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Article · March 2016

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Boron Equivalent For Nuclear Grade Natural Uranium – An Explanation

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Abstract

Boron equivalent for nuclear grade natural uranium is estimated using fundamental data to be 6 ppm and the procedure is explained.

Various impurities in nuclear grade natural uranium have a number of isotopes at different % natural abundances and also have widely varying thermal neutron absorption cross-sections. These impurities are permitted at different levels in the nuclear grade material. A product of concentration levels in ppm(c), percentages natural abundances of impurity element's isotopes (p) and thermal neutron absorption cross-sections in barns(n) divided by 100 (c.p.n/100) gives an impact factor as given in Table.2. These are added to give total impact factor. Table.1 gives the list of impurities and their allowed levels in nuclear grade natural uranium. Table 2 deals with isotopes of impurity elements, their % natural abundances, thermal neutron absorption cross – sections (barns, n) and respective impact factors.

Impurity Elements	Maximum concentration (c), µg/g
B	0.12
Cd	0.12
Sm	0.10
Eu	0.04
Gd	0.04
Dy	0.10
Er	0.10
Y	0.10
Ce	0.20
Yb	0.10
Th	10
Mg	25
Al	100
C	800
Cr	65
Mn	25
Fe	150
Co	1.2
Ni	100

Table1: Impurity elements and their concentration in nuclear grade natural uranium[1]

Total impact is obtained by sum of individual impact factors, which works out to be 4571.08. For 6ppm Boron as the only impurity, the estimated impact factor is 4535.33. Therefore, boron equivalent of the material is 6 ppm. For low enriched uranium fuels, the boron equivalent permitted may vary depending on the average neutron flux to be maintained. Part specification for nuclear grade uranium oxide which is in the enrichment level between 0.72% and 5% is given in ASTM standard[3].

Isotopes of impurity elements	% natural abundance (p)	Thermal neutron absorption cross – sections (barns),(n)	Impact factor (c.p.n/100)
B^{10}	19.70	3837	90.71
Cd^{113}	12.30	20000	295.20
Sm^{149}	13.82	41500	573.53
Eu^{153}	52.23	320	6.69
Gd^{155}	14.70	58000	341.04
Gd^{157}	15.68	240000	1505.28
Dy^{161}	18.88	600	11.33
Dy^{162}	25.53	140	3.57
Dy^{163}	24.97	130	3.25
Dy^{164}	28.18	2000	56.36
Er^{167}	22.94	700	16.06
Y^{89}	100.00	1.3	0.13
Ce^{140}	88.48	0.6	0.11
Ce^{142}	11.07	1	0.02
Yb^{168}	0.014	11000	0.15
Yb^{174}	31.84	46	1.46
Yb^{176}	12.73	7	0.09
Th^{232}	100.00	7.4	74.00
Mg^{24}	78.60	0.03	0.59
Mg^{25}	10.11	0.3	0.76
Mg^{26}	11.29	0.027	0.08
Al^{27}	100.00	0.235	23.5
C^{12}	99.89	0.0034	2.72
Cr^{50}	4.81	17	46.63
Cr^{52}	83.76	0.8	43.56
Cr^{53}	9.55	18	111.74
Mn^{55}	100.00	13.3	332.50
Fe^{54}	5.84	2.9	25.40
Fe^{56}	91.68	2.7	371.30
Fe^{57}	2.17	2.5	8.14
Co^{59}	100.00	19	22.80
Ni^{58}	67.76	4.4	298.14
Ni^{60}	26.16	2.6	68.02
Ni^{62}	3.66	15	54.90
Total impact factor			**4571.08**

Table 2: Isotopes of impurity elements, their % natural abundances, thermal neutron absorption cross – sections (barns, n) and respective impact factors[2]

Reference:

1. http://bts.barc.gov.in/AuthStatic/auth_static.php/UED/Pages/Uranium.html#U_NukGrade
2. Lange's handbook of chemistry 8th edition, 1952. Handbook publishers Inc., Sandusky, Ohio, USA.
3. Standard Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder, ASTM Designation C 753 – 99.