m}In$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{114m}In are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0 [b]	$\Delta\sigma_0$ [%]	Diff. [%]	σ_0 [b]	$\Delta\sigma_0$ [%]	σ_0 [b]	Diff. [%]	σ_0 [b]	Diff. [%]
8.1	9.9	-7.2	8.73	1.7	8.161	-6.5	8.195	-6.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0 [%]	Diff. [%]	Q_0	ΔQ_0 [%]	Q_0	Diff. [%]	Q_0	Diff. [%]
27.16	12.0	12.2	24.2	1.7	27.37	13.1	27.88	15.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 9.9% and is 7.2% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.7%. The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries contain no branching ratios. Assuming the branching ratio for thermal incident neutrons by Mughabghab [1] of 67.5%, the thermal cross section values in both libraries is slightly more than 6% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 12.0% and is larger by 12.2% in comparison with the Kayzero [2] value, which has an uncertainty of 1.7%. Assuming the branching ratio in the epithermal range for the production of the metastable nuclide by Mughabghab [1] of 68.7%, the Q_0 value derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries is larger than the Kayzero [2] value by 13.1% and 15.2%, respectively.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.986

g = 1.011

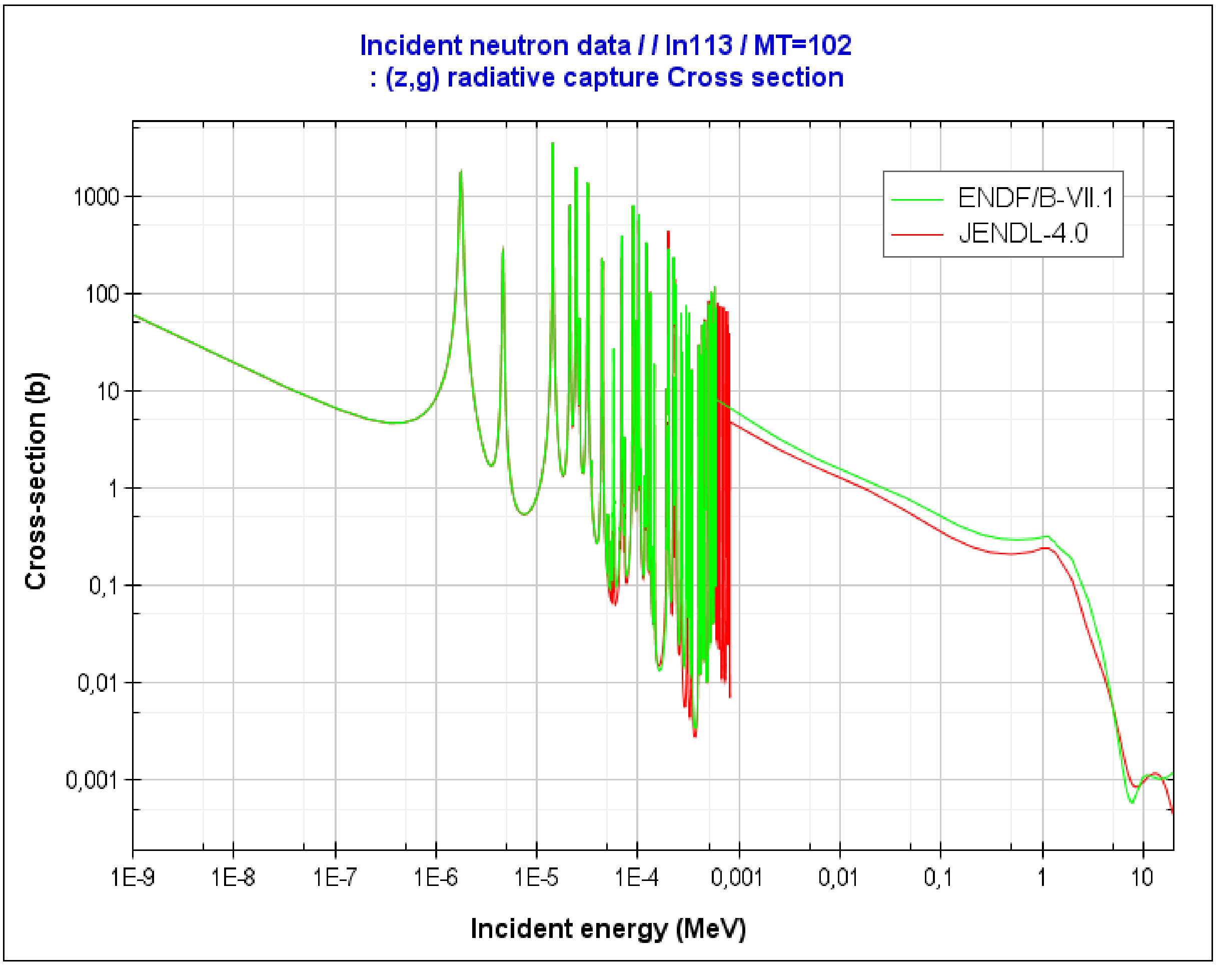
E_r = 8.524 eV

σ_0 = 8.195 b

Q_0 = 27.88

σ_h = 0.136 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.54. $^{115}In(n,\gamma)^{116m}In$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{116m}In are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
162.3	0.4	3.1	157.5	1.0	161.7	2.6	159.8	1.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
16.33	3.8	-2.8	16.8	1.9	15.89	-5.4	15.88	-5.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.4% and is 3.1% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.0%. The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries contain no branching ratios. Assuming the branching ratio for thermal incident neutrons by Mughabghab [1] of 80.3%, the values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are in excellent agreement with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.8% and is smaller by 2.8% in comparison with the Kayzero [2] value, which has an uncertainty of 1.9%. Assuming the branching ratio in the epithermal range for the production of the metastable nuclide by Mughabghab [1] of 80.3%, the values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are practically the same and are about 5.5% smaller than the Kayzero [2] value

The ENDF/B-VII.1 [5] library is selected because explicitly contains the branching ratios. The constants derived from this library are:

F_{cd} = 0.975

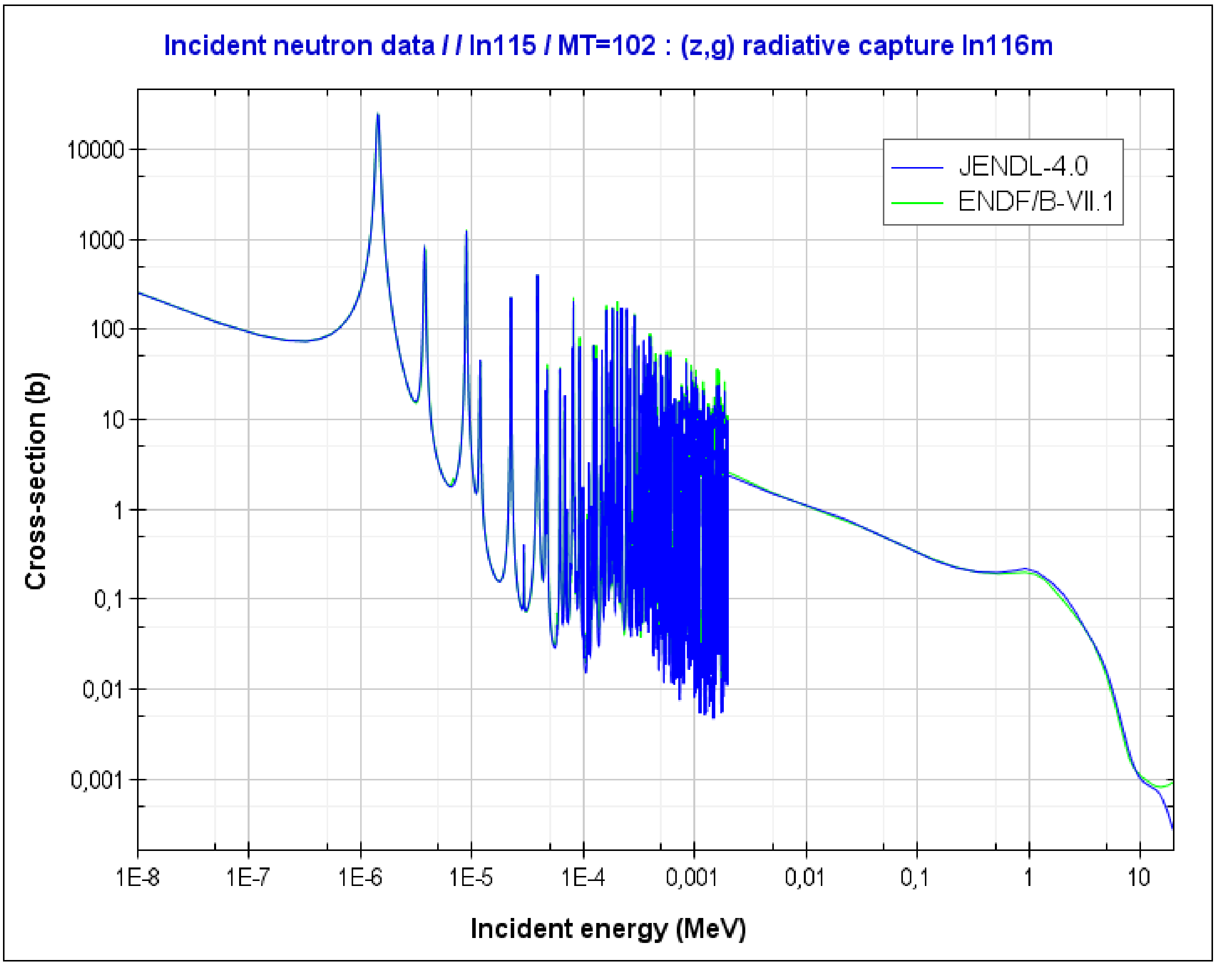
g = 1.018

E_r = 1.520 eV

σ_0 = 159.8 b

Q_0 = 15.88

σ_h = 0.128 b


Incident neutron data / / In115 / MT=102 : (z,g) radiative capture In116m
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.55. $^{112}Sn(n,\gamma)^{113g}Sn$

The thermal cross sections and the Q_0 values for the excitation of the residual in the ground state are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.56	3.6	3.6	0.540	1.3	0.5671	4.9	0.5603	3.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
34.12	11.1	-30	48.4	1.2	35.47	-27	35.41	-27

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.6% and is 3.6% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.3%. No branching ratios are given in the evaluated data libraries, so the branching ratio for thermal incident neutrons of 65.8% by Mughabghab [1] is used. In comparison with the Kayzero [2] values, the values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are larger by 4.9% and 3.7%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 11.1% and is smaller by 30% in comparison with the Kayzero [2] value, which has an uncertainty of 1.2%. The branching ratio is assumed independent of energy; the thermal value by Mughabghab [1] is used in the epithermal part as well. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] evaluated data libraries are consistent with the Mughabghab [1] value and are 27% smaller than the Kayzero [2] value.

The two evaluations are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.993

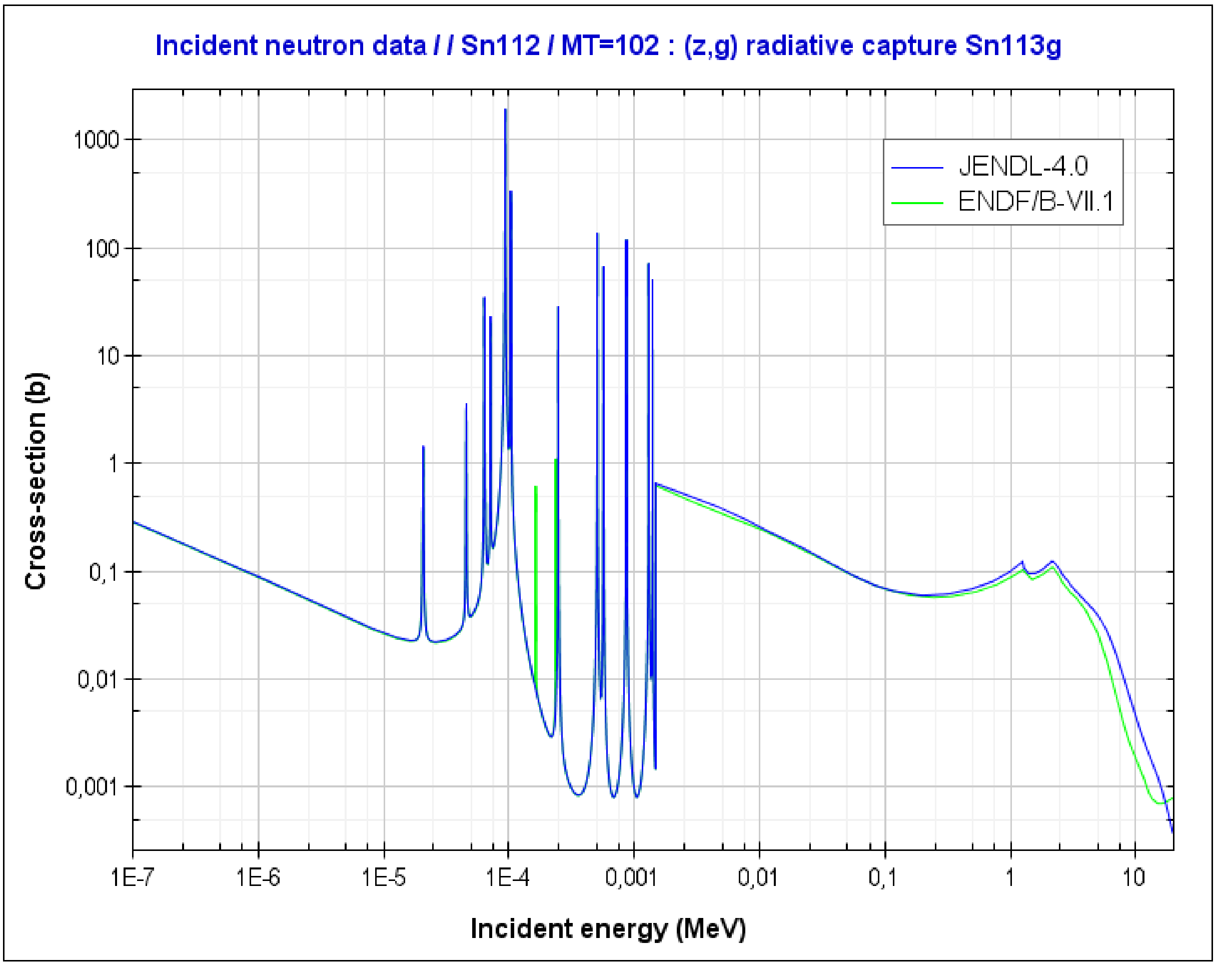
g = 0.998

E_r = 148.9 eV

σ_0 = 0.5603 b

Q_0 = 35.41

σ_h = 0.0723 b



Incident neutron data / / Sn112 / MT=102 : (z,g) radiative capture Sn113g
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
JENDL-4.0
ENDF/B-VII.1

2.5.56. $^{116}Sn(n,\gamma)^{117m}Sn$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{117m}Sn are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.006	33.3	-0.1	0.006	1.1	0.00578	-3.8	0.00589	-1.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
81.67	46.7	45.1	56.3	1.9	86.58	53.8	85.30	51.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 33.3% and is in full agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.1%. No branching ratios are given in the evaluated data libraries, so the branching ratio for the thermal incident neutrons of 4.62% by Mughabghab [1] is used. In comparison with the Kayzero [2] values, the values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller by 3.8 % and 1.9%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 46.7% and is larger by 45.1% in comparison with the Kayzero [2] value, which has an uncertainty of 1.9%. The branching ratio in the epithermal range for the production of the metastable nuclide of 4.12% by Mughabghab [1] is used. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] evaluated data libraries lie close to the Mughabghab [1] value and are 53.8% and 51.5% larger than the Kayzero [2] value.

The evaluated libraries are equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.998

g = 0.999

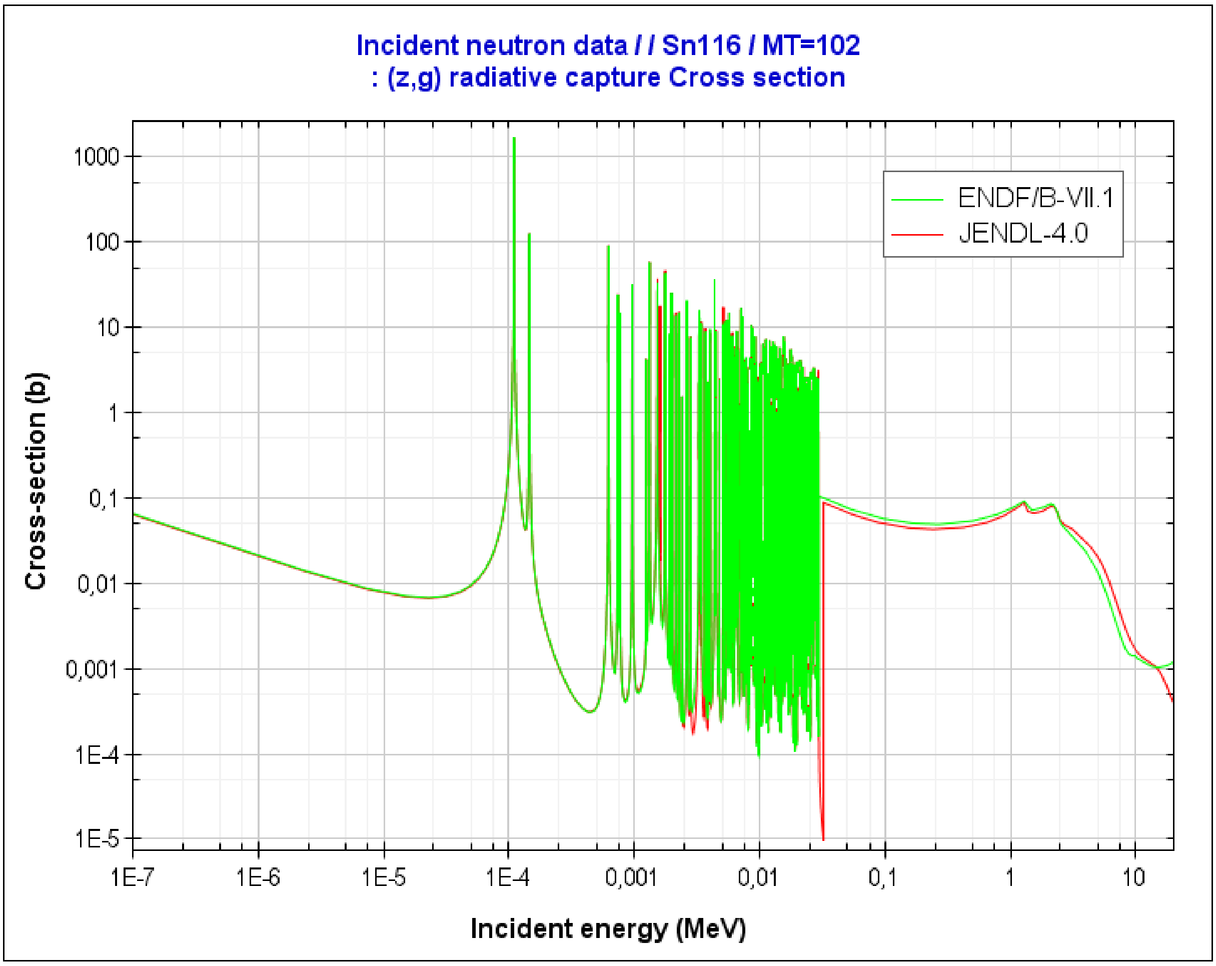
E_r = 183.9 eV

σ_0 = 0.00589 b

Q_0 = 85.30

σ_h = 0.00232 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.57. $^{122}Sn(n,\gamma)^{123m}Sn$

The thermal cross sections and the Q_0 values for the excitation of the metastable residual ^{123m}Sn are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.146	5.5	-0.1	0.146	0.8	0.1396	-4.5	0.1461	0.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
5.548	7.4	2.7	5.4	2.5	6.792	25.8	4.420	-18

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.5% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.8%; this does not include the uncertainty of the gamma-emission probability. The branching ratio by Mughabghab [1] suggests that the branching ratio for the excitation of the metastable residual is more than 99%, therefore the total capture cross sections are applicable. The value in the ENDF/B-VII.1 [5] library is in full agreement with the Mughabghab [1] and the Kayzero [2] values, while the JENDL-4.0 [4] value is 4.5% lower
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 7.4% and is larger by 2.7% in comparison with the Kayzero [2] value, which has an uncertainty of 2.5%. The value derived from the JENDL-4.0 [4] library is 25.8% higher, while the value from the ENDF/B-VII.1 [5] library is 18% lower

The ENDF/B-VII.1 [5] library is selected because of slightly better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.986

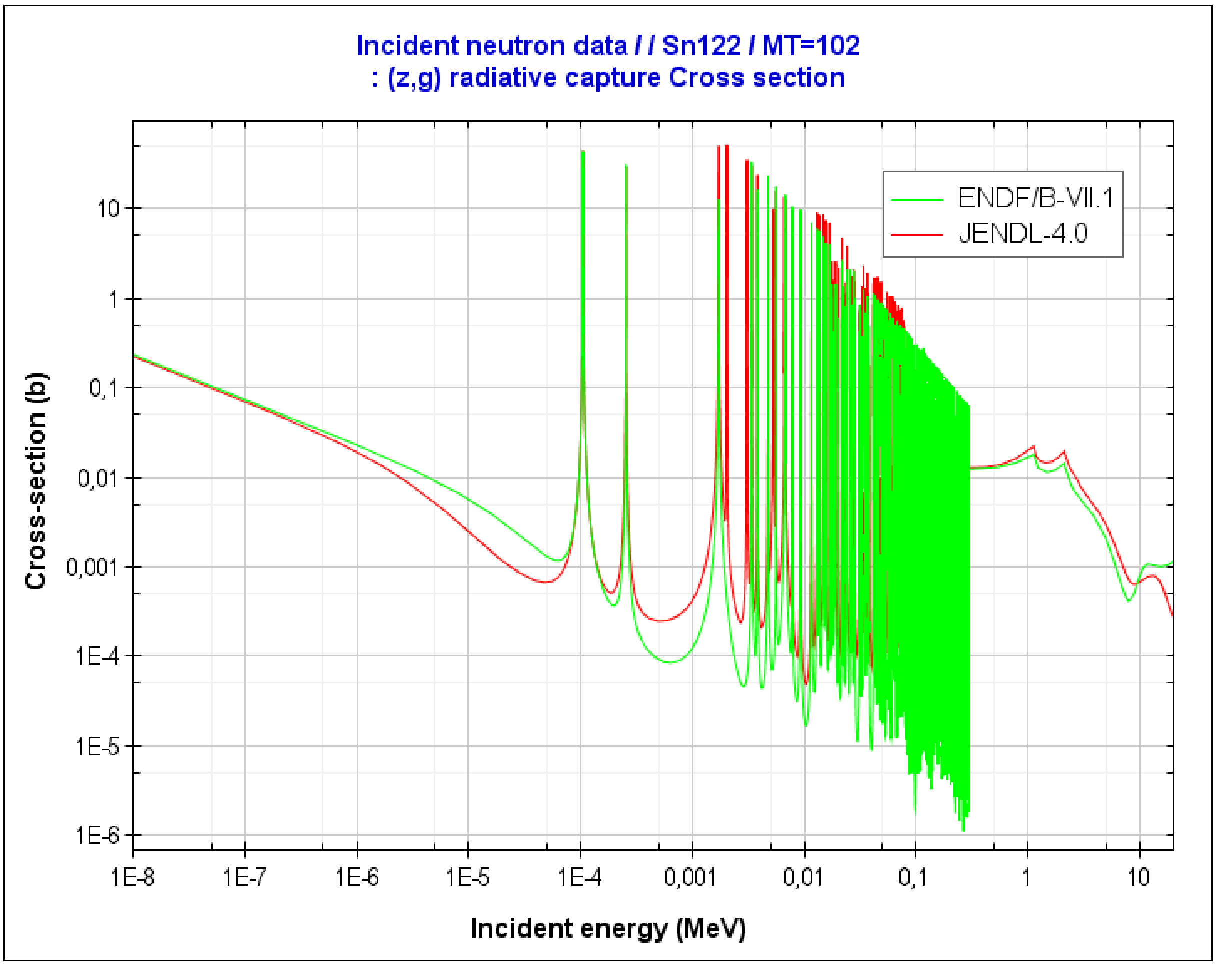
g = 0.998

E_r = 708.5 eV

σ_0 = 0.1461 b

Q_0 = 4.420

σ_h = 0.00973 b


Incident neutron data / / Sn122 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10

2.5.58. $^{124}Sn(n,\gamma)^{125g}Sn$

The thermal cross sections and the Q_0 values for the production of the ground state residual ^{125g}Sn are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.0042	31.0	-7.8	0.00456	1.3	0.004253	-6.6	0.004194	-7.9

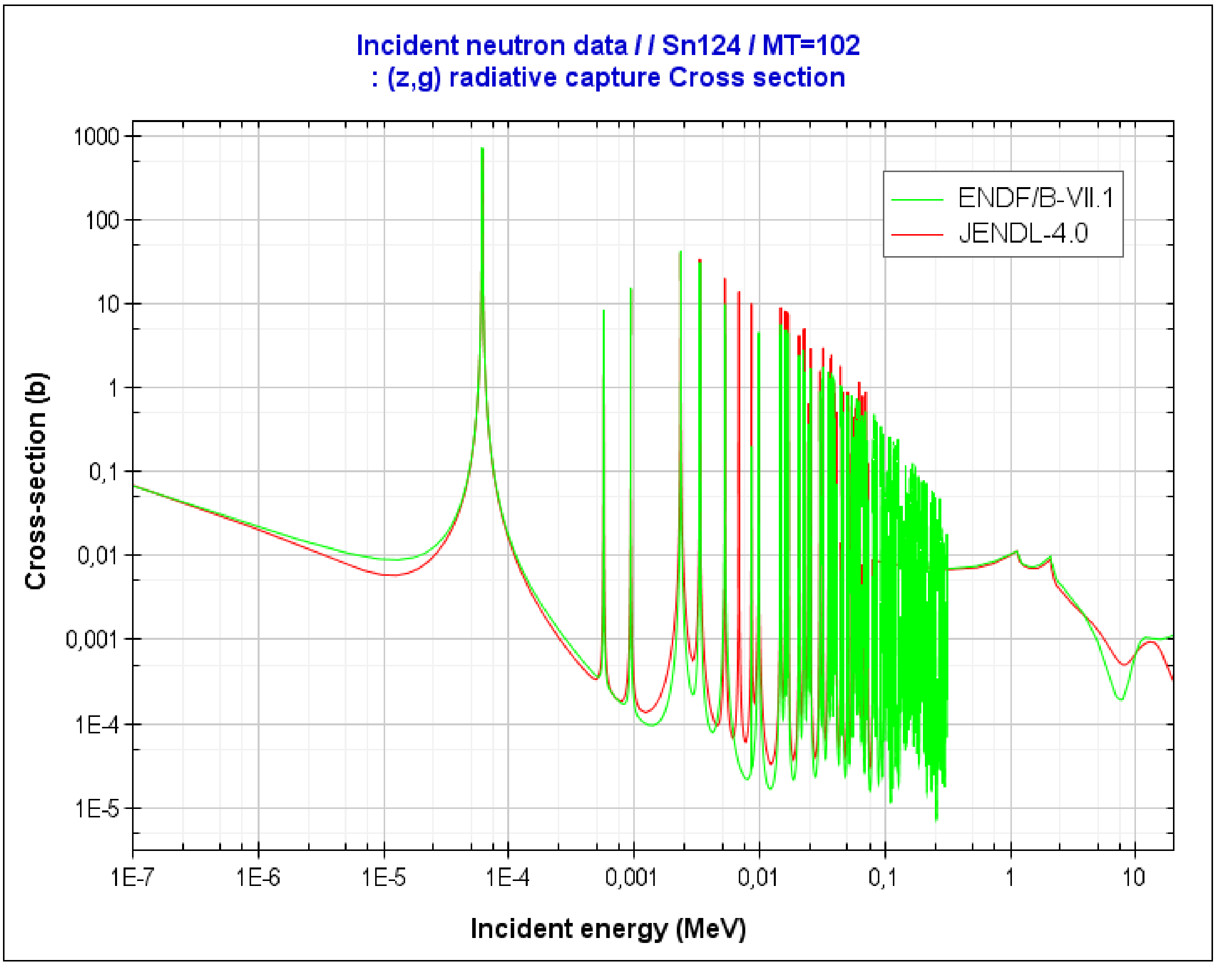
Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
19.76	43.2	14.9	17.2	12	19.07	10.9	19.91	15.7

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 31.0% and is 7.8% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.3%, mainly because the uncertainty of the gamma emission probability is not specified. No branching ratios are given in the evaluated data libraries, so the branching ratio for thermal incident neutrons of 3.13% by Mughabghab [1] is used. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries follow closely the recommended value by Mughabghab [1] and are lower than the Kayzero [2] value by 6.6% and 7.9%, respectively
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 43.2% and is larger by 14.9% in comparison with the Kayzero [2] value, which has an uncertainty of 12%. The branching ratio in the epithermal range for the production of the ground state nuclide of 1.03% by Mughabghab [1] is used. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the value by Mughabghab [1] and are higher by 10.9% and 15.7%, respectively.

The two libraries are essentially equivalent. The ENDF/B-VII.1 [5] library is selected because it is the most recent. The constants derived from this library are:

F_{cd}	=	0.998
g	=	0.999
E_r	=	69.27 eV
σ_0	=	0.004194 b
Q_0	=	19.91
σ_h	=	0.0000616 b

The plot is for the total capture cross section since the cross sections for the excitation of the ground state residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.59. $^{121}Sb(n,\gamma)^{122}Sb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
5.77	1.9	-8.6	6.31	1.6	5.995	-5.1	5.774	-8.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
35.01	10.1	6.1	33	3.5	35.66	8.1	35.71	8.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.9% and is 8.6% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.6%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller by 5.1% and 8.6%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 10.1% and is larger by 6.1% in comparison with the Kayzero [2] value, which has an uncertainty of 3.5%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie clos to the Mughabghab [1] value and are both about 8% larger.

The two libraries are almost equivalent. The JENDL-4.0 [4] library is selected because is marginally more consistent with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.992

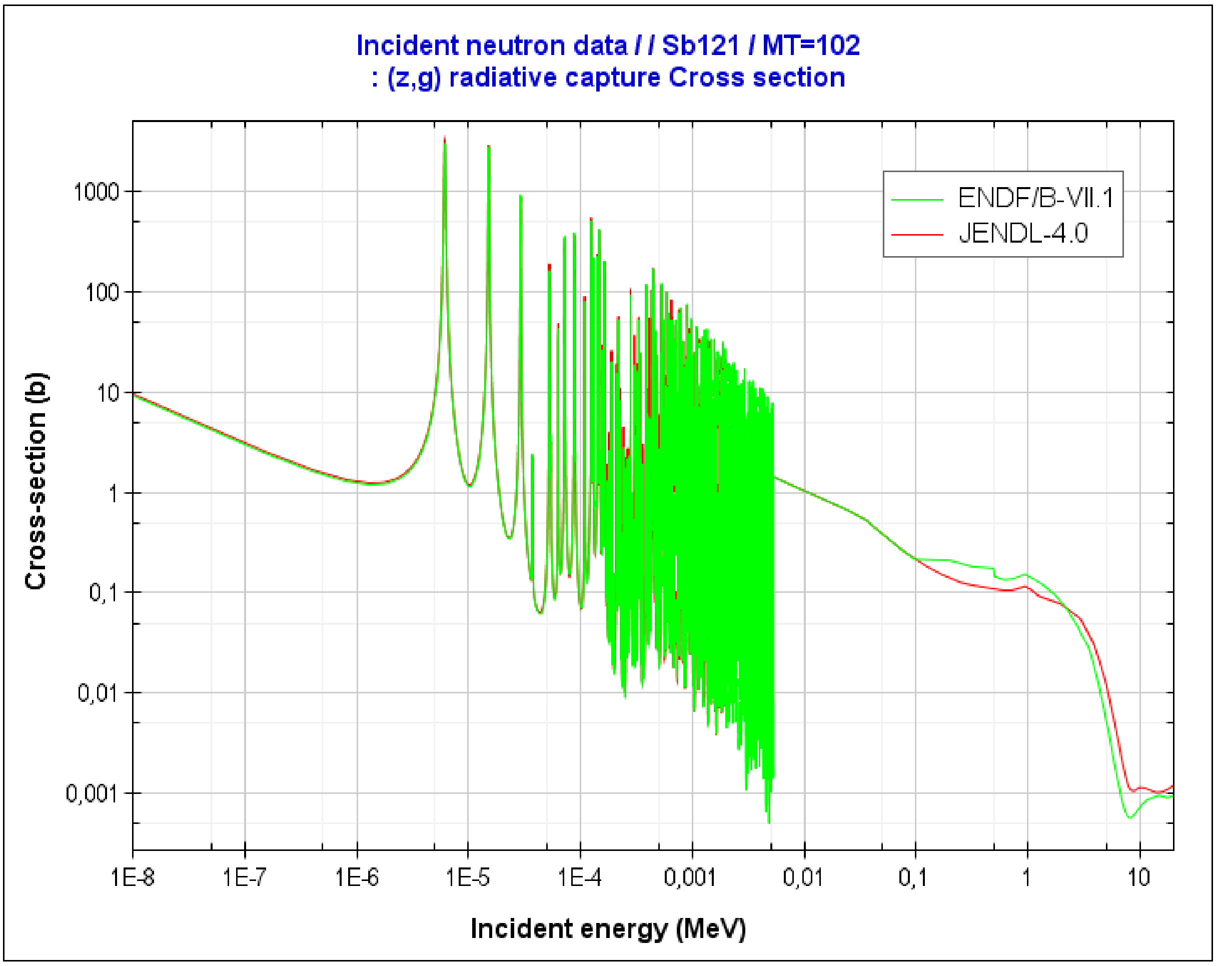
g = 1.002

E_r = 14.46eV

σ_0 = 5.995 b

Q_0 = 35.66

σ_h = 0.00818 b



Incident neutron data / / Sb121 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.60. $^{123}Sb(n,\gamma)^{124}Sb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
3.94	3.0	-3.2	4.071	13.9	4.189	2.9	3.876	-4.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
31.98	16.2	11.0	28.8	3.7	29.17	1.3	32.84	14.0

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.0% and is 3.2% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 13.9% (because the uncertainty of the gamma-emission probability is not known accurately). The value in the JENDL-4.0 [4] is 2.9% larger and in ENDF/B-VII.1 [5] is 4.8% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 16.2% and is larger by 11.0% in comparison with the Kayzero [2] value, which has an uncertainty of 3.7%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are larger by 1.3% and 14.0%, respectively.

The JENDL-4.0 [4] library is selected because slightly better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.998

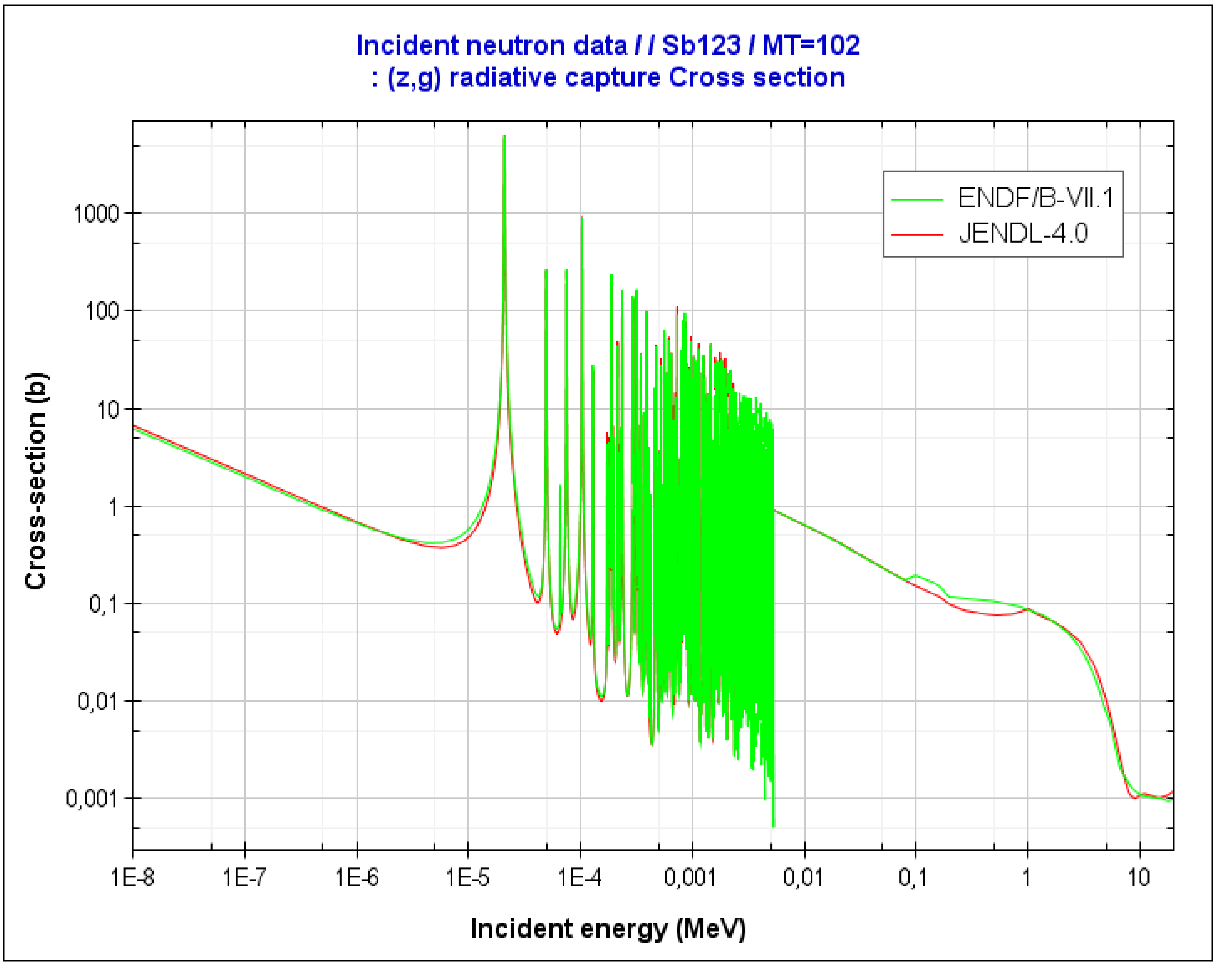
g = 0.999

E_r = 31.93 eV

σ_0 = 4.189 b

Q_0 = 29.17

σ_h = 0.00609 b


Incident neutron data / / Sb123 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.61. $^{123}Sb(n,\gamma)^{124\,m1+m2}Sb$

The thermal cross sections and the Q_0 values for the excitation of the metastable residual $^{124(m1+m2)}$Sb are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.056	18	-28	0.0779	13.9	0.05954	-24	0.05509	-29

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
31.98	18.0	60.7	19.9	-	29.17	46.6	32.84	65

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 18% and is 28% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 13.9% (because the uncertainty of the gamma-emission probability is not known accurately). No branching ratios are given in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries. The branching ratio for thermal incident neutrons is 1.42% by Mughabghab [1]. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are smaller by 24% and 29%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 18.0% and is larger by 60.7% in comparison with the Kayzero [2] value, which has no uncertainty given. The branching ratio is assumed independent of energy. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are smaller by 46.6% and 65%, respectively.

The JENDL-4.0 [4] library is selected because slightly better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.998

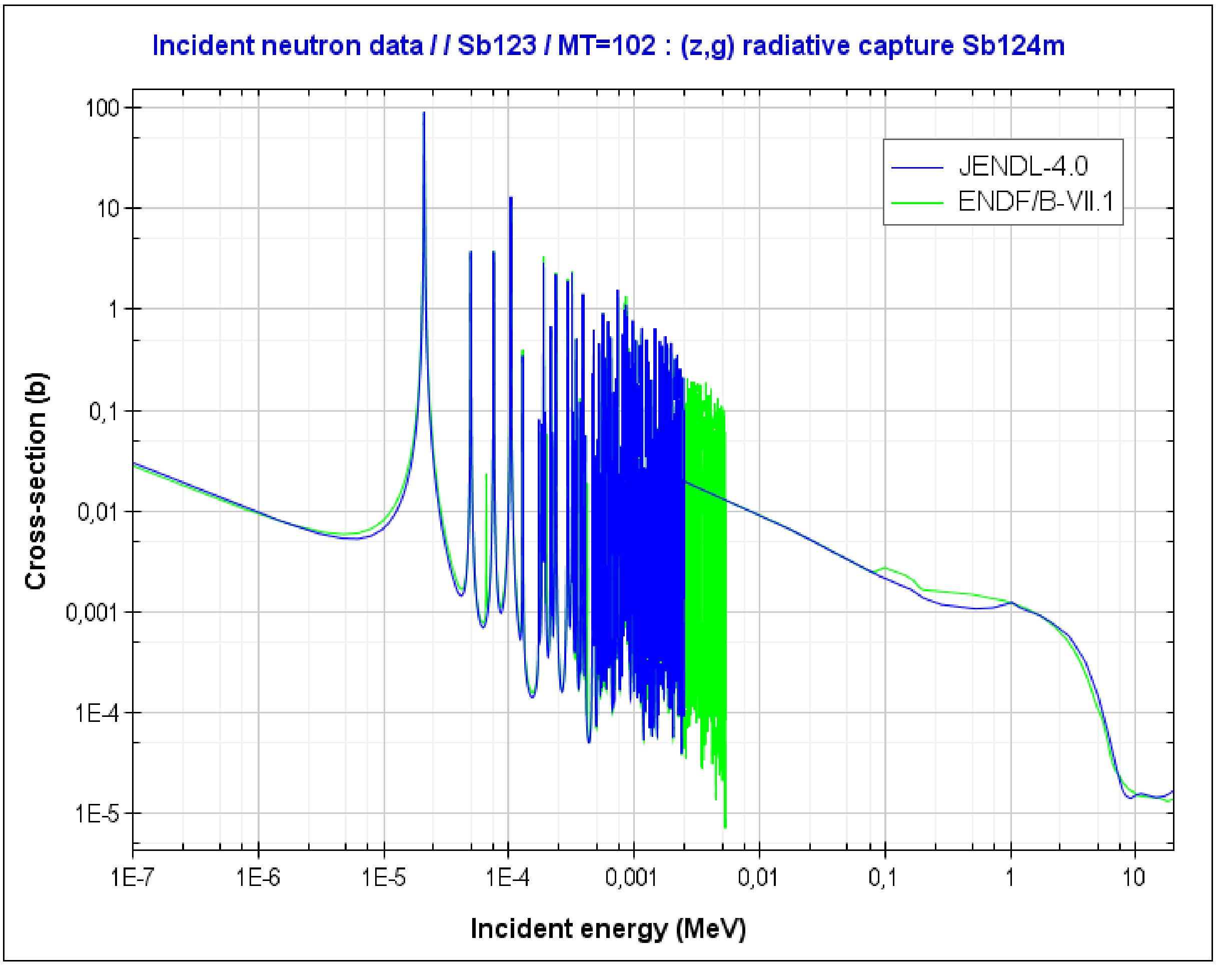
g = 0.999

E_r = 31.93 eV

σ_0 = 0.05954 b

Q_0 = 29.17

σ_h = 0.0000865 b


Incident neutron data / / Sb123 / MT=102 : (z,g) radiative capture Sb124m
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.62. $^{130}Te(n,\gamma)^{131g}Te$

The thermal cross sections and the Q_0 values for the excitation of the residual ^{131g}Te in the ground state are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.185	5.4	-2.5	0.190	2.0	0.1767	-6.8	0.1853	-2.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
2.051	14.2	14.0	1.8	5.8	1.324	-26	1.320	-27

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.4% and is 2.5% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.0%. No branching ratios are given in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries. The branching ratio for thermal incident neutrons is 94.9% by Mughabghab [1]. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are smaller by 6.8% and 2.3%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 14.2% and is larger by 14.0% in comparison with the Kayzero [2] value, which has an uncertainty of 5.8%. The branching ratio is assumed independent of energy and is 94.9% by Mughabghab [1]. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are smaller by 26% and 27%.

The ENDF/B-VII.1 [5] library is selected because its thermal cross section is in better agreement with the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 1.005

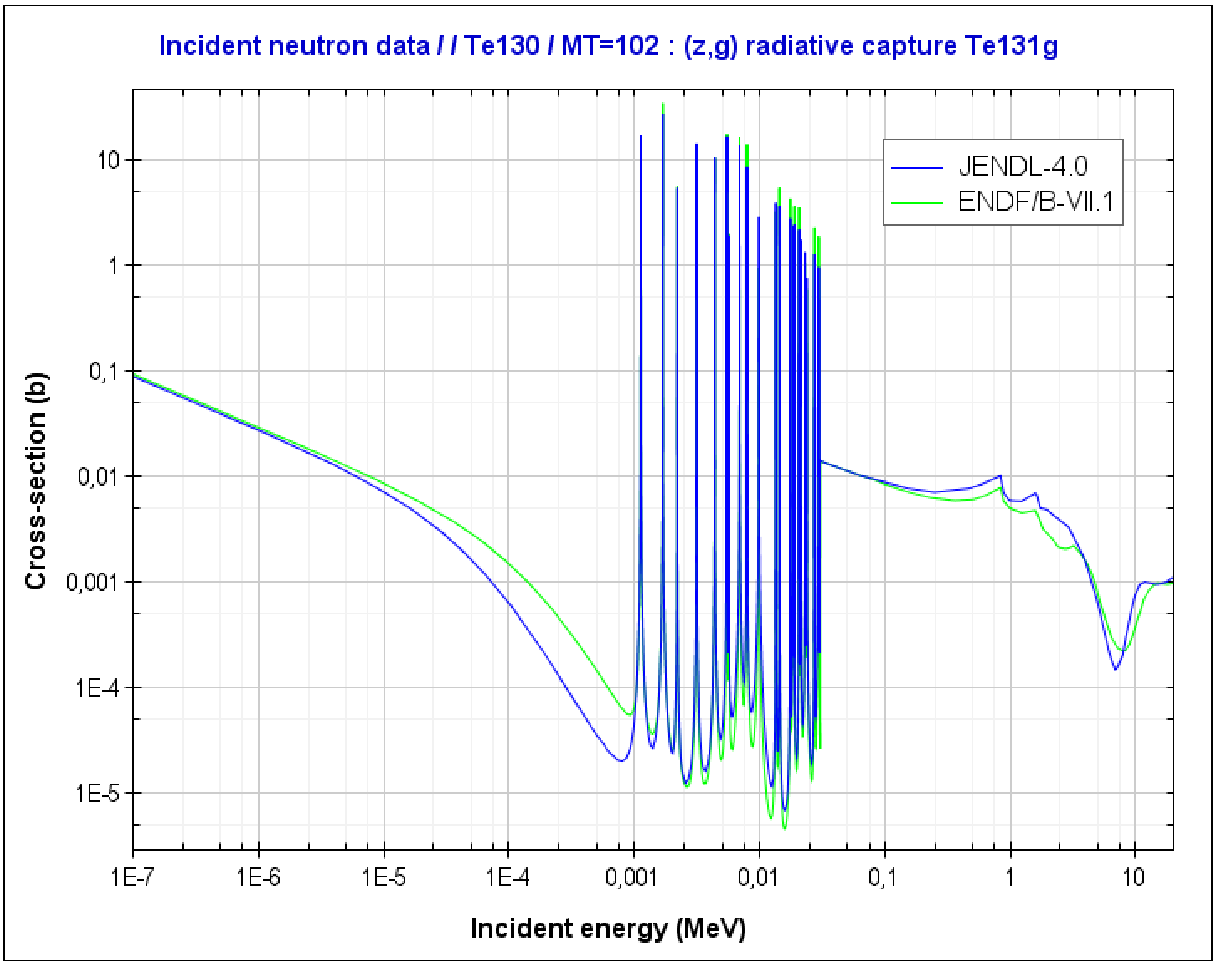
g = 0.998

E_r = 7983eV

σ_0 = 0.1853 b

Q_0 = 1.320

σ_h = 0.00418 b



Incident neutron data / / Te130 / MT=102 : (z,g) radiative capture Te131g
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.63. $^{127}I(n,\gamma)^{128}I$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
6.15	1.0	13.9	5.398	1.6	6.404	18.6	6.147	13.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
25.203	4.0	1.6	24.8	2.7	24.02	-3.2	26.08	5.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.0% and is 13.9% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.6%, but the uncertainty of the gamma-emission probability is not known). The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are larger by 18.6% and 13.9%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.0% and is larger by 1.6% in comparison with the Kayzero [2] value, which has an uncertainty of 2.7%. The value derived from the JENDL-4.0 [4] library is 3.2% smaller and ENDF/B-VII.1 [5] value is 5.2% larger than the Kayzero [2] value.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.989

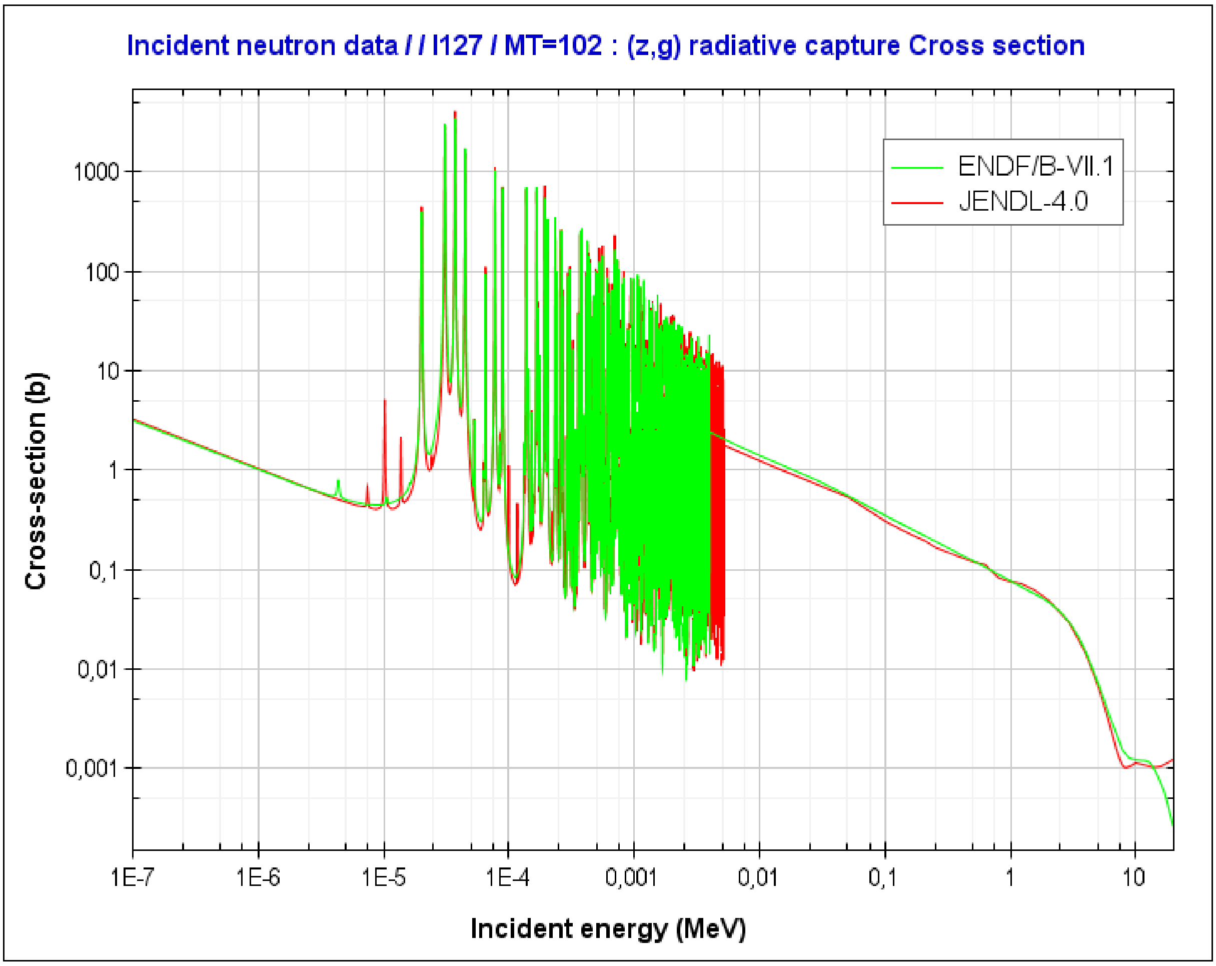
g = 0.998

E_r = 64.34 V

σ_0 = 6.147 b

Q_0 = 26.08

σ_h = 0.0717 b



Incident neutron data / / I127 / MT=102 : (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.64. $^{130}Ba(n,\gamma)^{131}Ba$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
8.7	10.3	2.6	8.48	2.0	8.703	2.6	8.681	2.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
20.23	11.1	-18	24.8	-	20.18	-19	20.03	-19

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 10.3% and is 2.6% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.0%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are larger by 2.6% and 2.3%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 11.1% and is smaller by 18% in comparison with the Kayzero [2] value, which has no uncertainty given. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are both 19% smaller than the Kayzero [2] value.

Note that the abundance of ^{130}Ba is 0.106%. The ENDF/B-VII.1 [5] library is selected, even though the two libraries are practically equivalent. The constants derived from this library are:

F_{cd} = 0.998

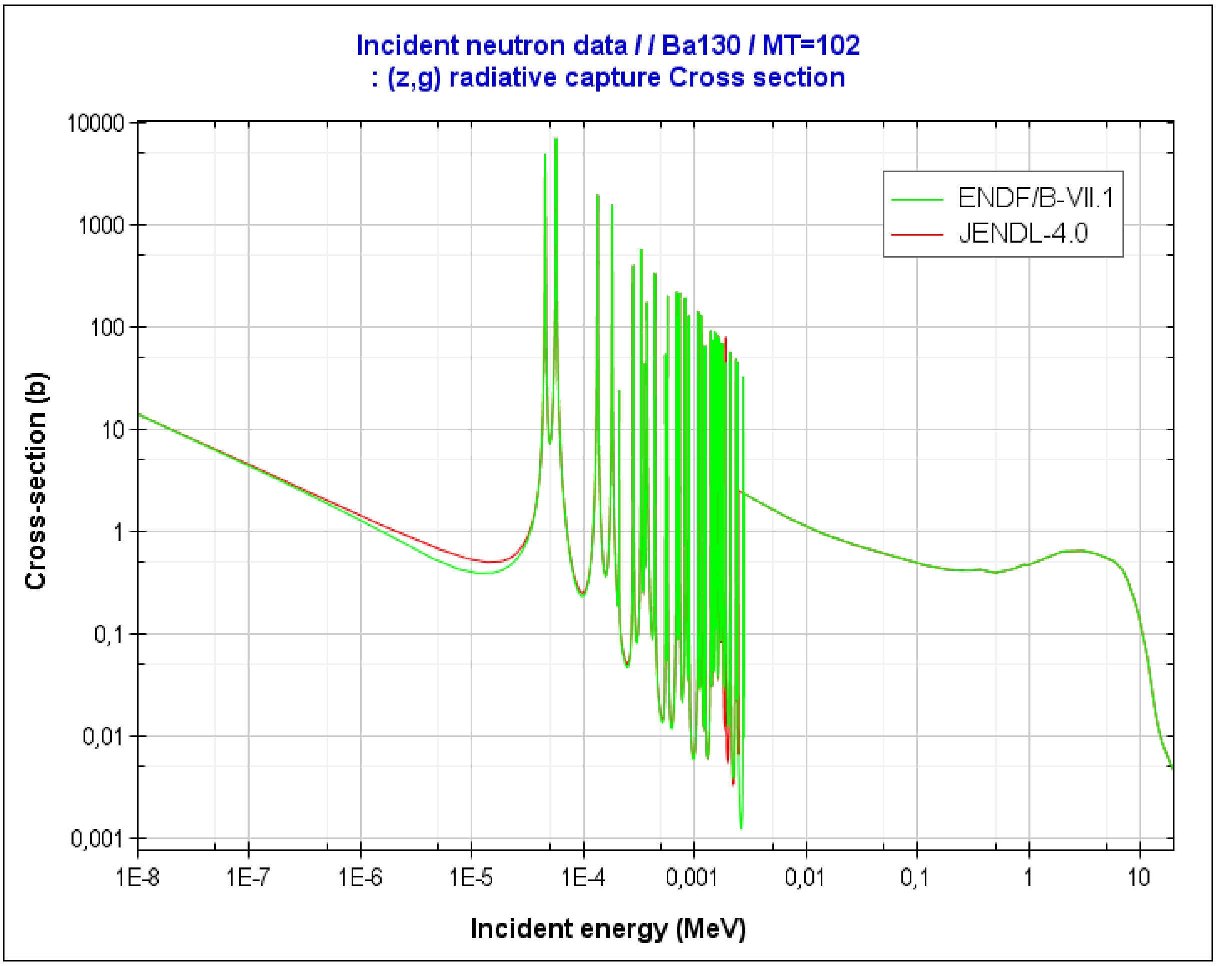
g = 0.997

E_r = 88.33 eV

σ_0 = 8.681 b

Q_0 = 20.03

σ_h = 0.529 b



Incident neutron data / / Ba130 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.65. $^{132}Ba(n,\gamma)^{133m}Ba$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{133m}Ba are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.500	-	-40	0.836	3.5	0.5003	-40	0.4666	-44

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
5.600	0.0	0.0	5.6	-	4.932	-12	9.326	66.5

- Thermal cross section by Mughabghab [1] has no uncertainty given and is 40% smaller than the value derived from the Kayzero [2] library, which has uncertainty of 3.5%. No branching ratios are given in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries. The branching ratio for thermal incident neutrons of 7.14% by Mughabghab [1] is assumed. The value in the JENDL-4.0 [4] library is 40% smaller and the value in the ENDF/B-VII.1 [5] library is 44% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 0.0% and is in perfect agreement with the Kayzero [2] value, which has no uncertainty given. The branching ratio in the epithermal range for the production of the metastable nuclide of 8.0% by Mughabghab [1] is assumed. The value derived from the JENDL-4.0 [4] library is 12% smaller and the value derived from the ENDF/B-VII.1 [5] library is 66.5% larger than the Kayzero [2] value.

Note that the abundance of ^{130}Ba is 0.101%. The ENDF/B-VII.1 [5] library is selected because of more realistic resonance structure and a much better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.988

g = 0.998

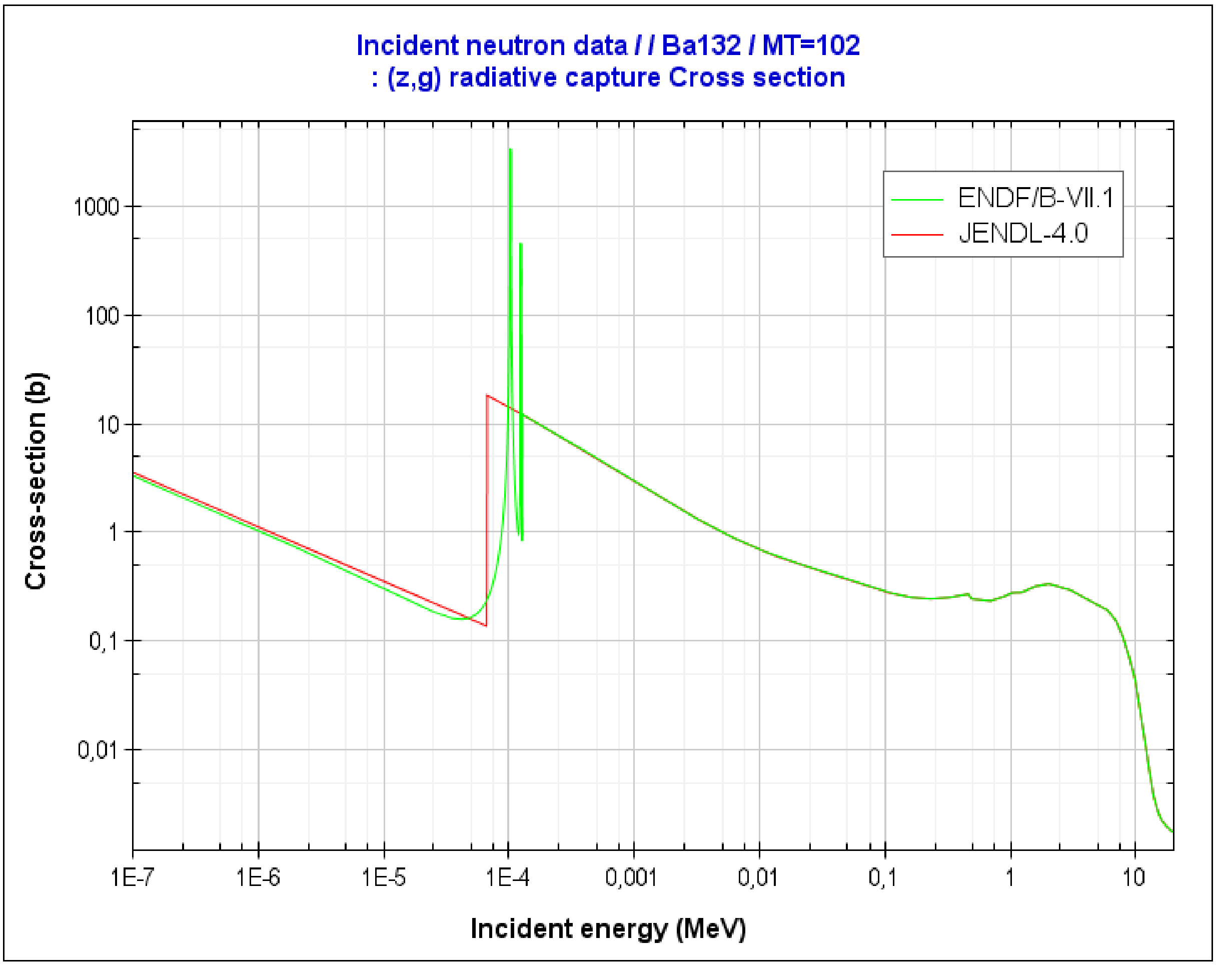
E_r = 218.6 eV

σ_0 = 0.4666 b

Q_0 = 9.326

σ_h = 0.219 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.66. $^{138}Ba(n,\gamma)^{139}Ba$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.404	9.9	-0.3	0.405	0.9	0.4044	-0.2	0.4036	-0.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.792	15.9	-10	0.88	-	0.675	-23	0.658	-25

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 9.9% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.9%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are in perfect agreement with the Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 15.9% and is smaller by 10% in comparison with the Kayzero [2] value, which has no uncertainty given. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are both lower by more than 20%.

The two libraries are equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.016

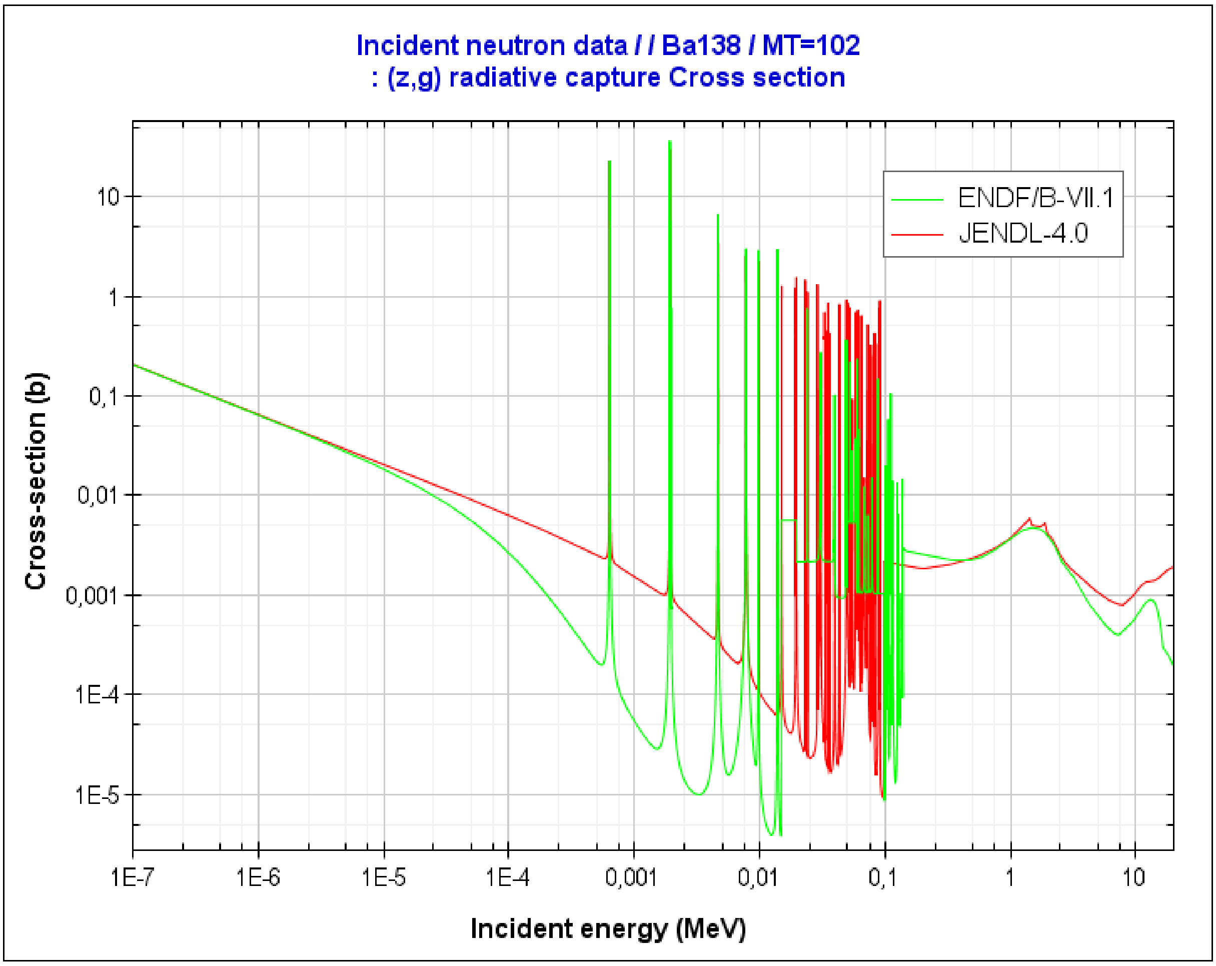
g = 0.998

E_r = 5337 eV

σ_0 = 0.4036 b

Q_0 = 0.658

σ_h = 0.00275 b


Incident neutron data / / Ba138 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.67. $^{139}La(n,\gamma)^{140}La$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
9.04	0.4	-3.9	9.407	0.7	8.942	-4.9	9.043	-3.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.338	5.0	7.9	1.24	-	1.275	2.8	1.227	-1.0

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.4% and is 3.9% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.7%. The value in the JENDL-4.0 [4] library is 4.9% lower while the value in the ENDF/B-VII.1 [5] library is 3.9% lower than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.0% and is larger by 7.9% in comparison with the Kayzero [2] value, which has no uncertainty given. The value in the JENDL-4.0 [4] library is 2.8% higher while the value in the ENDF/B-VII.1 [5] library is 1.0% lower than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because of better consistency with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 1.005

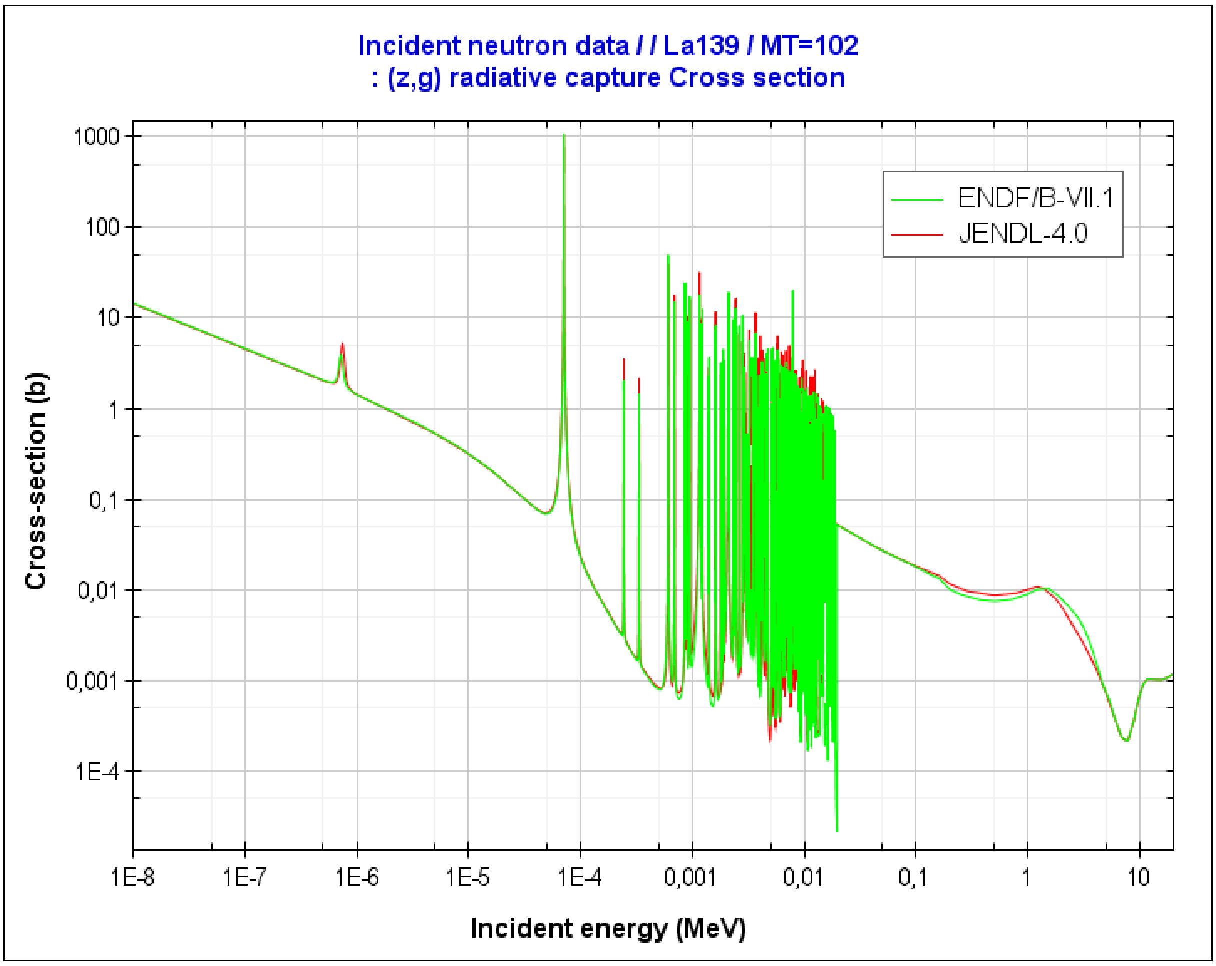
g = 0.998

E_r = 93.04 eV

σ_0 = 9.043 b

Q_0 = 1.227

σ_h = 0.00713 b


Incident neutron data / / La139 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.68. $^{140}Ce(n,\gamma)^{141}Ce$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.58	3.4	0.9	0.575	0.9	0.5705	-0.8	0.5776	0.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.931	9.9	12.2	0.83	-	0.577	-30	0.498	-40

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.4%, the difference from the value derived from the Kayzero [2] library is 0.9%, with quoted uncertainty of 0.9%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are in very good agreement with Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.9% and is larger by 12.2% in comparison with the Kayzero [2] value, which has no quoted uncertainty. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are lower by 30% and 40%, respectively.

The JENDL-4.0 [4] library is selected because the resonance integral is closer to the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 1.018

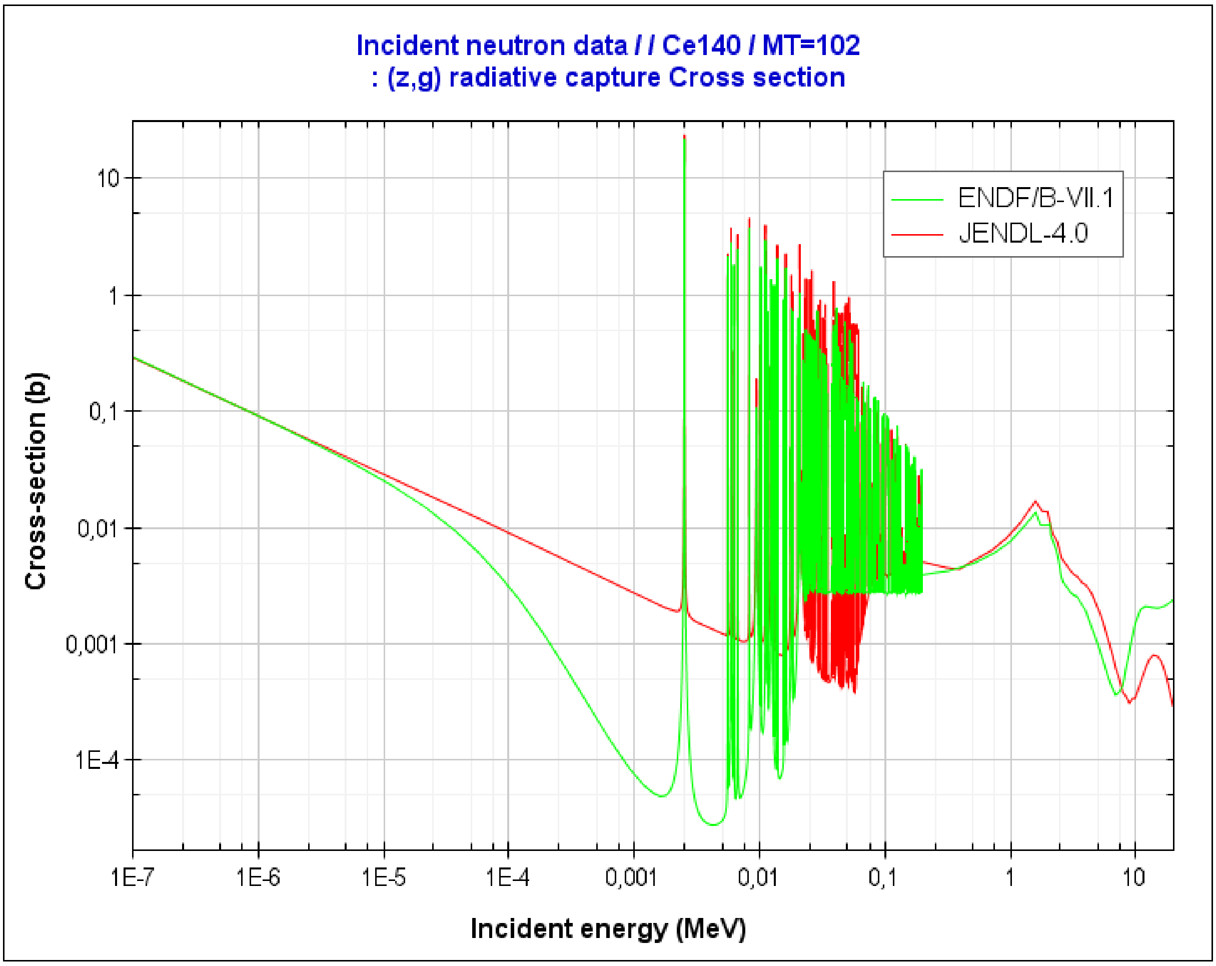
g = 0.999

E_r = 25035 eV

σ_0 = 0.5705 b

Q_0 = 0.577

σ_h = 0.00758 b



Incident neutron data / / Ce140 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
10
1
0,1
0,01
0,001
1E-4
Cross-section (b)
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.69. ^{142}Ce(n,γ)^{143}Ce

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.97	2.1	-0.3	0.97	0.8	0.9614	-1.1	0.9652	-0.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.186	4.8	-1.2	1.2	-	0.9024	-25	0.866	-28

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.1% and is excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.8%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are in very good agreement with Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.8% and is smaller by 1.2% in comparison with the Kayzero [2] value, which has no uncertainty given. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are lower by 25% and 28%, respectively.

The two libraries are practically equivalent. The JENDL-4.0 [4] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.009

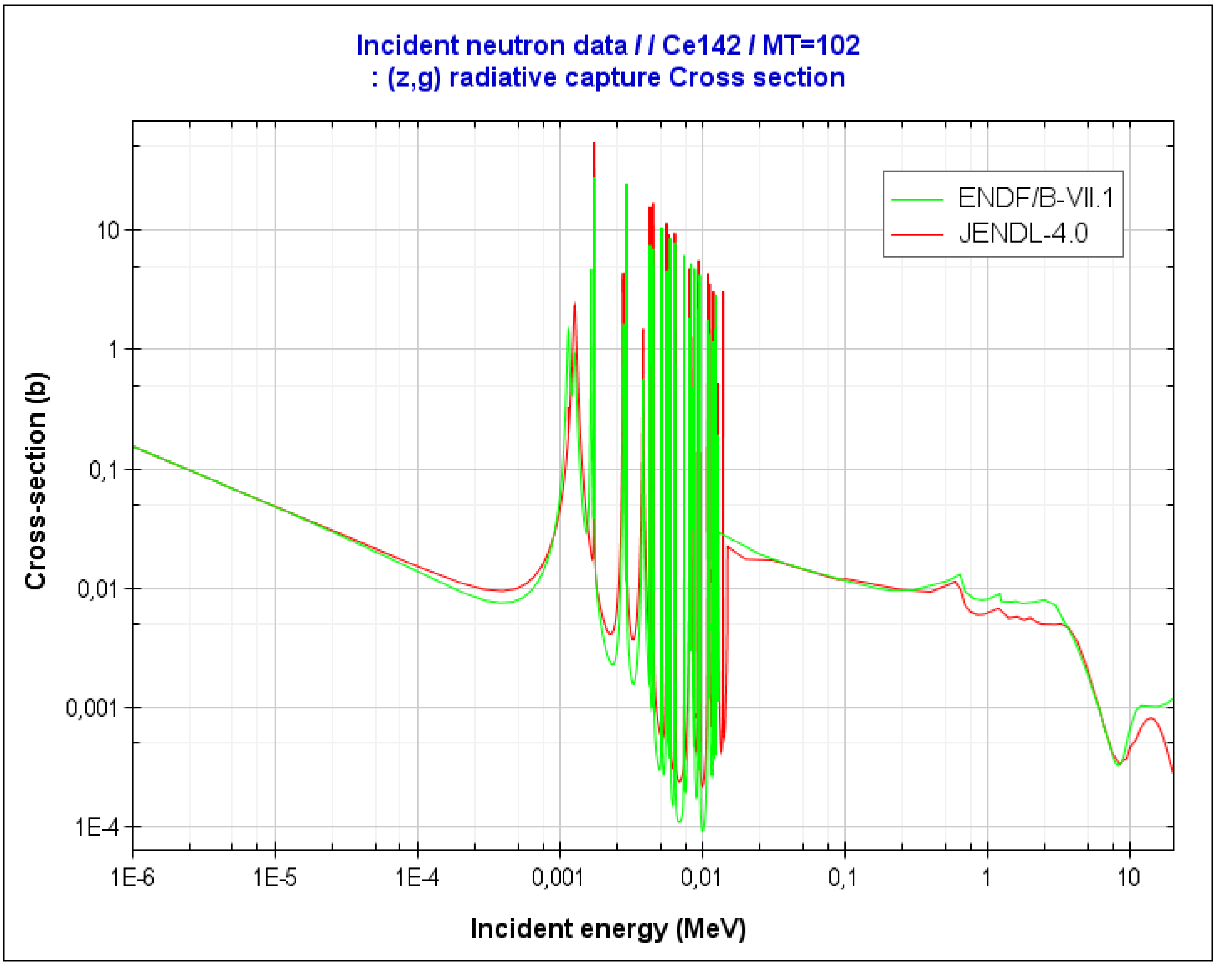
g = 0.999

E_r = 3327 eV

σ_0 = 0.9614 b

Q_0 = 0.9024

σ_h = 0.00604 b


Incident neutron data / / Ce142 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10
1
0,1
0,01
0,001
1E-4
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.70. ^{146}Nd(n,γ)^{147}Nd

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.49	4.0	13.2	1.32	1.9	1.490	13.2	1.490	13.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.725	6.8	-14	2.0	1.2	1.785	-11	1.934	-3.3

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 4.0% and is 13.2% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.9%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are both 13.2% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.8% and is smaller by 14% in comparison with the Kayzero [2] value, which has an uncertainty of 1.2%. The values derived ftom the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller by 11% and 3.3%, respectively.

Both libraries are equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.001

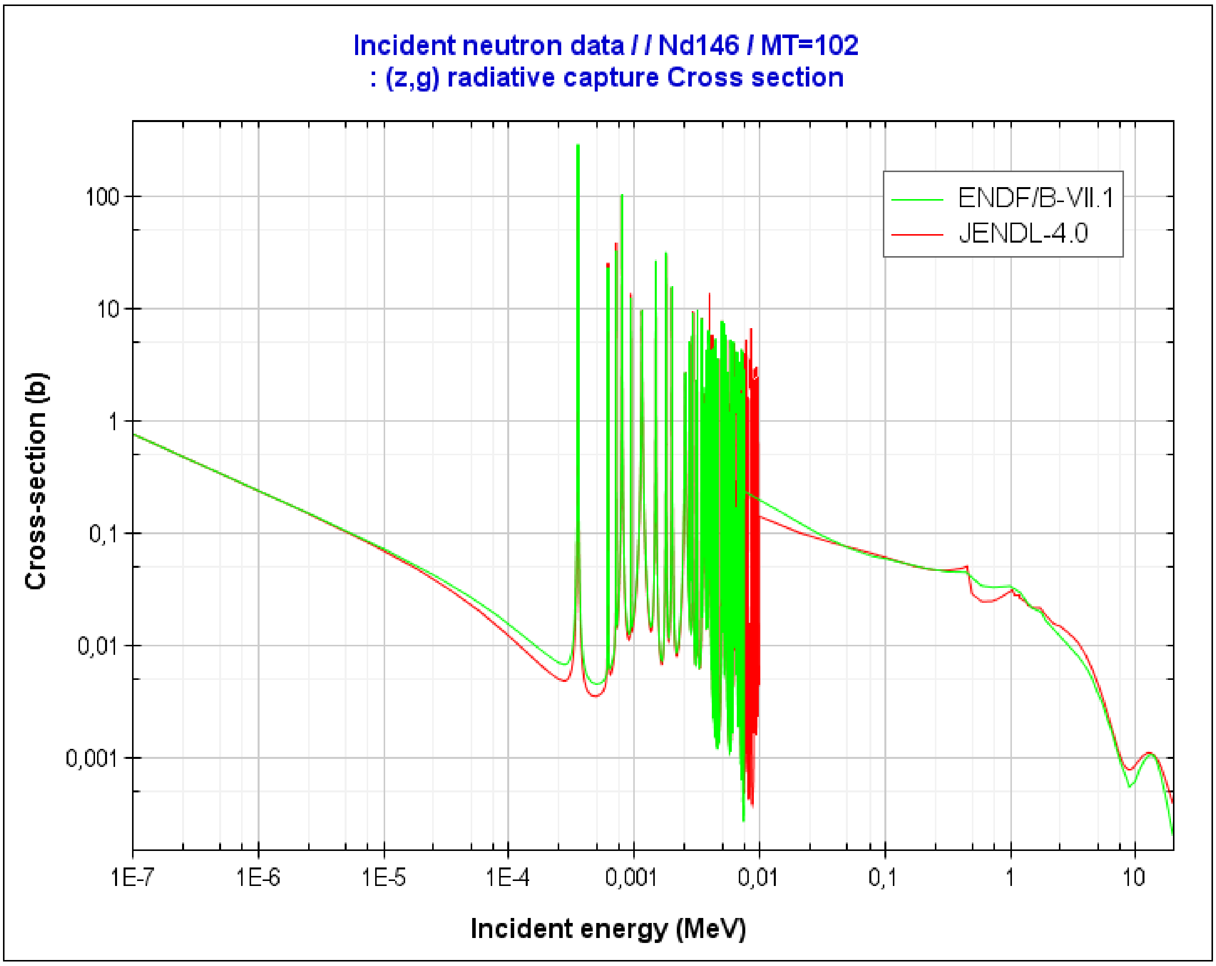
g = 0.998

E_r = 1766 eV

σ_0 = 1.490 b

Q_0 = 1.934

σ_h = 0.0223 b



Incident neutron data / / Nd146 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.71. $^{148}Nd(n,\gamma)^{149}Nd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
2.58	2.7	4.6	2.47	2.2	2.582	4.7	2.585	4.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
6.008	10.1	18.3	5.08	2.5	5.345	5.2	6.174	21.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.7% and is 4.6% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.2%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie very close to the Mughabghab [1] value and are 4.7% and 4.8% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 10.1% and is larger by 18.3% in comparison with the Kayzero [2] value, which has an uncertainty of 2.5%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are higher by 5.2% and 21.5%, respectively.

The ENDF/B-VII.1 [5] library is selected for consistency with the other Nd isotopes, even though the Q_0 value from the JENDL-4.0 [4] library seems to be closer to the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 0.993

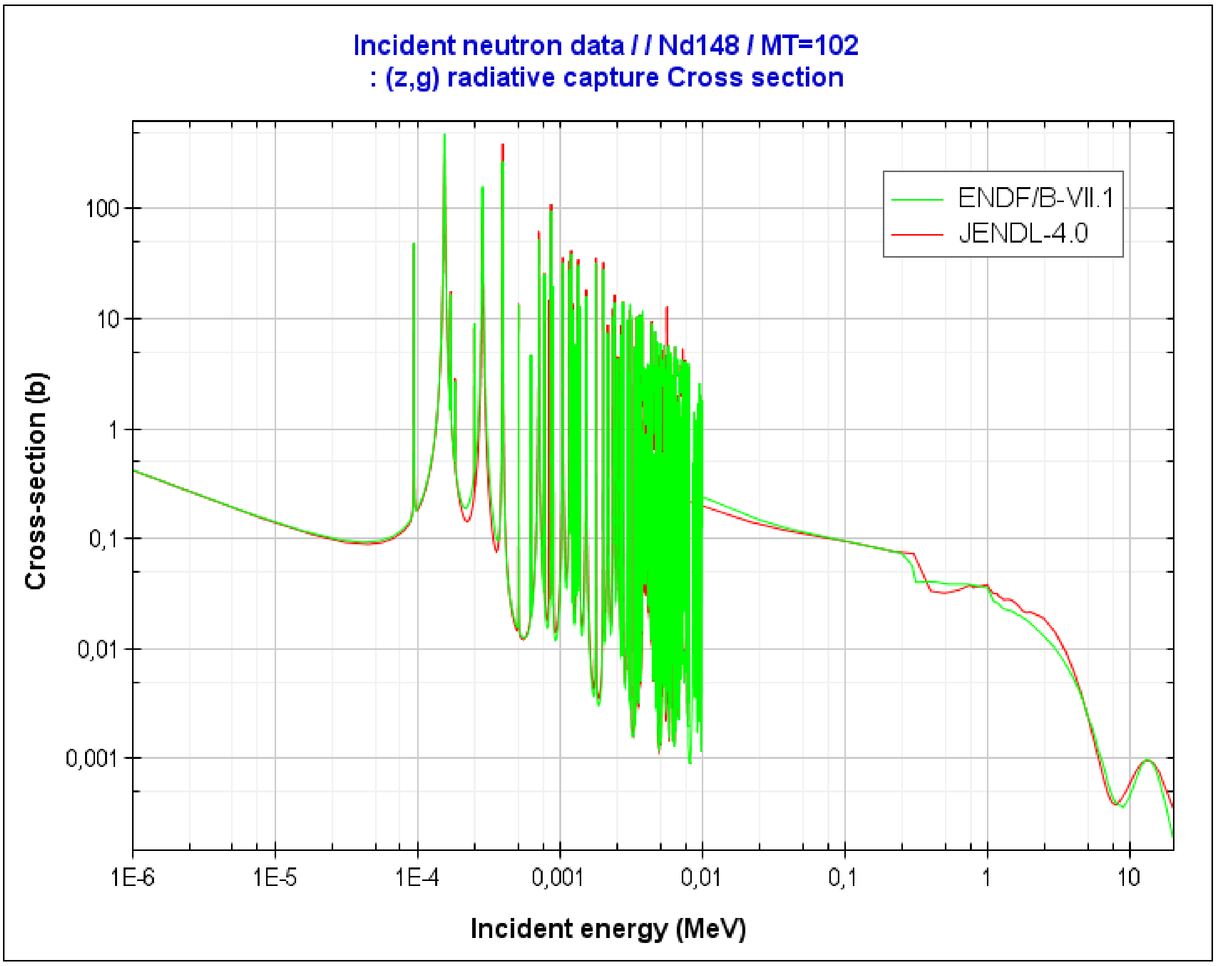
g = 0.999

E_r = 278.6 eV

σ_0 = 2.585 b

Q_0 = 6.174

σ_h = 0.0243 b


Incident neutron data / / Nd148 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.72. $^{150}Nd(n,\gamma)^{151}Nd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.04	3.8	-0.8	1.048	5.6	1.041	-0.7	1.041	-0.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
14.62	6.5	18.8	12.3	0.8	13.58	10.4	15.15	23.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.8% and is in very good agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 5.6%. The values from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are also in very good agreement.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.5% and is larger by 18.8% in comparison with the Kayzero [2] value, which has an uncertainty of 0.8%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are 10.4% and 23.2% higher, the latter being close to the Mughabghab [1] value.

The ENDF/B-VII.1 [5] library is selected for consistency with the other Nd isotopes and because the shape below the first resonance seems better, even though the Q_0 value from the JENDL-4.0 [4] library lies closer to the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 0.999

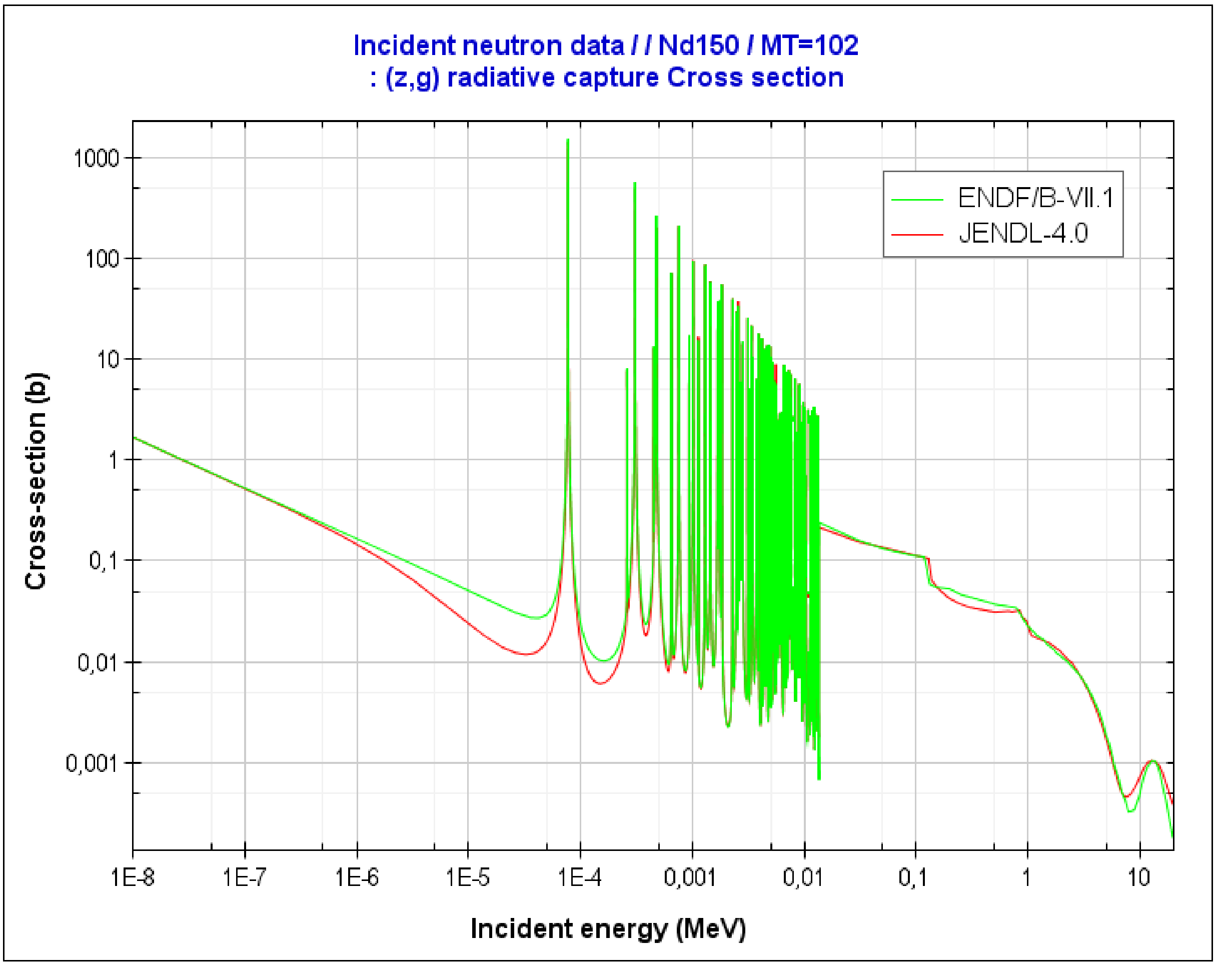
g = 0.998

E_r = 204.6 eV

σ_0 = 1.041 b

Q_0 = 15.15

σ_h = 0.0196 b



Incident neutron data / / Nd150 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
1000
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.73. $^{154}Sm(n,\gamma)^{155}Sm$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
8.3	6.0	7.6	7.715	4.5	8.396	8.8	8.326	7.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
4.337	12.6	0.9	4.3	7.0	4.323	0.5	4.314	0.3

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 6.0% and is 7.6% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 4.5%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the Mughabghab [1] velue and are 8.8% and 7.9% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 12.6% and is in very good agreement with the Kayzero [2] value, which has an uncertainty of 7.0%. The agreement of the values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] is equally good.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.992

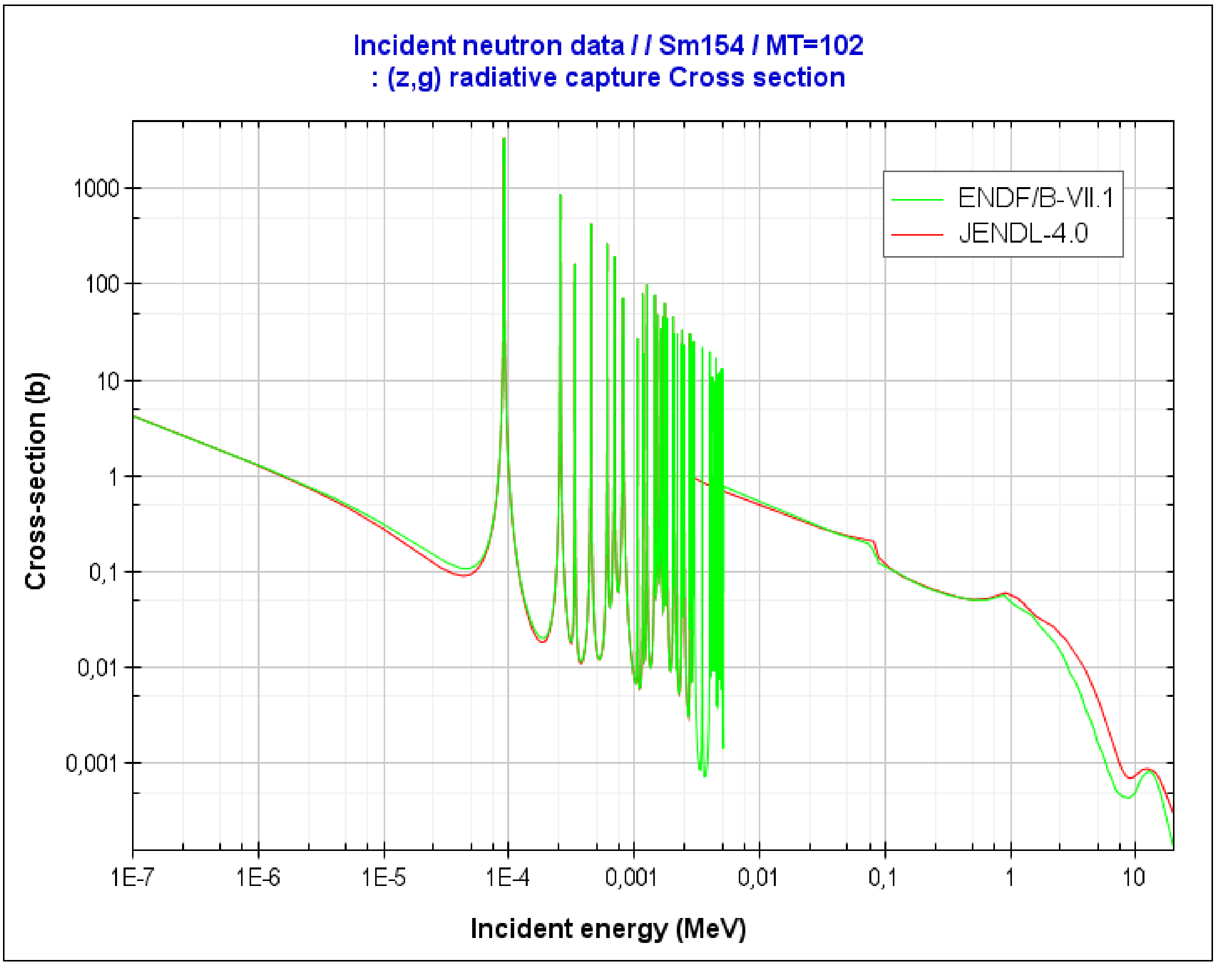
g = 0.998

E_r = 179.7 eV

σ_0 = 8.326 b

Q_0 = 4.314

σ_h = 0.00328 b



Incident neutron data / / Sm154 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
1000
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.74. $^{151}Eu(n,\gamma)^{152}Eu$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
9200	2.2	36.1	6762	1.4	9174	35.7	9189	35.9

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.359	9.3	-71	1.25	-	0.2523	-80	0.2734	-78

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.2%, but is larger than the value derived from the Kayzero [2] library by 36.1%, while the quoted uncertainty of this value is 1.4%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are both 36% larger than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.3% and is smaller by 71% in comparison with the Kayzero [2] value, for which no uncertainty is quoted. The values in the JENDL-4.0 [4] and ENDF/B-VII.1 [5] libraries are smaller by nearly 80%. Note that the Cd correction factor is very large and this is probably one of the reasons for the discrepancy.

The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.818

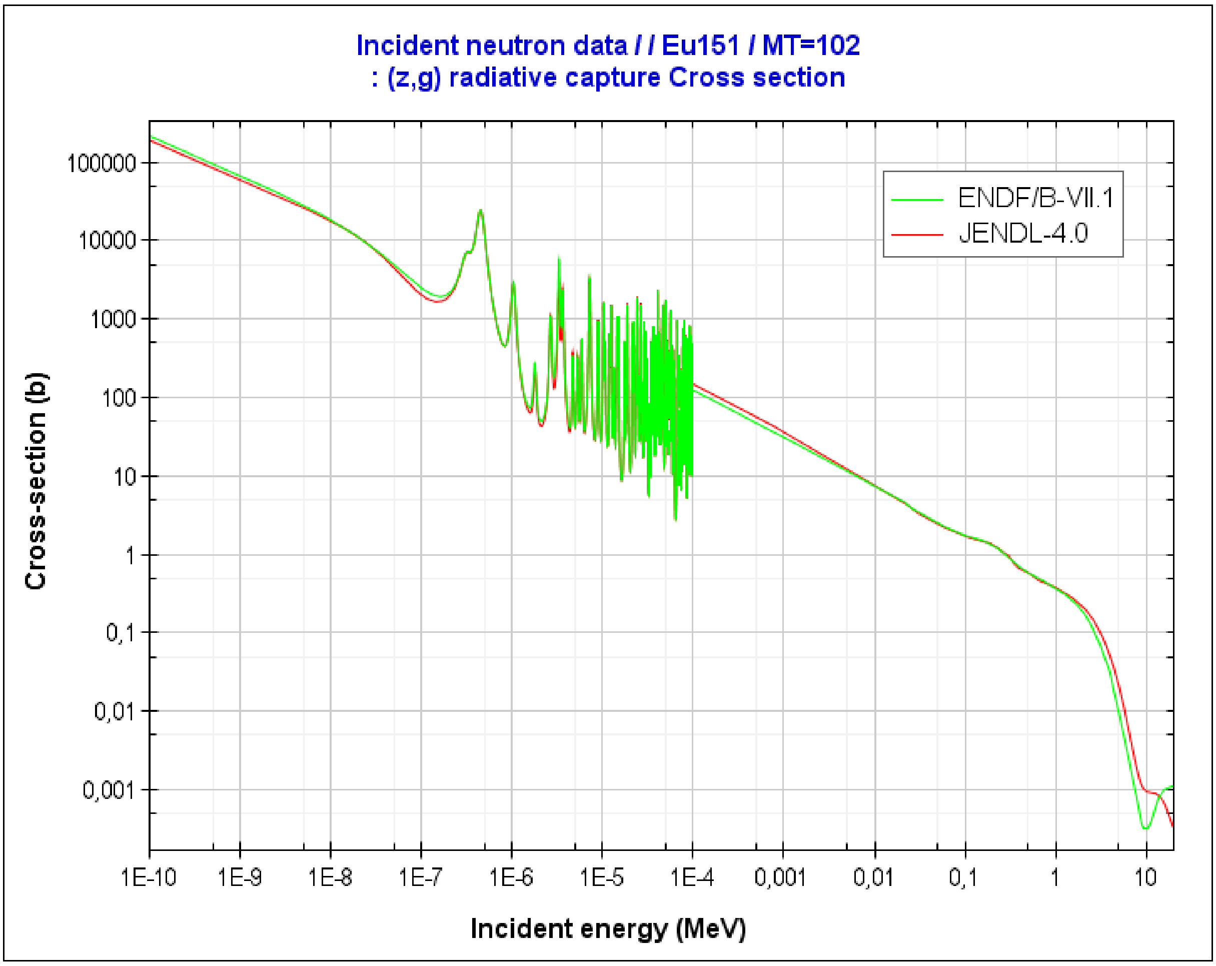
g = 0.945

E_r = 4.945 eV

σ_0 = 9189 b

Q_0 = 0.2734

σ_h = 0.333 b


Incident neutron data / / Eu151 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100000
10000
1000
100
10
1
0,1
0,01
0,001
1E-10
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.75. $^{151}Eu(n,\gamma)^{152m}Eu$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{152m}Eu are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
3304	6.1	2.6	3222	7.2	3295	2.3	3300	2.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.542	9.9	-55	1.2	-	0.3814	-68	0.4132	-66

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 6.1% and is 2.6% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 7.2%. The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries do not include the branching ratio. The branching ratio for thermal incident neutrons of 35.9% by Mughabghab [1] is assumed. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are about 2.4% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.9% and is smaller by 55% in comparison with the Kayzero [2] value, which has no uncertainty given. The branching ratio in the epithermal range for the production of the metastable nuclide of 54.4% by Mughabghab [1] is assumed. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are about 67% smaller than the Kayzero [2] value. Note the large Cd factor.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.818

g = 0.945

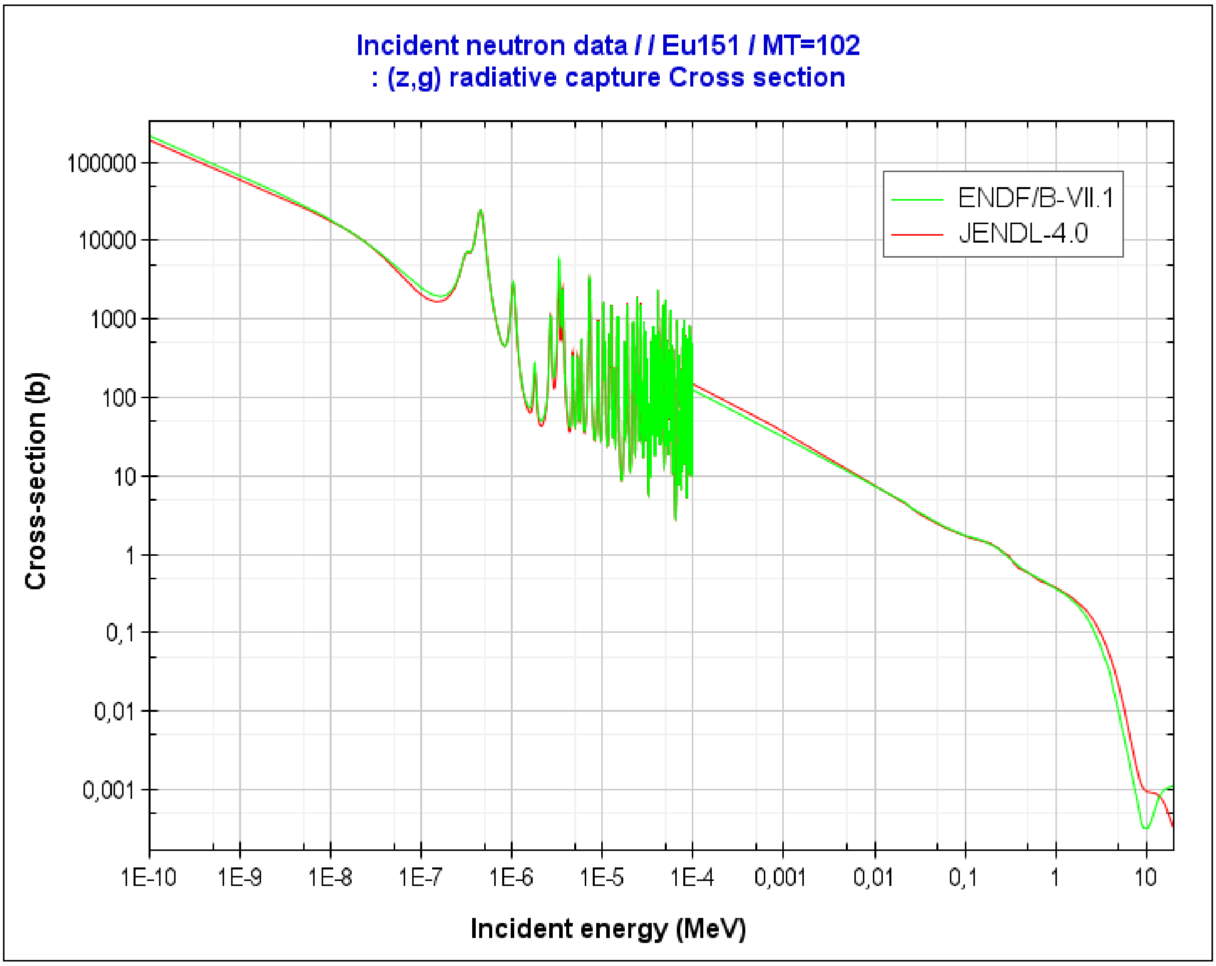
E_r = 4.945 eV

σ_0 = 3300 b

Q_0 = 0.4132

σ_h = 0.181 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.76. $^{153}Eu(n,\gamma)^{154}Eu$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
312	41.7	0.6	310	3.9	312.8	0.9	358.1	15.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
4.551	42.3	-20	5.66	-	4.498	-21	3.949	-30

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 41.7% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.9%. The value in the JENDL4 library is also in very good agreement with the Kayzero [2] value, while the ENDF/B-VII.1 [5] value is 15.5% higher.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 42.3% and is smaller by 20% in comparison with the Kayzero [2] value, which has no uncertainty given. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller by 21% and 30%, respectively.

The JENDL-4.0 [4] library is selected because it agrees better with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.995

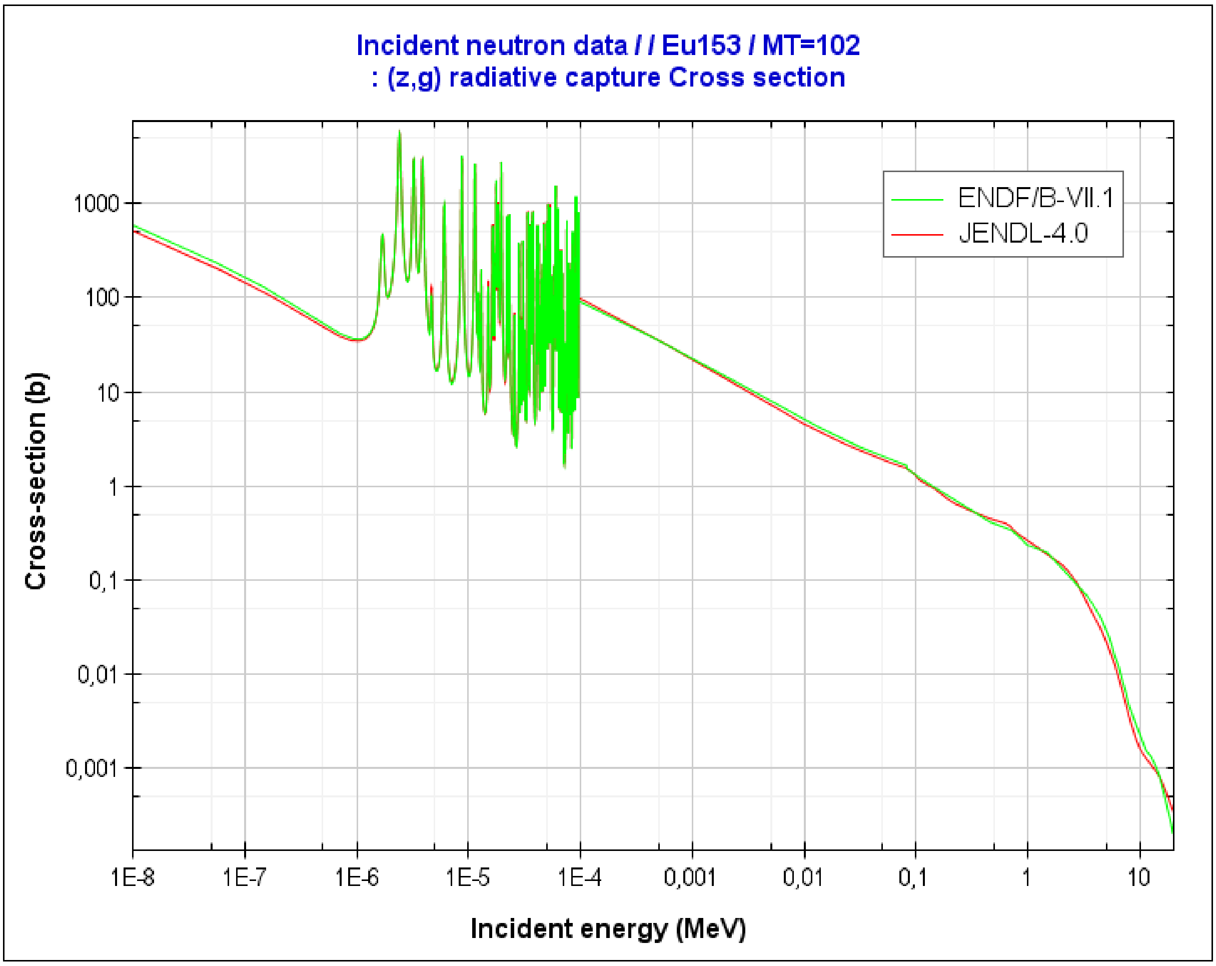
g = 0.985

E_r = 9.549 eV

σ_0 = 312.8 b

Q_0 = 4.498

σ_h = 0.238 b


Incident neutron data / / Eu153 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.77. $^{152}Gd(n,\gamma)^{153}Gd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
735	2.7	-3.2	759.3	6.1	735.2	-3.2	735.3	-3.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
2.748	8.4	257	0.77	15	1.250	62	0.742	-3.7

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.7% and is smaller than the value derived from the Kayzero [2] library by 3.2%, where the quoted uncertainty of the Kayzero [2] value is 6.1%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] evaluations are in very good agreement with Mughabghab [1] and slightly smaller than the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 8.4% and is larger by more than a factor of three in comparison with the Kayzero [2] value, which has an uncertainty of 15%. The value derived from the JENDL-4.0 [4] library is 62% higher, but the value derived from the ENDF/B-VII.1 [5] is only slightly smaller than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because the Q_0 value agrees better with the Kayzero [2] database. The constants derived from this library are:

F_{cd} = 1.014

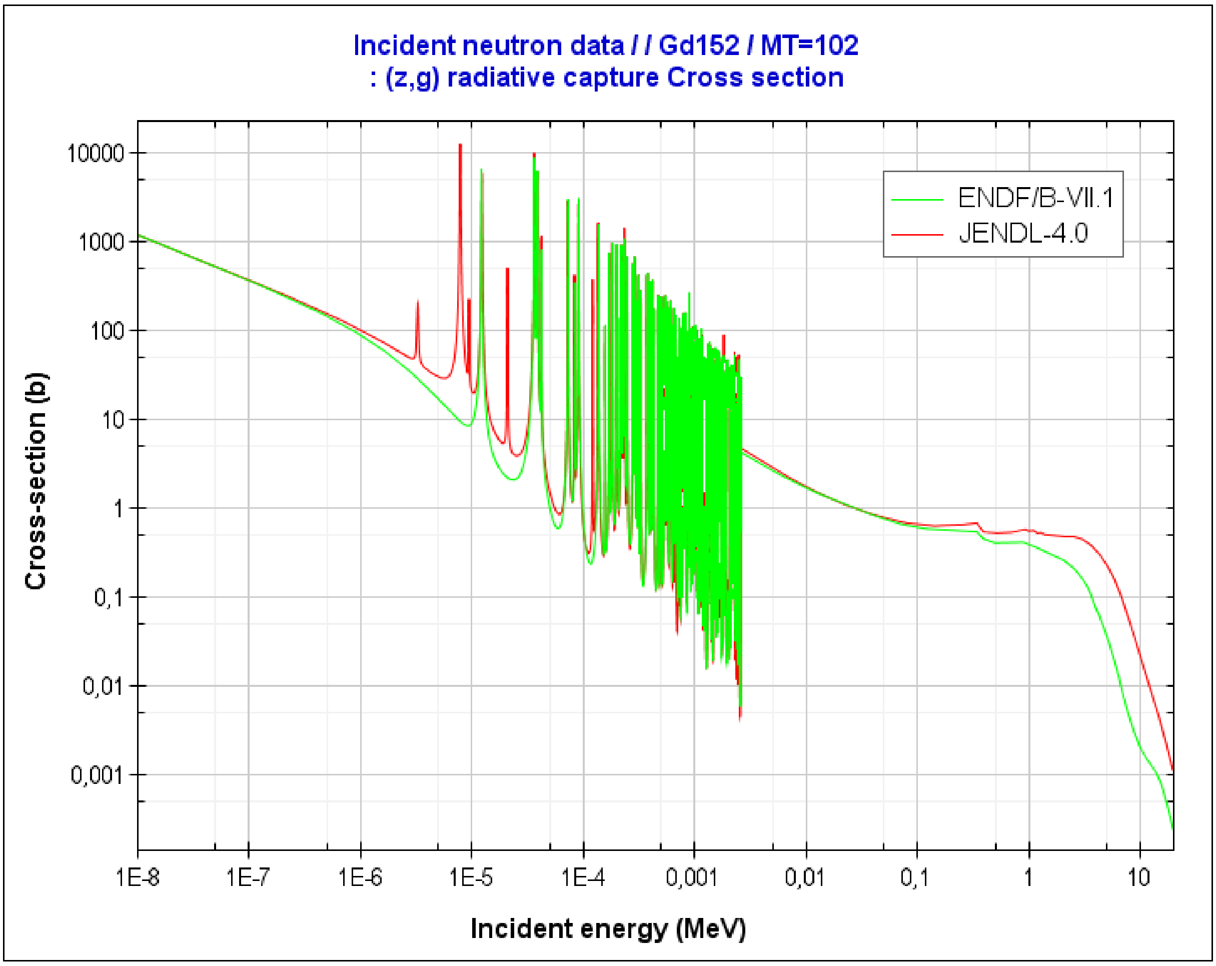
g = 0.995

E_r = 120.1 eV

σ_0 = 735.3 b

Q_0 = 0.742

σ_h = 0.286 b


Incident neutron data / / Gd152 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.78. $^{158}Gd(n,\gamma)^{159}Gd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
2.2	9.1	0.7	2.185	1.6	2.201	0.7	2.203	0.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
33.18	13.2	11.0	29.9	3.1	32.71	9.4	30.80	3.0

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 9.1% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.6%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are also in very good agreement.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 13.2% and is larger by 11.0% in comparison with the Kayzero [2] value, which has an uncertainty of 3.1%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are larger by 9.4% and 3.0%, respectively.

The ENDF/B-VII.1 [5] library is selected because its Q_0 value agrees slightly better with the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 0.999

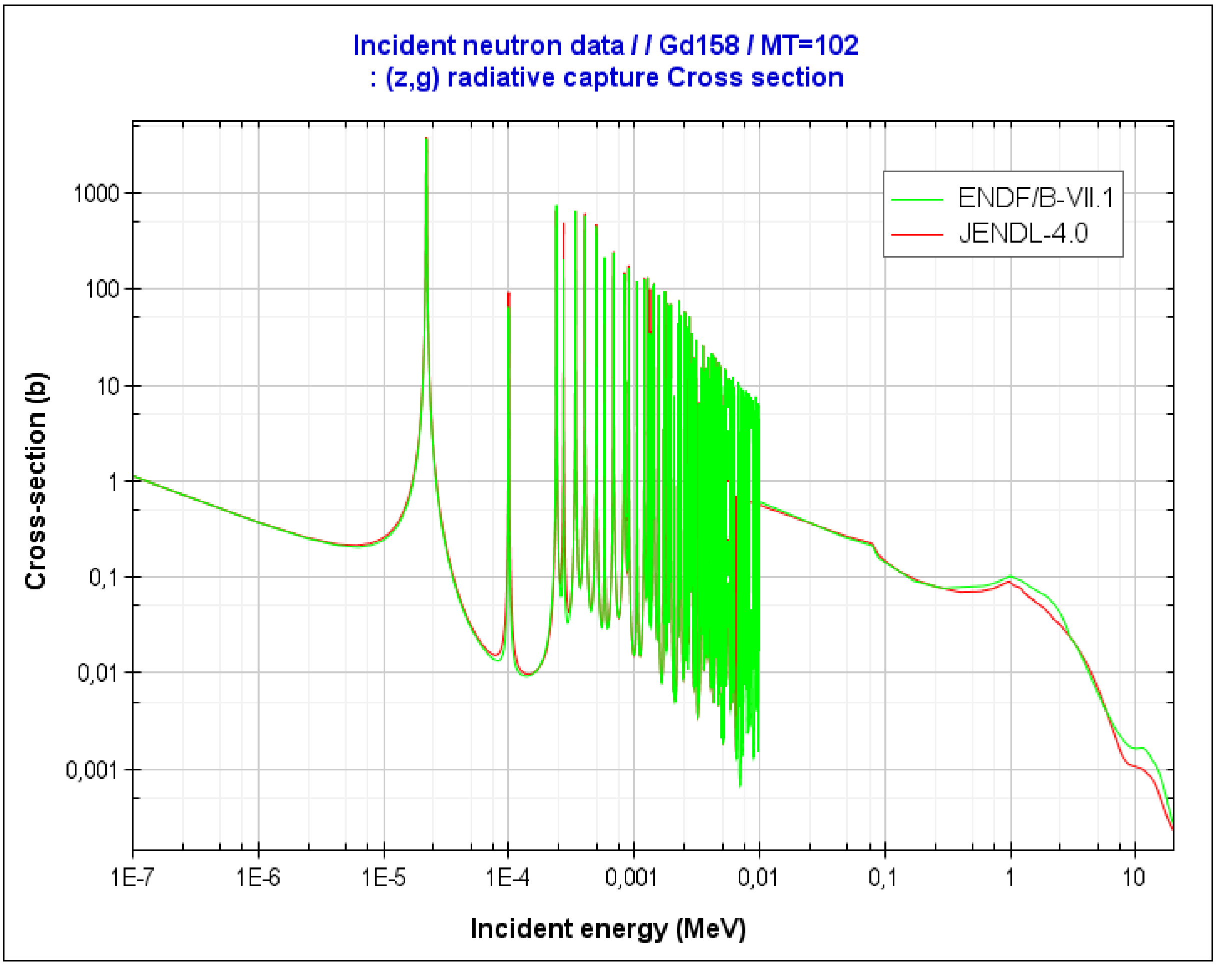
g = 0.999

E_r = 48.08 eV

σ_0 = 2.203 b

Q_0 = 30.80

σ_h = 0.0617 b


Incident neutron data / / Gd158 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.79. $^{160}Gd(n,\gamma)^{161}Gd$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
1.4	21.4	-10	1.559	1.6	0.7856	-50	1.410	-9.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
5.286	25.3	38.0	3.83	1.9	14.99	292	5.727	50

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 21.4% and is 10% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.6%. The value in the JENDL-4.0 [4] library is significantly smaller, while the value in the ENDF/B-VII.1 [5] library is smaller by 9.6% compared to the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 25.3% and is larger by 38.0% in comparison with the Kayzero [2] value, which has an uncertainty of 1.9%. The Q_0 value in the JENDL-4.0 [4] library is significantly larger (partly due to the smaller thermal cross section), while the value in the ENDF/B-VII.1 [5] library is larger by “only” 50% compared to the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because of a smaller contradiction with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.979

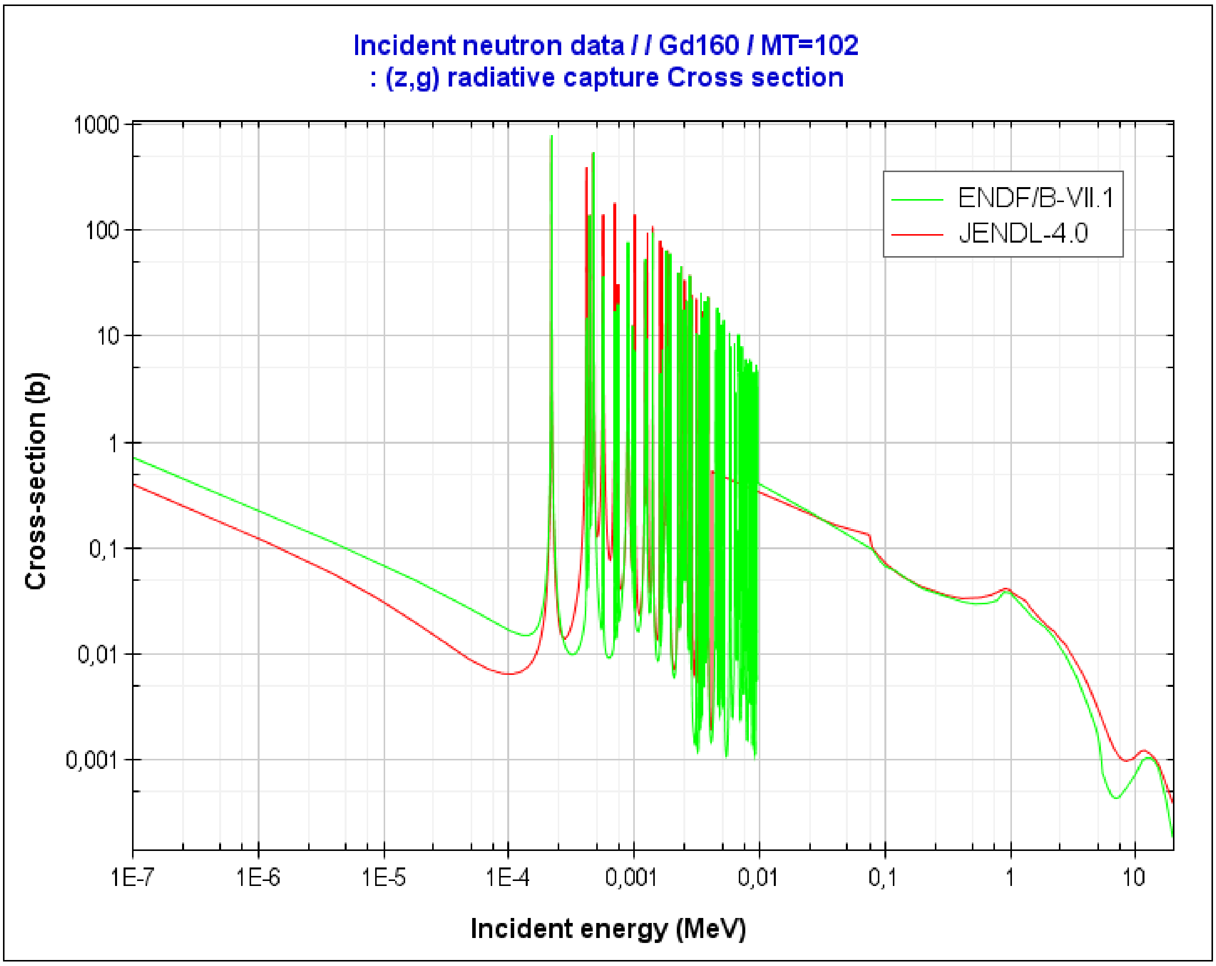
g = 0.999

E_r = 698.5 eV

σ_0 = 1.410 b

Q_0 = 5.727

σ_h = 0.0217 b



Incident neutron data / / Gd160 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.80. $^{159}Tb(n,\gamma)^{160}Tb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
23.4	1.7	-2.3	23.95	1.6	23.14	-3.4	23.36	-2.5

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
17.86	5.1	-0.2	17.9	3.8	17.65	-1.4	17.71	-1.1

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.7% and is 2.3% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.6%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller by 3.4% and 2.5%, respectively.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.1% and is in excellent agreement with the Kayzero [2] value, which has an uncertainty of 3.8%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are also in very good agreement with the Kayzero [2] value.

Both libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.992

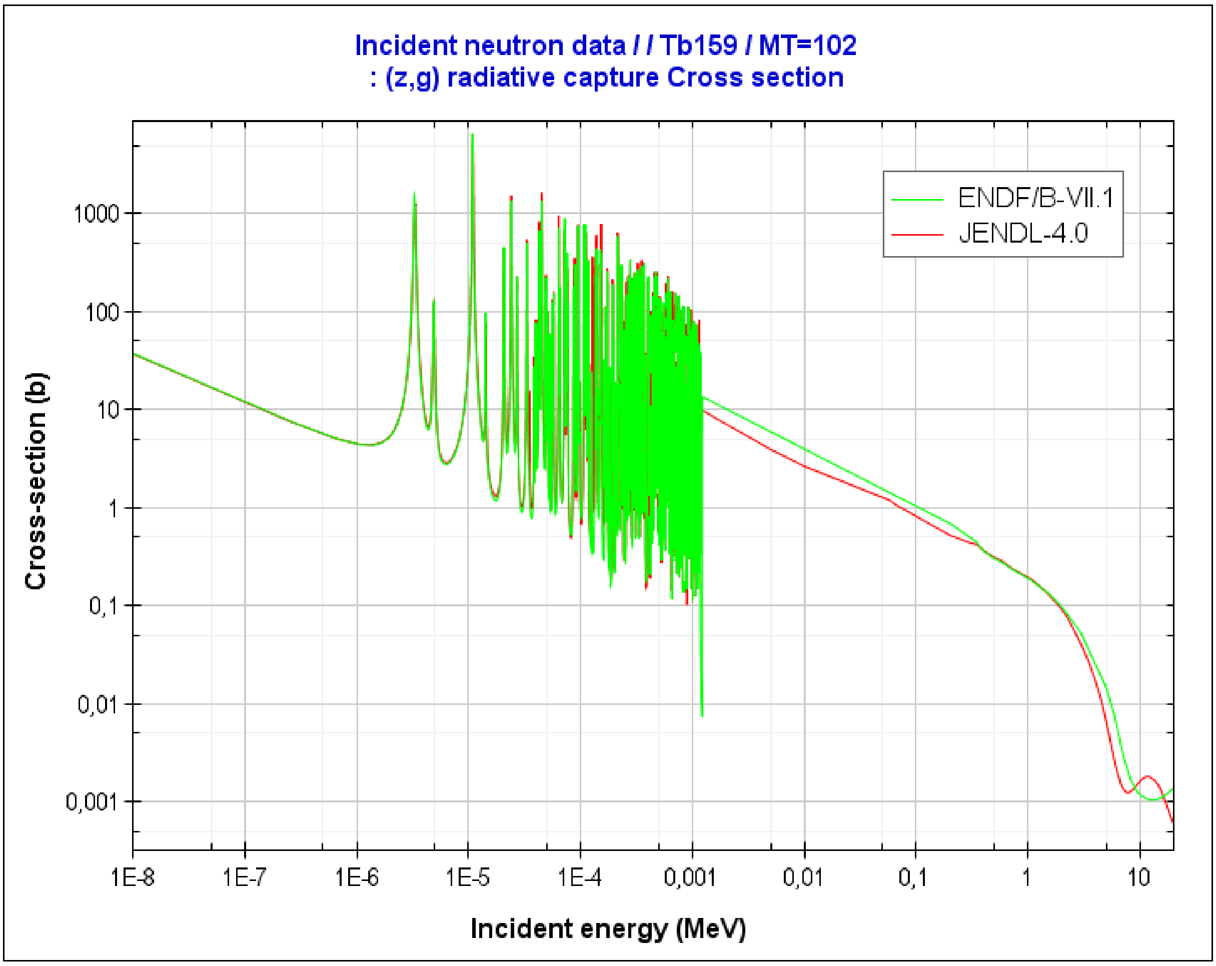
g = 1.000

E_r = 24.98 eV

σ_0 = 23.36 b

Q_0 = 17.71

σ_h = 0.179 b


Incident neutron data / / Tb159 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.81. $^{164}Dy(n,\gamma)^{165}Dy$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
2650	2.6	4.6	2533	2.3	2652	4.7	2654	4.8

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.129	6.4	-32	0.19	-	0.1135	-40	0.1142	-40

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.6% and is larger than the value derived from the Kayzero [2] library by 4.6%. The quoted uncertainty of the Kayzero [2] value is 2.3%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] values are in very good agreement with the Mughabghab [1] value and slightly bigger than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.4%, but is smaller by 32% from the Kayzero [2] value, for which no uncertainty is quoted. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller than the Kayzero [2] value by 40%, in fact even smaller than the value by Mughabghab [1].

The two major evaluations are equivalent. Arbitrarily the ENDF/B-VII.1 [5] library is selected, but it would be necessary to identify the reasons for the large discrepancies in the Q_0 values. The constants derived from the ENDF/B-VII.1 [5] library are:

F_{cd} = 1.104

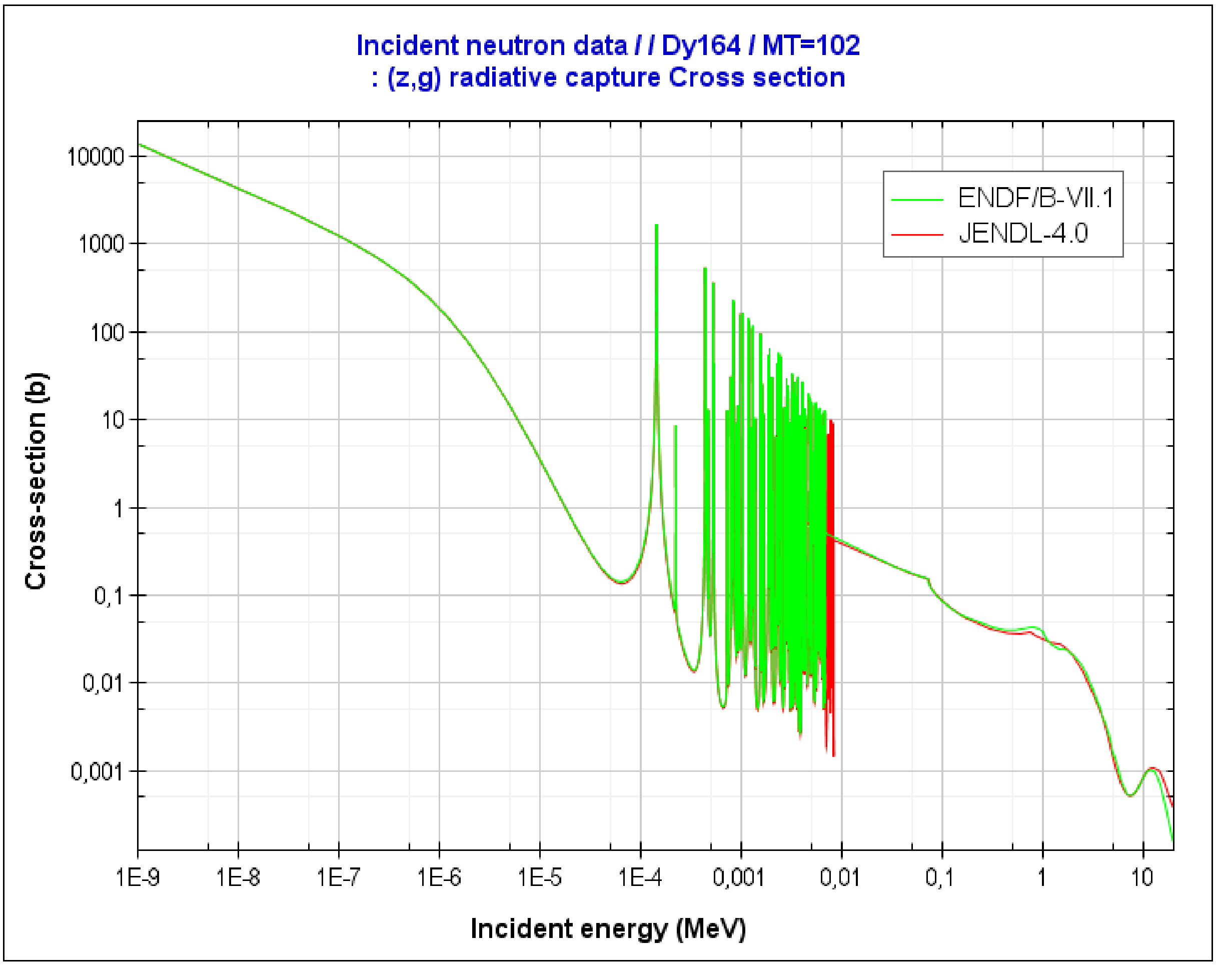
g = 0.986

E_r = 6.262 eV

σ_0 = 2654 b

Q_0 = 0.1142

σ_h = 0.0261 b



Incident neutron data / / Dy164 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.82. $^{165}Ho(n,\gamma)^{166}Ho$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JEFF-3.1 [6]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
61.2	1.8	3.9	58.89	3.4	63.47	7.8	64.71	9.9

Mughabghab [1]			Kayzero [2]		JEFF-3.1 [6]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
10.62	3.8	-2.6	10.9	2.4	10.63	-2.5	10.54	-3.3

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.8% and is 3.9% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.4%. The JENDL-4.0 [4] library does not contain this nuclide. The values from the JEFF-3.1 [6] and the ENDF/B-VII.1 [5] libraries are 7.8% and 9.9% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.8% and is smaller by 2.6% in comparison with the Kayzero [2] value, which has an uncertainty of 2.4%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the Mughabghab [1] value and are 2.5% and 3.3% smaller than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.994

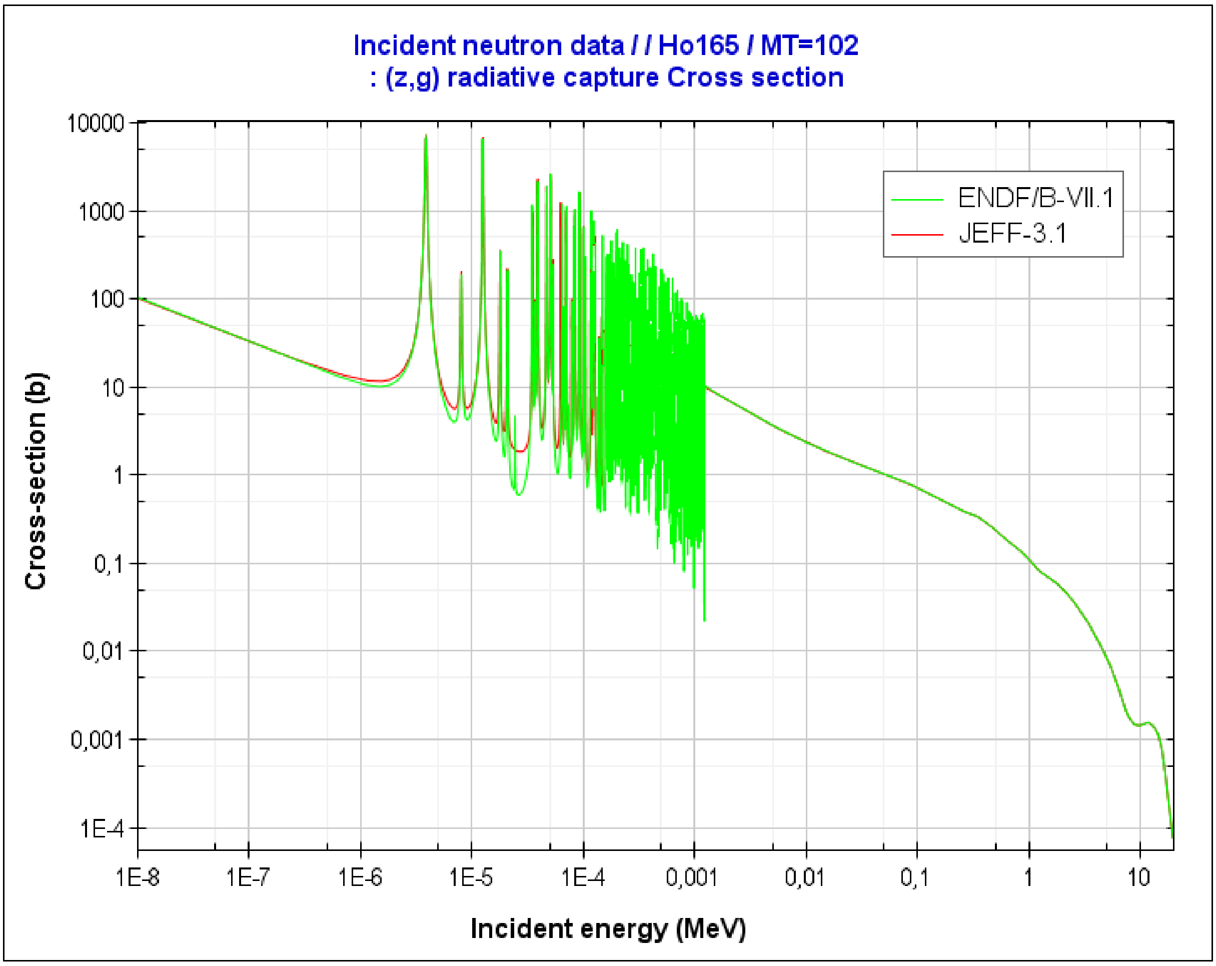
g = 0.998

E_r = 14.63 eV

σ_0 = 64.71 b

Q_0 = 10.54

σ_h = 0.115 b


Incident neutron data / / Ho165 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JEFF-3.1
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.83. $^{170}Er(n,\gamma)^{171}Er$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
8.85	3.4	-1.4	8.97	3.7	8.857	-1.3	8.855	-1.3

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
4.00	17.0	-9.5	4.42	3.3	5.213	17.9	4.720	6.8

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.4% and is 1.4% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.7%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are in full agreement with the Mughabghab [1] value and consistent with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 17.0% and is smaller by 9.5% in comparison with the Kayzero [2] value, which has an uncertainty of 3.3%. The value derived from the JENDL-4.0 [4] library is substantially larger, but the ENDF/B-VII.1 [5] value is only 6.8% higher than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is selected because it agrees well with the Kayzero [2] values. The constants derived from this library are:

F_{cd} = 0.987

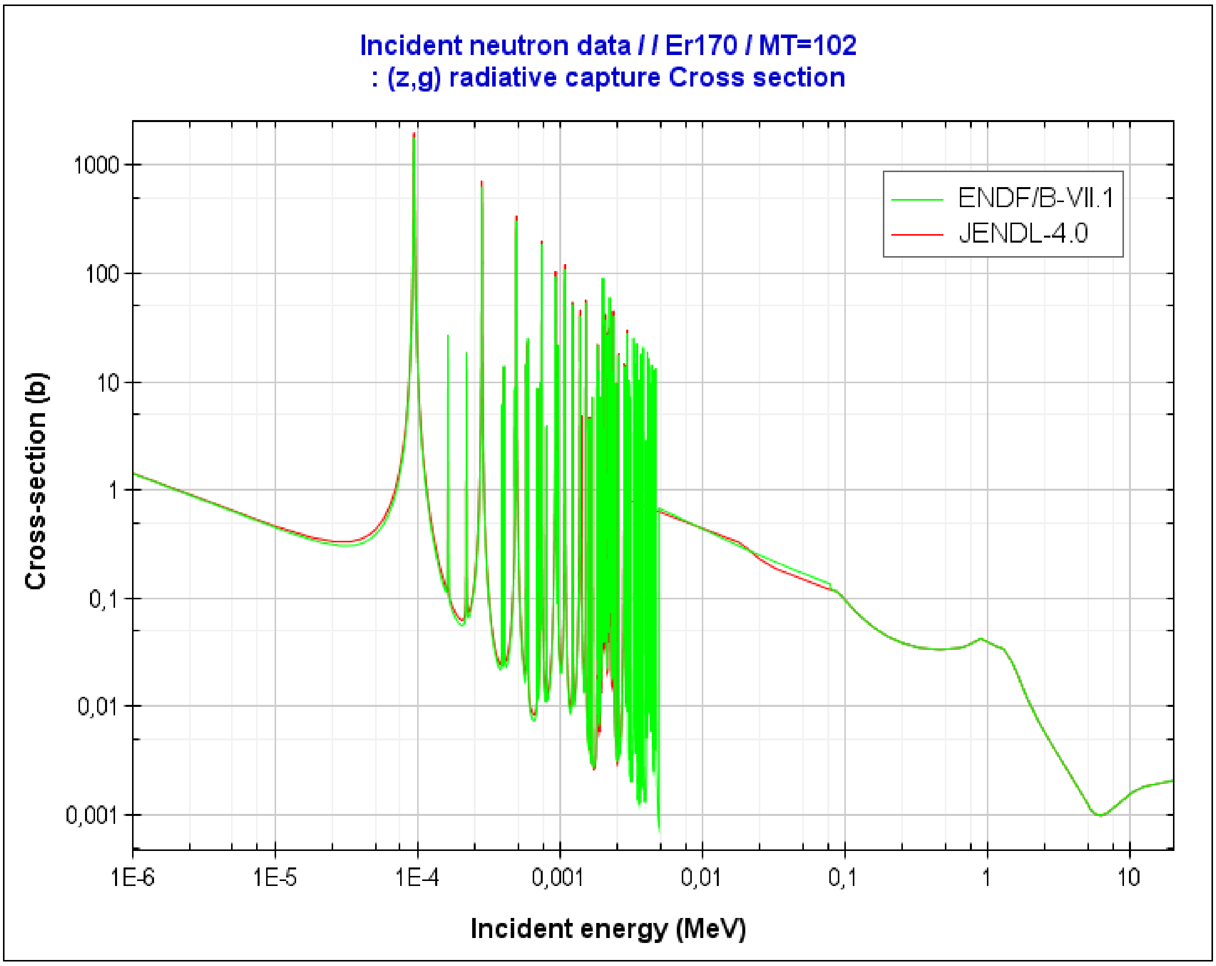
g = 0.999

E_r = 145.2 eV

σ_0 = 8.855 b

Q_0 = 4.720

σ_h = 0.0223 b


Incident neutron data / / Er170 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.84. $^{169}Tm(n,\gamma)^{170}Tm$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
105	1.9	-1.3	106	1.7	105.1	-1.2	105.1	-1.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
15.8	3.6	15.3	13.7	1.6	15.42	12.6	15.43	12.6

Of the most recent evaluated nuclear data libraries only the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries contains data for this nuclide.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.9%, and is 1.3% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 1.7%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are fully consistent with the Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.6% and is larger by 15.3% in comparison with the Kayzero [2] value, which has an uncertainty of 1.6%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the Mughabghab [1] value and are larger than the Kayzero [2] value by 12.6%.

The JENDL-4.0 [4] library is chosen for this nuclide even though the values from ENDF/B-VII.1 [5] are almost the same. The constants derived from this library are:

F_{cd} = 0.997

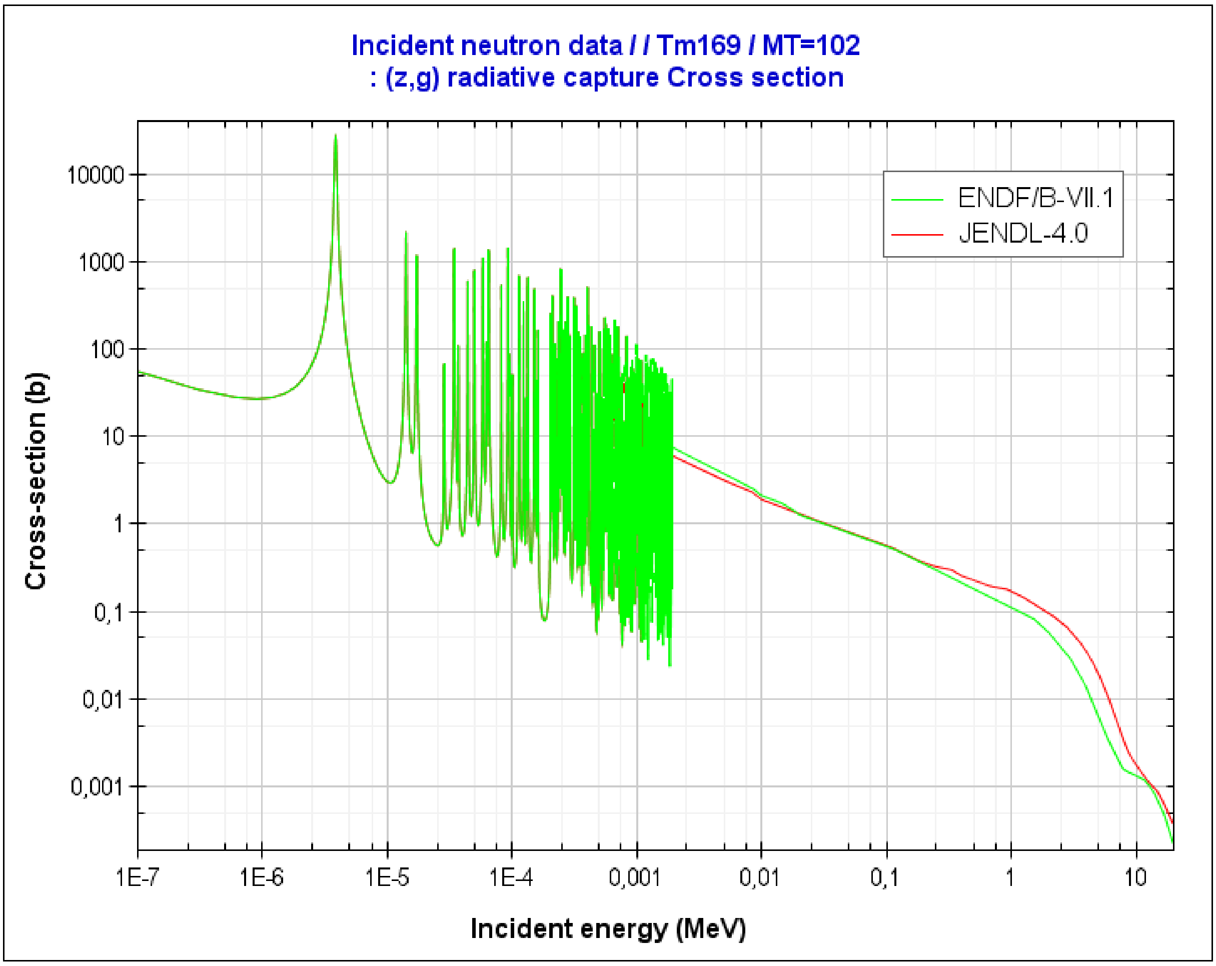
g = 1.004

E_r = 5.216 eV

σ_0 = 105.1 b

Q_0 = 15.42

σ_h = 0.138 b



Incident neutron data / / Tm169 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.85. $^{168}Yb(n,\gamma)^{169}Yb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
2300	7.4	-20	2888	10.6	2308	-20

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
9.26	8.8	86.3	4.97	-	7.998	61

Of the most recent evaluated nuclear data libraries only the JENDL-4.0 [4] library contains data for this nuclide.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 7.4% and is smaller than the value derived from the Kayzero [2] library by 20%. The uncertainty of the Kayzero [2] value is 10.6%. The value in the JENDL-4.0 [4] library is consistent with the Mughabghab [1] evaluation and is 20% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 8.8% and is larger by 86.3% in comparison with the Kayzero [2] value, which has no uncertainty given. The JENDL-4.0 [4] value lies in-between and is 61% higher than the Kayzero [2] value.

The JENDL-4.0 [4] library is practically the only option for this nuclide. The thermal cross section and particularly the Q_0 value (i.e the resonance integral) are very large. The discrepancies in these constants require an investigation. Note the large Cd correction factor. The constants derived from this library are:

F_{cd} = 0.856

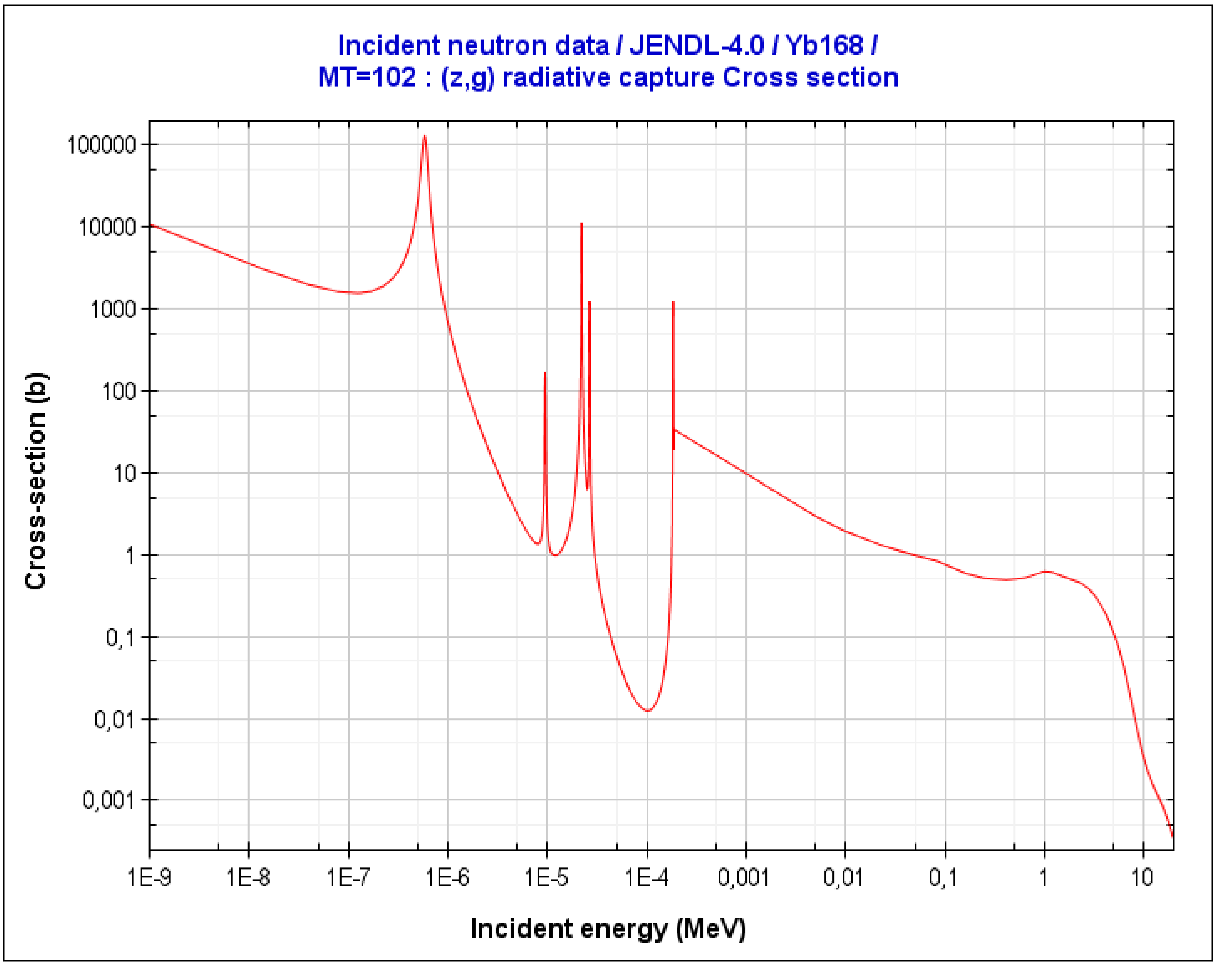
g = 1.062

E_r = 0.5799 eV

σ_0 = 2308 b

Q_0 = 7.998

σ_h = 0.450 b


Incident neutron data / JENDL-4.0 / Yb168 /
MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
100000
10000
1000
100
10
1
0,1
0,01
0,001
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.86. $^{174}Yb(n,\gamma)^{175}Yb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
63.2	2.4	1.6	62.20	2.4	63.22	1.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
0.427	11.4	-7.1	0.46	-	0.3807	-17

Of the most recent evaluated nuclear data libraries only the JENDL-4.0 [4] library contains data for this nuclide.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.4% and is in very good agreement with the value derived from the Kayzero [2] library, which has an assigned uncertainty of 2.4%. The value in the JENDL-4.0 [4] library is fully consistent with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 11.4% and is slightly smaller (by 7.1%) in comparison with the Kayzero [2] value, which has no uncertainty given. The value in the JENDL-4.0 [4] library is 17% smaller than the Kayzero [2] value.

The JENDL-4.0 [4] library is practically the only option for this nuclide. The constants derived from this library are:

F_{cd} = 1.032

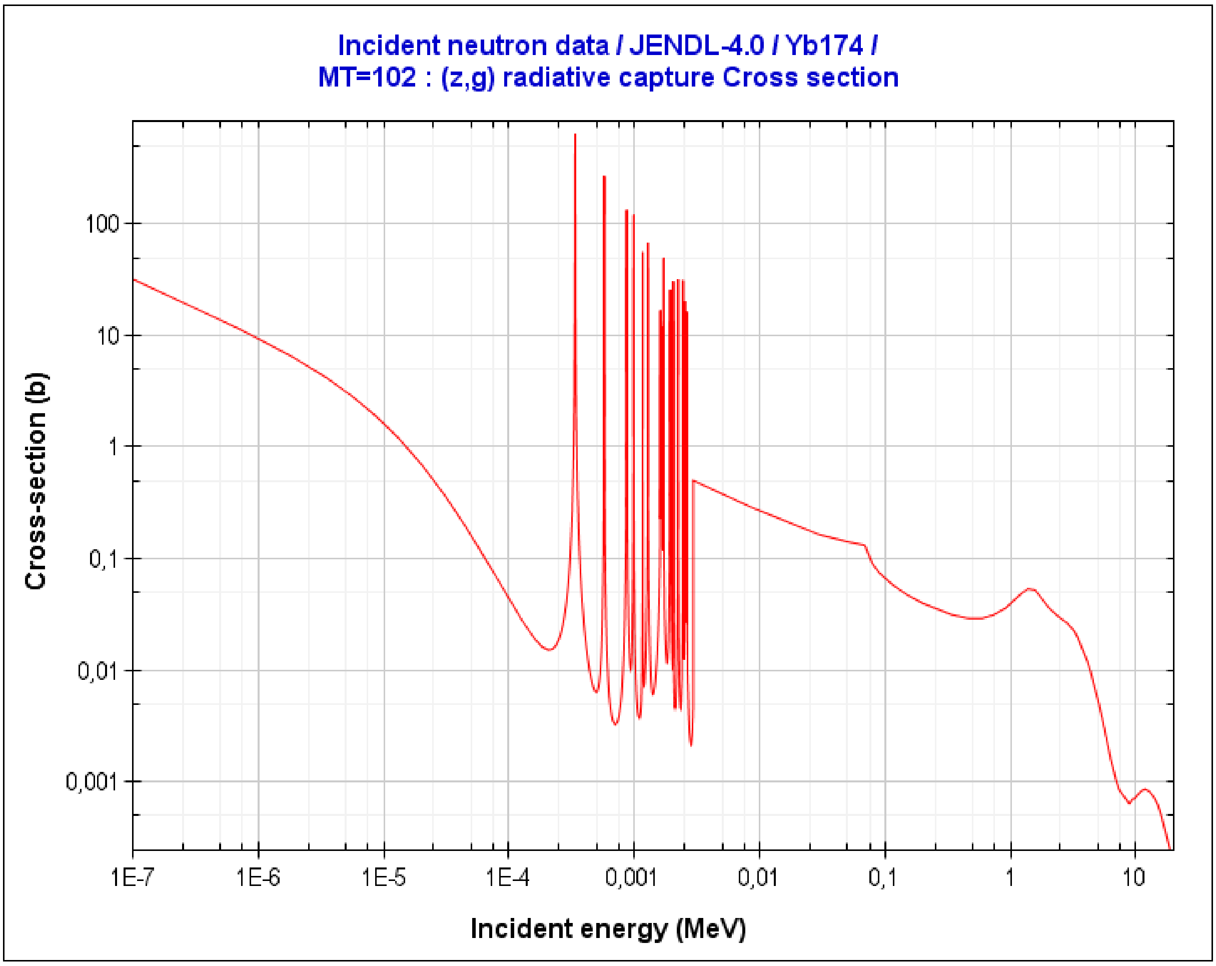
g = 0.998

E_r = 0.1155 eV

σ_0 = 63.22 b

Q_0 = 0.3807

σ_h = 0.0330 b


Incident neutron data / JENDL-4.0 / Yb174 /
MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.87. $^{176}Yb(n,\gamma)^{177}Yb$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
2.85	1.8	-2.6	2.93	7.0	2.824	-3.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
2.4	8.9	-3.2	2.5	1.8	2.445	-2.2

Of the most recent evaluated nuclear data libraries only the JENDL-4.0 [4] library contains data for this nuclide.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.8% and is 2.6% smaller than the value derived from the Kayzero [2] library, which has uncertainty of 7.0%. The value from the JENDL-4.0 [4] library is fully consistent with the value by Mughabghab [1] and is 3.4% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 8.9% and is smaller by only 3.2% in comparison with the Kayzero [2] value, which has an assigned uncertainty of 1.8%. The value from the JENDL-4.0 [4] library is consistent with the Kayzero [2] value, being smaller by 2.2%.

The JENDL-4.0 [4] library is practically the only option for this nuclide. The constants derived from this library are:

F_{cd} = 0.993

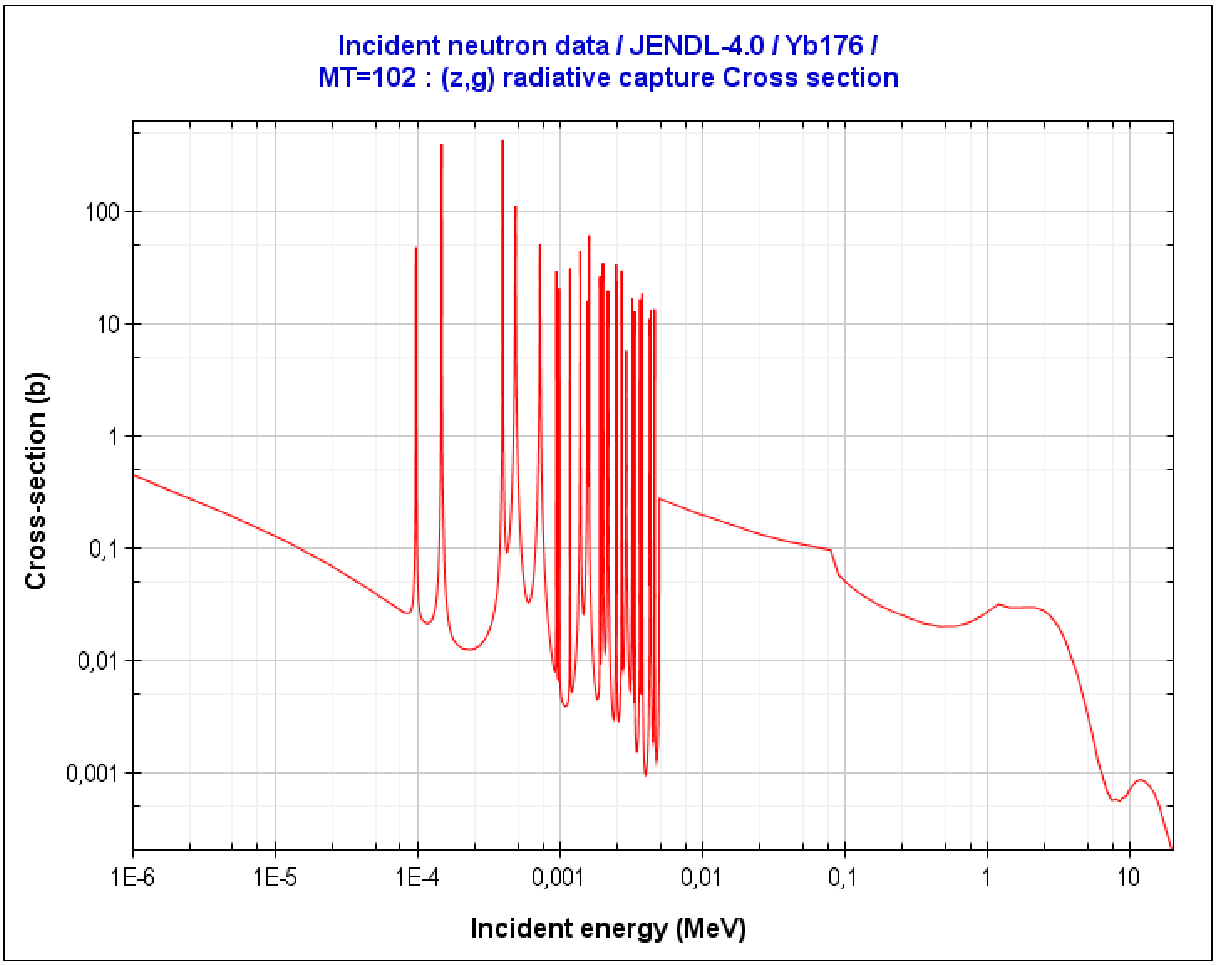
g = 0.998

E_r = 593.3 eV

σ_0 = 2.824 b

Q_0 = 2.445

σ_h = 0.0236 b


Incident neutron data / JENDL-4.0 / Yb176 /
MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.88. ^{175}Lu(n,γ)^{176m}Lu

The thermal cross sections and the Q_0 values for the excitation of the metastable residual ^{176m}Lu are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
16.7	2.4	-0.1	16.72	4.7	16.55	-1.0

Mughabghab [1]			Kayzero [2]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
32.9	6.0	-5.4	34.8	3.1	33.30	-4.3

Of the most recent evaluated nuclear data libraries only the ENDF/B-VII.1 [5] library contains data for this nuclide.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.4% and is in excellent agreement with the value derived from the Kayzero [2] library, which has an uncertainty of 4.7%. The ENDF/B-VII.1 [5] library does not include the branching ratio. The branching ratio for thermal incident neutrons of 71.7% by Mughabghab [1] is assumed. The value in the ENDF/B-VII.1 [5] is fully consistent with the Mughabghab [1] and the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.0% and is smaller by only 5.4% in comparison with the Kayzero [2] value, which has an assigned uncertainty of 3.1%. The branching ratio in the epithermal range for the production of the metastable nuclide of 88.7% by Mughabghab [1] is assumed. The value from the ENDF/B-VII.1 [5] library is smaller than the Kayzero [2] value by 4.3%.

The ENDF/B-VII.1 [5] library is practically the only option for this nuclide. The constants derived from this library are:

F_{cd} = 0.993

g = 1.001

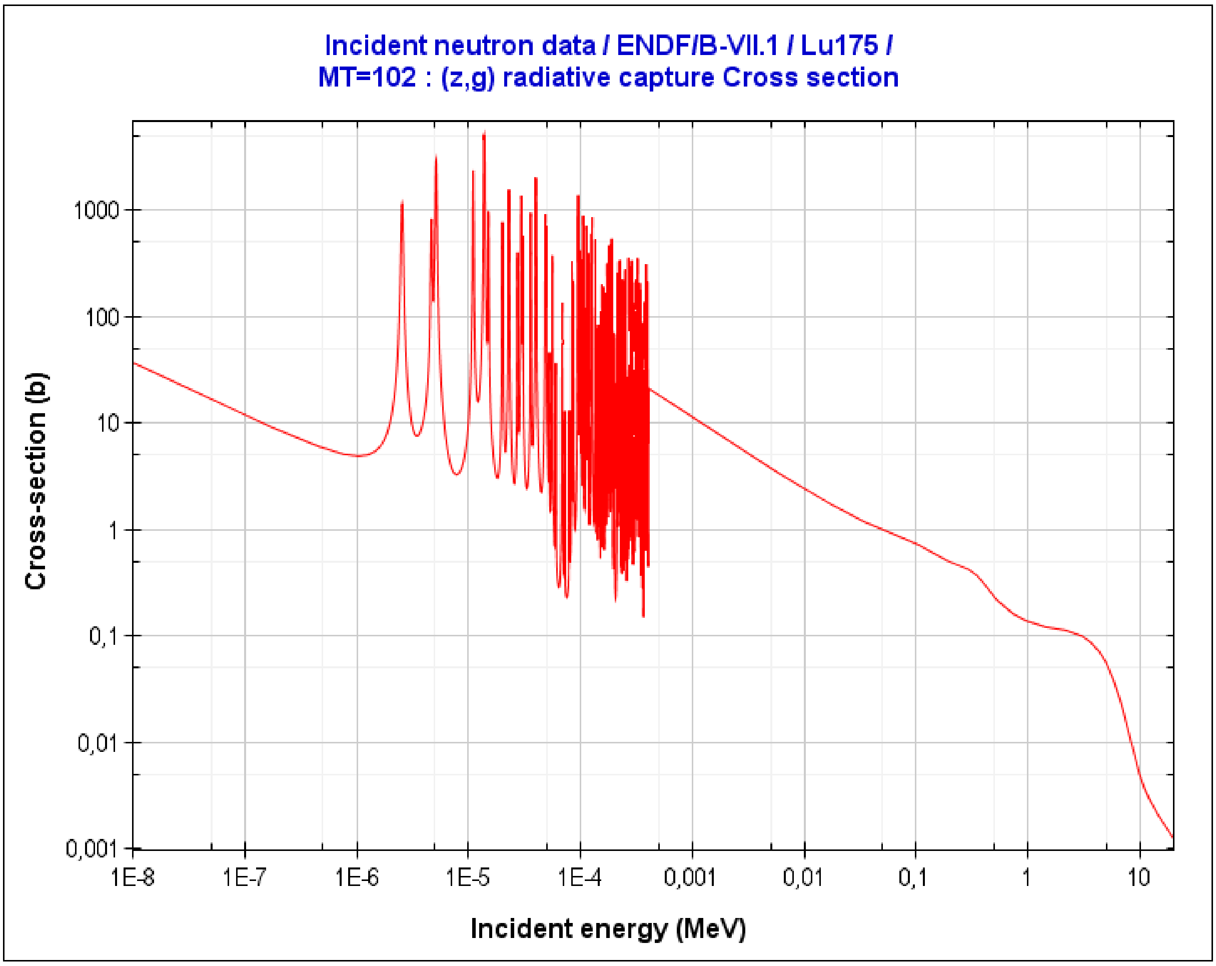
E_r = 17.73 eV

σ_0 = 16.55 b

Q_0 = 33.30

$\sigma_h \quad = \quad 0.140$ b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.89. $^{176}Lu(n,\gamma)^{177}Lu$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
2020	3.5	3.1	1960	2.4	2097	7.0

Mughabghab [1]			Kayzero [2]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
0.538	7.3	-68	1.67	-	0.434	-74

Of the most recent evaluated nuclear data libraries only the ENDF/B-VII.1 [5] library contains data for this nuclide.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.5% and is 3.1% larger than the value derived from the Kayzero [2] library, which has an uncertainty of 2.4%. The value in the ENDF/B-VII.1 [5] library is 7.0% larger.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 7.3% and is smaller by 68% in comparison with the Kayzero [2] value, which has no uncertainty given. The value from the ENDF/B-VII.1 [5] library is smaller than the Kayzero [2] value by 74%.

The ENDF/B-VII.1 [5] library is practically the only option for this nuclide. Note the large g-factor, which measures the departure from 1/v absorption. The constants derived from this library are:

F_{cd} = 0.988

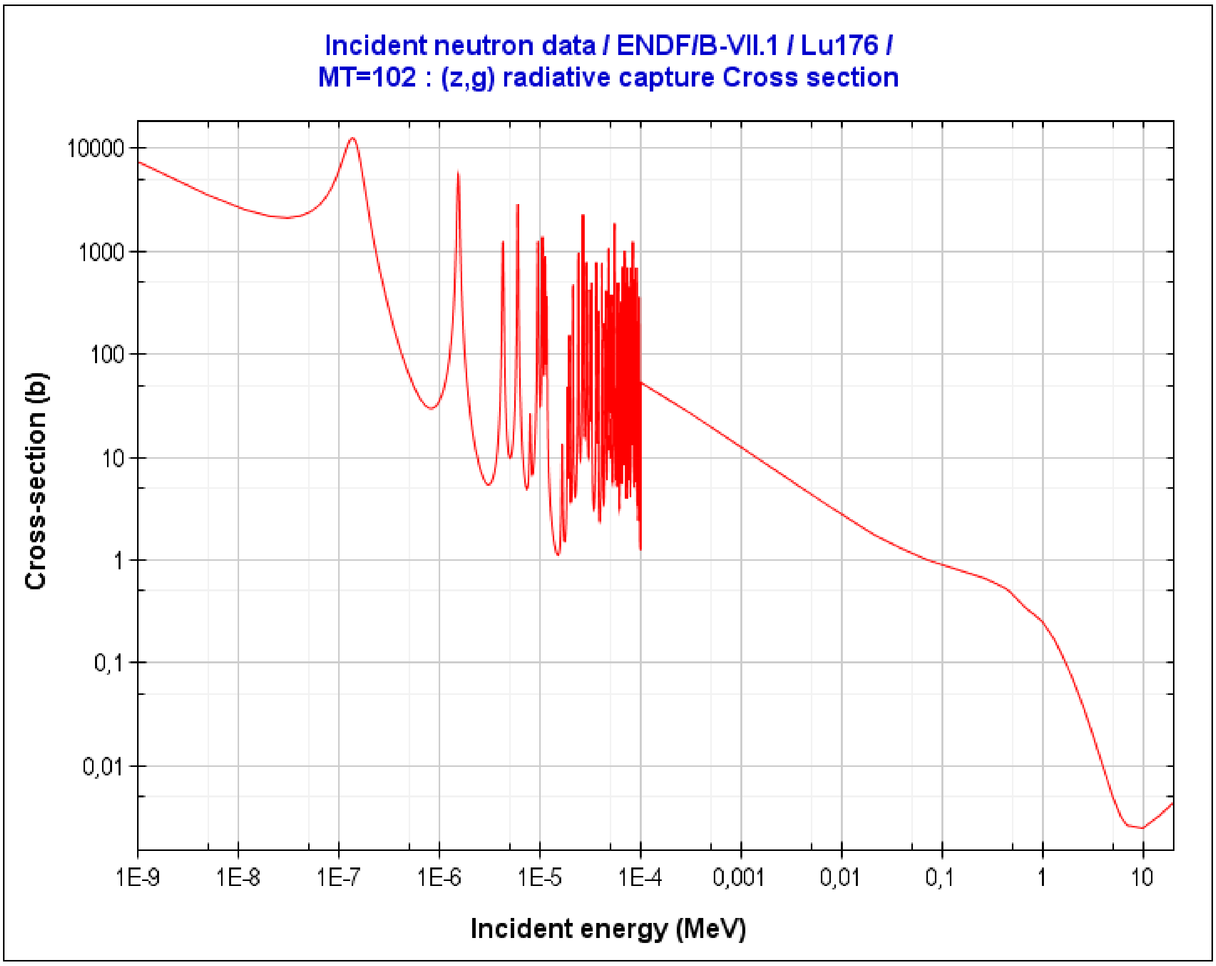
g = 1.710

E_r = 999999 eV

σ_0 = 2097 b

Q_0 = 0.434

σ_h = 0.195 b



Incident neutron data / ENDF/B-VII.1 / Lu176 /
MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.90. $^{174}Hf(n,\gamma)^{175}Hf$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1[5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
549	1.3	-4.7	576	6.3	562.4	-2.4	549.6	-4.6

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1[5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.559	5.0	-28	0.78	-	0.6709	-14	0.799	2.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.3% and is smaller by 4.7% in comparison with the value derived from the Kayzero [2] library, which has an uncertainty of 6.3%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are consistent with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 5.0% and is smaller by 28% in comparison with the Kayzero [2] value, which has no uncertainty given. The value form the JENDL-4.0 [4] library is 14% low, while the ENDF/B-VII.1 [5] value lies closer to the Kayzero [2] value, being higher by 2.5%.

The ENDF/B-VII.1 [5] library is selected because its Q_0 value lies much more closely to the Kayzero [2] value. The constants derived from this library are:

F_{cd} = 1.006

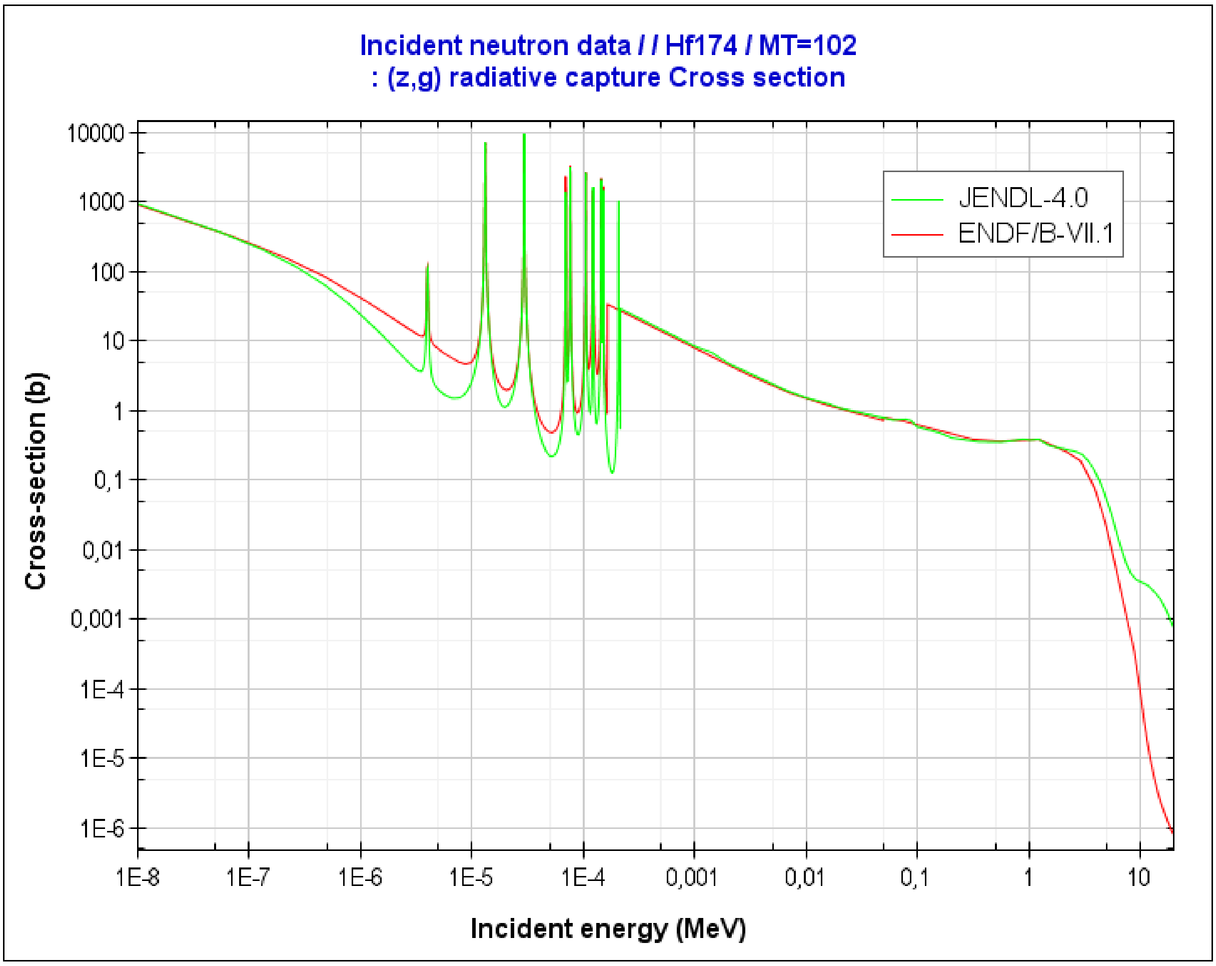
g = 0.985

E_r = 206.4 eV

σ_0 = 549.6 b

Q_0 = 0.799

σ_h = 0.274 b


Incident neutron data / / Hf174 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
JENDL-4.0
ENDF/B-VII.1

2.5.91. ^{178}Hf(n,γ)^{179m}Hf

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{179m}Hf are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
53	11.3	-8.9	58.2	0.2	53.04	-8.9	52.97	-9.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
22.4	11.4	35.0	16.6	-	22.75	37.1	22.25	34.0

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 11.3% and is 8.9% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.2% (excluding the uncertainty in the gamma-emission probability because it is not given). The branching ratio for thermal incident neutrons of 63.1% by Mughabghab [1] is assumed. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the Mughabghab [1] value and are about 9% smaller than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 11.4% and is larger by 35.0% in comparison with the Kayzero [2] value, which has no uncertainty given. The branching ratio is assumed independent of energy; the thermal value by Mughabghab [1] is used. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries lie close to the Mughabghab [1] value and are 37.1% and 34.0% larger than the Kayzero [2] value.

The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.000

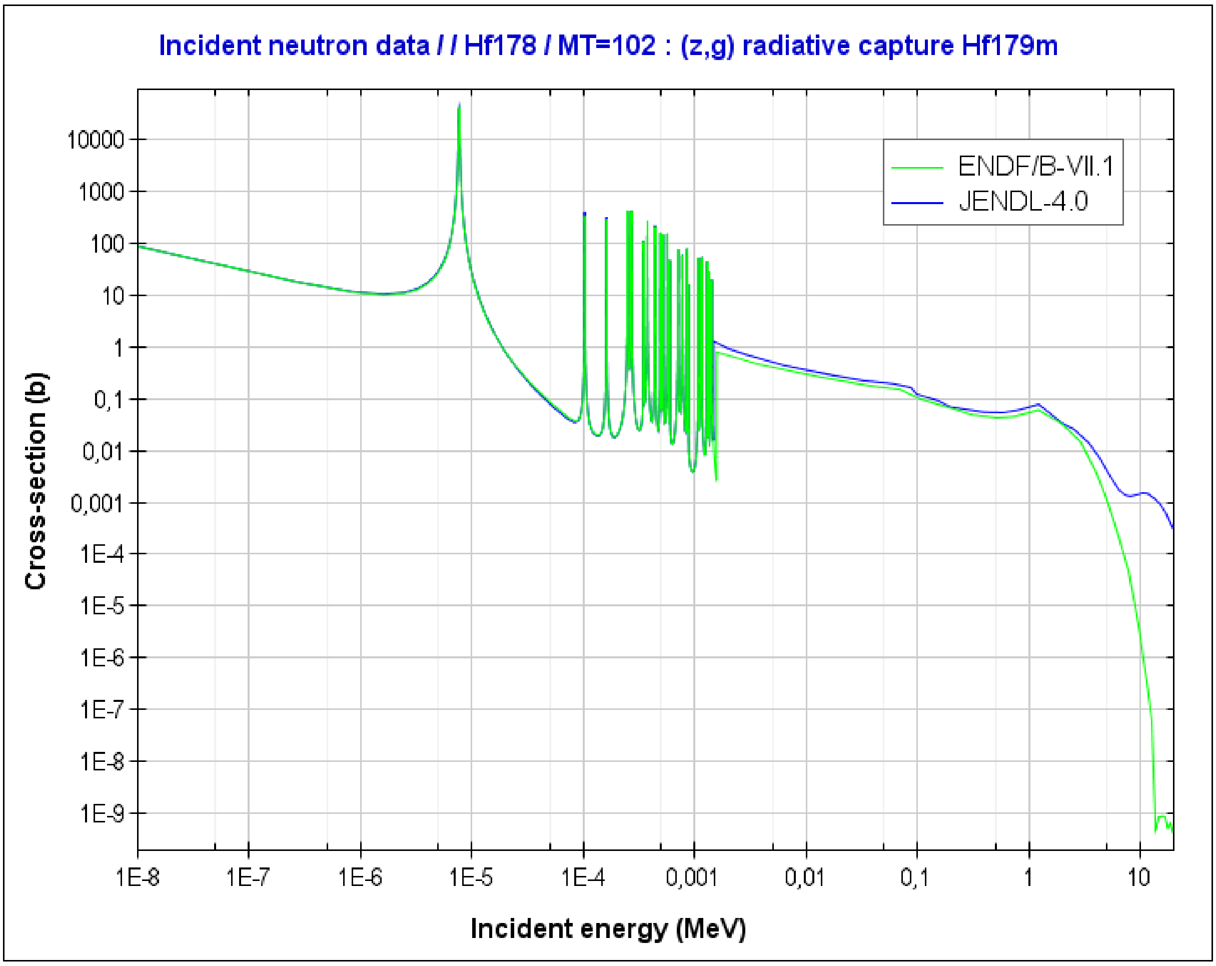
g = 1.001

E_r = 7.923 eV

σ_0 = 52.97 b

Q_0 = 22.25

σ_h = 0.0345 b


Incident neutron data / / Hf178 / MT=102 : (z,g) radiative capture Hf179m
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)
ENDF/B-VII.1
JENDL-4.0

2.5.92. ^{179}Hf(n,γ)^{180m}Hf

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{180m}Hf are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.445	0.7	-1.6	0.452	1.8	0.4397	-2.8	0.4646	2.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
15.5	8.7	7.7	14.4	2.4	12.61	-12	12.34	-14

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.7% and is smaller by 1.6% in comparison with the value derived from the Kayzero [2] library, which has an uncertainty of 1.8%. The branching ratio for thermal incident neutrons of 1.09% by Mughabghab [1] is assumed. The values in the JENDL-4.0 [4] is 2.8% smaller and the ENDF/B-VII.1 [5] value is 2.7% larger than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 8.7% and is larger by 7.7% in comparison with the Kayzero [2] value, which has an uncertainty of 2.4%. The branching ratio in the epithermal range for the production of the metastable nuclide of 1.10% by Mughabghab [1] is assumed. The values form the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are smaller than the Kayzero [2] value by 12% and 14%, respectively.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.994

g = 0.996

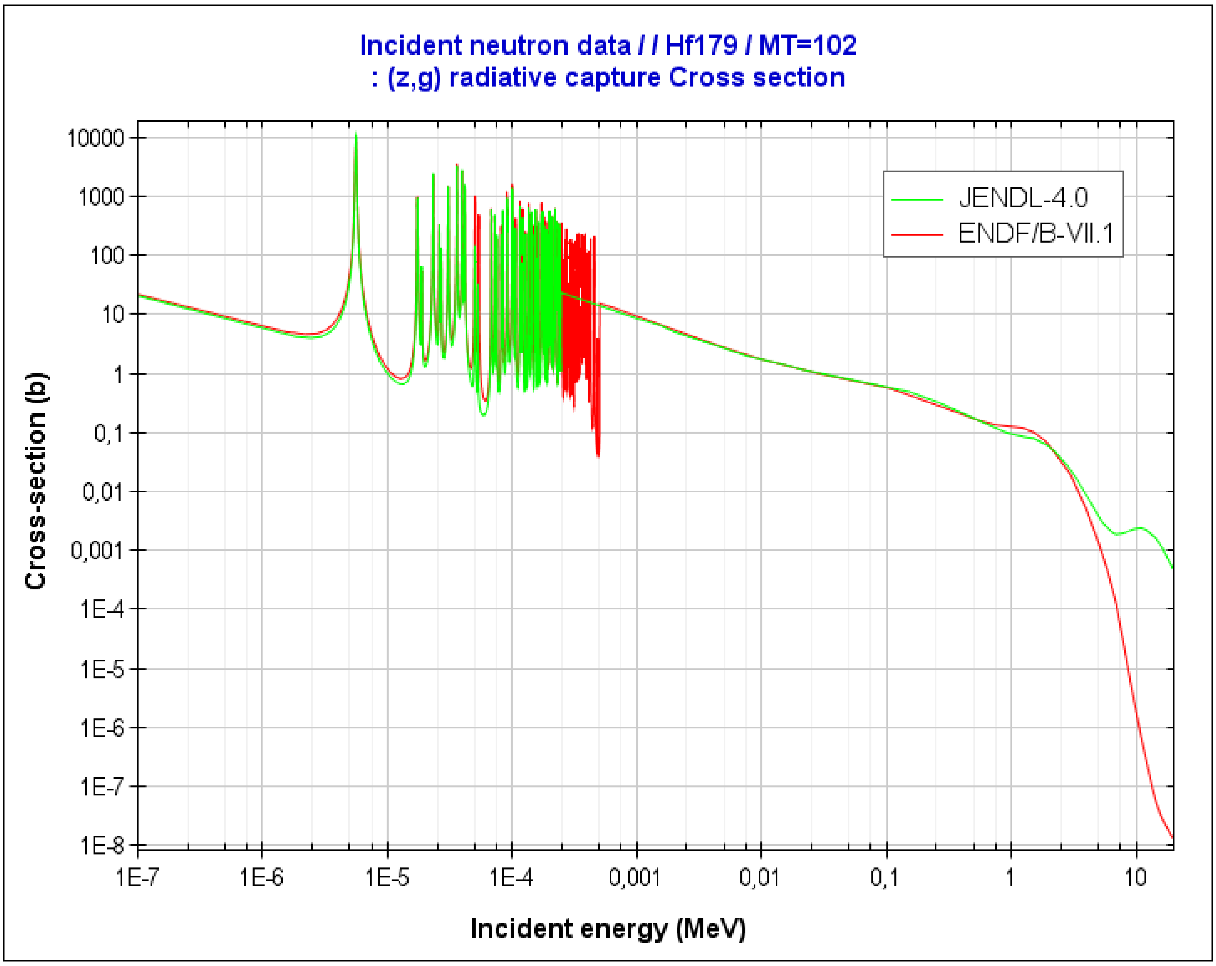
E_r = 21.56 eV

σ_0 = 0.4646 b

Q_0 = 12.34

σ_h = 0.00110 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.93. $^{180}Hf(n,\gamma)^{181}Hf$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
13.04	0.5	-1.0	13.2	3.7	12.92	-1.9	13.08	-0.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
2.531	3.1	0.4	2.52	3.6	2.248	-11	2.187	-13

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.5% and is smaller by 1.0% in comparison with the value derived from the Kayzero [2] library, which has an uncertainty of 3.7%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are in very good agreement with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.1% and is in full agreement with the Kayzero [2] value, which has an uncertainty of 3.6%. The values form the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are lower than the Kayzero [2] value by 11% and 13%, respectively.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.004

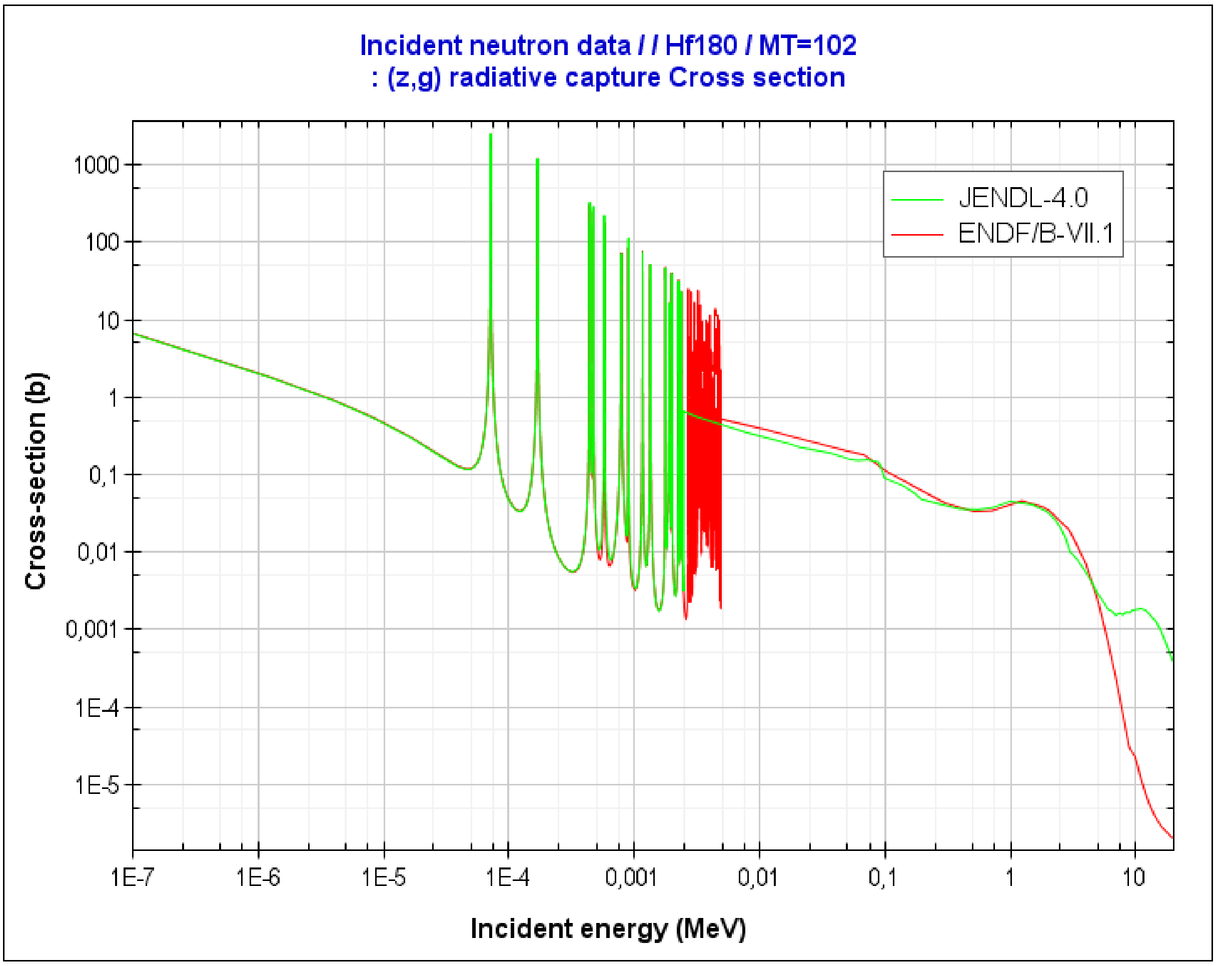
g = 0.998

E_r = 160.0 eV

σ_0 = 13.08 b

Q_0 = 2.187

σ_h = 0.0323 b


Incident neutron data / / Hf180 / MT=102
: (z,g) radiative capture Cross section
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.94. $^{181}Ta(n,\gamma)^{182}Ta$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
20.5	2.4	0.9	20.3	4.1	20.68	1.8	21.13	4.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
31.95	3.9	-4.1	33.3	-	31.89	-4.2	34.92	4.9

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.4% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 4.1%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are consistent with the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.9% and is smaller by 4.1% in comparison with the Kayzero [2] value, which has no uncertainty given. The value derived from the JENDL-4.0 [4] is smaller by 4.2% and the value in the ENDF/B-VII.1 [5] library is 4.9% higher.

The JENDL-4.0 [4] library is selected because it has more abundant resonance data, even though the sharp drop above 5 MeV is questionable, but this is not of primary importance for thermal neutron activation analysis. The constants derived from this library are:

F_{cd} = 0.995

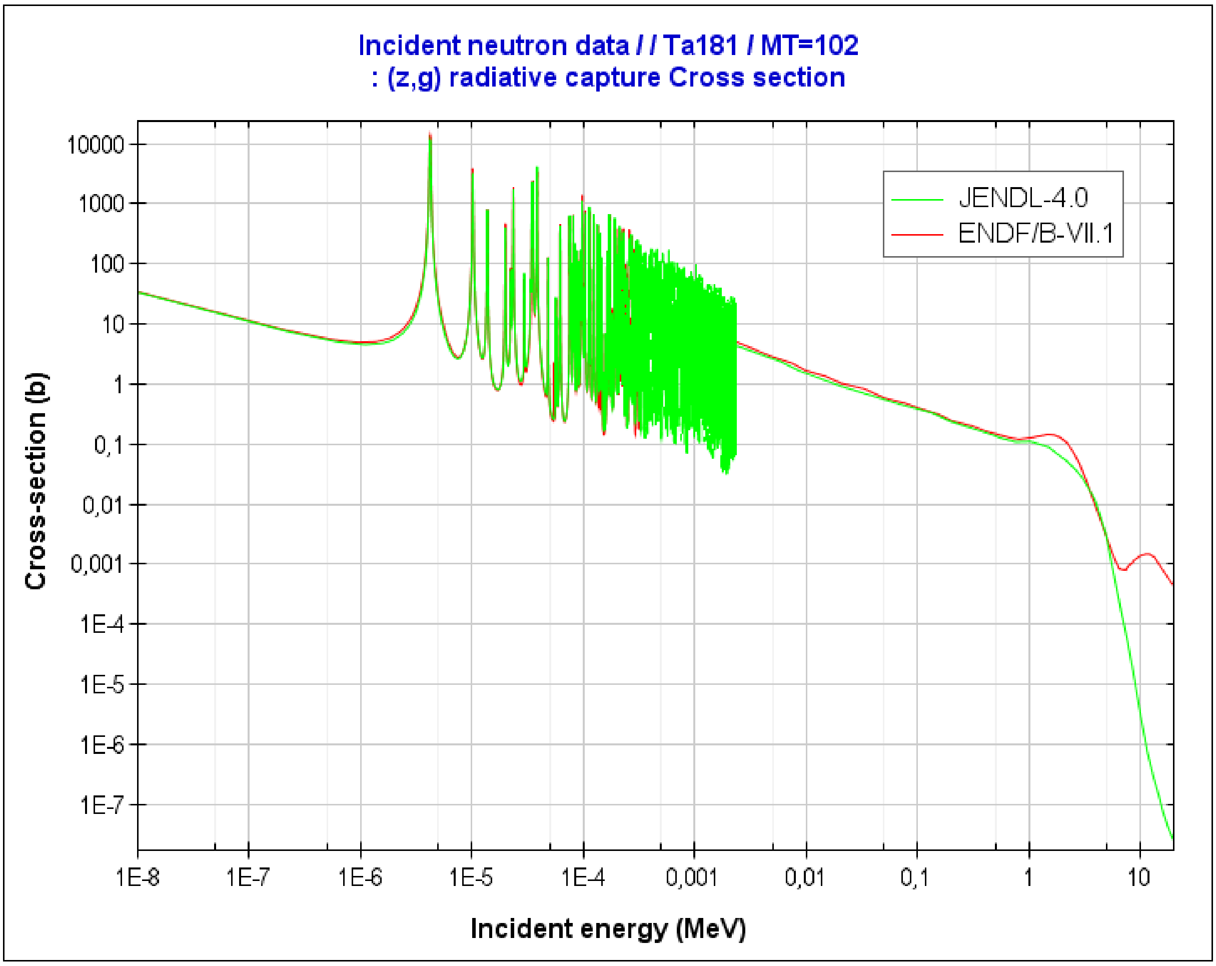
g = 1.002

E_r = 11.54 eV

σ_0 = 20.68 b

Q_0 = 31.89

σ_h = 0.0844 b



Incident neutron data / / Ta181 / MT=102
: (z,g) radiative capture Cross section
JENDL-4.0
ENDF/B-VII.1
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-7
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.95. $^{186}W(n,\gamma)^{187}W$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
38.1	1.3	10.0	34.65	3.0	38.11	10.0	38.10	10.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
12.60	3.4	0.1	12.59	1.8	12.41	-1.4	12.75	1.3

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.3% and is 10.0% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 3.0%. This difference is mainly due to the fact that a recent re-evaluation resulted in a change in the gamma-emission probability of around 20%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries both agree perfectly with the Mughabghab [1] value, which lies in the middle of the thermal cross section calculated from the k_0 value using the old and the new gamma-emission probabilities.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 3.4% and agrees very well with the Kayzero [2] value, which has an uncertainty of 1.8%, but this value was renormalized using the newly-estimated Cd correction factor F_{cd}. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] agree very well with the Kayzero [2] value.

The two libraries are equivalent. The differences in the thermal cross sections imply that the k_0 factor should not be calculated from the cross sections in the file. If the new gamma-emission probabilities are correct, the thermal capture cross section and the resonance integral should both be reduced by about 10%, but the Q_0 value is not affected. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.990

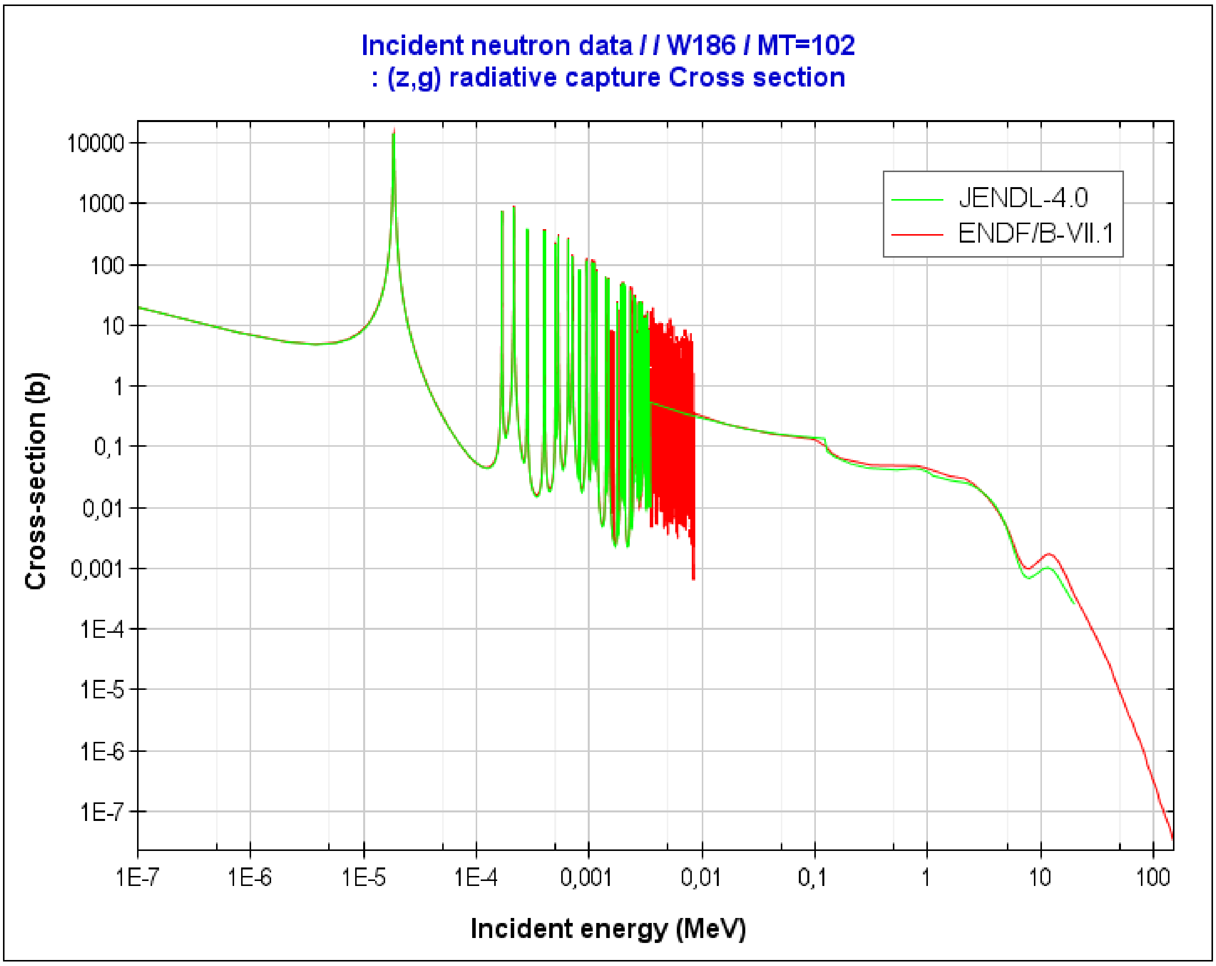
g = 1.000

E_r = 20.19 eV

σ_0 = 38.10 b

Q_0 = 12.75

σ_h = 0.0333 b


Incident neutron data / / W186 / MT=102
: (z,g) radiative capture Cross section
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-7
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
100
Incident energy (MeV)
JENDL-4.0
ENDF/B-VII.1

2.5.96. $^{184}Os(n,\gamma)^{185}Os$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
3000	5.0	-20	3755	50.2	3002	-20

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
0.20	9.8	-53	0.43	-	0.433	0.6

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.0% and is smaller by 20% in comparison with the value derived from the Kayzero [2] library, which has an uncertainty of 50.2%. The JENDL-4.0 [4] library is the only recent general purpose library which contains cross sections for this nuclide. The thermal capture cross section is within the assigned uncertainty interval.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 9.8% and is smaller by 53% in comparison with the Kayzero [2] value, which has no uncertainty given. The value derived from the JENDL-4.0 [4] library seems to agree with the Kayzero [2] value, but note that the cross section curve has no real resonance structure

The JENDL-4.0 [4] evaluation is practically the only option for this nuclide, but should be used with caution because it has no real resonance data, as evident from the figure. Note that the natural abundance of ^{184}Os is only 0.02%, so a direct measurement of the cross sections is extremely difficult. Constants for NAA derived from the cross section curves are not of much value, but are nevertheless listed below:

F_{cd} = 1.026

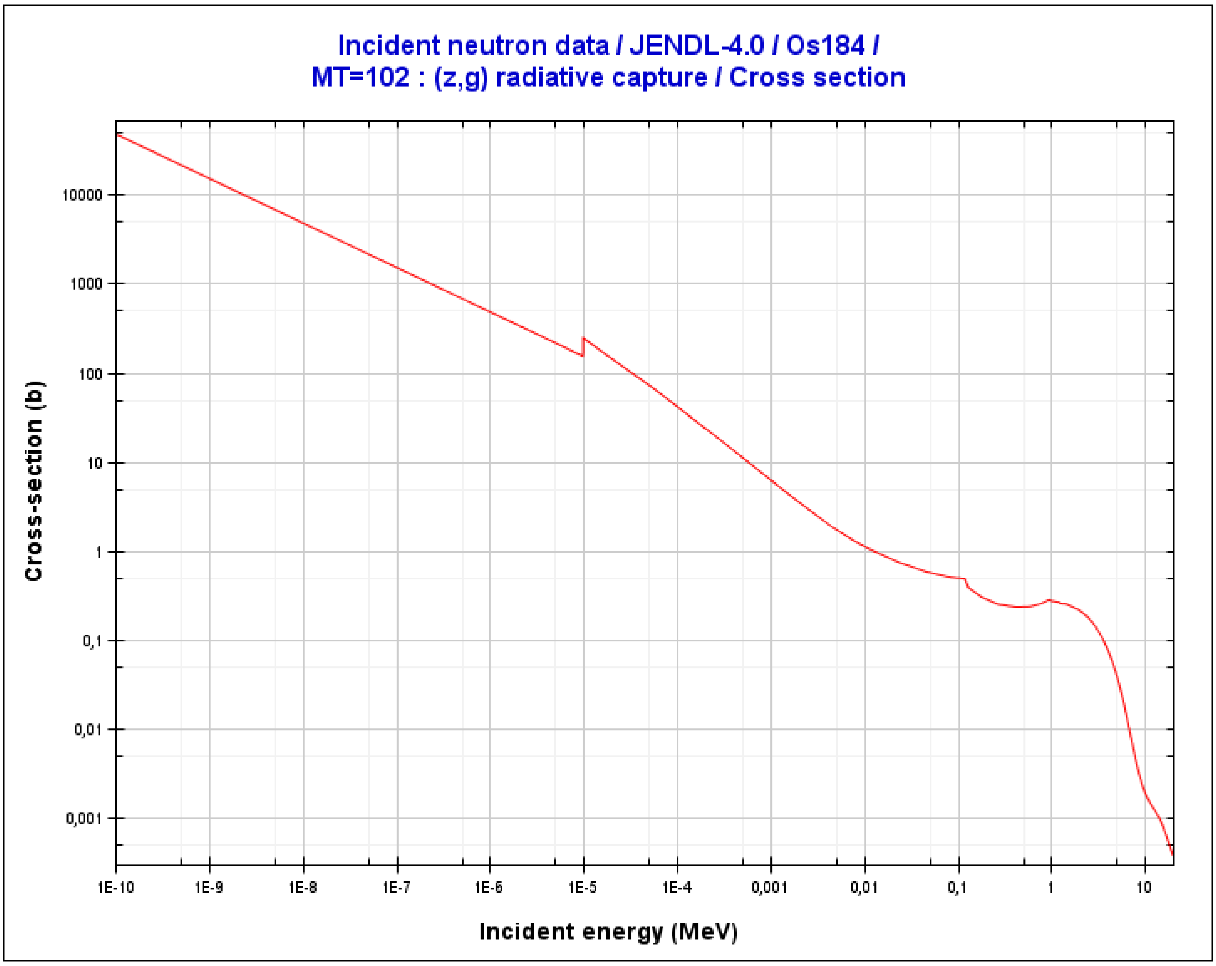
g = 0.999

E_r = 29565 eV

σ_0 = 3002 b

Q_0 = 0.433

σ_h = 0.203 b


Incident neutron data / JENDL-4.0 / Os184 /
MT=102 : (z,g) radiative capture / Cross section
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-10
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.97. $^{190}Os(n,\gamma)^{191}Os$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
13.1	2.3	244	3.81	1.6	13.11	244

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
2.44	6.7	20.3	2.03	-	1.892	-6.8

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 2.3%, but the difference of more than a factor of three is observed, compared to the value derived from the Kayzero [2] library which has an assigned uncertainty of 1.6%. The cross section in the JENDL-4.0 [4] library matches the Mughabghab [1] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 6.7% and is larger by 20.3% in comparison with the Kayzero [2] value, which has no uncertainty given. The value derived from the JENDL-4.0 [4] library is 6.8% lower than the Kayzero [2] value.

The JENDL-4.0 [4] library is practically the only option for this nuclide. The constants derived from this library are:

F_{cd} = 0.916

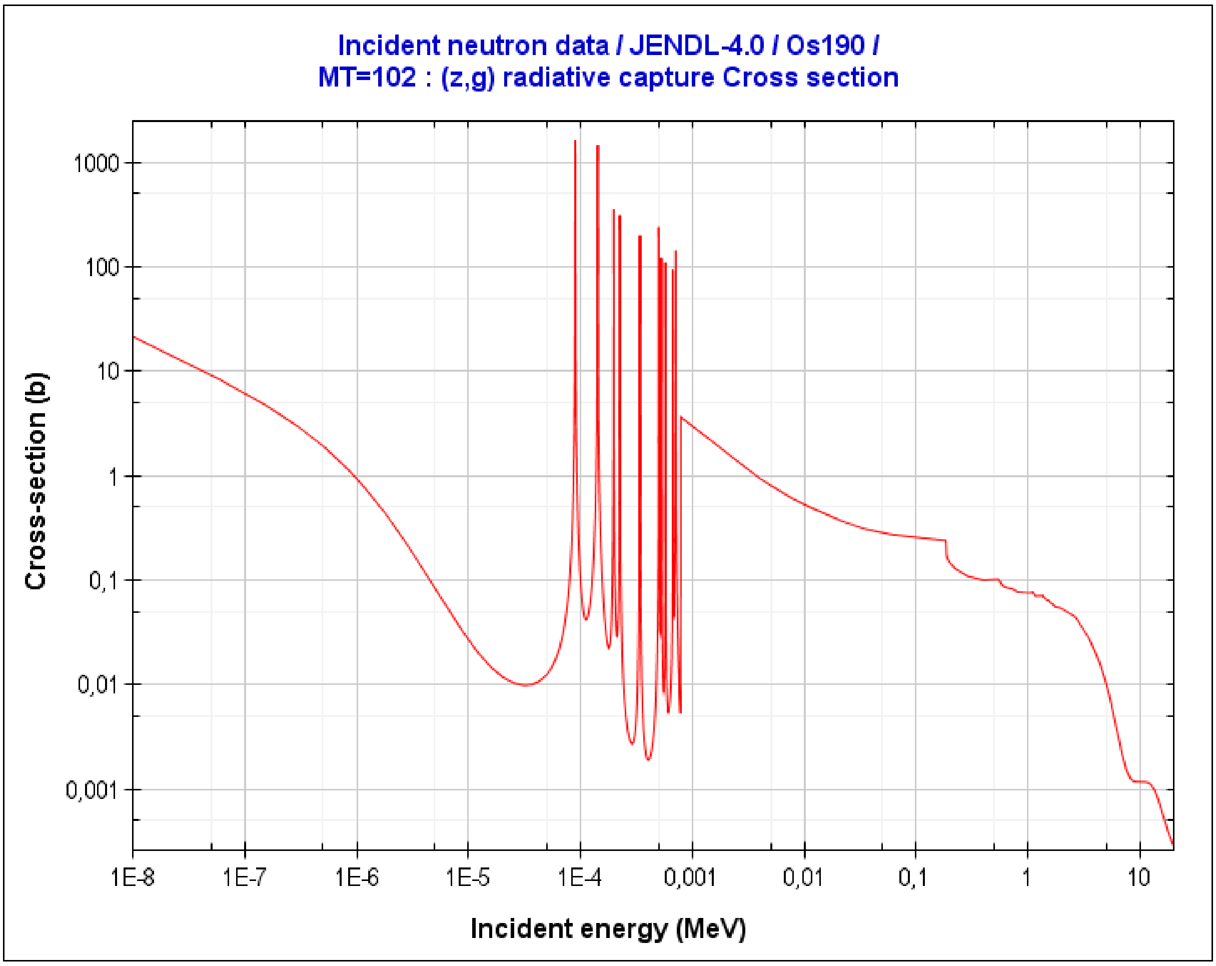
g = 0.986

E_r = 676.3 eV

σ_0 = 13.11 b

Q_0 = 1.892

σ_h = 0.0645 b


Incident neutron data / JENDL-4.0 / Os190 /
MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.98. $^{192}Os(n,\gamma)^{193}Os$

The thermal capture cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
3.12	5.1	-2.1	3.19	5.2	3.118	-2.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
2.244	7.7	-4.1	2.34	-	3.265	39.5

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 5.1% and is smaller by 2.1%,in comparison with Kayzero [2] value, which uncertainty is 5.2%. The cross section in the JENDL-4.0 [4] library is consistent with both, the Mughabghab [1] value and the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 7.7% and is smaller by 4.1% in comparison with the Kayzero [2] value, which has no uncertainty given. The value derived from the JENDL-4.0 [4] library is 39.5% higher than the Kayzero [2] value.

The JENDL-4.0 [4] library is practically the only option for this nuclide. The constants derived from this library are:

F_{cd} = 0.993

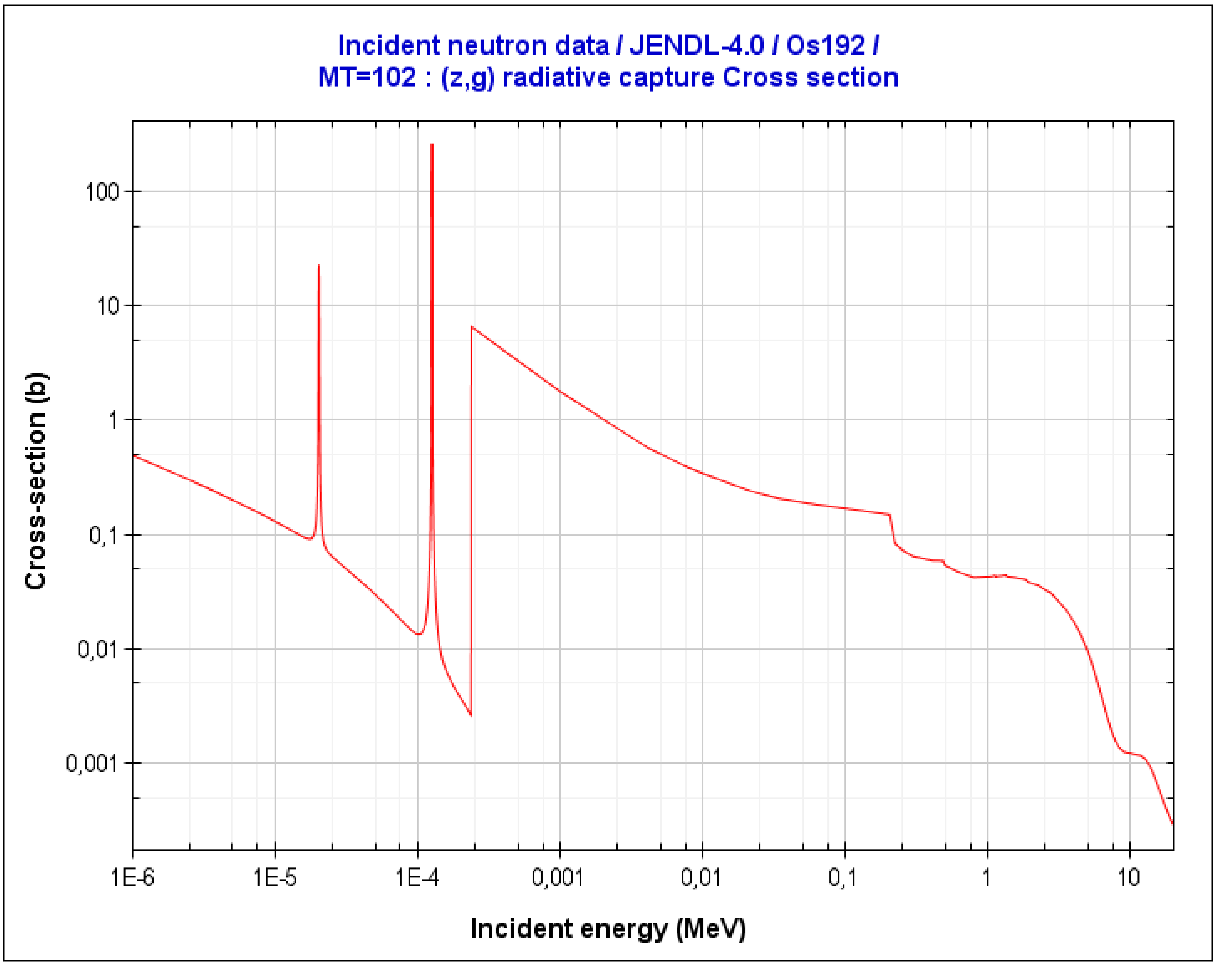
g = 0.998

E_r = 774.2 eV

σ_0 = 3.118 b

Q_0 = 3.265

σ_h = 0.0414 b



Incident neutron data / JENDL-4.0 / Os192 /
MT=102 : (z,g) radiative capture Cross section
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.99. $^{198}Pt(n,\gamma)^{199}Pt$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		TENDL-2012 [9]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
3.61	3.0	7.1	3.37	2.2	3.593	6.6

Mughabghab [1]			Kayzero [2]		TENDL-2012 [9]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
17.18	4.4	1.0	17	1.8	13.88	-18

No major libraries contain this nuclide. The cross sections are only available in the EAF-2010 and the TENDL-2012 [9] libraries.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 3.0%, the difference from the value derived from the Kayzero [2] library is 7.1%, and the quoted uncertainty of this value is 2.2%. The value in the TENDL-2012 [9] library lies close to the Mughabghab [1] value and is 6.6% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.4% and is larger by 1.0% in comparison with the Kayzero [2] value, which has an uncertainty of 1.8%. The value derived from the TENDL-2012 [9] library is 18% smaller.

The TENDL-2012 [9] library is selected because it is the only general purpose library containing this nuclide. The constants derived from this library are:

F_{cd} = 0.979

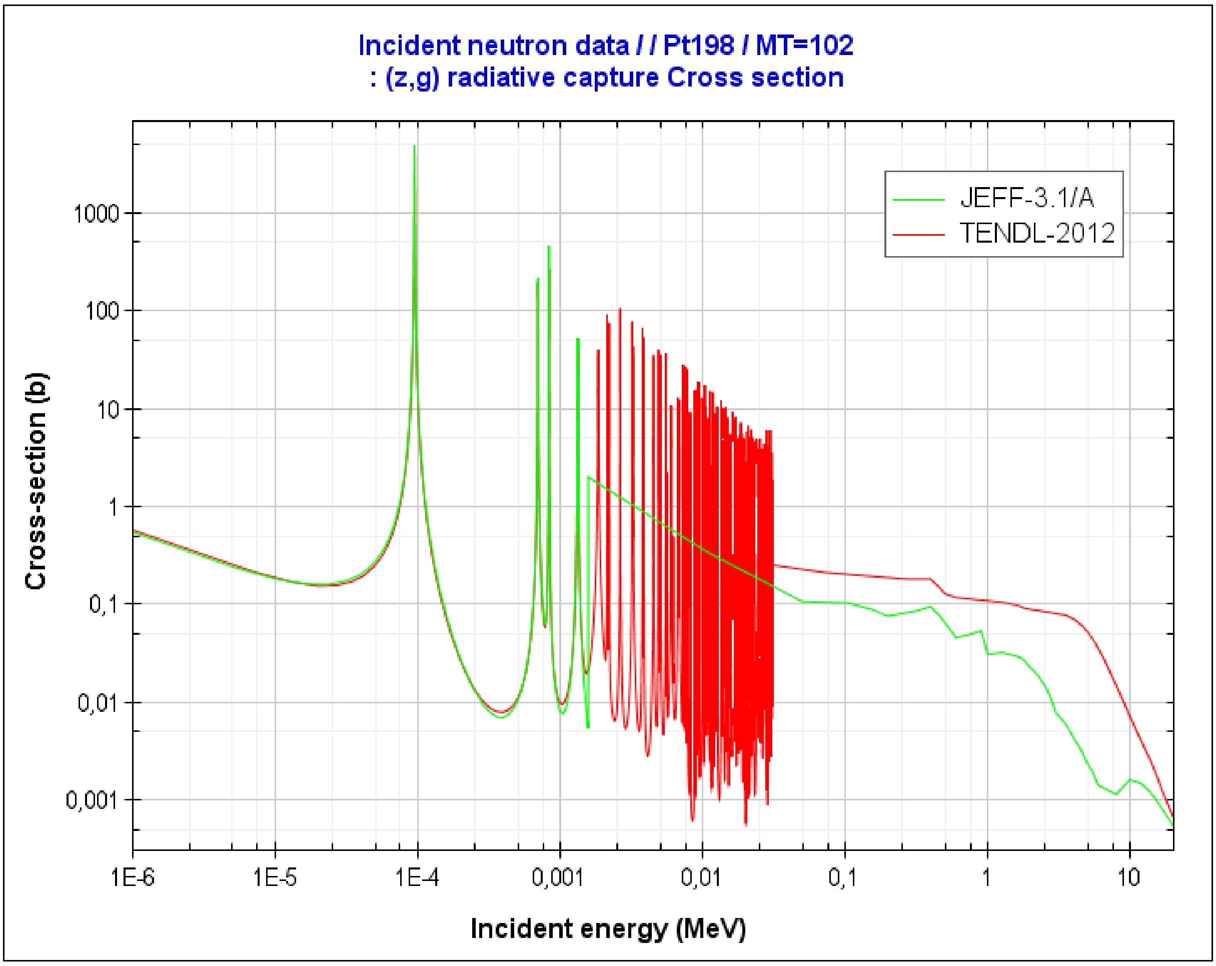
g = 0.998

E_r = 131.1 eV

σ_0 = 3.593 b

Q_0 = 13.88

σ_h = 0.100 b


Incident neutron data / / Pt198 / MT=102
: (z,g) radiative capture Cross section
JEFF-3.1/A
TENDL-2012
1000
100
10
1
0,1
0,01
0,001
Cross-section (b)
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.100. $^{197}Au(n,\gamma)^{198}Au$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
98.65	0.1	0.0	98.65	0.1	98.66	0.0	98.72	0.1

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
15.71	1.8	0.0	15.71	1.8	15.89	1.2	15.89	1.2

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.1% and is fully consistent with the value derived from the Kayzero [2] library, as well as with the values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 1.8% and is fully consistent with the Kayzero [2] value, as well as with the values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries.

The two libraries are practically equivalent. The ENDF/B-VII.1 [5] library is selected because the energy range extends to higher energies. The constants derived from this library are:

F_{cd} = 0.998

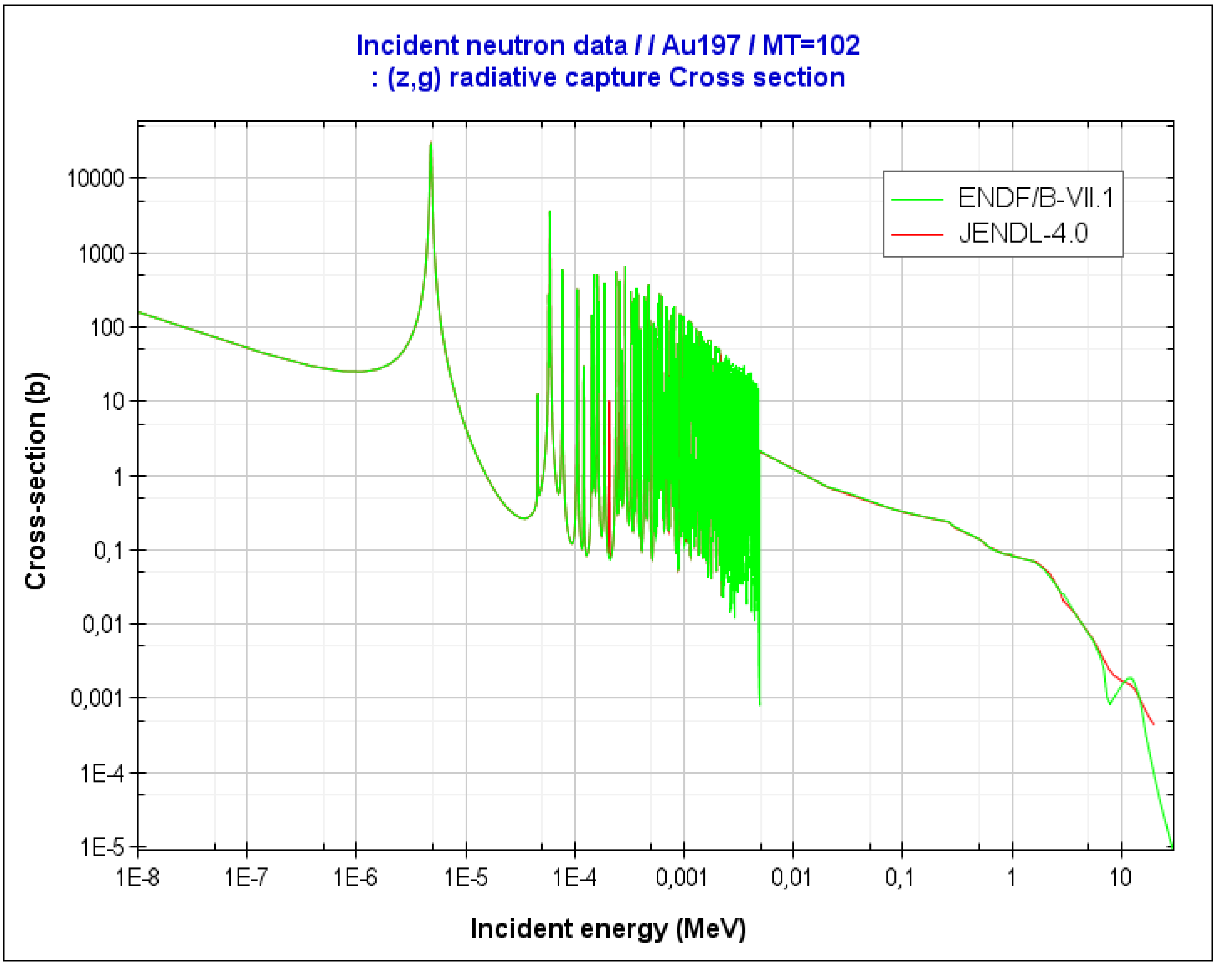
g = 1.004

E_r = 5.621 eV

σ_0 = 98.72 b

Q_0 = 15.89

σ_h = 0.0756 b


Incident neutron data / / Au197 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10000
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.101. $^{196}Hg(n,\gamma)^{197m}Hg$

The thermal cross sections and the Q_0 values for the production of the metastable residual ^{197m}Hg are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]
107.3	1.4	12.5	95.4	6.7	107.3	12.4

Mughabghab [1]			Kayzero [2]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.
	[%]	[%]		[%]		[%]
0.549	4.3	12.0	0.49	-	0.434	-11

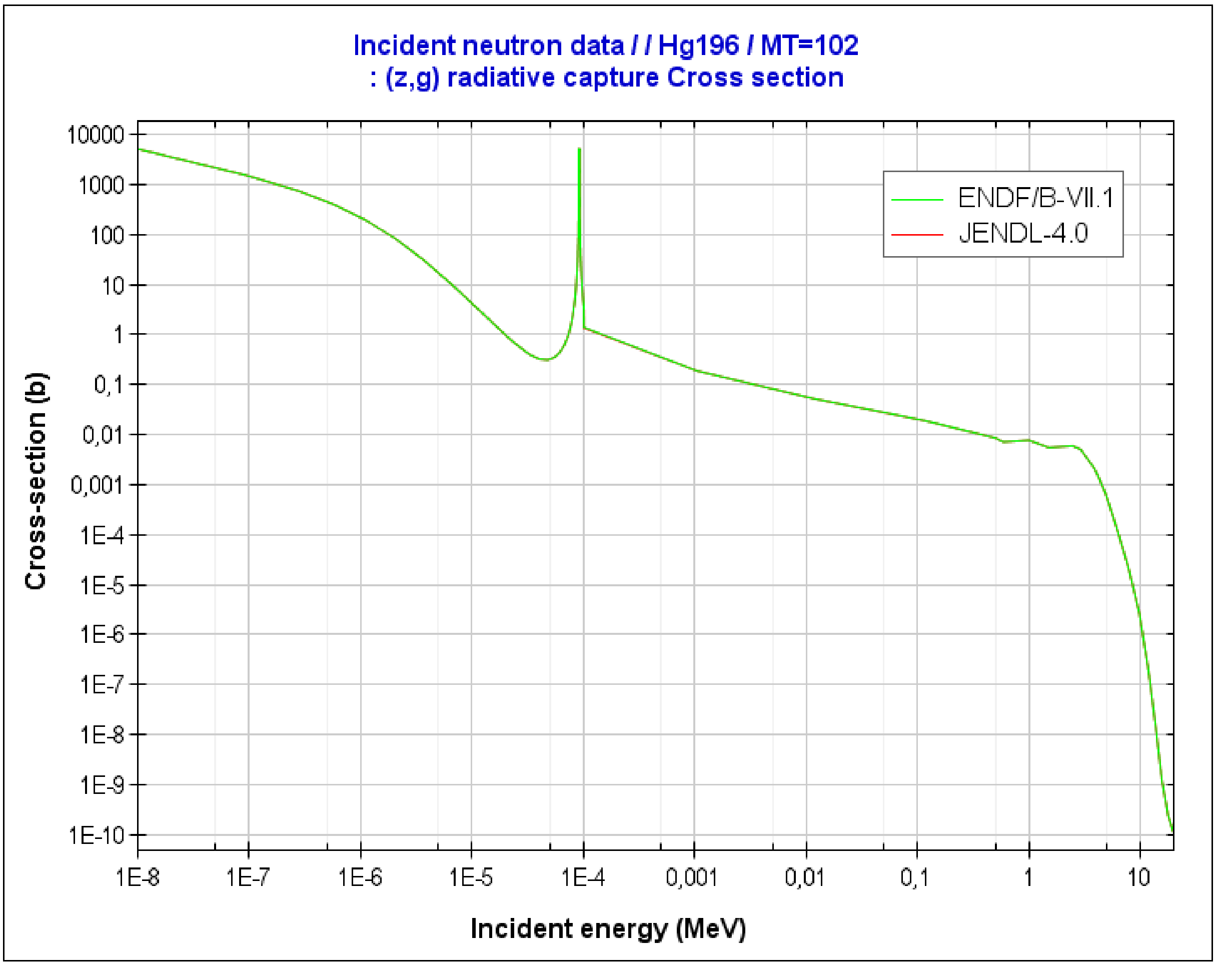
The nuclide is present in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries. It was a joint evaluation effort between the Japanese and the US evaluation teams, therefore the capture cross sections in both libraries are the same, but neither of them contains the branching ratios for the production of the metastable residual.

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.4%, the difference from the value derived from the Kayzero [2] library is 12.5%, and the quoted uncertainty of this value is 6.7%. No branching ratios are given in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries. The branching ratio for thermal incident neutrons of 3.48% by Mughabghab [1] is assumed. The cross section values in the ENDF/B-VII.1 [5] library matches the Mughabghab [1] value and is 12.4% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.3% and is larger by 12.0% in comparison with the Kayzero [2] value, which has no uncertainty given. The branching ratio in the epithermal range for the production of the metastable nuclide of 12.5% by Mughabghab [1] is assumed. The value derived from the ENDF/B-VII.1 [5] library is smaller than the Kayzero [2] value by 11%.

The JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are equivalent for this nuclide. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd}	=	1.097
g	=	0.986
E_r	=	6.152 eV
σ_0	=	107.3 b
Q_0	=	0.434
σ_h	=	0.000756 b

The plot is for the total capture cross section since the cross sections for the excitation of the metastable residual differ only by the branching ratio, which is assumed constant in the thermal and in the epithermal range.



2.5.102. $^{202}Hg(n,\gamma)^{203}Hg$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
4.89	1.0	12.7	4.339	1.9	4.956	14.2	4.956	14.2

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
0.859	4.9	-2.4	0.88	-	0.624	-29	0.622	-29

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 1.0%, the difference from the value derived from the Kayzero [2] library is 12.7%, and the quoted uncertainty of this value is 1.9%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries agree with the value by Mughabghab [1] and are 14.2% higher than the Kayzero [2] value.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 4.9% and is smaller by 2.4% in comparison with the Kayzero [2] value, which has no uncertainty given. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are both 29% lower than the Kayzero [2] value.

Th JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are practically equivalent. The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 1.017

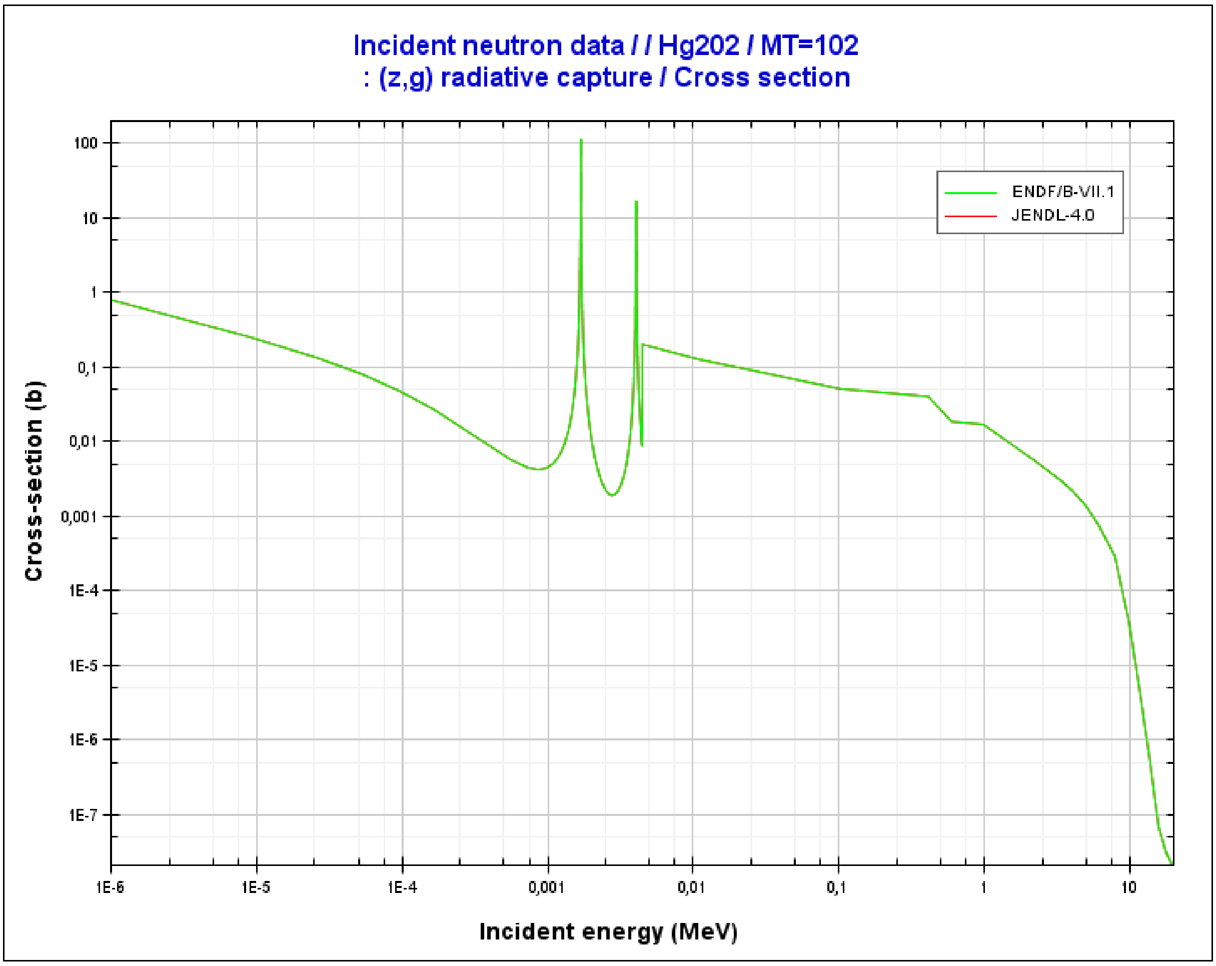
g = 0.999

E_r = 9719 eV

σ_0 = 4.956 b

Q_0 = 0.622

σ_h = 0.0130 b


Incident neutron data / / Hg202 / MT=102
: (z,g) radiative capture / Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
100
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.103. $^{204}Hg(n,\gamma)^{205}Hg$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
0.43	23.3	-2.1	0.44	2.2	0.4316	-1.7	0.4316	-1.7

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
1.977	33.1	-0.2	1.98	-	6.226	214	6.226	214

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 23.3% and is 2.1% smaller than the value derived from the Kayzero [2] library, which is given with an uncertainty of 2.2%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are the same and fully agree with the Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 33.1% and is in excellent agreement with the Kayzero [2] value, which has no uncertainty given. The Values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are by more than a factor of three higher.

The cross sections in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] are the same, but they do not contain real resonance data, only the scattering radius is given. The ENDF/B-VII.1 [5] library is arbitrarily selected. Although the constants for NAA derived from this library are not of much use for practical applications, they are as follows:

F_{cd} = 0.995

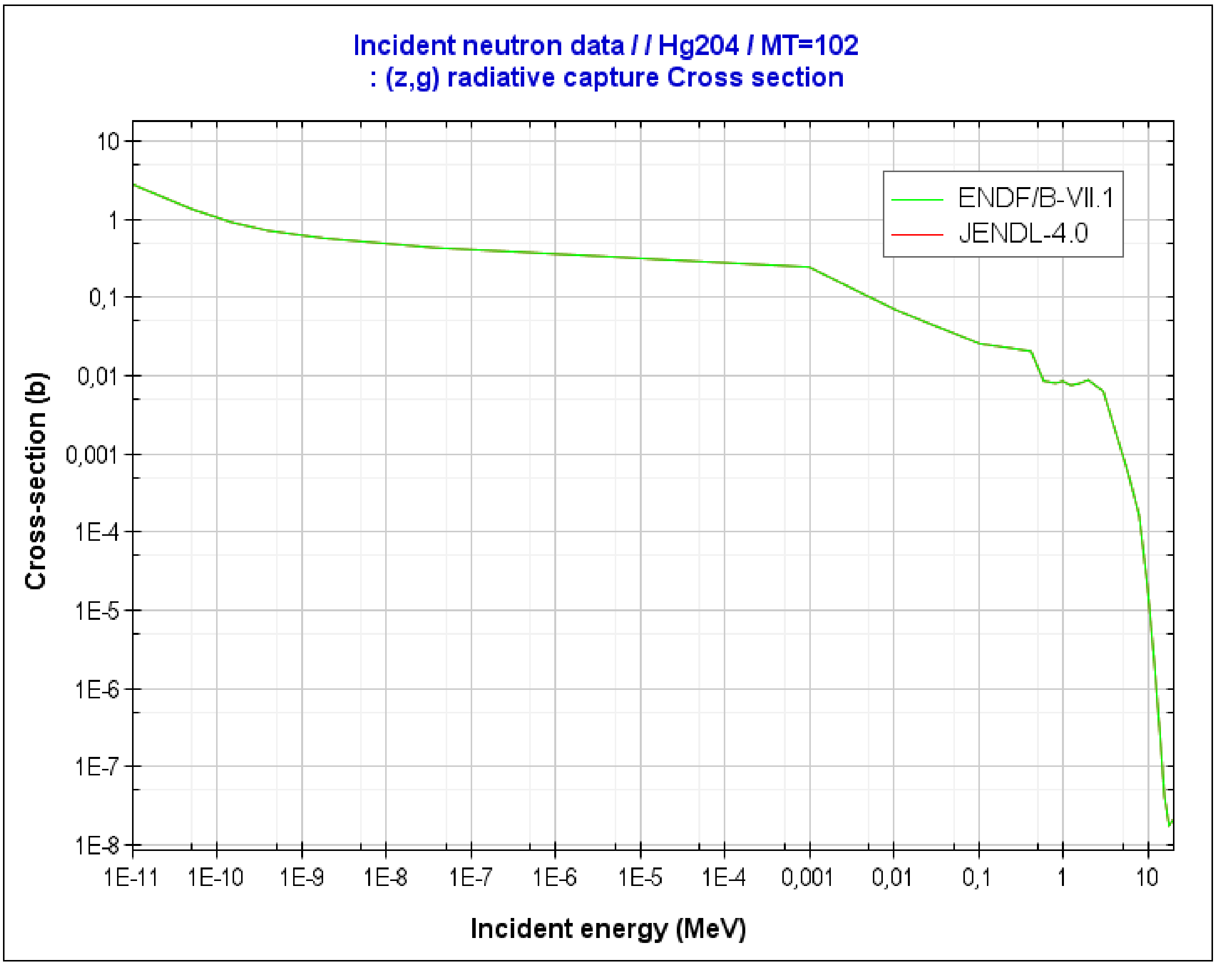
g = 1.109

E_r = 64.47 eV

σ_0 = 0.4316 b

Q_0 = 6.226

σ_h = 0.00845 b



Incident neutron data / / Hg204 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
10
1
0,1
0,01
0,001
1E-4
1E-5
1E-6
1E-7
1E-8
1E-11
1E-10
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.104. $^{232}Th(n,\gamma)\,^{233}Th$

The thermal cross sections and the Q_0 alues are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
7.35	0.4	0.1	7.341	0.5	7.338	0.0	7.339	0.0

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
11.33	1.8	-1.4	11.5	3.6	11.47	-0.3	11.46	-0.4

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.4% and is 0.1% larger than the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.5%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are fully consistent with the Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 1.8% and is smaller by 1.4% in comparison with the Kayzero [2] value, which has an uncertainty of 3.6%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are also consistent with the Mughabghab [1] and the Kayzero [2] values.

The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.992

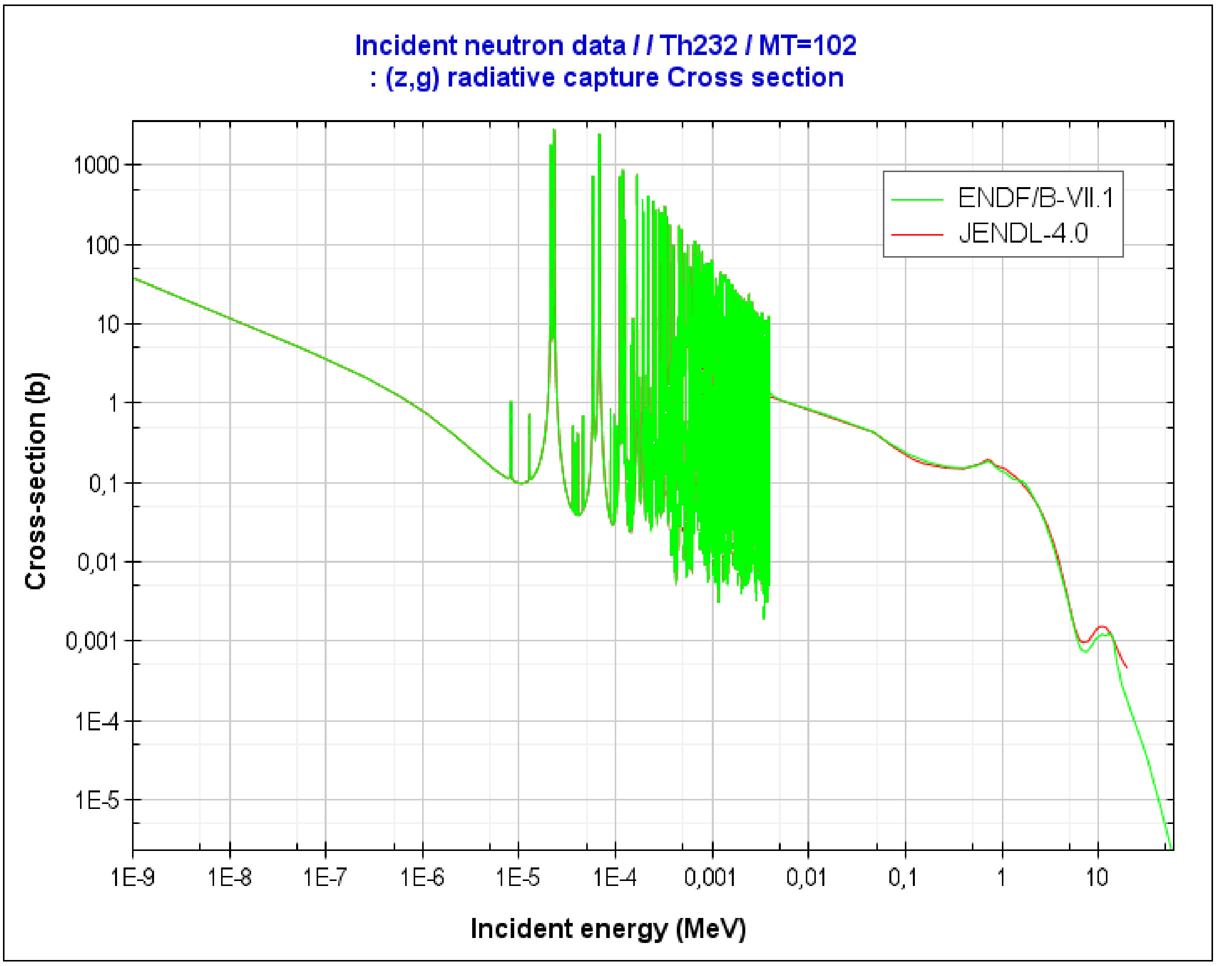
g = 0.993

E_r = 72.08 eV

σ_0 = 7.339 b

Q_0 = 11.46

σ_h = 0.0932 b



Incident neutron data / / Th232 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-5
Cross-section (b)
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

2.5.105. $^{238}U(n,\gamma)^{239}U$

The thermal cross sections and the Q_0 values are as follows:

Mughabghab [1]			Kayzero [2] / Nudat [3]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
σ_0	$\Delta\sigma_0$	Diff.	σ_0	$\Delta\sigma_0$	σ_0	Diff.	σ_0	Diff.
[b]	[%]	[%]	[b]	[%]	[b]	[%]	[b]	[%]
2.68	0.7	-1.6	2.72	0.9	2.684	-1.4	2.684	-1.4

Mughabghab [1]			Kayzero [2]		JENDL-4.0 [4]		ENDF/B-VII.1 [5]	
Q_0	ΔQ_0	Diff.	Q_0	ΔQ_0	Q_0	Diff.	Q_0	Diff.
	[%]	[%]		[%]		[%]		[%]
103.4	1.3	0.0	103.4	1.3	102.6	-0.7	102.5	-0.8

- Thermal cross section by Mughabghab [1] is quoted with an uncertainty of 0.7% and is in excellent agreement with the value derived from the Kayzero [2] library, which is given with an uncertainty of 0.9%. The values in the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are also in excellent agreement with the Mughabghab [1] and the Kayzero [2] values.
- The Q_0 value according to Mughabghab [1] has an assigned uncertainty of 1.3% and is in excellent agreement with the Kayzero [2] value, which has an uncertainty of 1.3%. The values derived from the JENDL-4.0 [4] and the ENDF/B-VII.1 [5] libraries are also in very good agreement with the Mughabghab [1] and the Kayzero [2] values

The ENDF/B-VII.1 [5] library is arbitrarily selected. The constants derived from this library are:

F_{cd} = 0.993

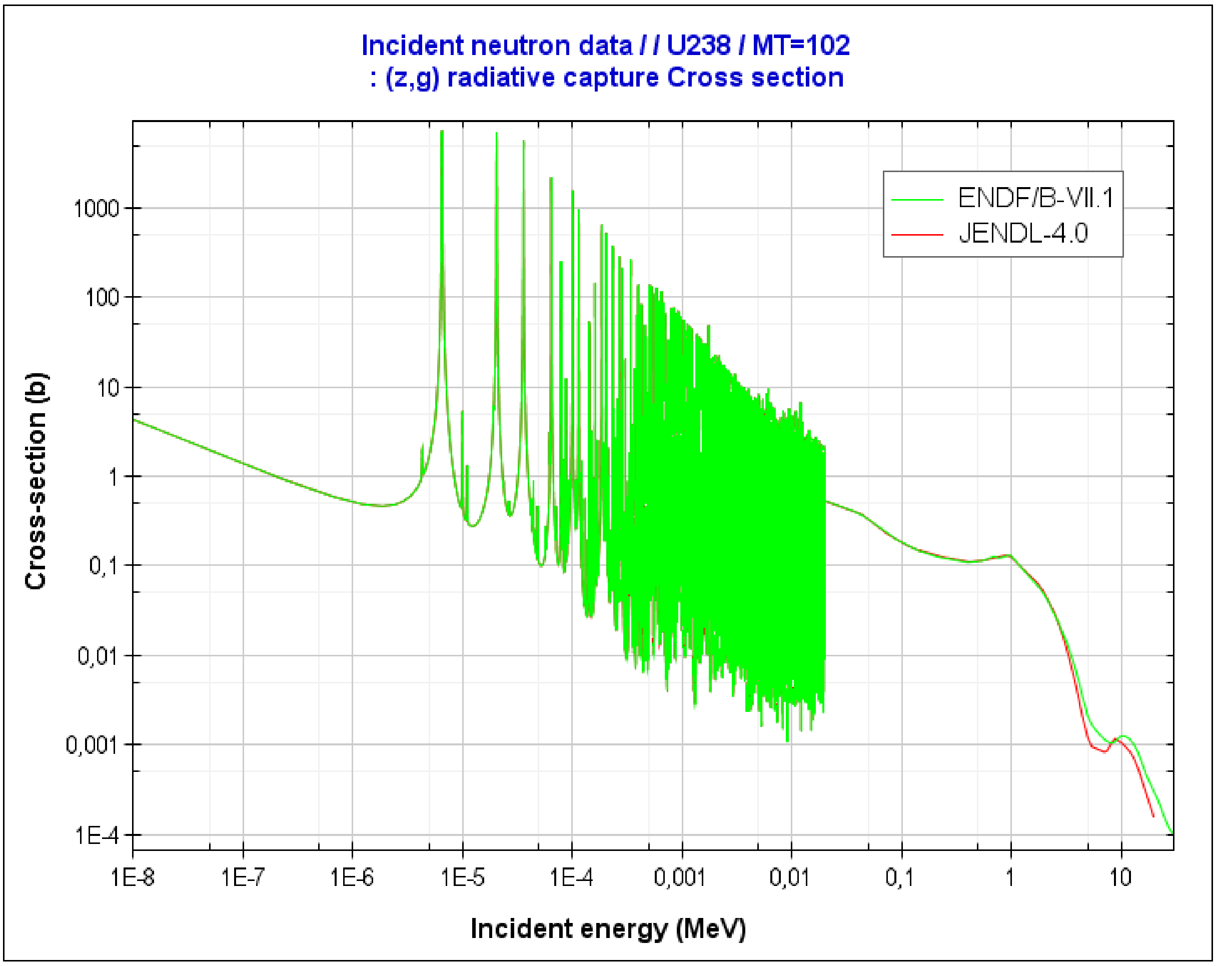
g = 1.001

E_r = 18.25 eV

σ_0 = 2.684 b

Q_0 = 102.5

σ_h = 0.0689 b


Incident neutron data / / U238 / MT=102
: (z,g) radiative capture Cross section
ENDF/B-VII.1
JENDL-4.0
Cross-section (b)
1000
100
10
1
0,1
0,01
0,001
1E-4
1E-8
1E-7
1E-6
1E-5
1E-4
0,001
0,01
0,1
1
10
Incident energy (MeV)

Discussion

For a series of neutron induced reactions, integral parameters, used in the k_0 method, have been calculated from state-of-the-art energy dependent cross sections and systematically compared to the existing k_0 database.

The agreement is satisfactory (to within a few percent) for materials, important for nuclear applications (e.g. U, Th, etc.). However, for some less important materials (e.g. ^{132}Ba), almost no resonances are known, therefore large deviations which might exceed 50%, are not unexpected.

When there are substantial differences in the σ_0 and the calculated Q_0 values compared to the ones in the Kayzero [2] database, it is recommended to keep the current Kayzero [2] value (particularly for Q_0 and the E_r). Every effort should be made to re-measure the k_0 and Q_0 values, taking great care to understand in depth any deviation from the $1/E$ shape in the spectrum by multiple-monitor activation measurements as well as by computation and using the new E_r value for the correction. If the discrepancy with the calculated value is reduced, use the new values.

3. Conclusions

During the CRP a compilation of newly measured k_0 and Q_0 values determined since 2003 has been produced, a number of which were measured within the CRP. These new values have been validated by analysis of previously measured reference materials. Hence these values form a basis for future recommendation and integration into the relevant international data libraries.

The k_0 database, including new measurements, was used to generate improved σ_0 and $P\gamma$ values for inclusion in the EGAF database. Thus the updated EGAF database will provide a self consistent set of k_0, σ_0 and $P\gamma$ values. These values can be considered for adoption in the next evaluation of k_0 values.

A set of consistent neutron energy dependent cross section files has been produced through adjustment of existing evaluations to the relevant integral constants of k_0-NAA, i.e. σ_0, Q_0, and is available from the IAEA.

Neutron energy dependent cross section measurements have been made and, in combination with measured k_0 and Q_0 values, new evaluated data files have been produced.

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APPENDIX I: Comparison of different algorithms used for determining detector efficiency (Z. Revay)

An exercise was organized to compare the different methods used at the participating laboratories for the determination of the detector efficiency. There are many common and different characteristics of these methods, that is why it is important to investigate and compare their performance.

Participating Laboratories:

Common properties. The algorithms in all participating laboratories were developed for neutron activation analysis, or prompt gamma activation analysis, i.e. for the detection of neutron induced gamma radiation. All methods describe the counting efficiency with one continuous curve in the necessary energy range (from 50 keV up to at least 2.5 MeV). The curve itself is given in analytic form (but may consist of several parts). The functions are described as one of more polynomials on a log-log scale. The functions are fitted to measured data points, i.e. actual efficiency values determined for gamma-ray lines of calibrated sources based on the following expression:

$$\varepsilon = \frac{A}{a\, P_\gamma\, t} \tag{1}$$

where A is the net peak area, a is the activity of the source in Bq, P_γ is the emission probability of the given gamma-ray line (taken from the literature) and t is the measurement time (live time in s).

Discrepancies. The major discrepancy between the methods is the number of fitted parameters, the number of polynomials used to describe the whole energy range and the joining points of the different ranges.

As there is no standardized method for determining the efficiency, the question is if these procedures are all equally appropriate.

The question was raised because a few common simplifications (the assumption of linear function on a log-log scale between 300 and 3000 keV) made questionable the used models.

As it is well-known, full-energy peak efficiency is affected by a series of physical effects, the absorption in the aluminum window and the dead layer of the detector, the photo effect, single and multiple Compton scattering and pair production. The superposition of these effects does not result in a straight line. As it was shown in the semi-empirical description of the detector, all these effects are significant, at different energies, though [20]. The semiepirical function of the 25-% HPGe detector at Budapest is shown in the next figure.

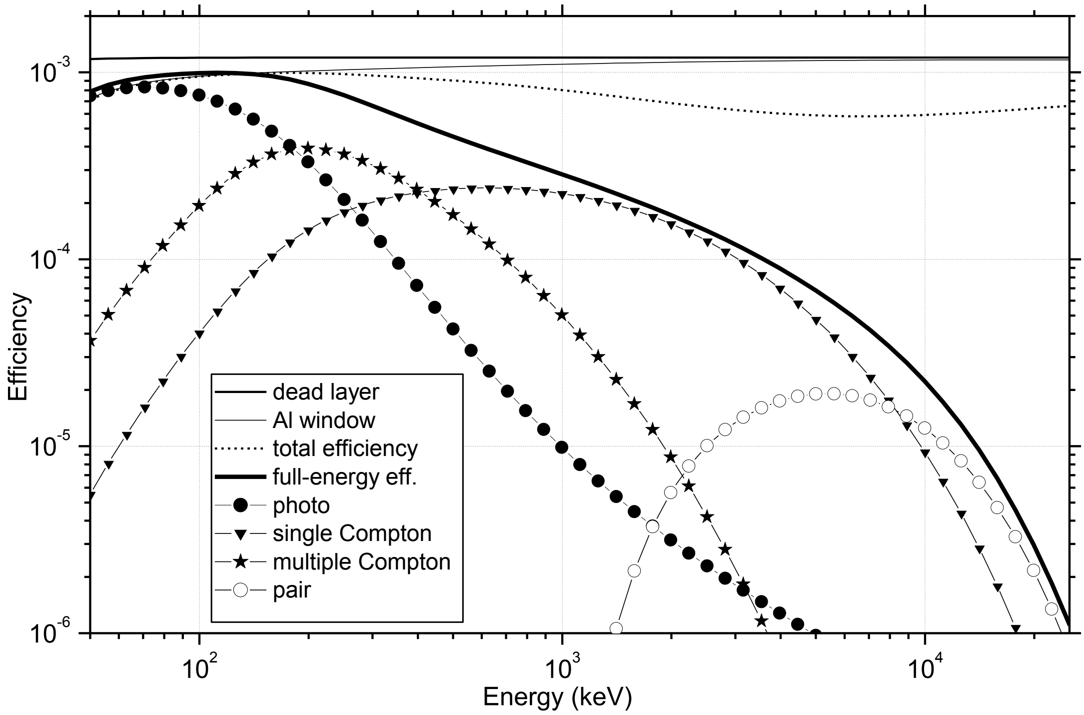

Fig. 1. Semi-empirical description of the efficiency function of a typical HPGe detector

As can be seen, the maximum of the function can found at about 100 keV, which comes from the product of the gamma-ray absorption in the aluminum window and the detector dead layer with the contribution of the photo effect. The photo effect drops drastically above 100 keV, and at about 200 keV and 300 keV the contribution from the single and multiple Compton scatterings (followed by the total energy absorption of the photon) becomes higher. While the contribution of single Compton scattering also drops quickly at low energies, that from multiple scattering covers a broad energy range from the lowest to the highest energies, thus becoming the most important part of the whole function. It dominates other effects between 500 keV and 5000 keV. At the highest energies the contribution of the pair production also becomes significant, but that is unimportant in the NAA energy range. Because of the overlaps of these functions dips and rises appear over the general tendency of the function, as can be seen in the next figure.

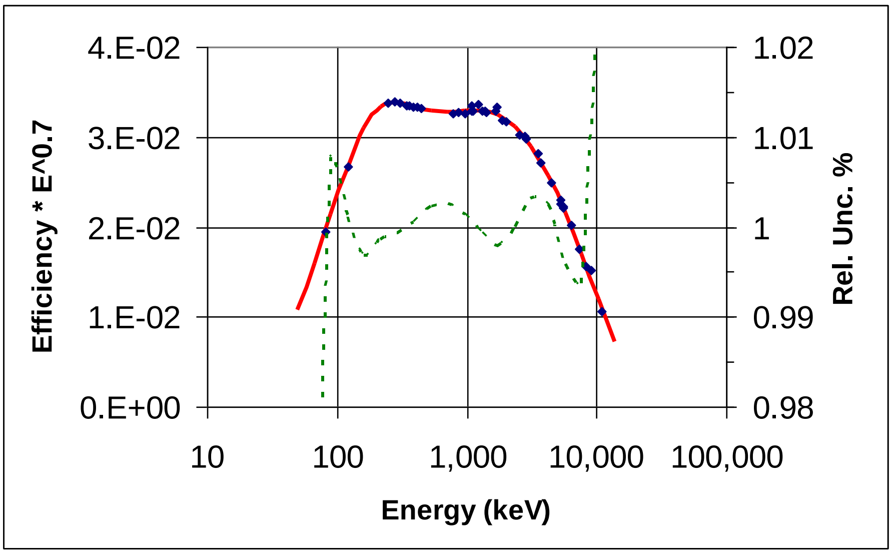

Fig. 2. The measured and fitted efficiency of the 25-% HPGe detector at Budapest multiplied with $E^{0.7}$.

As can be seen, the middle energy range cannot be fitted with a straight line, it has two edges at about 300 keV and above 2 MeV, and a dip around 600 keV. The next figure shows a simple trend-line fit made with Excel in the middle energy range between about 300 keV and 3 MeV. As can be seen the straight line fits the actual efficiency curve quite well, an acceptable correlation factor value can also be obtained.

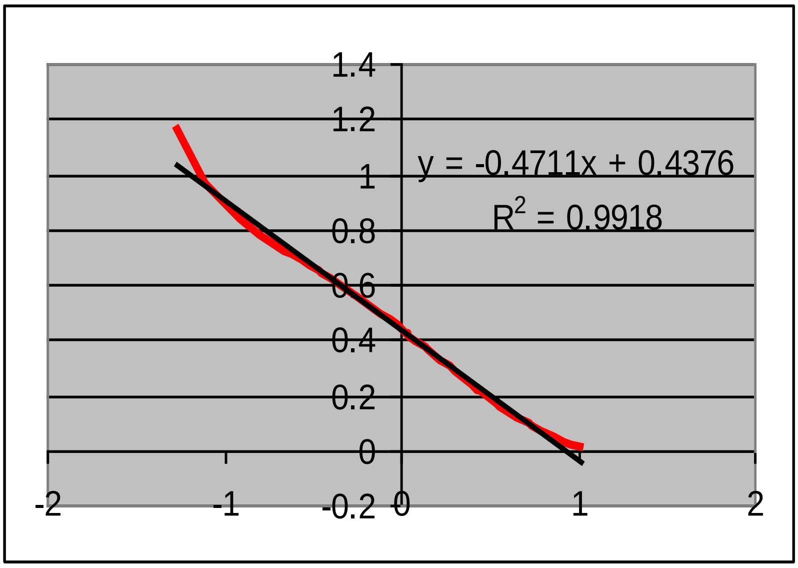

Fig. 3. The mid energy range of the efficiency curve fitted with a straight line

In some cases the mid-energy dip of the efficiency curve is clearly visible even when using the standard plot, se below:

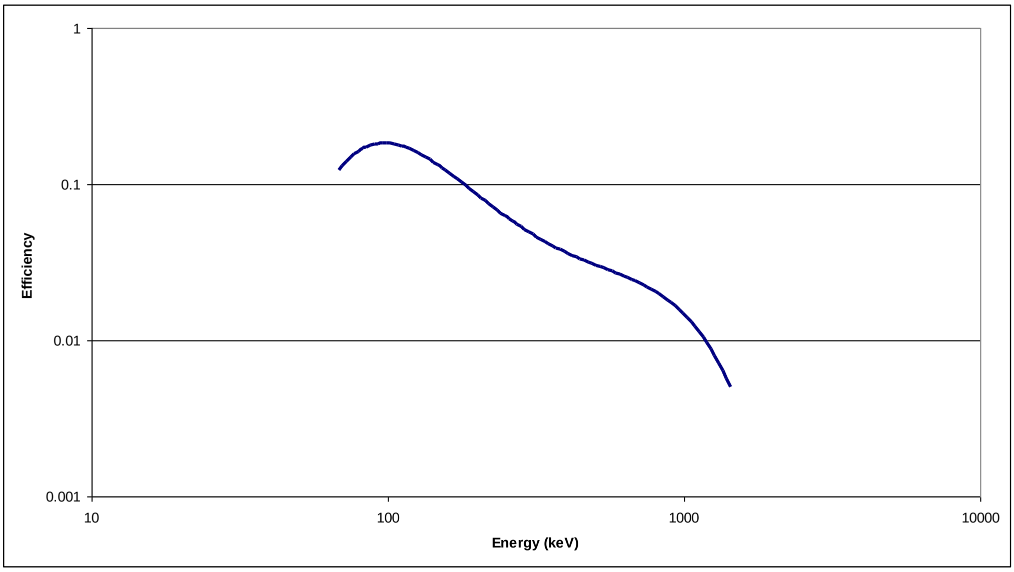

Fig. 4. The efficiency curve of a 15-% HPGe detector as measured in contact counting geometry.

All these fact draw the attention of the analytical chemists that the efficiency functions have to be determined carefully. A special care has to be taken for the mid energy "dip" of the curve.

Efficiency proficiency test

The proficiency test was performed in two trials. The first comparison failed because of the use of a few wrong literature data. In the second test everybody received data approved by Richard B. Firestone to use the latest literature values.

Three nuclides were chose for the sake of simplicity: ^{133}Ba, ^{152}Eu and ^{226}Ra. The spectra were taken at the Institute of Isotopes with a 25-% n-type HPGe detector manufactured by Canberra using standard analog NIM based electronics and Canberra S-100 MCA card. The spectra were evaluated with Hypermet-PC [21, 22]. Tables 1–3 show the results.

Table 1. Spectroscopic and measured data for ^{133}Ba. (Half-life: 3850±4 days*, estimated activity: 94.24 Bq ± 0.80% measurement date: 1/6/2008)

E*	unc	Emis Prob*	unc	Area	rel unc%
30.852	0.001	0.968	0.008	426	12.9
53.1622	0.0006	0.0214	0.0003	30566	1.7
79.6142	0.0012	0.0265	0.0005	39810	2.6
80.9979	0.0011	0.329	0.003	520114	0.5
160.612	0.0016	0.00638	0.00004	9179	1.6
223.2368	0.0013	0.00453	0.00003	5628	3.4
276.3989	0.0012	0.0716	0.0005	77386	0.4
302.8508	0.0005	0.1834	0.0013	183961	0.1
356.0129	0.0007	0.6205	0.0019	548587	0.2
383.8485	0.0012	0.0894	0.0006	74456	0.7

Table 2. Spectroscopic and measured data for ^{152}Eu. (Half-life: 4940±5 days*, Certified activity 203.9 kBq, rel. unc.: 0.70%, measurement date: 7/11/1978)

E*	unc	Emis Prob*	unc	Area	rel unc%
39.91	0.001	0.585	0.006	2511	12.7
121.7817	0.0003	0.2841	0.0013	3666976	0.2
244.6974	0.0008	0.0755	0.0004	739064	0.2
295.9387	0.0017	0.00442	0.00003	37457	0.8
344.2785	0.0012	0.2658	0.0012	590	26.5
367.7891	0.002	0.00862	0.00005	2329	7.5
411.1165	0.0012	0.02237	0.0001	2014814	0.1
443.965	0.003	0.0312	0.0003	1118	9.1
488.6792	0.002	0.004137	0.000024	368	24.7
586.265	0.003	0.00462	0.00004	62221	0.6
678.623	0.005	0.0047	0.00004	440	18.6
688.67	0.005	0.00841	0.00006	147787	0.2
778.9045	0.0024	0.1296	0.0006	7197	1
867.38	0.003	0.04241	0.00023	193768	0.3
919.337	0.004	0.00429	0.00005	1579	4.9

E*	unc	Emis Prob*	unc	Area	rel unc%
963.39	0.012	0.001341	0.00002	23622	0.7
964.079	0.018	0.1449	0.0006	2414	3.3
1085.837	0.01	0.1013	0.0006	600	11.3
1089.737	0.005	0.0173	0.0001	8777	1.3
1112.076	0.003	0.134	0.0006	385	19.3
1212.948	0.011	0.01415	0.00009	1053	10.5
1299.142	0.008	0.01632	0.00009	382	28.4
1408.013	0.003	0.2084	0.0009	2965	2.2
1457.643	0.011	0.00498	0.00004	828	6.5

Table 3. Spectroscopic and measured data for ^{226}Eu (Half-life: 586200±2200 days*, estimated activity 101.79 kBq, measurement date: 1/6/2008)

E	unc	Emis Prob	unc	Area	rel unc%
53.2275	210000	0.01066	0.00014	78515	1.3
2118.536	0.008	0.01148	0.00011	994054	0.1
186.211	0.013	0.03533	0.00028	257110	0.3
241.997	0.003	0.0719	0.0006	452086	0.2
295.224	0.002	0.1828	0.0014	994054	0.1
351.932	0.002	0.3534	0.0027	1711	17
609.316	0.003	0.4516	0.0033	3899	4.9
665.453	0.022	0.01521	0.00011	186	72.5
768.367	0.011	0.0485	0.00038	1416	10.9
806.185	0.011	0.01255	0.00011	3383	6.7
934.061	0.012	0.03074	0.00025	1164	14.9
1120.287	0.01	0.1478	0.0011	789	45.9
1155.19	0.02	0.01624	0.00014	7528	6.7
1238.11	0.012	0.05785	0.00045	1678085	0.2
1280.96	0.02	0.01425	0.00012	444	31.1
1377.669	0.012	0.03954	0.00033	361	24.4
1401.516	0.014	0.01324	0.00011	12717	1.2
1407.993	0.007	0.02369	0.00019	17704	1
1509.217	0.008	0.02108	0.00021	673	13.6
1661.316	0.013	0.01037	0.0001	1123	8.2
1729.64	0.012	0.02817	0.00023	83	97.2
1764.539	0.015	0.1517	0.0012	7027	1.7
1847.42	0.025	0.02	0.00018	828	12.8
2204.071	0.021	0.0489	0.001	11550	1.4
2447.673	0.01	0.01536	0.00015	122	112.6

*IAEA recommendation 2003

Comparison

Six different methods have been compared; the comparison with one of them finally failed. Most data arrived without uncertainties and there were incompatibility problems (date formats etc.); finally the comparison with method D could not be performed. The basis properties of the different methods are shown below.

Number of points: 56 (except D)

A:

method: Hypermet

function: 8th-order orthonormal polynomial

B:

method: Excel

Function: 50–250 3rd-order poly, 250– 1st-order poly (straight line)

C:

method: Excel

function: 6-order poly

D:

method: k0-IAEA

function: unknown

number of points: 21

E:

method: kayzero

function: 50–250: 3rd-order, 250– 1st-order

F:

method: Excel

function: 5th-order polynomial

The results of the comparison are shown in the next table.

Table 4. The statistical comparison of the different methods

	calculated/measured	Average Z score	st. dev	χ^2
A	1.0002	–0.0018	0.89	0.77
B	1.0042	0.41	1.36	2.0
C	1.0204	2.94	3.81	23
D	*1.07*	*11*	*4.5*	*150*
D (mod)	*1.02*	*4.61*		
D (mod2)	*0.995*	*–0.86*		*54*
E	0.996	–0.55	1.21	1.7
F	1.0002	0.061	1.13	1.3

Conclusions

Because of irresolvable formatting and compatibility problems method "D" could not be compared with the others. The other methods resulted in acceptable Z score and χ^2 values.

It was concluded that any of the above mentioned methods can be used for the description of the efficiency. It is highly recommended to use uncertainties for precise analytical work.

Though the statistical tests were not specifically sensitive to this, it is recommended to avoid the convention of using a straight line approach in the middle energy region. A 2nd or a 3rd order polynomial should be used instead.

APPENDIX II: Comparison of the IUPAC and EGAF k0 Factors (R. Firestone)

IUPAC recommended Neutron Activation Analysis (NAA) k_0 factors have been compared with k_0 factors calculated from evaluated total thermal neutron capture radiative cross sections σ_0 from the Evaluated Gamma-ray Activation File (EGAF) and γ-ray transition probabilities from the Table of Radionuclides and the Evaluated Nuclear Structure Data File (ENSDF). Discrepancies were found for some isotopes and are discussed here.

Discussion

The Neutron Activation Analysis (NAA) k_0 factor $(k_{0,Au})_\gamma$ for a γ-ray emitted by neutron activation on a target of element *x* is defined as the ratio of the thermal neutron capture γ-ray cross section, $\sigma_\gamma = \sigma_{0,x} P_\gamma$, to the comparator Au γ-ray cross section for the 411.8-keV transition from neutron capture as shown in Equation (1). Here $\sigma_{0,x}$ is the total thermal neutron radiative cross section ($\sigma_{0,Au}$=98.65 b), and P_γ is the γ-ray transition probability ($P_{411.8}$=0.9554).

$$(k_{0,Au})_\gamma = \frac{M_{Au}\theta_x \sigma_{0,x} P_\gamma}{M_x \theta_{Au} \sigma_{0,Au} P_{Au}} \tag{1}$$

The k_0 factor is weighted by the mass, $\frac{\theta_\gamma}{M_x}$, where M_x is the atomic mass (M_{Au}=196.96655) and θ is the isotopic abundance (θ_{Au}=100). The k_0 formalism directly relates the ratio of γ-ray intensities from different elements produced by neutron activation of a target to the ratio of their abundance by wt% in the target.

Recommended k_0 factors for the principal γ-rays from more than 130 isotopes and isomers are given in a IUPAC report [23] based largely on measurements by De Corte and Simonits [2]. Comparable k_0 factors can be derived from the Evaluated Gamma-ray Activation File (EGAF) [24] database using Eq (1). In EGAF the σ_0 values are derived from thermal neutron cross section measurements at the Budapest Reactor [25] and recommended values in the Atlas of Neutron Resonances [26]. The γ-ray transition probabilities P_γ taken from either the *Table of Radionuclides* produced by the Decay Data Evaluation Project [27] or the Evaluated Nuclear Structure Data File (ENSDF) [28]. The EGAF and IUPAC recommended k_0 factors are compared in Table 1.

Results

Most k_0 values derived from the EGAF σ_0 and P_γ data agree very well with the IUPAC recommended values. It should be noted that in many cases with multiple γ-rays most k_0 are in good agreement but there are some exceptional outliers. Since relative P_γ data from decay studies are usually reliable, these data should be considered when adopting new k_0 values. Some significant discrepancies are discussed below.

Sulfur: The IUPAC k_0 value for the 3103.361-keV γ-ray is 64% of the adopted value probably because the ^{36}S terrestrial abundance is known to vary considerably. The determination of sulfur by activation analysis is not recommended.

Potassium: Two γ-rays with energies of 312.6- and 1524.6-keV are recommended for k_0 analysis. Agreement between the IUPAC and EGAF k0 values is satisfactory for the higher energy transition but not for the lower energy one. The relative P_γ values for the two transitions should be good favoring the EGAF measurement. Since that γ-ray is much weaker it is recommended that only the higher energy transition be used in k_0 analysis.

Calcium: The IUPAC and EGAF k_0 values agree for the 8.7 min and 4.5 d Ca activities but not for the 159.381-keV g-ray from the 3.3 d activity. Additional measurements are recommended to resolve this discrepancy.

Zinc: The adopted k_0 factors for 1115.539 keV γ-ray from ^{65}Zn (244.01 d) are about 6% higher than IUPAC values. The IUPAC k_0 value corresponds to a lower σ_0 than recommended in the Atlas. It is recommended that this k_0 value be re-measured.

Germanium: The k_0 value measured at the Budapest Reactor for the 139.68 keV γ-ray from ^{76m}Ge (47.7 s) is significantly larger than the IUPAC value. It is recommended here that the Budapest value be adopted.

Arsenic: Discrepancies in the EGAF and IUPAC k_0 values for γ-rays from ^{75}As (26.24 h) appear to be due to problems with the P_γ values. New decay scheme measurements are recommended.

Niobium: The adopted cross section to ^{93m}Nb is σ_0=0.104(4) b. No value exists in the Atlas. A large uncertainty in the γ-decay branching ratio for ^{94m}Nb (6.263 m) limits the analytical sensitivity of these k_0 values.

Tin: IUPAC k_0 data 125mSn (9.52 m) and 125Sb (2.75855 y) systematically lower than EGAF values. In these cases the P_γ ratios appear to be problematic and should be remeasured.

Neodymium: The IUPAC k_0 for ^{151}Pm (28.4 h) is 10% lower than that calculated from the EGAF data. This suggests either a problem with P_γ or σ_0.

Osmium: The IUPAC k_0 value for the 129.431-keV γ-ray from ^{191}Os (15.4 d) is highly discrepant EGAF value which is based on the well determined cross sections for ^{191}Os and ^{191m}Os. It is recommended that this k0 value be re-measured.

Conclusions

This comparison of IUPAC and EGAF k_0 factors has shown that while the agreement between both databases is generally excellent there is still plenty of room for improvement. A broader effort to reconcile the differences between these databases would lead to a significant improvement in the k_0, σ_0 and P_γ values that are used in numerous nuclear applications. We plan to continue to work on developing a single, self-consistent nuclear constants database in consultation with the many research communities that are involved.

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
19F	11.163±0.008 s	1633.602±0.015	0.000998 ± 0.000012	0.001028 ± 0.000010	0.97 ± 0.01
23Na	14.9574±0.002 h	1368.626±0.005	0.0468 ± 0.0003	0.04918 ± 0.00036	0.95 ± 0.01
23Na	14.9574±0.002 h	2754.007±0.011	0.0462 ± 0.0004	0.04911 ± 0.00036	0.94 ± 0.01
26Mg	9.458±0.012 m	170.686±0.15	0.00000302 ± 0.00000003	0.0000029 ± 0.0000004	1.05 ± 0.13
26Mg	9.458±0.012 m	843.76±0.03	0.0002530 ± 0.0000010	0.000258 ± 0.000006	0.98 ± 0.02
26Mg	9.458±0.012 m	1014.46±0.04	0.000098 ± 0.000002	0.000100 ± 0.000003	0.98 ± 0.03
27Al	2.2414±0.0012 m	1778.987±0.015	0.0175 ± 0.0001	0.01797 ± 0.00023	0.97 ± 0.01
30Si	157.3±0.3 m	1266.15±0.1	0.000000145 ± 0.000000001	0.000000133 ± 0.000000011	1.09 ± 0.09
36S	5.05±0.02 m	3103.361±0.02	0.00000196 ± 0.00000004	0.00000305 ± 0.00000010	0.64 ± 0.02
37Cl	37.23±0.014 m	1642.43±0.06	0.00197 ± 0.00003	0.00206 ± 0.00004	0.96 ± 0.02
37Cl	37.23±0.014 m	2167.54±0.05	0.00266 ± 0.00003	0.00274 ± 0.00007	0.97 ± 0.03
40Ar	109.61±0.04 m	1293.64±0.04	0.0332 ± 0.0003	0.03322 ± 0.00067	1.00 ± 0.02
41K	12.36±0.012 h	312.6±0.25	0.0000159 ± 0.0000002	0.0000184 ± 0.0000011	0.86 ± 0.05
41K	12.36±0.012 h	1524.6±0.3	0.000946 ± 0.000006	0.000991 ± 0.000015	0.96 ± 0.02
46Ca	3.3492±0.0006 d	159.381±0.015	0.00000086 ± 0.00000001	0.00000100 ± 0.00000004	0.86 ± 0.04
46Ca	4.536±0.003 d	489.23±0.1	0.000000091 ± 0.000000002	0.000000086 ± 0.000000006	1.06 ± 0.07
46Ca	4.536±0.003 d	807.86±0.1	0.0000000920 ± 0.0000000002	0.000000086 ± 0.000000006	1.07 ± 0.07
46Ca	4.536±0.003 d	1297.09±0.1	0.000000954 ± 0.000000002	0.00000098 ± 0.00000006	0.98 ± 0.06
48Ca	8.718±0.006 m	3084.4±0.1	0.0001010 ± 0.0000009	0.0000995 ± 0.0000018	1.01 ± 0.02
45Sc	83.788±0.022 d	889.271±0.002	1.220 ± 0.005	1.213 ± 0.014	1.01 ± 0.01
45Sc	83.788±0.022 d	1120.537±0.003	1.220 ± 0.013	1.213 ± 0.014	1.01 ± 0.02
50Ti	5.76±0.01 m	320.076±0.006	0.000374 ± 0.000004	0.000375 ± 0.000007	1.00 ± 0.02
50Ti	5.76±0.01 m	928.63±0.04	0.0000265 ± 0.0000003	0.0000269 ± 0.0000005	0.98 ± 0.02
51V	3.743±0.005 m	1434.06±0.01	0.196 ± 0.002	0.198 ± 0.003	0.99 ± 0.02
50Cr	27.703±0.003 d	320.0824±0.0004	0.00262 ± 0.00013	0.00272 ± 0.00005	0.96 ± 0.05
55Mn	2.57878±0.0046 h	846.7638±0.0019	0.496 ± 0.003	0.5042 ± 0.0019	0.98 ± 0.01
55Mn	2.57878±0.0046 h	1810.726±0.004	0.1350 ± 0.0005	0.1372 ± 0.0021	0.98 ± 0.02
55Mn	2.57878±0.0046 h	2113.092±0.006	0.07170 ± 0.00014	0.0724 ± 0.0016	0.99 ± 0.02
58Fe	44.495±0.008 d	142.651±0.002	0.00000133 ± 0.00000002	0.00000133 ± 0.00000003	1.00 ± 0.03
58Fe	44.495±0.008 d	192.349±0.005	0.00000378 ± 0.00000002	0.00000400 ± 0.00000007	0.94 ± 0.02
58Fe	44.495±0.008 d	334.8±0.2	0.000000382 ± 0.000000004	0.000000362 ± 0.000000011	1.05 ± 0.03
58Fe	44.495±0.008 d	1099.245±0.003	0.0000777 ± 0.0000004	0.0000776 ± 0.0000012	1.00 ± 0.02
58Fe	44.495±0.008 d	1291.59±0.006	0.0000593 ± 0.0000002	0.0000593 ± 0.0000010	1.00 ± 0.02
59Co	10.467±0.006 m	58.603±0.007	0.01510 ± 0.00012	0.0155 ± 0.0003	0.98 ± 0.02
59Co	5.271±0.0008 y	1173.228±0.003	1.320 ± 0.005	1.314 ± 0.004	1.00 ± 0.01

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
59Co	5.271±0.0008 y	1332.492±0.004	1.320 ± 0.007	1.315 ± 0.004	1.00 ± 0.01
59Co	10.467±0.006 m	1332.492±0.004	0.00175 ± 0.00003	0.00179 ± 0.00022	0.98 ± 0.12
64Ni	2.5172±0.0003 h	366.27±0.03	0.0000251 ± 0.0000003	0.0000255 ± 0.0000004	0.99 ± 0.02
64Ni	2.5172±0.0003 h	1115.53±0.04	0.0000814 ± 0.0000004	0.0000819 ± 0.0000012	0.99 ± 0.02
64Ni	2.5172±0.0003 h	1481.84±0.05	0.0001270 ± 0.0000008	0.0001252 ± 0.0000017	1.01 ± 0.02
63Cu	12.701±0.002 h	1345.77±0.16	0.000498 ± 0.000004	0.000514 ± 0.000011	0.97 ± 0.02
65Cu	5.12±0.14 m	1039.231±0.006	0.00186 ± 0.00001	0.00197 ± 0.00003	0.95 ± 0.02
64Zn	244.01±0.09 d	1115.539±0.002	0.00572 ± 0.00002	0.00608 ± 0.00016	0.94 ± 0.02
68Zn	13.76±0.02 h	438.634±0.018	0.000398 ± 0.000002	0.000410 ± 0.000017	0.97 ± 0.04
70Zn	2.45±0.1 m	121.51±0.04	0.000000109 ± 0.000000003	0.000000131 ± 0.000000015	0.83 ± 0.10
70Zn	2.45±0.1 m	511.56±0.04	0.00000155 ± 0.00000003	0.00000140 ± 0.00000012	1.11 ± 0.10
71Ga	14.1±0.02 h	629.96±0.04	0.0149 ± 0.0002	0.0137 ± 0.0003	1.09 ± 0.03
71Ga	14.1±0.02 h	834.03±0.03	0.0523 ± 0.0003	0.0529 ± 0.0005	0.99 ± 0.01
71Ga	14.1±0.02 h	894.25±0.1	0.00546 ± 0.00005	0.00547 ± 0.00010	1.00 ± 0.02
71Ga	14.1±0.02 h	1050.69±0.05	0.00383 ± 0.00003	0.00383 ± 0.00007	1.00 ± 0.02
71Ga	14.1±0.02 h	2201.66±0.07	0.0148 ± 0.0002	0.0143 ± 0.0003	1.03 ± 0.02
71Ga	14.1±0.02 h	2490.98±0.07	0.00419 ± 0.00007	0.00425 ± 0.00013	0.99 ± 0.03
71Ga	14.1±0.02 h	2507.79±0.07	0.00716 ± 0.00009	0.00708 ± 0.00014	1.01 ± 0.02
74Ge	47.7±0.5 s	139.68±0.03	0.000573 ± 0.000009	0.000676 ± 0.000025	0.85 ± 0.03
74Ge	82.78±0.04 m	198.606±0.0012	0.0000615 ± 0.0000006	0.000052 ± 0.000005	1.18 ± 0.12
74Ge	82.78±0.04 m	468.8±0.2	0.0000120 ± 0.0000001	0.0000098 ± 0.0000010	1.23 ± 0.13
74Ge	82.78±0.04 m	617.7±0.2	0.00000469 ± 0.00000005	0.0000050 ± 0.0000005	0.94 ± 0.10
76Ge	52.9±0.6 s	159.7±0.1	0.0000245 ± 0.0000002	0.000024 ± 0.000003	1.00 ± 0.11
76Ge	11.3±0.01 h	211.03±0.03	0.0000390 ± 0.0000004	0.0000425 ± 0.0000024	0.92 ± 0.05
76Ge	11.3±0.01 h	215.5±0.03	0.0000355 ± 0.0000004	0.0000395 ± 0.0000023	0.90 ± 0.05
76Ge	11.3±0.01 h	264.44±0.03	0.000069 ± 0.000001	0.000074 ± 0.000004	0.93 ± 0.05
76Ge	11.3±0.01 h	367.4±0.03	0.0000194 ± 0.0000002	0.0000193 ± 0.0000010	1.00 ± 0.05
76Ge	11.3±0.01 h	416.33±0.03	0.0000306 ± 0.0000003	0.0000301 ± 0.0000016	1.02 ± 0.05
76Ge	11.3±0.01 h	558.02±0.03	0.0000228 ± 0.0000002	0.0000222 ± 0.0000012	1.03 ± 0.06
76Ge	11.3±0.01 h	631.82±0.03	0.0000104 ± 0.0000001	0.0000096 ± 0.0000005	1.08 ± 0.06
76Ge	11.3±0.01 h	714.35±0.03	0.0000114 ± 0.0000001	0.0000099 ± 0.0000005	1.15 ± 0.06
76Ge	11.3±0.01 h	1085.19±0.03	0.00000835 ± 0.00000008	0.0000083 ± 0.0000004	1.00 ± 0.05
75As	26.24±0.09 h	559.1±0.05	0.0483 ± 0.0008	0.053 ± 0.003	0.92 ± 0.05
75As	26.24±0.09 h	563.23±0.05	0.00140 ± 0.00002	0.00141 ± 0.00008	1.00 ± 0.06
75As	26.24±0.09 h	657.05±0.05	0.00661 ± 0.00009	0.0073 ± 0.0004	0.91 ± 0.05

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
75As	26.24±0.09 h	1212.92±0.05	0.00152 ± 0.00002	0.00169 ± 0.00011	0.90 ± 0.06
75As	26.24±0.09 h	1216.08±0.05	0.00373 ± 0.00003	0.00401 ± 0.00023	0.93 ± 0.05
74Se	119.79±0.04 d	121.1155±0.0011	0.00194 ± 0.00001	0.00203 ± 0.00005	0.96 ± 0.03
74Se	119.79±0.04 d	136.0001±0.0006	0.00676 ± 0.00007	0.00685 ± 0.00016	0.99 ± 0.03
74Se	119.79±0.04 d	264.6576±0.0009	0.00711 ± 0.00005	0.00694 ± 0.00014	1.02 ± 0.02
74Se	119.79±0.04 d	279.5422±0.001	0.00300 ± 0.00004	0.00294 ± 0.00006	1.02 ± 0.02
74Se	119.79±0.04 d	400.6572±0.0008	0.00143 ± 0.00001	0.00135 ± 0.00003	1.06 ± 0.02
76Se	17.36±0.05 s	161.9194±0.0015	0.0249 ± 0.0005	0.0240 ± 0.0008	1.04 ± 0.21
79Br	17.68±0.02 m	616.3±0.5	0.00692 ± 0.00002	0.0070 ± 0.0009	0.99 ± 0.12
79Br	17.68±0.02 m	665.8±0.2	0.001220 ± 0.000006	0.00113 ± 0.00013	1.08 ± 0.13
81Br	35.282±0.007 h	554.348±0.002	0.0238 ± 0.0003	0.0231 ± 0.0004	1.03 ± 0.02
81Br	35.282±0.007 h	619.106±0.004	0.0145 ± 0.0001	0.01415 ± 0.00024	1.02 ± 0.02
81Br	35.282±0.007 h	698.374±0.005	0.00938 ± 0.00009	0.00919 ± 0.00018	1.02 ± 0.02
81Br	35.282±0.007 h	776.517±0.003	0.0276 ± 0.0002	0.0271 ± 0.0005	1.02 ± 0.02
81Br	35.282±0.007 h	827.828±0.006	0.00799 ± 0.00007	0.00781 ± 0.00016	1.02 ± 0.02
81Br	35.282±0.007 h	1044.002±0.005	0.00914 ± 0.00006	0.00919 ± 0.00018	0.99 ± 0.02
81Br	35.282±0.007 h	1317.473±0.01	0.00891 ± 0.00003	0.00870 ± 0.00017	1.02 ± 0.02
81Br	35.282±0.007 h	1474.88±0.01	0.00542 ± 0.00003	0.00539 ± 0.00010	1.00 ± 0.02
85Rb	18.642±0.018 d	1077±0.4	0.000765 ± 0.000008	0.000764 ± 0.000010	1.00 ± 0.02
87Rb	17.78±0.11 m	898.03±0.04	0.000101 ± 0.000002	0.000101 ± 0.000005	1.00 ± 0.05
87Rb	17.78±0.11 m	1836±0.05	0.000157 ± 0.000002	0.000156 ± 0.000008	1.00 ± 0.05
87Rb	17.78±0.11 m	2677.892±0.021	0.0000147 ± 0.0000002	0.0000146 ± 0.0000007	1.01 ± 0.05
84Sr	67.63±0.04 m	231.86±0.02	0.0000692 ± 0.0000007	0.0000687 ± 0.0000015	1.01 ± 0.02
84Sr	64.85±0.007 d	514.007±0.003	0.0000915 ± 0.0000008	0.0000921 ± 0.0000011	0.99 ± 0.02
86Sr	2.815±0.012 h	388.531±0.003	0.00149 ± 0.00001	0.001550 ± 0.000024	0.96 ± 0.02
89Y	3.19±0.06 h	202.53±0.03	0.0000236 ± 0.0000004	0.000023 ± 0.000005	1.03 ± 0.21
89Y	3.19±0.06 h	479.51±0.07	0.0000223 ± 0.0000002	0.000021 ± 0.000004	1.05 ± 0.21
94Zr	64.032±0.006 d	724.193±0.003	0.0000890 ± 0.0000011	0.0000888 ± 0.0000011	1.00 ± 0.02
94Zr	64.032±0.006 d	756.729±0.012	0.000110 ± 0.000001	0.0001091 ± 0.0000014	1.01 ± 0.02
94Zr	34.991±0.006 d	765.803±0.006	0.000217 ± 0.000004	0.0002003 ± 0.0000024	1.08 ± 0.02
96Zr	16.744±0.011 h	254.17±0.14	0.000000182 ± 0.000000004	0.000000155 ± 0.000000010	1.17 ± 0.08
96Zr	16.744±0.011 h	355.4±0.09	0.000000292 ± 0.000000006	0.000000284 ± 0.000000015	1.03 ± 0.06
96Zr	16.744±0.011 h	507.64±0.08	0.000000679 ± 0.000000007	0.00000068 ± 0.00000003	0.99 ± 0.05
96Zr	16.744±0.011 h	602.37±0.14	0.000000190 ± 0.000000004	0.000000188 ± 0.000000011	1.01 ± 0.06
96Zr	72.1±0.7 m	657.94±0.09	0.0000124 ± 0.0000001	0.0000125 ± 0.0000004	0.99 ± 0.03

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
96Zr	16.744±0.011 h	703.76±0.05	0.000000136 ± 0.000000003	0.000000137 ± 0.000000008	0.99 ± 0.06
96Zr	16.744±0.011 h	743.36±0.03	0.00001240 ± 0.00000004	0.0000127 ± 0.0000004	0.98 ± 0.03
93Nb	6.263±0.004 m	871.091±0.018	0.000097 ± 0.000002	0.000115 ± 0.000015	0.85 ± 0.11
98Mo	2.7479±0.0005 d	140.511±0.001	0.000527 ± 0.000003	0.000612 ± 0.000018	0.86 ± 0.03
98Mo	2.7479±0.0005 d	181.068±0.008	0.0000415 ± 0.0000003	0.0000411 ± 0.0000012	1.01 ± 0.03
98Mo	2.7479±0.0005 d	366.421±0.015	0.00000836 ± 0.00000011	0.00000816 ± 0.00000024	1.02 ± 0.03
98Mo	2.7479±0.0005 d	739.5±0.017	0.0000846 ± 0.0000006	0.0000828 ± 0.0000022	1.02 ± 0.03
98Mo	2.7479±0.0005 d	777.921±0.02	0.0000297 ± 0.0000002	0.0000292 ± 0.0000009	1.02 ± 0.03
100Mo	14.61±0.03 m	80.92±0.03	0.0000180 ± 0.0000005	0.0000154 ± 0.0000005	1.17 ± 0.05
100Mo	14.22±0.01 m	127.22±0.03	0.0000120 ± 0.0000006	0.0000109 ± 0.0000004	1.10 ± 0.07
100Mo	14.61±0.03 m	191.92±0.02	0.0000725 ± 0.0000012	0.0000744 ± 0.0000011	0.97 ± 0.02
100Mo	14.61±0.03 m	195.93±0.04	0.0000111 ± 0.0000002	0.0000114 ± 0.0000003	0.97 ± 0.03
100Mo	14.22±0.01 m	306.83±0.03	0.000373 ± 0.000005	0.000368 ± 0.000017	1.01 ± 0.05
100Mo	14.61±0.03 m	408.69±0.06	0.00000585 ± 0.00000006	0.0000063 ± 0.0000003	0.93 ± 0.04
100Mo	14.61±0.03 m	499.65±0.03	0.00000563 ± 0.00000006	0.00000574 ± 0.00000019	0.98 ± 0.03
100Mo	14.22±0.01 m	545.05±0.06	0.0000249 ± 0.0000003	0.0000246 ± 0.0000008	1.01 ± 0.03
100Mo	14.61±0.03 m	695.56±0.06	0.0000279 ± 0.0000005	0.0000275 ± 0.0000007	1.01 ± 0.03
100Mo	14.61±0.03 m	713.04±0.09	0.0000137 ± 0.0000001	0.0000138 ± 0.0000007	1.00 ± 0.05
100Mo	14.61±0.03 m	877.39±0.04	0.0000153 ± 0.0000002	0.0000133 ± 0.0000008	1.15 ± 0.07
100Mo	14.61±0.03 m	1011.05±0.14	0.00000375 ± 0.00000006	0.0000037 ± 0.0000003	1.02 ± 0.08
100Mo	14.61±0.03 m	1012.47±0.04	0.0000580 ± 0.0000013	0.000054 ± 0.000003	1.08 ± 0.07
100Mo	14.61±0.03 m	1160.98±0.04	0.0000182 ± 0.0000002	0.0000166 ± 0.0000006	1.10 ± 0.04
100Mo	14.61±0.03 m	1304±0.04	0.0000130 ± 0.0000001	0.0000112 ± 0.0000003	1.16 ± 0.04
100Mo	14.61±0.03 m	1532.49±0.04	0.0000273 ± 0.0000003	0.0000254 ± 0.0000008	1.08 ± 0.04
96Ru	2.9±0.1 d	215.7±0.03	0.000225 ± 0.000001	0.000222 ± 0.000007	1.02 ± 0.03
102Ru	39.26±0.02 d	497.084±0.006	0.00689 ± 0.00003	0.00695 ± 0.00019	0.99 ± 0.03
102Ru	39.26±0.02 d	610.33±0.02	0.000430 ± 0.000002	0.000440 ± 0.000012	0.98 ± 0.03
104Ru	4.44±0.02 h	129.782±0.004	0.000092 ± 0.000001	0.000107 ± 0.000003	0.86 ± 0.03
104Ru	4.44±0.02 h	262.83±0.1	0.000131 ± 0.000002	0.000124 ± 0.000003	1.06 ± 0.03
104Ru	35.36±0.06 h	306.1±0.2	0.000101 ± 0.000002	0.000096 ± 0.000006	1.05 ± 0.06
104Ru	35.36±0.06 h	318.9±0.1	0.000357 ± 0.000006	0.000360 ± 0.000012	0.99 ± 0.04
104Ru	4.44±0.02 h	469.37±0.1	0.000326 ± 0.000005	0.000329 ± 0.000010	0.99 ± 0.03
104Ru	4.44±0.02 h	676.36±0.08	0.000295 ± 0.000009	0.000296 ± 0.000010	1.00 ± 0.05
104Ru	4.44±0.02 h	724.3±0.03	0.000887 ± 0.000015	0.000885 ± 0.000009	1.00 ± 0.02
103Rh	42.3±0.4 s	555.81±0.04	0.0692 ± 0.0010	0.064 ± 0.003	1.09 ± 0.05

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
108Pd	13.7012±0.0024 h	88.0336±0.001	0.00171 ± 0.00002	0.00159 ± 0.00003	1.08 ± 0.02
108Pd	4.696±0.003 m	188.9±0.1	0.000494 ± 0.000002	0.00054 ± 0.00003	0.92 ± 0.05
108Pd	13.7012±0.0024 h	309.1±0.3	0.00000190 ± 0.00000004	0.00000178 ± 0.00000009	1.07 ± 0.06
108Pd	13.7012±0.0024 h	311.4±0.1	0.0000148 ± 0.0000002	0.0000136 ± 0.0000009	1.09 ± 0.07
108Pd	13.7012±0.0024 h	415.2±0.2	0.00000885 ± 0.00000009	0.0000047 ± 0.0000003	1.87 ± 0.11
108Pd	13.7012±0.0024 h	602.6±0.2	0.00000343 ± 0.00000003	0.0000037 ± 0.0000003	0.92 ± 0.07
108Pd	13.7012±0.0024 h	636.3±0.1	0.00000462 ± 0.00000005	0.0000044 ± 0.0000003	1.06 ± 0.06
108Pd	13.7012±0.0024 h	647.3±0.1	0.0000113 ± 0.0000001	0.0000109 ± 0.0000006	1.03 ± 0.06
108Pd	13.7012±0.0024 h	781.4±0.1	0.00000461 ± 0.00000005	0.0000053 ± 0.0000004	0.86 ± 0.06
110Pd	5.5±0.1 h	172.18±0.08	0.0000107 ± 0.0000002	0.0000106 ± 0.0000005	1.01 ± 0.05
107Ag	2.382±0.011 m	433.938±0.005	0.00159 ± 0.00003	0.00190 ± 0.00014	0.84 ± 0.06
107Ag	2.382±0.011 m	618.86±0.05	0.000933 ± 0.000009	0.00100 ± 0.00009	0.93 ± 0.08
107Ag	2.382±0.011 m	632.98±0.05	0.00610 ± 0.00012	0.0067 ± 0.0003	0.91 ± 0.05
109Ag	249.78±0.02 d	446.812±0.003	0.00136 ± 0.00002	0.001358 ± 0.000025	1.00 ± 0.03
109Ag	249.78±0.02 d	620.3553±0.0017	0.00102 ± 0.00001	0.00101 ± 0.00003	1.01 ± 0.03
109Ag	24.56±0.11 s	657.76±0.0011	0.0306 ± 0.0001	0.039 ± 0.003	0.79 ± 0.07
109Ag	249.78±0.02 d	657.76±0.0011	0.0350 ± 0.0003	0.0351 ± 0.0004	1.00 ± 0.01
109Ag	249.78±0.02 d	687.0091±0.0018	0.00243 ± 0.00003	0.00240 ± 0.00003	1.01 ± 0.02
109Ag	249.78±0.02 d	677.6217±0.0012	0.00393 ± 0.00005	0.0039314 ± 0.0000541	1.00 ± 0.02
109Ag	249.78±0.02 d	706.676±0.0015	0.00603 ± 0.00005	0.00614 ± 0.00008	0.98 ± 0.02
109Ag	249.78±0.02 d	744.2755±0.0018	0.00169 ± 0.00002	0.001754 ± 0.000025	0.96 ± 0.02
109Ag	249.78±0.02 d	763.9424±0.0017	0.00827 ± 0.00006	0.00831 ± 0.00011	1.00 ± 0.01
109Ag	249.78±0.02 d	818.0244±0.0018	0.00269 ± 0.00003	0.00273 ± 0.00004	0.99 ± 0.02
109Ag	249.78±0.02 d	884.6781±0.0013	0.0269 ± 0.0002	0.0276 ± 0.0006	0.98 ± 0.02
109Ag	249.78±0.02 d	937.485±0.003	0.0127 ± 0.0001	0.01285 ± 0.00019	0.99 ± 0.02
109Ag	249.78±0.02 d	1384.293±0.002	0.00912 ± 0.00007	0.00921 ± 0.00022	0.99 ± 0.02
109Ag	249.78±0.02 d	1475.779±0.0023	0.00150 ± 0.00001	0.00150 ± 0.00003	1.00 ± 0.02
109Ag	249.78±0.02 d	1505.028±0.002	0.00484 ± 0.00004	0.00490 ± 0.00008	0.99 ± 0.02
109Ag	249.78±0.02 d	1562.294±0.0018	0.000435 ± 0.000004	0.000451 ± 0.000012	0.96 ± 0.03
114Cd	53.46±0.05 h	336.241±0.025	0.000773 ± 0.000013	0.00072 ± 0.00004	1.07 ± 0.06
114Cd	53.46±0.05 h	527.901±0.007	0.000477 ± 0.000007	0.000431 ± 0.000024	1.11 ± 0.06
113In	49.51±0.01 d	190.27±0.03	0.00106 ± 0.00001	0.00099 ± 0.00010	1.07 ± 0.11
113In	49.51±0.01 d	558.43±0.03	0.000286 ± 0.000002	0.00027 ± 0.00003	1.06 ± 0.10
113In	49.51±0.01 d	725.24±0.03	0.000290 ± 0.000002	0.00027 ± 0.00003	1.07 ± 0.11
115In	54.29±0.17 m	138.326±0.008	0.101 ± 0.001	0.093 ± 0.008	1.09 ± 0.09

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
115In	54.29±0.17 m	416.86±0.03	0.754 ± 0.008	0.78 ± 0.07	0.96 ± 0.08
115In	54.29±0.17 m	818.7±0.2	0.336 ± 0.004	0.32 ± 0.03	1.04 ± 0.09
115In	54.29±0.17 m	1097.3±0.2	1.60 ± 0.02	1.59 ± 0.12	1.01 ± 0.08
115In	54.29±0.17 m	1293.54±0.15	2.29 ± 0.02	2.38 ± 0.18	0.96 ± 0.07
115In	54.29±0.17 m	1507.4±0.2	0.269 ± 0.004	0.282 ± 0.023	0.95 ± 0.08
115In	54.29±0.17 m	2112.1±0.4	0.418 ± 0.005	0.44 ± 0.03	0.96 ± 0.08
112Sn	115.09±0.03 d	255.134±0.01	0.00000195 ± 0.00000001	0.00000197 ± 0.00000011	0.99 ± 0.05
112Sn	115.09±0.03 d	391.698±0.003	0.0000599 ± 0.0000005	0.0000608 ± 0.0000024	0.99 ± 0.04
116Sn	13.76±0.04 d	156.02±0.03	0.000000323 ± 0.000000005	0.00000032 ± 0.00000011	1.01 ± 0.34
116Sn	13.76±0.04 d	158.56±0.02	0.0000133 ± 0.0000001	0.000013 ± 0.000004	1.00 ± 0.33
122Sn	40.06±0.01 m	160.32±0.05	0.0001020 ± 0.0000005	0.000098 ± 0.000003	1.04 ± 0.03
124Sn	2.75855±0.00025 y	176.314±0.002	0.000000247 ± 0.000000003	0.000000312 ± 0.000000007	0.79 ± 0.02
124Sn	9.52±0.05 m	331.9±0.2	0.000118 ± 0.000002	0.000146 ± 0.000004	0.81 ± 0.03
124Sn	9.64±0.03 d	332.1±0.05	0.000000057 ± 0.000000001	0.000000064 ± 0.000000003	0.90 ± 0.04
124Sn	2.75855±0.00025 y	427.874±0.004	0.00000123 ± 0.00000001	0.00000135 ± 0.00000003	0.91 ± 0.02
124Sn	2.75855±0.00025 y	463.365±0.004	0.000000443 ± 0.000000004	0.000000478 ± 0.000000011	0.93 ± 0.02
124Sn	2.75855±0.00025 y	606.713±0.003	0.000000171 ± 0.000000002	0.000000227 ± 0.000000005	0.75 ± 0.02
124Sn	2.75855±0.00025 y	635.95±0.003	0.000000491 ± 0.000000005	0.000000511 ± 0.000000012	0.96 ± 0.02
124Sn	9.64±0.03 d	822.48±0.05	0.000000210 ± 0.000000002	0.000000194 ± 0.000000008	1.08 ± 0.05
124Sn	9.64±0.03 d	1067.1±0.05	0.000000464 ± 0.000000005	0.000000439 ± 0.000000010	1.06 ± 0.03
121Sb	2.7238±0.0002 d	564.24±0.04	0.0438 ± 0.0007	0.0429 ± 0.0014	1.02 ± 0.04
121Sb	2.7238±0.0002 d	692.65±0.04	0.00238 ± 0.00005	0.00234 ± 0.00011	1.02 ± 0.05
123Sb	93±5 s	498.4±0.1	0.000143 ± 0.000001	0.00014 ± 0.00003	1.02 ± 0.21
123Sb	93±5 s	602.72±0.04	0.000143 ± 0.000001	0.00014 ± 0.00003	1.00 ± 0.20
123Sb	60.2±0.03 d	602.726±0.0023	0.0296 ± 0.0002	0.0289 ± 0.0004	1.03 ± 0.02
123Sb	93±5 s	645.82±0.04	0.000143 ± 0.000001	0.00014 ± 0.00003	1.00 ± 0.20
123Sb	60.2±0.03 d	645.852±0.0019	0.00221 ± 0.00002	0.00219 ± 0.00003	1.01 ± 0.02
123Sb	60.2±0.03 d	722.782±0.003	0.00319 ± 0.00003	0.00318 ± 0.00005	1.00 ± 0.02
123Sb	60.2±0.03 d	1690.971±0.004	0.0141 ± 0.0002	0.01404 ± 0.00021	1.00 ± 0.02
123Sb	60.2±0.03 d	2090.93±0.007	0.00158 ± 0.00003	0.00162 ± 0.00003	0.97 ± 0.03
130Te	8.0233±0.0019 d	80.185±0.002	0.0000249 ± 0.0000003	0.0000285 ± 0.0000015	0.87 ± 0.05
130Te	8.0233±0.0019 d	284.305±0.005	0.0000662 ± 0.0000004	0.000067 ± 0.000003	0.99 ± 0.05
130Te	8.0233±0.0019 d	364.489±0.005	0.000867 ± 0.000007	0.00089 ± 0.00005	0.98 ± 0.05
130Te	8.0233±0.0019 d	636.989±0.004	0.0000758 ± 0.0000008	0.000078 ± 0.000004	0.97 ± 0.05
127I	24.99±0.02 m	442.901±0.01	0.0112 ± 0.0002	0.01146 ± 0.00018	0.98 ± 0.02

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
127I	24.99±0.02 m	526.557±0.014	0.00107 ± 0.00003	0.001094 ± 0.000014	0.98 ± 0.03
133Cs	2.912±0.002 h	127.502±0.003	0.00548 ± 0.00009	0.00533 ± 0.00010	1.03 ± 0.03
133Cs	2.0652±0.0004 y	563.246±0.005	0.0414 ± 0.0007	0.0391 ± 0.0007	1.06 ± 0.03
133Cs	2.0652±0.0004 y	569.331±0.003	0.0734 ± 0.0011	0.0720 ± 0.0012	1.02 ± 0.02
133Cs	2.0652±0.0004 y	604.721±0.002	0.476 ± 0.010	0.457 ± 0.008	1.04 ± 0.03
133Cs	2.0652±0.0004 y	795.864±0.004	0.415 ± 0.008	0.400 ± 0.007	1.04 ± 0.03
133Cs	2.0652±0.0004 y	801.953±0.004	0.0411 ± 0.0008	0.0407 ± 0.0007	1.01 ± 0.03
130Ba	11.5±0.06 d	123.804±0.003	0.0000390 ± 0.0000003	0.0000441 ± 0.0000008	0.88 ± 0.02
130Ba	11.5±0.06 d	133.617±0.005	0.00000324 ± 0.00000003	0.00000323 ± 0.00000006	1.00 ± 0.02
130Ba	11.5±0.06 d	216.088±0.014	0.0000275 ± 0.0000004	0.0000302 ± 0.0000008	0.91 ± 0.03
130Ba	11.5±0.06 d	373.256±0.012	0.0000192 ± 0.0000001	0.0000213 ± 0.0000004	0.90 ± 0.02
130Ba	11.5±0.06 d	486.507±0.012	0.0000034 ± 0.0000000	0.00000318 ± 0.00000005	1.08 ± 0.02
130Ba	11.5±0.06 d	496.321±0.005	0.0000684 ± 0.0000001	0.0000712 ± 0.0000012	0.96 ± 0.02
130Ba	11.5±0.06 d	620.094±0.007	0.00000234 ± 0.00000002	0.00000219 ± 0.00000004	1.07 ± 0.02
132Ba	38.9±0.1 h	275.925±0.007	0.00000227 ± 0.00000002	0.00000226 ± 0.00000006	1.01 ± 0.03
138Ba	83.06±0.28 m	165.8575±0.0011	0.00105 ± 0.00001	0.00104 ± 0.00015	1.01 ± 0.14
139La	1.6785±0.00017 d	328.762±0.008	0.0287 ± 0.0003	0.0277 ± 0.0004	1.04 ± 0.02
139La	1.6785±0.00017 d	487.021±0.012	0.0637 ± 0.0006	0.0621 ± 0.0009	1.03 ± 0.02
139La	1.6785±0.00017 d	815.772±0.019	0.0332 ± 0.0002	0.0318 ± 0.0003	1.04 ± 0.01
139La	1.6785±0.00017 d	1596.21±0.04	0.134 ± 0.002	0.1302 ± 0.0020	1.03 ± 0.02
140Ce	32.508±0.01 d	145.4433±0.0014	0.00366 ± 0.00003	0.00368 ± 0.00007	0.99 ± 0.02
142Ce	33.039±0.006 h	231.55±0.002	0.0000337 ± 0.0000005	0.0000330 ± 0.0000009	1.02 ± 0.03
142Ce	33.039±0.006 h	293.266±0.002	0.000689 ± 0.000004	0.000688 ± 0.000014	1.00 ± 0.02
142Ce	33.039±0.006 h	350.619±0.003	0.0000514 ± 0.0000003	0.0000519 ± 0.0000012	0.99 ± 0.02
142Ce	33.039±0.006 h	664.571±0.015	0.0000918 ± 0.0000014	0.0000915 ± 0.0000020	1.00 ± 0.03
142Ce	33.039±0.006 h	721.929±0.013	0.0000878 ± 0.0000008	0.0000867 ± 0.0000019	1.01 ± 0.02
141Pr	19.12±0.04 h	1575.85±0.15	0.00612 ± 0.00004	0.0061 ± 0.0007	1.00 ± 0.12
146Nd	10.98±0.01 d	91.105±0.002	0.00102 ± 0.00003	0.00097 ± 0.00005	1.06 ± 0.06
146Nd	10.98±0.01 d	120.48±0.05	0.0000128 ± 0.0000001	0.0000139 ± 0.0000015	0.92 ± 0.10
146Nd	10.98±0.01 d	275.374±0.015	0.0000286 ± 0.0000006	0.0000277 ± 0.0000020	1.03 ± 0.12
146Nd	10.98±0.01 d	319.411±0.018	0.0000678 ± 0.0000006	0.000068 ± 0.000005	1.00 ± 0.07
146Nd	10.98±0.01 d	398.155±0.02	0.0000290 ± 0.0000003	0.0000301 ± 0.0000023	0.96 ± 0.08
146Nd	10.98±0.01 d	439.895±0.022	0.0000422 ± 0.0000006	0.000042 ± 0.000003	1.02 ± 0.08
146Nd	10.98±0.01 d	531.016±0.022	0.000456 ± 0.000005	0.00045 ± 0.00003	1.00 ± 0.07
146Nd	10.98±0.01 d	685.9±0.04	0.0000268 ± 0.0000003	0.0000281 ± 0.0000020	0.96 ± 0.07

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
148Nd	1.728±0.001 h	114.314±0.011	0.000405 ± 0.000004	0.00039 ± 0.00003	1.05 ± 0.07
148Nd	1.728±0.001 h	208.147±0.009	0.0000571 ± 0.0000006	0.0000513 ± 0.0000011	1.06 ± 0.07
148Nd	1.728±0.001 h	211.309±0.007	0.000526 ± 0.000005	0.000522 ± 0.000023	1.01 ± 0.05
148Nd	1.728±0.001 h	240.22±0.007	0.0000772 ± 0.0000008	0.000079 ± 0.000004	0.97 ± 0.05
148Nd	1.728±0.001 h	267.693±0.008	0.000116 ± 0.000001	0.000122 ± 0.000004	0.95 ± 0.03
148Nd	1.728±0.001 h	270.166±0.007	0.000212 ± 0.000002	0.000216 ± 0.000007	0.93 ± 0.05
148Nd	53.08±0.05 h	285.95±0.01	0.000061 ± 0.000001	0.0000625 ± 0.0000013	0.98 ± 0.02
148Nd	1.728±0.001 h	326.554±0.01	0.000091 ± 0.000001	0.000092 ± 0.000003	0.99 ± 0.03
148Nd	1.728±0.001 h	540.509±0.01	0.000135 ± 0.000001	0.000133 ± 0.000005	1.02 ± 0.04
148Nd	1.728±0.001 h	654.831±0.013	0.000166 ± 0.000002	0.000161 ± 0.000009	1.03 ± 0.06
150Nd	12.44±0.07 m	255.68±0.01	0.000131 ± 0.000001	0.000126 ± 0.000005	1.04 ± 0.05
150Nd	28.4±0.04 h	340.08±0.01	0.000173 ± 0.000002	0.000192 ± 0.000011	0.90 ± 0.05
150Nd	12.44±0.07 m	1180.89±0.02	0.000109 ± 0.000001	0.000113 ± 0.000005	0.96 ± 0.04
152Sm	1.92855±0.00005 d	69.673±0.00013	0.0352 ± 0.0004	0.0364 ± 0.0009	0.97 ± 0.03
152Sm	1.92855±0.00005 d	103.18012±0.00017	0.231 ± 0.001	0.225 ± 0.006	1.03 ± 0.03
154Sm	22.3±0.2 m	141.411±0.011	0.000483 ± 0.000006	0.00052 ± 0.00004	0.97 ± 0.03
154Sm	22.3±0.2 m	245.73±0.05	0.000905 ± 0.000013	0.00097 ± 0.00006	0.97 ± 0.03
151Eu	9.3116±0.0013 h	121.777±0.005	1.48 ± 0.02	1.52 ± 0.18	0.98 ± 0.12
151Eu	13.522±0.016 y	121.7817±0.0003	12.8 ± 0.1	12.85 ± 0.20	1.00 ± 0.02
151Eu	13.522±0.016 y	244.6974±0.0008	3.44 ± 0.01	3.42 ± 0.05	1.01 ± 0.02
151Eu	13.522±0.016 y	344.2785±0.0012	11.9 ± 0.1	12.03 ± 0.18	0.99 ± 0.02
151Eu	9.3116±0.0013 h	344.31±0.03	0.498 ± 0.005	0.52 ± 0.03	0.96 ± 0.05
151Eu	13.522±0.016 y	443.965±0.003	1.39 ± 0.02	1.267 ± 0.021	1.10 ± 0.02
151Eu	13.522±0.016 y	778.9045±0.0024	5.70 ± 0.05	5.87 ± 0.09	0.97 ± 0.02
151Eu	9.3116±0.0013 h	841.594±0.008	3.02 ± 0.03	3.08 ± 0.36	0.98 ± 0.12
151Eu	13.522±0.016 y	867.38±0.003	1.88 ± 0.02	1.92 ± 0.03	0.98 ± 0.02
151Eu	9.3116±0.0013 h	963.39±0.012	2.49 ± 0.03	2.53 ± 0.29	0.98 ± 0.11
151Eu	13.522±0.016 y	1112.076±0.003	6.07 ± 0.05	6.07 ± 0.09	1.00 ± 0.02
151Eu	13.522±0.016 y	1408.013±0.0003	9.36 ± 0.06	9.43 ± 0.14	0.99 ± 0.02
153Eu	8.601±0.004 y	247.9288±0.0007	0.155 ± 0.002	0.156 ± 0.004	0.99 ± 0.03
153Eu	8.601±0.004 y	591.755±0.003	0.108 ± 0.002	0.112 ± 0.003	0.96 ± 0.03
153Eu	8.601±0.004 y	723.3014±0.0022	0.446 ± 0.007	0.455 ± 0.012	0.98 ± 0.03
153Eu	8.601±0.004 y	756.802±0.0023	0.108 ± 0.001	0.103 ± 0.003	1.05 ± 0.03
153Eu	8.601±0.004 y	873.1834±0.0023	0.272 ± 0.004	0.276 ± 0.007	0.99 ± 0.03
153Eu	8.601±0.004 y	996.25±0.05	0.230 ± 0.002	0.238 ± 0.006	0.97 ± 0.03

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
153Eu	8.601±0.004 y	1274.429±0.004	0.777 ± 0.009	0.792 ± 0.021	0.98 ± 0.03
152Gd	240.4±1 d	97.431±0.00021	0.00586 ± 0.00008	0.00574 ± 0.00018	1.02 ± 0.03
152Gd	240.4±1 d	103.18012±0.00017	0.00421 ± 0.00006	0.00418 ± 0.00013	1.01 ± 0.03
158Gd	18.479±0.007 h	363.543±0.0018	0.000849 ± 0.000013	0.00086 ± 0.00004	0.99 ± 0.05
160Gd	3.55±0.05 m	102.315±0.01	0.000788 ± 0.000008	0.00062 ± 0.00005	1.27 ± 0.11
160Gd	3.55±0.05 m	165.213±0.015	0.000107 ± 0.000001	0.000115 ± 0.000012	0.93 ± 0.09
160Gd	3.55±0.05 m	283.55±0.03	0.000284 ± 0.000003	0.000266 ± 0.000021	1.07 ± 0.08
160Gd	3.55±0.05 m	314.92±0.02	0.00103 ± 0.00001	0.00102 ± 0.00008	1.01 ± 0.08
160Gd	3.55±0.05 m	360.94±0.02	0.00272 ± 0.00003	0.00269 ± 0.00019	1.01 ± 0.07
160Gd	3.55±0.05 m	480.12±0.02	0.000104 ± 0.000000	0.000120 ± 0.000010	0.87 ± 0.07
159Tb	73.2±0.2 d	86.7877±0.0003	0.0420 ± 0.0005	0.0403 ± 0.0006	1.04 ± 0.02
159Tb	73.2±0.2 d	197.0341±0.001	0.0162 ± 0.0008	0.01587 ± 0.00022	1.02 ± 0.05
159Tb	73.2±0.2 d	215.6452±0.0011	0.0127 ± 0.0001	0.01231 ± 0.00017	1.03 ± 0.01
159Tb	73.2±0.2 d	298.5783±0.0017	0.0825 ± 0.0100	0.0801 ± 0.0012	1.03 ± 0.13
159Tb	73.2±0.2 d	879.378±0.002	0.0942 ± 0.0009	0.0922 ± 0.0012	1.02 ± 0.02
159Tb	73.2±0.2 d	962.311±0.003	0.0305	0.0301 ± 0.0005	1.01
159Tb	73.2±0.2 d	966.166±0.002	0.0784	0.0769 ± 0.0011	1.02
159Tb	73.2±0.2 d	1177.954±0.003	0.0471 ± 0.0005	0.0456 ± 0.0006	1.03 ± 0.11
159Tb	73.2±0.2 d	1199.89±0.03	0.00753 ± 0.00010	0.00730 ± 0.00010	1.03 ± 0.02
159Tb	73.2±0.2 d	1271.873±0.005	0.0235 ± 0.0002	0.0228 ± 0.0003	1.03 ± 0.02
159Tb	73.2±0.2 d	1312.14±0.04	0.00898 ± 0.00008	0.00876 ± 0.00017	1.02 ± 0.02
164Dy	2.334±0.001 h	94.7±0.003	0.357 ± 0.005	0.376 ± 0.009	0.95 ± 0.03
164Dy	1.257±0.006 m	108.16±0.003	0.188 ± 0.002	0.192 ± 0.007	0.98 ± 0.04
164Dy	2.334±0.001 h	279.763±0.012	0.0488 ± 0.0004	0.0528 ± 0.0012	0.92 ± 0.02
164Dy	2.334±0.001 h	361.68±0.02	0.0836 ± 0.0006	0.0894 ± 0.0020	0.93 ± 0.02
164Dy	1.257±0.006 m	515.467±0.025	0.0925 ± 0.0009	0.096 ± 0.006	0.95 ± 0.03
164Dy	2.334±0.001 h	633.415±0.02	0.0562 ± 0.0009	0.0606 ± 0.0014	0.93 ± 0.03
164Dy	2.334±0.001 h	715.328±0.02	0.0523 ± 0.0006	0.0572 ± 0.0013	0.91 ± 0.02
165Ho	26.795±0.029 h	80.5725±0.0013	0.0494 ± 0.0005	0.0498 ± 0.0010	0.99 ± 0.02
165Ho	26.795±0.029 h	1379.446±0.01	0.00695 ± 0.00011	0.0071 ± 0.0003	0.98 ± 0.04
165Ho	26.795±0.029 h	1581.852±0.015	0.00140 ± 0.00003	0.00141 ± 0.00004	0.99 ± 0.03
165Ho	26.795±0.029 h	1662.424±0.015	0.000875 ± 0.000006	0.00090 ± 0.00004	0.98 ± 0.04
170Er	7.516±0.002 h	111.621±0.004	0.00341 ± 0.00003	0.00348 ± 0.00018	0.98 ± 0.05
170Er	7.516±0.002 h	116.656±0.006	0.000381 ± 0.000004	0.000390 ± 0.000016	0.98 ± 0.04
170Er	7.516±0.002 h	124.017±0.004	0.00152 ± 0.00001	0.00154 ± 0.00007	0.98 ± 0.05

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
170Er	7.516±0.002 h	237.14±0.04	0.0000523 ± 0.0000005	0.0000513 ± 0.0000024	1.02 ± 0.05
170Er	7.516±0.002 h	295.901±0.014	0.00479 ± 0.00007	0.00491 ± 0.00021	0.98 ± 0.04
170Er	7.516±0.002 h	308.291±0.018	0.0104 ± 0.0002	0.0109 ± 0.0005	0.95 ± 0.04
169Tm	127.8±0.6 d	84.25474±0.00008	0.0326 ± 0.0005	0.0325 ± 0.0015	1.00 ± 0.05
168Yb	32.018±0.005 d	63.12044±0.00004	0.0204 ± 0.0002	0.01988 ± 0.00012	1.03 ± 0.01
168Yb	32.018±0.005 d	109.77924±0.00004	0.00779 ± 0.00008	0.00784 ± 0.00004	0.99 ± 0.01
168Yb	32.018±0.005 d	130.52293±0.00006	0.00507 ± 0.00005	0.005137 ± 0.000025	0.99 ± 0.01
168Yb	32.018±0.005 d	177.21307±0.00006	0.0104 ± 0.0001	0.01007 ± 0.00005	1.03 ± 0.01
168Yb	32.018±0.005 d	197.95675±0.00007	0.0164 ± 0.0002	0.01622 ± 0.00006	1.01 ± 0.01
168Yb	32.018±0.005 d	307.73757±0.00009	0.00434 ± 0.00004	0.004535 ± 0.000022	0.96 ± 0.01
174Yb	4.185±0.001 d	113.805±0.004	0.00942 ± 0.00012	0.0092 ± 0.0003	1.02 ± 0.04
174Yb	4.185±0.001 d	137.658±0.006	0.000569 ± 0.000003	0.00056 ± 0.00004	1.02 ± 0.08
174Yb	4.185±0.001 d	144.863±0.005	0.00159 ± 0.00002	0.001602 ± 0.000054	0.99 ± 0.04
174Yb	4.185±0.001 d	282.522±0.014	0.0146 ± 0.0001	0.0146 ± 0.0005	1.00 ± 0.03
174Yb	4.185±0.001 d	396.329±0.02	0.0312 ± 0.0002	0.0313 ± 0.0011	1.00 ± 0.03
176Yb	1.911±0.003 h	121.6±0.1	0.000164 ± 0.000002	0.000157 ± 0.000011	1.05 ± 0.07
176Yb	1.911±0.003 h	138.6±0.1	0.0000648 ± 0.0000007	0.000064 ± 0.000005	1.01 ± 0.09
176Yb	1.911±0.003 h	150.3±0.1	0.000894 ± 0.000009	0.00092 ± 0.00006	0.97 ± 0.07
176Yb	1.911±0.003 h	899.2±0.1	0.0000312 ± 0.0000000	0.0000315 ± 0.0000014	0.99 ± 0.04
176Yb	1.911±0.003 h	941.8±0.1	0.0000487 ± 0.0000005	0.0000486 ± 0.0000014	1.00 ± 0.03
176Yb	1.911±0.003 h	1028.3±0.3	0.0000294 ± 0.0000003	0.0000295 ± 0.0000011	1.02 ± 0.05
176Yb	1.911±0.003 h	1080.5±0.4	0.000268 ± 0.000003	0.000265 ± 0.000008	1.01 ± 0.03
176Yb	1.911±0.003 h	1120±0.4	0.0000274 ± 0.0000003	0.0000268 ± 0.0000008	1.02 ± 0.05
176Yb	1.911±0.003 h	1150.1±0.2	0.0000296 ± 0.0000003	0.0000310 ± 0.0000011	0.95 ± 0.04
176Yb	1.911±0.003 h	1241.8±0.4	0.000162 ± 0.000002	0.000159 ± 0.000008	1.02 ± 0.05
175Lu	3.664±0.019 h	88.361±0.009	0.0173 ± 0.0003	0.0166 ± 0.0011	1.05 ± 0.07
176Lu	6.647±0.04 d	112.9498±0.0004	0.0415 ± 0.0004	0.0420 ± 0.0012	0.99 ± 0.03
176Lu	6.647±0.04 d	208.3662±0.0004	0.0714 ± 0.0007	0.0703 ± 0.0020	1.02 ± 0.03
174Hf	70±2 d	343.4±0.08	0.00906 ± 0.00009	0.0091 ± 0.0004	1.00 ± 0.04
178Hf	18.67±0.04 s	214.335±0.003	0.1770 ± 0.0004	0.170 ± 0.015	1.04 ± 0.09
179Hf	5.47±0.04 h	93.325±0.012	0.000124 ± 0.000001	0.000125 ± 0.000003	0.99 ± 0.02
179Hf	5.47±0.04 h	215.426±0.008	0.000591 ± 0.000009	0.000575 ± 0.000009	1.03 ± 0.02
179Hf	5.47±0.04 h	332.275±0.011	0.000674 ± 0.000014	0.000666 ± 0.000011	1.01 ± 0.03
179Hf	5.47±0.04 h	443.163±0.015	0.000588 ± 0.000011	0.000552 ± 0.000011	1.07 ± 0.03
179Hf	5.47±0.04 h	500.697±0.013	0.000102 ± 0.000001	0.000130 ± 0.000003	0.78 ± 0.02

Table 1. Comparison of IUPAC recommended k_0 values with values derived from the EGAF database.

Target	Half-life	Eγ (keV)	k_0(IUPAC)	k_0(EGAF)	k_0(IUPAC)/k_0(Adopt)
180Hf	42.39±0.06 d	133.021±0.019	0.0237 ± 0.0001	0.0229 ± 0.0008	1.03 ± 0.03
180Hf	42.39±0.06 d	345.93±0.06	0.00793 ± 0.00008	0.0080 ± 0.0003	0.99 ± 0.03
180Hf	42.39±0.06 d	482.18±0.09	0.0456 ± 0.0004	0.0427 ± 0.0013	1.07 ± 0.03
181Ta	114.43±0.03 d	67.75±0.0002	0.0908 ± 0.0009	0.098 ± 0.003	0.93 ± 0.03
181Ta	114.43±0.03 d	100.1065±0.0003	0.0318 ± 0.0003	0.0334 ± 0.0008	0.95 ± 0.03
181Ta	114.43±0.03 d	152.4308±0.0003	0.0161 ± 0.0001	0.0164 ± 0.0004	0.98 ± 0.03
181Ta	114.43±0.03 d	222.1096±0.0004	0.0178 ± 0.0002	0.0177 ± 0.0004	1.00 ± 0.03
181Ta	114.43±0.03 d	1121.301±0.0017	0.0827 ± 0.0007	0.0826 ± 0.0020	1.00 ± 0.03
181Ta	114.43±0.03 d	1189.05±0.0017	0.0388 ± 0.0003	0.0384 ± 0.0009	1.01 ± 0.03
181Ta	114.43±0.03 d	1221.407±0.0017	0.0645 ± 0.0005	0.0639 ± 0.0016	1.01 ± 0.03
181Ta	114.43±0.03 d	1231.016±0.0017	0.0272 ± 0.0002	0.0271 ± 0.0007	1.00 ± 0.03
186W	23.72±0.06 h	134.247±0.007	0.0113 ± 0.0001	0.01168 ± 0.00016	0.97 ± 0.01
186W	23.72±0.06 h	479.55±0.022	0.0297 ± 0.0003	0.02998 ± 0.00021	0.99 ± 0.01
186W	23.72±0.06 h	551.52±0.04	0.00691 ± 0.00004	0.00692 ± 0.00005	1.00 ± 0.01
186W	23.72±0.06 h	618.26±0.04	0.00865 ± 0.00004	0.00854 ± 0.00006	1.01 ± 0.01
186W	23.72±0.06 h	685.73±0.04	0.0371 ± 0.0002	0.03743 ± 0.00024	0.99 ± 0.01
186W	23.72±0.06 h	772.89±0.05	0.00561 ± 0.00004	0.00566 ± 0.00004	0.99 ± 0.01
185Re	3.7186±0.0017 d	122.33±0.1	0.00279 ± 0.00003	0.00283 ± 0.00006	0.98 ± 0.02
185Re	3.7186±0.0017 d	137.157±0.008	0.0433 ± 0.0003	0.0443 ± 0.0008	0.98 ± 0.02
187Re	18.59±0.04 m	92.43±0.03	0.000777 ± 0.000012	0.00075 ± 0.00003	1.04 ± 0.05
187Re	18.59±0.04 m	105.96±0.1	0.00150 ± 0.00002	0.00156 ± 0.00010	0.96 ± 0.06
187Re	17.005±0.004 h	155.041±0.004	0.0777 ± 0.0005	0.079 ± 0.004	0.98 ± 0.05
187Re	17.005±0.004 h	477.992±0.025	0.00529 ± 0.00004	0.0053 ± 0.0005	1.00 ± 0.09
187Re	17.005±0.004 h	632.981±0.021	0.00683 ± 0.00010	0.0067 ± 0.0006	1.03 ± 0.09
187Re	17.005±0.004 h	634.98±0.07	0.000808 ± 0.000013	0.00077 ± 0.00007	1.05 ± 0.09
187Re	17.005±0.004 h	829.47±0.04	0.00217 ± 0.00002	0.00213 ± 0.00017	1.02 ± 0.08
187Re	17.005±0.004 h	931.345±0.01	0.00285 ± 0.00003	0.00286 ± 0.00022	1.00 ± 0.08
184Os	93.6±0.5 d	646.116±0.009	0.00643 ± 0.00010	0.0064 ± 0.0003	1.00 ± 0.05
190Os	15.4±0.1 d	129.431±0.005	0.00291 ± 0.00005	0.0110 ± 0.0006	0.27 ± 0.01
192Os	30.11±0.01 h	138.92±0.03	0.000535 ± 0.000008	0.000538 ± 0.000013	0.99 ± 0.03
192Os	30.11±0.01 h	142.132±0.017	0.00000949 ± 0.00000015	0.0000091 ± 0.0000014	1.04 ± 0.16
192Os	30.11±0.01 h	251.63±0.04	0.0000304 ± 0.0000003	0.0000302 ± 0.0000018	1.00 ± 0.06
192Os	30.11±0.01 h	280.446±0.022	0.000179 ± 0.000001	0.000175 ± 0.000003	1.02 ± 0.02
192Os	30.11±0.01 h	298.82±0.05	0.0000283 ± 0.0000003	0.0000263 ± 0.0000013	1.08 ± 0.06
192Os	30.11±0.01 h	321.59±0.022	0.000178 ± 0.000002	0.000178 ± 0.000003	1.00 ± 0.02

APPENDIX III: Installation and validation of the k0_IAEA software at the JSI using the SMELS materials (R. Jaćimović)

The k0_IAEA software was successfully installed at the Jožef Stefan Institute (JSI) at the beginning of 2004 using version 1.0. As one of beta testers of the software, we were able to follow its development and provide our experiences to the authors (original programmers Dr. M. Blaauw and Dr. M.A. Bacchi) so that the program becomes "user-friendly" and versatile. This was the basic idea supported by the IAEA and initiated by Dr. Matthias Rossbach. Already in the beginning of 2006, the next version 2.00 of the k0_IAEA software was incorporated, and included a peak area evaluation routine to facilitate its use for processing of gamma spectra in various formats. In the middle of 2006 version 3.00 of the software was released, followed by version 4.00 at the end of 2008 and next version 4.04 in February 2009, where an option to use recommended gamma lines was developed. This paper describes the influence on the final results of the different versions of the k0_IAEA software in the validation step using the SMELS Type I, II and III materials. For statistical evaluation, the relative bias (in %) and E_n-number were applied.

BACKGROUND

The k_0-method of neutron activation analysis (NAA) was introduced by Simonits and De Corte in 1975 [29]. The method is a "quasi" absolute technique, which uses gold as the standard and the composite nuclear constants for analytically interesting nuclides are normalised to the nuclear data of gold. The k_0-method of NAA requires a nuclear reactor, a multi-channel analyser (MCA) and an absolutely calibrated HPGe. During the last 30 years the k_0-method has been introduced into many laboratories around the world for multi-element NAA and been continuously improved, including its nuclear data [2]. The k_0-method was introduced at the JSI in Ljubljana at the end of 1988. Since then we have implemented all the recommended procedures for applying the k_0-standardization method using the Institute's TRIGA Mark II reactor. Validation of the k_0 method at the JSI [30] was established via the analysis of different reference and certified reference materials issued by the IAEA, NIST, BCR and IRMM using the KAYZERO/SOLCOI software [31].

In the framework of the IAEA Coordinated Research Project (CRP) entitled "Reference Database for Neutron Activation Analysis", the JSI participated through project No. 13279 entitled "Measurements and calibrations of the neutron spectrum in different irradiation channels of the TRIGA Mark II reactor, Slovenia". The duration of the JSI project was from July 2005 to November 2009. One of the objectives of the CRP was continuous updating of the k0_IAEA software, which has been available for cost-free distribution since the beginning of 2005 [32, 33] on request to the IAEA.

The objective of this work was to validate the k0_IAEA software during its continuous updating using the synthetic multi-element standards (SMELS) [34] which have been prepared for the validation of the k_0-standardization of NAA. SMELS consist of three different series of a polymer matrix each spiked with different elements, so that each material can be used for elemental analysis by monitoring short lived (Type I contains Au, Cl, Cs, Cu, I, La, Mn and V), medium (Type II contains As, Au, Br, Ce, Mo, Pr, Sb, Th, Yb and Zn) and long-lived (Type III contains Au, Co, Cr, Cs, Fe, In, Sb, Sc, Se, Sr, Th, Tm, Yb, Zn and Zr) radionuclides. The SMELS materials were irradiated in two typical irradiation channels (PT and IC-40) of the 250 kW TRIGA Mark II reactor. The elemental concentration calculations were performed by different versions of the k0_IAEA program using the same input parameters.

EXPERIMENTAL

Installation of k0_IAEA software

Detector calibration

In the k0_IAEA software, a mixture of methods is incorporated using one measurement of e.g. ^{137}Cs to determine the peak-to-total curve in its entirety and one measurement for the efficiency curve fit (usually a ^{152}Eu point source with known activity), knowing the peak-to-total ratio and taking into account coincidence summing. After fitting the curve to the points, the efficiencies are converted from the actual calibration counting geometry to point-source geometry and stored in the permanent database for the particular HPGe detector. This procedure was expected to be stable and applicable to most counting geometries used in INAA with HPGe coaxial detectors and even to end-cap well-type detectors.

Figure 1 shows the dimensions of a coaxial HPGe detector with 40% relative efficiency (called OR4) at the JSI and the full-energy peak efficiency curve at a reference position (200 mm). For efficiency calibration of detector OR4, two calibrated point sources of ^{137}Cs and ^{152}Eu were used.

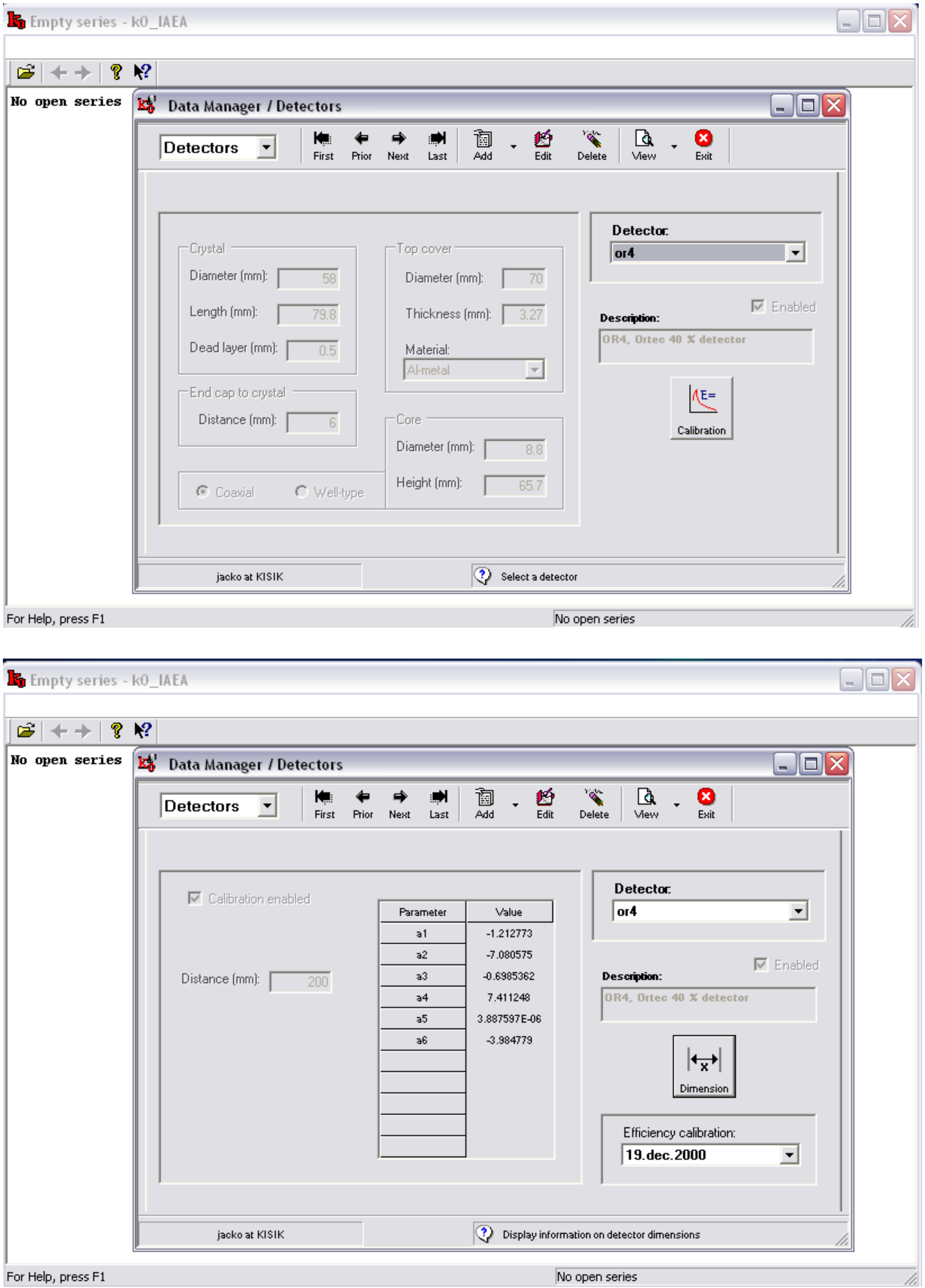

Fig. 1. Dimensions and efficiency calibration of an HPGe detector called OR4 (40 % relative efficiency).

Irradiation facility characterization

In k_0-standardization of NAA, the simplified HØGDAHL convention is used. In the k0_IAEA software this convention was adapted and all references to the cadmium cut-off energy have been removed from the k_0 formulas [32]. This approach is valid only if the capture cross-section is indeed $1/v$ in the thermal region below 0.65 eV. If not, the so-called WESTCOTT g-factor is to be adapted to the thermal cross-section. This factor is a function of the temperature T of the neutron velocity distribution and is taken into account in the program. In addition, threshold reactions e.g. (n,p), (n,2n), (n,α), etc., are taken into account assuming that a uranium fission spectrum is applicable to all k_0 irradiation facilities.

In order to test the software, in the Permanent Database of the software we stored the data obtained from our previous studies [35]. Table 1 shows parameters needed to be stored in the permanent database of the software for two typical irradiation channels (pneumatic tube (PT) and carousel facility channel IC-40) of the TRIGA reactor. The parameters were determined with the "Cd-ratio for multi monitor" method, except for T_n, which was estimated from the moderator temperature of the TRIGA reactor recorded in the operator's logbook.

Table 1. Data stored in the Permanent Database on irradiation facilities of the TRIGA reactor

Irr. Channel	Φ_{th}, m^{-2} s^{-1}	Φ_f, m^{-2} s^{-1}	f	α	T_n, K
PT	(3.38±0.07)×E16	(1.04±0.04)×E16	27.99±0.56	-0.0146±0.0050	310±10
IC-40	(1.09±0.02)×E16	(1.33±0.06)×E15	28.63±0.60	-0.0011±0.0005	305±10

Notes:
Φ_{th} – thermal flux; Φ_f – fast flux; f – thermal to epithermal flux ratio; α – parameter which represents the epithermal flux deviation from the ideal $1/E$ distribution; T_n – neutron temperature

Characterization of SMELS materials

Each SMELS sample (about 50-60 mg) was sealed into a pure polyethylene ampoule (inside diameter 8 mm and 2 mm high, SPRONK system, Lexmond, The Netherlands). Samples and standards (Al-0.1%Au IRMM-530R disc of 6 mm in diameter and 0.1 mm thick) were stacked together and fixed in the polyethylene ampoule in sandwich form and irradiated in two typical irradiation channels (PT and IC-40) of the TRIGA reactor of the JSI. SMELS Type I was irradiated for 1 minute in the PT of the reactor at a thermal neutron flux of 3.5×10^{12} cm^{-2} s^{-1}, while SMELS Type II and Type III were irradiated separately for 2 and 1 hours, respectively, in IC-40 of the carousel facility of the reactor at a thermal neutron flux of 1.1×10^{12} cm^{-2} s^{-1}. Three replicates of each material were applied.

After irradiation, each sample of SMELS Type I was measured twice after 4 and 50 minutes cooling time. Measurements were performed on the absolutely calibrated HPGe detector (Ortec, USA) with 40 % relative efficiency, called OR4. A sample of SMELS Type II was also measured twice after 1 and 2 days cooling time. A sample of SMELS Type III was measured only once after 7 days cooling time. Measurements were carried out at such distances that the dead time was kept below 10 % with negligible random coincidences. The detector OR4 was connected to a CANBERRA S100 multichannel analyzer.

The HyperLab [36] program was used for peak area evaluation, whereas for determination of f (thermal to epithermal flux ratio) and α (a parameter which represents the epithermal flux deviation from the ideal 1/E distribution), the "Cd-ratio" method for multi monitor was applied [30, 35]. The values obtained for f and α presented in Table 1 were used to calculate the element concentrations. The elemental concentrations and effective solid angle calculations were carried out with the k0_IAEA software package using its different updates. For the purpose of testing the software, the same input parameters (flux parameters, efficiency calibration, net peak area, etc.) were used.

RESULTS AND DISCUSSION

For statistical evaluation of accuracy, the E_n-number [37] was used. The E_n-number is defined by the following equation:

$$E_n = \frac{X_{lab} - X_{ref}}{\sqrt{(U_{lab})^2 + (U_{ref})^2}} \tag{1}$$

where the numerator gives the absolute difference between the experimental result (X_{lab}) and the assigned value (X_{ref}) of the elemental concentration, and U_{ref} and U_{lab} are the expanded uncertainties (k=2) of the assigned and experimental mass fraction, respectively. The expanded Laboratory uncertainty with a coverage factor of k=2 is calculated as follows:

$$U_{lab} = 2 \cdot U_{lab\_comb} = 2 \cdot \sqrt{(St.dev.)^2 + u_{method}^2} \tag{2}$$

where *St.dev.* is the standard deviation of independent measurements (n=3) and u_{method} is the estimated uncertainty of the k0_IAEA software (3.5% with a coverage factor k=1).

In k0_IAEA software, uncertainty is calculated by considering sources of uncertainty such as literature values for $T_{1/2}$, $\bar{E}_r$, Q_0 and k_0, the irradiation, decay and measuring times, the true-coincidence factor (COI), Au composition in the Al-0.1%Au alloy, masses of sample and standard, neutron flux parameters (f, α, fast flux and neutron temperature) and detection efficiency.

To compare the results obtained by k0_IAEA software with the reference data, the criterion $|E_n| \leq 1$ was applied meaning that the performance of the methods was satisfactory, and if $|E_n| > 1$ the performance was unsatisfactory. The relative bias (%) was also used for comparison.

Table 2 shows the relevant nuclear data in k0_IAEA program ver. 4.04 used for validation purposes. In the software, data are stored in four files called “decay_schemes”, “base_cat”, “k0_lists” and “prompt_lists”. It should be noted that these data were entered in January 2009 in the updated version 4.01. Later on, in ver. 4.04 in February 2009, an option for reporting the final result using only recommended gamma lines (recommended data of k_0-factors) was implemented.

Figs. 2-4 show the results obtained for SMELS Type I, II and III by different versions of the k0_IAEA software: ver. 3.11, ver. 4.00 and ver. 4.04. To calculate elemental concentrations, all gamma lines from radionuclides in the software's library were used. In Fig. 4 for SMELS Type III, large changes in the results for Se obtained by ver. 4.04. can be seen. The reason was the changes to the nuclear data in the library. This is well documented in updated version 4.01 (January 2009), where a bug in the decay scheme of ^{75}Se was investigated. The authors of the software estimated that these major changes would bias the results in older versions by about 17%. This statement has been confirmed in this work (see Fig. 4).

Finally, a comparison of data obtained for SMELS Type I, II and III materials by k0_IAEA ver. 4.04 using only recommended gamma lines with literature data was done. The results of the study are presented numerically in Table 3 and graphically in Fig. 5. For statistical evaluation, the relative bias (in %) and E_n-number were applied. As can be seen, the data obtained in this work are in good agreement with assigned values, except for Co and Tm in SMELS Type III, where E_n-numbers exceed 1. It should be noted that data for Co exceed 1 very slightly (E_n = 1.02), which was not the case for Tm (E_n = 2.55). This bias for Tm (^{170}Tm, E_γ = 84.3 keV) can be correlated with the chosen efficiency calibration approach in the software for the low energy range below < 100 keV.

Table 2. Relevant nuclear data in k0_IAEA software ver. 4.04 used for analysis of SMELS materials

El.	Target	σ_0, m^2	$\bar{E}_r$, eV	Q_0	Nuclide	λ, s^{-1}	E_γ, keV	I_γ, %	k_0
Cl	Cl-37	4.441E-29	1.37E+04	6.90E-001	Cl-38	3.102162E-04	1642.4	3.100E+1	1.97E-03
							2167.5	4.200E+1	2.66E-03
Sc	Sc-45	1.665E-27	1.10E+03	4.30E-001	Sc-46	9.570007E-08	889.3	1.000E+2	1.22E+00
							1120.5	1.000E+2	1.22E+00
V	V-51	4.790E-28	7.23E+03	5.50E-001	V-52	3.080654E-03	1434	1.000E+2	1.96E-01
Cr	Cr-50	1.525E-27	7.53E+03	5.30E-001	Cr-51	2.895805E-07	320.1	9.830E+0	2.62E-03
Mn	Mn-55	1.316E-27	4.68E+02	1.05E+000	Mn-56	7.467166E-05	846.8	9.890E+1	4.96E-01
							1810.7	2.720E+1	1.35E-01
							2113.1	1.430E+1	7.17E-02
Fe	Fe-58	1.307E-28	6.37E+02	9.75E-001	Fe-59	1.802979E-07	142.6	1.020E+0	1.33E-06
							192.3	2.684E+0	3.78E-06
							334.8	2.696E-1	3.82E-07
							1099.2	5.610E+1	7.77E-05
							1291.6	4.360E+1	5.93E-05
Co	Co-59	1.660E-27	1.36E+02	1.99E+000	Co-60	4.167048E-09	1173.2	9.990E+1	1.32E+00
							1332.5	1.000E+2	1.32E+00
Co	Co-59	2.070E-27	1.36E+02	2.00E+000	Co-60m	1.100613E-03	58.6	2.028E+0	1.51E-02
							1332.5	2.500E-1	1.75E-03
Cu	Cu-63	4.497E-28	1.04E+03	1.14E+000	Cu-64	1.515951E-05	511	3.800E+1	3.70E-02
							1345.9	4.840E-1	4.98E-04
Cu	Cu-65	2.480E-28	7.66E+02	1.06E+000	Cu-66	2.265187E-03	1039.2	7.400E+0	1.86E-03
Zn	Zn-64	7.250E-29	2.56E+03	1.91E+000	Zn-65	3.286578E-08	1115.5	5.080E+1	5.72E-03
Zn	Zn-68	6.990E-30	5.90E+02	3.19E+000	Zn-69m	1.398818E-05	438.6	9.475E+1	3.98E-04
As	As-75	3.884E-28	1.06E+02	1.36E+001	As-76	7.313160E-06	559.1	4.502E+1	4.83E-02
							563.2	1.200E+0	1.40E-03
							657.1	6.172E+0	6.61E-03
							1212.9	1.430E+0	1.52E-03
							1216.1	3.421E+0	3.73E-03
Se	Se-74	4.997E-27	2.94E+01	1.08E+001	Se-75	6.152800E-08	121.1	1.714E+1	1.94E-03
							136	5.830E+1	6.76E-03

El.	Target	σ_0, m^2	$\bar{E}_r$, eV	Q_0	Nuclide	λ, s^{-1}	E_γ, keV	I_γ, %	k_0
							264.7	5.850E+1	7.11E-03
							279.5	2.479E+1	3.00E-03
							400.7	1.137E+1	1.43E-03
Br	Br-79	8.382E-28	6.93E+01	1.10E+001	Br-80	4.356129E-05	616.3	6.690E+0	6.92E-03
							666.3	1.080E+0	1.22E-03
Br	Br-81	1.529E-29	1.52E+02	1.93E+001	Br-82	5.454540E-06	554.3	7.037E+1	2.38E-02
							619.1	4.324E+1	1.45E-02
							698.4	2.788E+1	9.38E-03
							776.5	8.309E+1	2.76E-02
							827.8	2.382E+1	7.99E-03
							1044	2.726E+1	9.14E-03
							1317.5	2.699E+1	8.91E-03
							1474.9	1.641E+1	5.42E-03
Sr	Sr-84	1.540E-29	1.00E+00	1.33E+001	Sr-85	1.237282E-07	514	9.973E+1	9.15E-05
Sr	Sr-86	7.718E-29	7.95E+02	4.11E+000	Sr-87m	6.888761E-05	388.4	8.210E+1	1.49E-03
Zr	Zr-94	5.167E-30	6.26E+03	5.05E+000	Zr-95	1.239220E-07	724.2	4.420E+1	8.90E-05
							756.7	5.450E+1	1.10E-04
Zr	Zr-94	5.167E-30	6.26E+03	5.05E+000	Nb-95	1.239220E-07	765.8	9.980E+1	2.17E-06
Zr	Zr-96	2.068E-30	3.38E+02	2.48E+002	Zr-97	1.113113E-05	254.2	1.250E+0	1.82E-07
							355.4	2.270E+0	2.92E-07
							507.1	5.060E+0	6.79E-07
							602.4	1.390E+0	1.90E-07
							703.7	9.280E-1	1.36E-07
							1148	2.643E+0	3.41E-07
Zr	Zr-96	2.068E-30	3.38E+02	2.48E+002	Nb-97	3.679711E-07	657.9	9.830E+1	1.24E-05
Zr	Zr-96	2.068E-30	3.38E+02	2.48E+002	Nb-97m	1.113113E-05	743.3	9.795E+1	1.24E-05
Mo	Mo-98	1.307E-29	2.41E+02	5.31E+001	Mo-99	2.569361E-06	181.1	6.257E+0	4.15E-05
							366.4	1.160E+0	8.36E-06
							739.5	1.210E+1	8.46E-05
							778	4.350E+0	2.97E-05
Mo	Mo-98	1.307E-29	2.41E+02	5.31E+001	Tc-99m	2.569361E-06	140.48	4.543E+0	5.27E-04
In	In-113	8.545E-28	6.41E+00	2.42E+001	In-114m	1.548933E-07	190.3	1.540E+1	1.06E-03

El.	Target	σ_0, m^2	$\bar{E}_r$, eV	Q_0	Nuclide	λ, s^{-1}	E_γ, keV	I_γ, %	k_0
							558.4	1.280E-1	2.86E-04
							725.2	4.330E+0	2.90E-04
Sb	Sb-121	6.398E-28	8.00E+01	3.30E+001	Sb-122	2.940349E-06	564.1	7.000E+1	4.38E-02
							692.8	3.820E+0	2.38E-03
Sb	Sb-123	4.000E-28	2.82E+01	2.88E+001	Sb-124	1.332647E-07	602.7	9.780E+1	2.96E-02
							645.9	7.380E+0	2.21E-03
							722.8	1.090E+1	3.19E-03
							1691	4.710E+1	1.41E-02
							2090.9	5.490E+0	1.58E-03
Sb	Sb-123	8.496E-30	2.82E+01	1.99E+001	Sb-124m1	5.719036E-04	498.4	2.450E-2	1.43E-04
							602.7	9.780E+1	1.43E-04
							645.8	7.380E+0	1.43E-04
I	I-127	4.093E-28	5.76E+01	2.48E+001	I-128	4.579581E-04	442.9	1.690E+1	1.12E-02
							526.6	1.570E+0	1.07E-03
Cs	Cs-133	3.043E-27	9.27E+00	1.27E+001	Cs-134	1.065201E-08	563.2	8.583E+0	4.14E-02
							569.3	1.540E+1	7.34E-02
							604.7	9.780E+1	4.76E-01
							795.9	8.541E+1	4.15E-01
							801.9	8.730E+0	4.11E-02
Cs	Cs-133	2.764E-28	9.27E+00	1.18E+001	Cs-134m	6.616525E-05	127.5	1.261E+1	5.48E-03
La	La-139	9.303E-28	7.60E+01	1.24E+000	La-140	4.781011E-06	328.8	2.070E+1	2.87E-02
							487	4.600E+1	6.37E-02
							815.8	2.360E+1	3.32E-02
							1596.5	9.546E+1	1.34E-01
Pr	Pr-141	1.115E-27	2.96E+02	1.51E+000	Pr-142	1.005926E-05	1575.6	3.700E+0	6.12E-03
Tm	Tm-169	8.084E-27	4.80E+00	1.37E+001	Tm-170	6.229665E-08	84.3	3.260E+0	3.26E-02
Yb	Yb-168	2.908E-25	6.10E-01	4.97E+000	Yb-169	2.505320E-07	63.1	4.380E+1	2.04E-02
							109.8	1.742E+1	7.79E-03
							130.5	1.119E+1	5.17E-03
							177.2	2.150E+1	1.04E-02
							198	3.490E+1	1.64E-02
							307.7	1.080E+1	4.34E-03

El.	Target	σ_0, m^2	$\bar{E}_r$, eV	Q_0	Nuclide	λ, s^{-1}	E_γ, keV	I_γ, %	k_0
Yb	Yb-174	1.249E-26	6.02E+02	4.60E-001	Yb-175	1.914687E-06	113.8	1.910E+0	9.42E-03
							137.7	1.170E-1	5.69E-04
							144.9	3.320E-1	1.59E-03
							282.5	3.060E+0	1.46E-02
							396.3	6.500E+0	3.12E-02
Au	Au-197	9.870E-27	5.65E+00	1.57E+001	Au-198	2.978480E-06	411.8	9.550E+1	≡ 1.0
Th	Th-232	8.089E-28	5.44E+01	1.15E+001	Pa-233	2.971310E-07	300.1	6.200E+0	4.37E-03
							312	3.600E+1	2.52E-02
							340.5	4.170E+0	2.95E-03
							375.4	5.760E-1	4.49E-04
							398.6	1.190E+0	9.26E-04
							415.8	1.510E+0	1.16E-03

Notes:

σ_0 – cross-section for reference velocity v_0 = 2200 m s^{-1}; $\bar{E}_r$ – effective resonance energy; Q_0 – resonance integral ($1/E$) to 2200 m s^{-1} cross-section ratio (= I_0/σ_0); λ – decay constant (= $ln(2)/T_{1/2}$); $T_{1/2}$ – half-life; E_γ – gamma energy; I_γ – absolute gamma intensity; k_0 – compound nuclear constant from molar mass (M), nuclide abundance in the isotopic composition of the element (θ), absolute gamma intensity (γ) and the cross-section of reference velocity v_0 = 2200 m s^{-1} (σ_0); $k_0 = \dfrac{M_{Au}\,\Theta_a\,\gamma_a\,\sigma_{0,a}}{M_a\,\Theta_{Au}\,\gamma_{Au}\,\sigma_{0,Au}}$

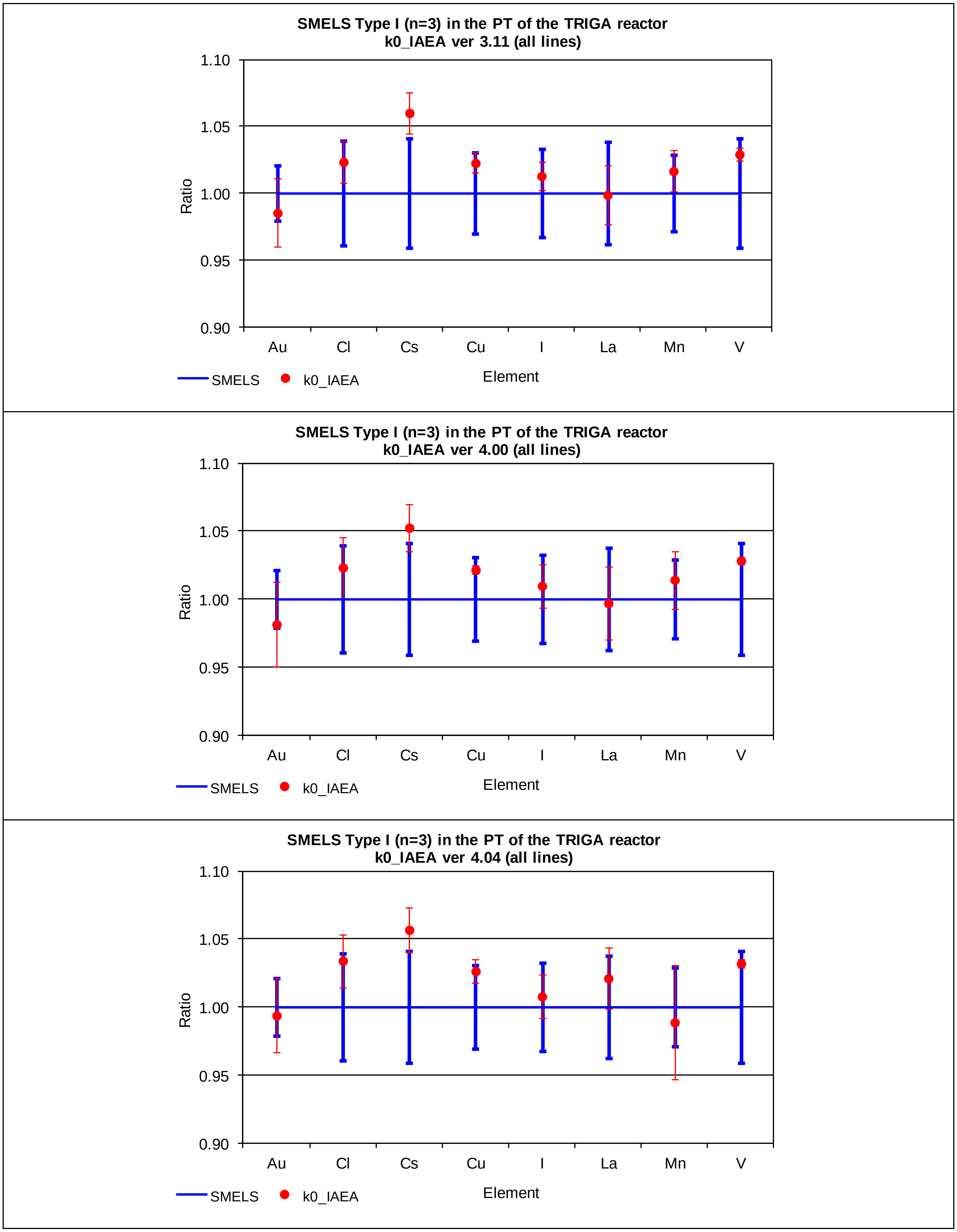

Fig. 2. Results for SMELS Type I obtained by different versions of k0_IAEA software. Error bar for SMELS is given with a 95% confidence interval, while for k0_IAEA only the standard deviation of three independent determinations at the PT of the TRIGA reactor is presented.

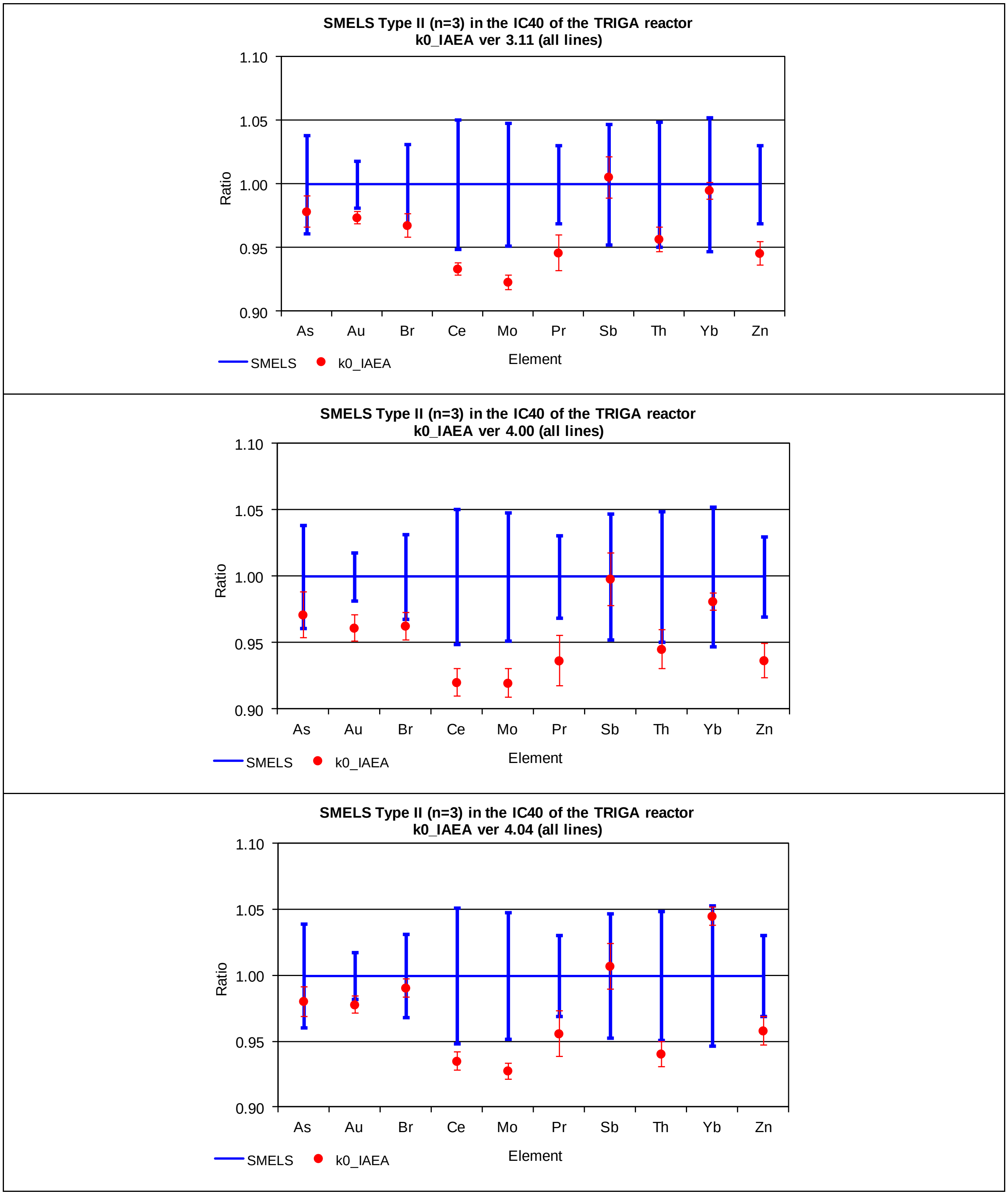

Fig. 3. Results for SMELS Type II obtained by different versions of k0_IAEA software. Error bar for SMELS is given with a 95% confidence interval, while for k0_IAEA only the standard deviation of three independent determinations at the IC-40 of the TRIGA reactor is presented.

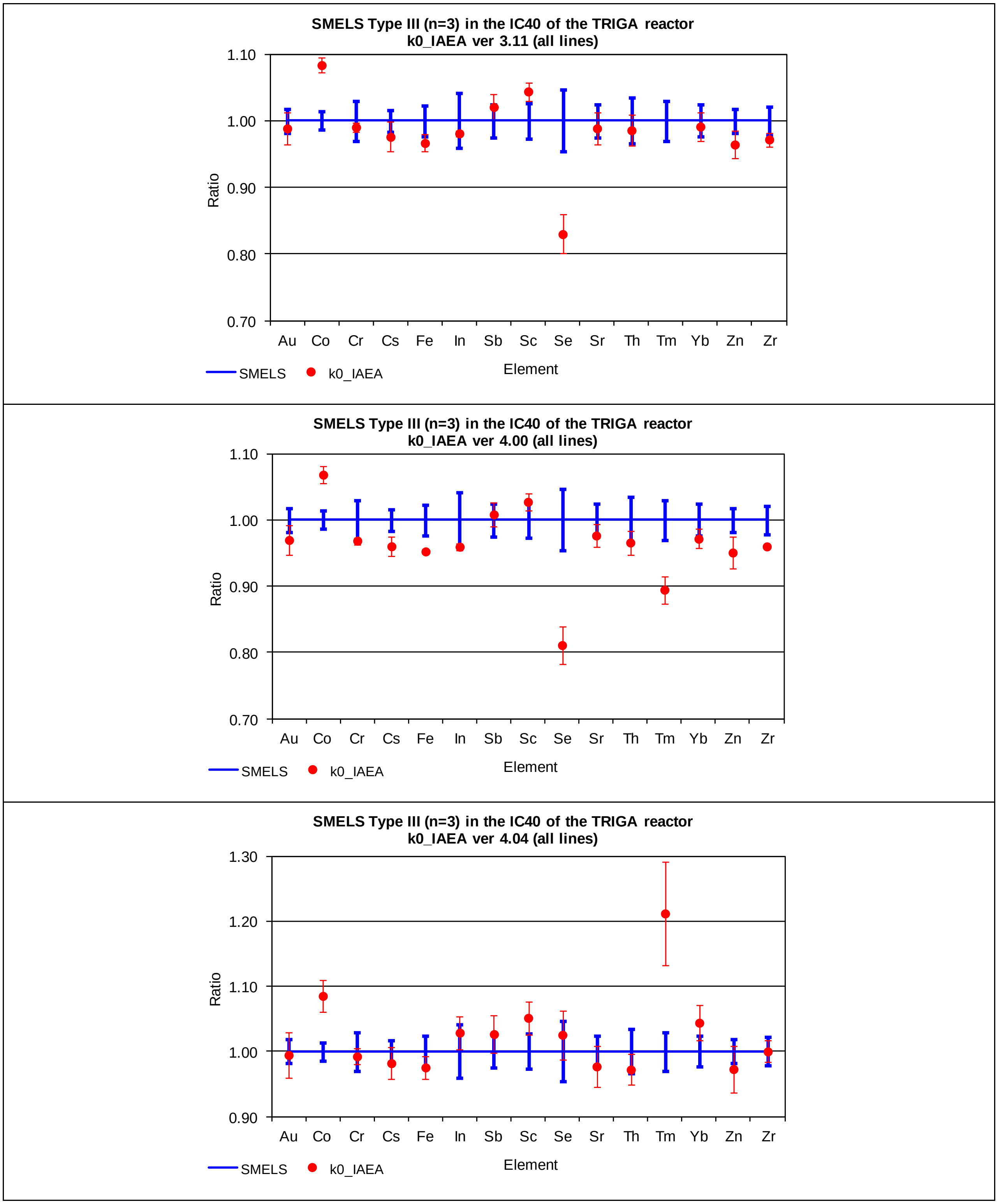

Fig. 4. Results for SMELS Type III obtained by different versions of k0_IAEA software. Error bar for SMELS is given with a 95% confidence interval, while for k0_IAEA only the standard deviation of three independent determinations at the IC-40 of the TRIGA reactor is presented.

Table 3. Comparison of data obtained at JSI for SMELS by k0_IAEA software ver. 4.04 using only recommended gamma lines with literature data [38]

SMELS	El.	Assigned v. ± U_{ref}* mg/kg			N	This work ± U_{lab}* mg/kg			n	Relative bias, %	E_n
Type I	Au	82.7	±	1.7	8	81.6	±	7.1	3	-1.33	0.15
	Cl	4330	±	170	8	4447	±	343.0	3	2.70	0.31
	Cs	897	±	37	8	945	±	71.2	3	5.35	0.60
	Cu	3930	±	120	8	4018	±	291.0	3	2.24	0.28
	I	152	±	5	7	152	±	11.2	3	0.00	0.00
	La	265	±	10	8	269	±	22.2	3	1.51	0.16
	Mn	113.9	±	3.3	8	114.3	±	9.9	3	0.35	0.04
	V	39.0	±	1.6	8	40.1	±	2.8	3	2.82	0.34
Type II	As	92.3	±	3.6	9	90.1	±	3.3	3	-2.38	0.30
	Au	3.93	±	0.07	9	3.83	±	0.14	3	-2.54	0.36
	Br	157	±	5	7	155	±	6	3	-1.27	0.16
	Ce	15600	±	800	7	14513	±	516	3	-6.97	0.83
	Mo	5170	±	250	8	4778	±	170	3	-7.58	0.93
	Pr	1193	±	37	8	1135	±	42	3	-4.86	0.63
	Sb	172	±	8	9	172	±	7	3	0.00	0.00
	Th	3670	±	180	9	3434	±	123	3	-6.43	0.78
	Yb	187	±	10	9	195	±	7	3	4.28	0.47
	Zn	6570	±	200	8	6218	±	224	3	-5.36	0.72
Type III	Au	0.901	±	0.016	8	0.898	±	0.040	3	-0.33	0.04
	Co	24.30	±	0.33	9	26.4	±	1.0	3	8.64	1.02
	Cr	86.7	±	2.6	9	86.2	±	3.1	3	-0.58	0.07
	Cs	20.80	±	0.34	8	20.4	±	0.9	3	-1.92	0.22
	Fe	8200	±	190	9	8013	±	305	3	-2.28	0.29
	In	462	±	19	9	476	±	19	3	3.03	0.33

SMELS	El.	Assigned v. ± U_{ref}* mg/kg			N	This work ± U_{lab}* mg/kg			n	Relative bias, %	E_n
	Sb	51.2	±	1.3	7	52.7	±	2.2	3	2.93	0.33
	Sc	1.140	±	0.031	9	1.200	±	0.048	3	5.26	0.60
	Se	131	±	6	9	136	±	8	3	3.82	0.30
	Sr	8150	±	200	9	7979	±	358	3	-2.10	0.23
	Th	26.2	±	0.9	9	25.5	±	1.0	3	-2.67	0.31
	Tm	23.3	±	0.7	7	29.3	±	1.1	3	25.75	<u>2.55</u>
	Yb	20.7	±	0.5	9	21.7	±	0.9	3	4.83	0.53
	Zn	618	±	11	9	603	±	26	3	-2.43	0.28
	Zr	4580	±	100	9	4592	±	176	3	0.26	0.03

Notes:
* – Estimated expanded uncertainty with a coverage factor k=2; N – number of withheld labs results; n – number of replicates

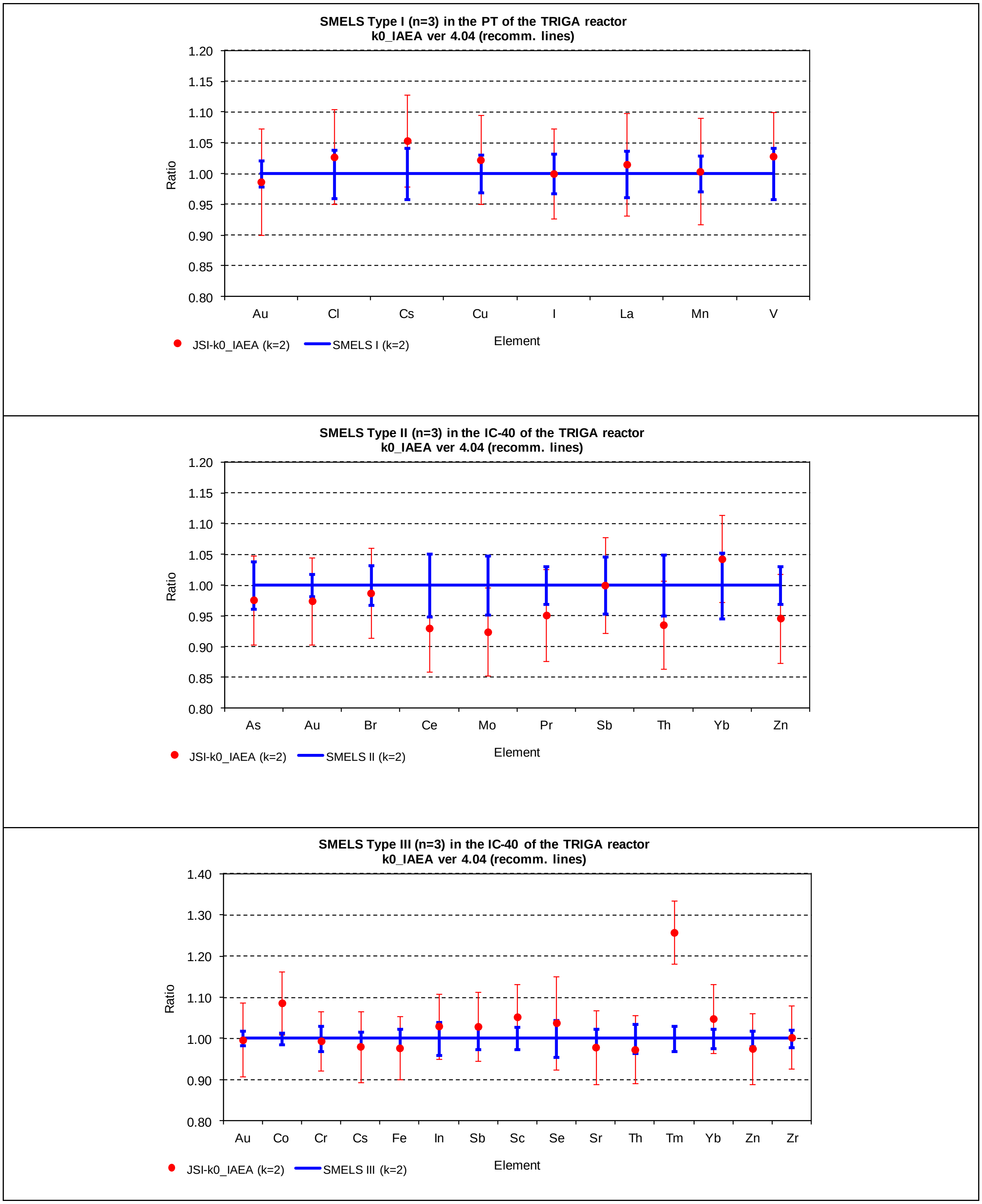

Fig. 5. Results for SMELS Type I, II and III obtained by k0_IAEA software ver. 4.04 using only recommended gamma lines. Error bars are given with a 95% confidence interval (k=2).

CONCLUSIONS

The k_0-standardization method of INAA was applied at the JSI according to the holistic approach developed in the k0_IAEA software. For the purpose of validating the software, the SMELS materials (Type I, II and III) were used. In order to follow improvements incorporated during the process of development, the same input parameters (flux parameters, efficiency calibration, net peak area, etc.) were used. This also allowed the discovery of possible systematic errors in the nuclear database used in the program, including data for Q_0 and k_0-factors.

In this work the E_n-number was used for evaluation of the data obtained by k0_IAEA software for SMELS materials. Based on this E_n-number the results obtained by the k0_IAEA program are in good agreement with assigned values, except for Co and Tm in SMELS Type III, where E_n-numbers exceed 1. This confirmed our inference that the determination of elements by k0_IAEA software where their radiounuclides emit gamma energies lower < 100 keV may be systematically biased due to the chosen efficiency calibration approach. However, this is a general problem in absolute calibration of HPGe detectors and needs further investigation.

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