Designation: C 1233 – 03

Standard Practice for Determining Equivalent Boron Contents of Nuclear Materials[1]

This standard is issued under the fixed designation C 1233; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard details a recommended practice for the calculation of the Equivalent Boron Content (EBC) values for elements that are of potential significance as thermal neutron poisons. The values are determined from a knowledge of the atomic weight of elements and the thermal neutron absorption cross section in barns. This practice is illustrated by using the EBC factors of Table 1 which are based on thermal neutron (2200 m/s) absorption cross sections. Other EBC factors may be used depending upon the actual neutron energy characteristics of the applicable reactor system.

1.2 The following elements do not require to be included in the EBC calculations, as their EBC factors are less than or equal to 0.0001.

aluminum	fluorine	rubidium
barium	lead	silicon
beryllium	neon	tin
bismuth	oxygen	zirconium
carbon	magnesium	
cerium	phosphorus	

Their contribution to the total poison effect is not considered significant.

2. Referenced Documents

2.1 *ASTM Standards:*

C 696 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets[2]

C 698 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Mixed Oxides $((U,Pu)O_2)$[2]

C 699 Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of, and Physical Tests on, Beryllium Oxide Powder[2]

C 761 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Uranium Hexafluoride[2]

C 799 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Uranyl Nitrate Solutions[2]

C 859 Terminology Relating to Nuclear Materials[2]

3. Terminology

3.1 Terms shall be defined in accordance with Terminology C 859.

4. Methods For EBC Determination

4.1 Agreement shall be reached between the buyer and seller as to which elements shall be analyzed for calculation of their EBC. It is recommended that B, Cd, Dy, Eu, Sm, and Gd be included in this calculation. Analytical methods for such elements shall be those given in Methods C 696, C 699, and C 799, and Test Methods C 698 and C 761 as applicable or as otherwise agreed upon between buyer and seller.

4.2 The individual EBC values are calculated using the EBC factors from Table 1 as follows:

$$EBC\ of\ impurity = (EBC\ factor)(\mu g\ of\ impurity/g\ base\ material)$$

where:

$$EBC\ factor = \frac{(atomic\ mass\ boron)(\sigma a\ impurity)}{(atomic\ mass\ impurity)(\sigma a\ boron)}, \text{ and}$$

σa = atomic neutron absorption cross section in barns.

The values given in Table 1 have been calculated using a value of 764 Barns for the neutron absorption cross section (σa) of boron. This value may vary in nature according to the isotopic composition of the elements. If an alternative value is chosen the EBC factors must be recalculated using the chosen value.

4.3 If the concentration of any of the elements used in the calculation is reported as "less than" values, these values shall be used in calculating the EBC.

4.4 A total EBC value, if required, is determined by the summation of individual EBC values.

[1] This practice is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.02 on Fuel and Fertile Material Specifications.

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[2] *Annual Book of ASTM Standards*, Vol 12.01.

TABLE 1 Equivalent Boron Content Factors

Element	Neutron Absorption Cross Section[A] (Barns) at 2200 m/s	Atomic Mass[B]	EBC Factor
Antimony	5.1[C]	121.75	0.0006
Argon	0.68	39.95	0.0002
Arsenic	4.5	74.92	0.0008
Boron	764[D]	10.81	1.0000
Bromine	6.9	79.91	0.0012
Cadmium	2520	112.41	0.3172
Calcium	0.43	40.08	0.0002
Cesium	29	132.91	0.0031
Chlorine	33.5	35.45	0.0132
Chromium	3.07	52.00	0.0008
Cobalt	37.2	58.93	0.0089
Copper	3.78	63.54	0.0008
Dysprosium	940	162.50	0.0818
Erbium	159.2	167.26	0.0135
Europium	4565	151.97	0.4250
Gadolinium	48890	157.25	4.3991
Gallium	2.9	69.72	0.0006
Germanium	2.3[C]	72.59	0.0004
Gold	98.65	196.97	0.0071
Hafnium	104.1	178.49	0.0083
Holmium	64.7	164.93	0.0056
Hydrogen	0.33	1.01	0.0046
Indium	193.8[C]	114.82	0.0239
Iodine	6.2	126.90	0.0007
Iridium	425.30	192.22	0.0313
Iron	2.56[C]	55.85	0.0006
Krypton	25.00	83.80	0.0042
Lanthanum	8.97[C]	138.91	0.0009
Lithium	70.6[E]	6.94	0.1439
Lutetium	76.4	174.97	0.0062
Manganese	13.3	54.94	0.0034
Mercury	372.3	200.59	0.0263
Molybdenum	2.55[C]	95.94	0.0004
Neodymium	50.5[C]	144.24	0.0050
Nickel	4.49[C]	58.69	0.0011
Niobium	1.15	92.91	0.0002
Nitrogen	1.90	14.01	0.0019
Osmium	16.00	190.20	0.0012
Palladium	6.90	106.42	0.0009
Platinum	10.30	195.08	0.0007
Potassium	2.1[C]	39.10	0.0008
Praseodymium	11.5	140.91	0.0012
Rhenium	89.70	186.21	0.0068
Rhodium	145.20	102.91	0.0200
Ruthenium	2.56[C]	101.07	0.0004
Samarium	5670	150.36	0.5336
Scandium	27.20	44.96	0.0086
Selenium	11.70	78.96	0.0021
Silver	63.3	107.87	0.0083
Sodium	0.53	22.99	0.0003
Strontium	1.28[C]	87.62	0.0002
Sulphur	0.52	32.06	0.0002
Tantalum	20.6	180.95	0.0016
Tellurium	4.70	127.60	0.0005
Terbium	23.4	158.92	0.0021
Thallium	3.43	204.37	0.0002
Thorium	7.37	232.04	0.0004
Thulium	105	168.93	0.0088
Titanium	6.1	47.88	0.0018
Tungsten	18.4	183.85	0.0014
Vanadium	5.08	50.94	0.0014
Xenon	23.90	131.29	0.0026
Ytterbium	35.5	173.04	0.0029
Yttrium	1.28	88.91	0.0002
Zinc	1.11	65.39	0.0002

[A] *Neutron Cross Sections*, Vol 1, Parts A and B, Academic Press, New York, 1981 and 1984, respectively.
[B] Holden, N. E., and Martin, R. L., *Pure and Applied Chemistry*, Vol 56, p. 653, 1984.
[C] In the absence of other data, the neutron capture cross section for a Maxwellian flux is used.
[D] Cross section is primarily due to a single isotope, whose isotopic abundance is variable in nature. The value can vary between 733 and 779 barns depending upon the source. See Holden, N. E., *Neutron Capture Cross Section Standards* for BNL-325, Fourth Ed., BNL-NCS-51388, January 1981.
[E] Cross section is primarily due to a single isotope, whose isotopic abundance is variable in nature. The value can vary between 69 and 72 barns depending upon the source. See Holden, N. E., *Neutron Capture Cross Section Standards* for BNL-325, Fourth Ed., BNL-NCS-51388, January 1981.

4.5 Plutonium, thorium and uranium have not been included, as they are fissionable elements.

5. Keywords

5.1 boron; neutron absorption; nuclear materials; nuclear poisons