Appendix H

Recommended Values of Physical Constants to be Used in ENDF

H.1 Sources for Fundamental Constants

The basic source for Fundamental Constants used by CSEWG in evaluating and processing ENDF data are the values reported in **The 2018 CODATA Recommended Values of the Fundamental Physical Constants** (Source 1) as taken from the NIST Reference on Constants, Units, and Uncertainties Web site[1]

These are supplemented by the mathematical constants from **Wolfram MathWorld** [2] (Source 2).

H.2 Fundamental Constants and Derived Data

Values of the Fundamental Physics Constants, as approved by CSEWG, are given in this Appendix. These values should be used until updates are approved by CSEWG.

Values for quantities which are derived from these fundamental constants, and which were previously given in the body of this manual, are also presented in this section with the expressions by which they have been replaced in the body of this Manual. These values may not appear in subsequent revisions of this Appendix.

[1]The information was prepared by Eite Tiesinga, Peter J. Mohr, David B. Newell, and Barry N. Taylor (2019), "The 2018 CODATA Recommended Values of the Fundamental Physical Constants" (Web Version 8.0). Database developed by J. Baker, M. Douma, and S. Kotochigova. Available at http://physics.nist.gov/constants, National Institute of Standards and Technology, Gaithersburg, MD 20899.

[2]The information was extracted from **Wolfram MathWorld** located at http://mathworld.wolfram.com/

H.3 Use of Fundamental Constants by Code Developers

Code developers are encouraged to locate any values for fundamental physics constants that may be currently buried deep within their codes, and to replace these values by the expressions given here; the values would then be specified in only one location in the code. This ensures internal consistency, and expedites any necessary updates.

Code developers should double-check that numerical constants (e.g., π or e) are represented to a degree of accuracy consistent with the precision of the computers on which the codes are to be run.

In subsequent revisions of this manual, values for derived quantities may not be given. Instead, code developers should calculate those quantities by directly evaluating the expressions. This will ensure that values are as precise as the computer permits.

H.4 Use of Fundamental Constants by Evaluators

Evaluators should use the fundamental constants, mass numbers, Q-values, etc., as specified in Tables H.1, H.2, and H.3, for evaluations submitted for acceptance by ENDF.

Evaluators are encouraged to specify values for "hidden" physical constants within the File 1 comments of the ENDF file in order to prevent future confusion in the event of changes in the accepted values.

Table H.1: Fundamental Constants

Expression	Definition	Numeric value	Units	Source
e	natural logarithmic base	2.718 281 828 52	—	2
π	Archimedes' constant	3.141 592 653 59	—	2
e	elementary charge	$1.602\,176\,634\,8 \times 10^{-19}$	C	1
$\alpha^{-1} = 10^7\hbar/(c\,e)$	inverse fine-structure constant	137.035 999 084	—	1
u	atomic mass unit (amu)	$9.314\,941\,024\,2 \times 10^{8}$	$\mathrm{eV/c^2}$	1
h	Planck's constant	$4.135\,667\,696 \times 10^{-15}$	eV s	1
$\hbar = h/2\pi$	Reduced Planck's constant	$6.582\,119\,569 \times 10^{-16}$	eV s	1
k	Boltzmann's constant	$8.617\,333\,262 \times 10^{-5}$	$\mathrm{eV\,K^{-1}}$	1
c	speed of light (in vacuum)	299 792 458	$\mathrm{m\,s^{-1}}$	1
N_A	Avogadro's number	$6.022\,140\,76 \times 10^{23}$	$\mathrm{mol^{-1}}$	1

In Table H.4, the relative differences between the CODATA2014 and CODATA2018 values are given. The relative differences were calculated as:

$$\Delta = \frac{C_{14} - C_{18}}{C_{14}}, \tag{H.1}$$

where C_{14} and C_{18} are the CODATA2014 and CODATA2018 values, respectively.

Table H.2: Masses

Expression	Definition	Numeric value (u)	Source
m_n	neutron mass	1.008 664 915 95	1
m_e	electron mass	$5.485\,799\,090\,65 \times 10^{-4}$	1
$m_{\bar{e}}$	positron mass	$5.485\,799\,090\,65 \times 10^{-4}$	1
m_p	proton mass	1.007 276 466 621	1
m_d	deuteron mass	2.013 553 212 745	1
m_t	triton mass	3.015 500 716 21	1
m_{3He}	^{3}He mass (helion)	3.014 932 247 175	1
m_α	α mass	4.001 506 179 127	1

Table H.3: Energies needed to break particles into their constituent nucleons.

Symbol	Full name	Numeric value	Source
d	deuteron	2.224 566 MeV	1
t	triton	8.481 798 MeV	1
^{3}He	^{3}He	7.718 043 MeV	1
α	alpha	28.29 566 MeV	1

The following table gives values which were previously given in the body of this Manual, along with the expressions which should be used in the future for these values. These expressions have been substituted for the values at the appropriate places in the Manual. **These values should not be used in any future applications; instead, please use the values for the Fundamental Constants as specified in this Appendix**. (For example for m_p/m_n, do not use 0.99862; use the value derived from the values for m_p and m_n).

Table H.4: Relative differences between CODATA2014 and CODATA2018 values as calculated with Equation H.1.

Symbol	Δ
e	-8.24×10^{-9}
$\alpha^{-1} = 10^7 \hbar/(c\, e)$	4.01×10^{-10}
u	-7.54×10^{-9}
h	-8.22×10^{-9}
$\hbar = h/2\pi$	-8.36×10^{-9}
k	-3.44×10^{-7}
c	0.00
N_A	1.61×10^{-8}
m_n	-6.94×10^{-11}
m_e	9.11×10^{-12}
$m_{\bar{e}}$	9.11×10^{-12}
m_p	2.56×10^{-10}
m_d	0.00
m_t	3.65×10^{-11}
m_{3He}	-1.48×10^{-10}
m_α	0.00

Table H.5: Derived quantities whose values were formerly given in the body of the Manual

Location	**Value previously given in the Manual**	**Units for value**	**Expression**
§0.18	0.998 62		m_p/m_n
	1.996 26		m_d/m_n
	2.989 60		m_t/m_n
	2.989 03		m_{3He}/m_n
	3.967 13		m_a/m_n
§4.7	3.0560×10^{-8}	1 / (eV barn steradian)	$m_n u/(2h^2c^2) \times 10^{-28}$
Eq. (6.9)	$4.784\ 53 \times 10^{-6}$	$(10^{-12}\text{cm})^2$ eV / amu	$2u/(\hbar^2 c^2)$
Eq. (6.10)	$2.480\ 58 \times 10^4$	eV / amu	$u\alpha^2/2$
§D.3	$2.196\ 771 \times 10^{-3}$	10^{-12}cm $(\text{eV})^{-1/2}$	$\sqrt{2m_n}/\hbar$