UCRL-SM-228335

Program ZAUPDATE: Define material equivalences for ENDF/B-VII.0 Data for use in TART input files

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Overview

The recently released ENDF/B-VII.0 [1] neutron data has been processed into temperature dependent form [2], and has now been translated from the ENDF-6 format to the Livermore ENDL format, making it available for use with the TART [3] Monte Carlo neutron/photon transport code. The ENDF/B-VII.0 general purpose data library contains evaluations for 393 materials (elements and isotopes). The TART Monte Carlo neutron/photon transport code's standard neutron data library currently contains evaluations for 116 materials (elements and isotopes).

Not all materials in TART's standard library are included in the ENDF/B-VII.0 library. This is mostly because ENDF/B-VII.0 has replaced elemental evaluations by isotopic evaluations, e.g., TART library contains natural iron (ZA=26000), whereas ENDF/B-VII.0 contains data for the four (4) naturally occurring isotopes of iron. There are also cases where there is a one-to-one equivalence, e.g., TART C-12 or C-13, and ENDF/B-VII.0 natural C (ZA=6000). There are also essentially mono-isotopic elements which are identified in one library as natural and in the other as the isotope, e.g., ZA=18000 vs. 18040 (99.6%) and ZA=23051 vs. 23000. There are also a few evaluations for isotopes in TART's current library that have no equivalent in ENDF/B-VII.0.

TART has been in continuous use for decades and over this time thousands of files have been created defining TART input parameters. This ZAUPDATE code is designed to allow these existing TART input parameter files to be automatically updated to use the ENDF/B-VII.0 data. The only TART input parameters that need to be replaced are those defining materials; in TART terminology **matl** and **matlwp** input lines.

Procedures

An entire TART input parameter file is read and translated; the file may contain any number of TART problems, e.g., the first test case for this code was to translate the standard 68 critical problems, which are all contained in a single file.

The only TART input parameter lines changed are **matl** and **matlwp** lines. These input lines define the composition of materials; **matl** defines composition in terms of atom fractions pr per-cent, and **matlwp** defines composition in terms of weight fractions or per-cent (hence the wp in matlwp). All other lines are copied from the Old to the New TART input parameter file.

The **matl** and **matlwp** lines define the composition of each material as follows,

matl nm density F1 iza1 F2 iza2 F3 iza3………

Where,

nm	= the material number, used to assign materials to spatial zones
density	= density of the material in grams/cc
F1	= atom fraction of a constituent
iza1	= ZA identification of a constituent, e.g., Fe56 = 26056

The input form is identical for **matlwp**, except that F is interpreted as a weight fraction.

Each material may contain any number of constituents. Each constituent MUST be defined by a pair (F, iza), defining the fraction and identification. The sum of the fractions need not be normalized; TART will do this for you. For example, water composed of two parts H1 to one part O16, may be defined as 2.0 1001 1.0 8016, or, 200.0 1001 100.0 8016, or, 0.6667 1001 0.3333 8016, or any other form in which the ratio of constituents is 2:1. This code will replace the (F,iza) pairs using an equivalence list; see the entire equivalence list later in this report.

1) Regardless of the fractional weights defined in the equivalence list file, for **matl** the sum of the fractions are internally normalized to unity, and for **matlwp** the sum of the product of the fractions times atomic weight are internally normalized to unity.

2) **matl** input is atom fractions, so that the Old atom fraction is multiplied by the equivalence fractions and then properly normalized.

3) **matlwp** input is weight fractions, so that the Old weight fraction is multiplied by the equivalence fractions TIMES its atomic weight and then properly normalized.

For example, the below TART input line defines natural iron (ZA=26000) at a density of 7.78 grams/cc,

```
matl      1   7.78  100.0        26000
```

This code would replace the above line by the following two lines, replacing natural iron by its four (4) naturally occurring isotopes, properly weighted by their natural abundance,

```
matl      1  7.78000D+00  5.84500D+00  26054  9.17540D+01  26056 &
                          2.11900D+00  26057  2.82000D-01  26058
```

Running requirements

This code is written in extremely simple, conservative FORTRAN and requires very little memory, so it should run on any computer. The running time for even very long TART input parameter files is trivial, i.e., the code finishes almost instantaneously.

Input/Output files

Unit	Filename	Definition
2	ZAUPDATE.INP	Input Parameters
3	ZAUPDATE.LST	Output Report
10	ZAUPDATE.DAT	Old and NEW Material Definitions
10	(as input)	Old TART input file
11	(as input)	New TART input file

Input Parameters (read from ZAUPDATE.INP)

The input parameters file ZAUPDATE.INP MUST contains two (2) lines to define the Old (original) TART input file and the New (final) TART input file. The former is read by this code and the latter is created by this code.

Line	Columns	Format	Definition
1	1-60	A60	Old TART input file
2	1-60	A60	New TART input file

Evaluations in TART Standard Library not included in ENDF/B-VII.0

There are still a few evaluations included in the TART library that are not currently in ENDF/B-VII.0; these are all listed below. The list includes seven (7) evaluations that include S(α, β) thermal scattering law data, two (2) TART defined fission product files, the neutron (Z=0,A=1), and four (4) additional materials. For compatibility with existing TART input files that may use these materials, all of these have been added to the TART ENDF/B-VII.0 Library.

TART input	Description	TART input	Description
0-Nu- 1	Neutron	10-Ne- 20	
1-H -801	H1 bound in Water	39-Y - 88	
1-H -901	H1 bound in poly	78-Pt- 0	
1-H -902	H2 bound in D2O	90-Th-231	
4-Be-809	Be bound in Be metal	99-FF-120	Fission Products #1
4-Be-909	Be bound in BeO	99-FF-125	Fission Products #2
6-C -912	C bound in graphite		
8-O -916	O bound in BeO		

Materials in TART Standard Neutron Data Library (Not in ENDF/B-VII.0)

0-Nu-1	15-P -31	51-Sb-Nat	92-U -240
1-H -1	16-S -32	53-I -127	93-Np-235
1-H -2	17-Cl-Nat	54-Xe-Nat	93-Np-236
1-H -3	18-Ar-Nat	54-Xe-134	93-Np-237
1-H -801	19-K -Nat	56-Ba-138	93-Np-238
1-H -901	20-Ca-Nat	63-Eu-Nat	94-Pu-237
1-H -902	22-Ti-Nat	64-Gd-Nat	94-Pu-238
2-He-3	23-V -51	67-Ho-165	94-Pu-239
2-He-4	24-Cr-Nat	72-Hf-Nat	94-Pu-240
3-Li-6	25-Mn-55	73-Ta-181	94-Pu-241
3-Li-7	26-Fe-Nat	74-W -Nat	94-Pu-242
4-Be-7	27-Co-59	75-Re-185	94-Pu-243
4-Be-9	28-Ni-Nat	75-Re-187	95-Am-241
4-Be-809	28-Ni-58	**78-Pt-Nat**	95-Am-242
4-Be-909	29-Cu-Nat	79-Au-197	95-Am-243
5-B -10	30-Zn-Nat	**80-Hg-Nat**	96-Cm-242
5-B -11	31-Ga-Nat	82-Pb-Nat	96-Cm-243
6-C -12	33-As-74	83-Bi-209	96-Cm-244
6-C -912	33-As-75	90-Th-231	96-Cm-245
7-N -14	**39-Y -88**	90-Th-232	96-Cm-246
7-N -15	39-Y -89	90-Th-233	96-Cm-247
8-O -16	40-Zr-Nat	91-Pa-233	96-Cm-248
8-O -916	41-Nb-93	92-U -233	97-Bk-249
9-F -19	42-Mo-Nat	92-U -234	98-Cf-249
10-Ne-20	47-Ag-107	92-U -235	98-Cf-250
11-Na-23	47-Ag-109	92-U -236	98-Cf-251
12-Mg-Nat	48-Cd-Nat	92-U -237	98-Cf-252
13-Al-27	49-In-Nat	92-U -238	**99-FF-120**
14-Si-Nat	50-Sn-Nat	92-U -239	**99-FF-125**

Evaluations in ENDF/B-VII.0 not included in the TART ENDF/B-VII Library

ENDF/B-VII.0 includes evaluations for 393 materials. However, four (4) of these are for both ground and metastable targets; for these the metastable target are not included in the TART ENDF/B-VII Library. Therefore the TART ENDF/B-VII Library includes 388 ENDF/B-VII.0 evaluations, plus the above fourteen (14) evaluations in TART's standard library not included in ENDF/B-VII.0, for a total of 403 materials.

ZAUPDATE.DAT Equivalence Data

The table below defines the material equivalences uses by this code. Whenever the material identification (ZA) "TART input" is found in the TART input file, it is replaced by the "ENDF/B" equivalent. The atom % and atomic weights are used to define new fractions for the TART input.

For example, the below TART input line defines natural iron (ZA=26000) at a density of 7.78 grams/cc,

```
matl      1   7.78  100.0        26000
```

This code would replace the above line by the following two lines, replacing natural iron by its four (4) naturally occurring isotopes, properly weighted by their natural abundance,

```
matl      1  7.78000D+00  5.84500D+00  26054  9.17540D+01  26056 &
                          2.11900D+00  26057  2.82000D-01  26058
```

TART input	ENDF/B	Atom %	Atomic wt.
6-C - 12	6-C - 0	100.0	12.011000
6-C - 13	6-C - 0	100.0	12.011000
12-Mg- 0	12-Mg- 24	78.99	23.985000
	12-Mg- 25	10.00	24.985800
	12-Mg- 26	11.01	25.982600
14-Si- 0	14-Si- 28	92.2296	27.976900
	14-Si- 29	4.6832	28.976500
	14-Si- 30	3.0872	29.973800
16-S - 0	16-S - 32	94.93	31.972100
	16-S - 33	0.76	32.971500
	16-S - 34	4.29	33.967900
	16-S - 36	0.02	35.967100
17-Cl- 0	17-Cl- 35	75.78	34.968900
	17-Cl- 37	24.22	36.965900
18-Ar- 0	18-Ar- 40	99.6003	39.962400
19-K - 0	19-K - 39	93.2581	38.963700
	19-K - 40	0.0117	39.964000
	19-K - 41	6.7302	40.961800
20-Ca- 0	20-Ca- 40	96.941	39.962600
	20-Ca- 42	0.647	41.958600
	20-Ca- 43	0.135	42.958800
	20-Ca- 44	2.086	43.955500
	20-Ca- 46	0.004	45.953700
	20-Ca- 48	0.187	47.952500
22-Ti- 0	22-Ti- 46	8.25	45.952600
	22-Ti- 47	7.44	46.951800
	22-Ti- 48	73.72	47.947900
	22-Ti- 49	5.41	48.947900
	22-Ti- 50	5.18	49.944800
23-V - 51	23-V - 0	100.0	50.941500
24-Cr- 0	24-Cr- 50	4.345	49.946000
	24-Cr- 52	83.789	51.940500
	24-Cr- 53	9.501	52.940600
	24-Cr- 54	2.365	53.938900
26-Fe- 0	26-Fe- 54	5.845	53.939600
	26-Fe- 56	91.754	55.934900
	26-Fe- 57	2.119	56.935400
	26-Fe- 58	0.282	57.933300
28-Ni- 0	28-Ni- 58	68.0769	57.935300
	28-Ni- 60	26.2231	59.930800
	28-Ni- 61	1.1399	60.931100
	28-Ni- 62	3.6345	61.928300
	28-Ni- 64	0.9256	63.928000

29-Cu-	0	29-Cu- 63	69.17	62.929600
		29-Cu- 65	30.83	64.927800
31-Ga-	0	31-Ga- 69	60.108	68.925600
		31-Ga- 71	39.892	70.924700
40-Zr-	0	40-Zr- 90	51.45	89.904700
		40-Zr- 91	11.22	90.905600
		40-Zr- 92	17.15	91.905000
		40-Zr- 94	17.38	93.906300
		40-Zr- 96	2.80	95.908300
42-Mo-	0	42-Mo- 92	14.84	91.906800
		42-Mo- 94	9.25	93.905100
		42-Mo- 95	15.92	94.905800
		42-Mo- 96	16.68	95.904700
		42-Mo- 97	9.55	96.906000
		42-Mo- 98	24.13	97.905400
		42-Mo-100	9.63	99.907500
48-Cd-	0	48-Cd-106	1.25	105.90600
		48-Cd-108	0.89	107.90400
		48-Cd-110	12.49	109.90300
		48-Cd-111	12.80	110.90400
		48-Cd-112	24.13	111.90300
		48-Cd-113	12.22	112.90400
		48-Cd-114	28.73	113.90300
		48-Cd-116	7.49	115.90500
49-In-	0	49-In-113	4.29	112.90400
		49-In-115	95.71	114.90400
50-Sn-	0	50-Sn-112	0.97	111.90500
		50-Sn-114	0.66	113.90300
		50-Sn-115	0.34	114.90300
		50-Sn-116	14.54	115.90200
		50-Sn-117	7.68	116.90300
		50-Sn-118	24.22	117.90200
		50-Sn-119	8.59	118.90300
		50-Sn-120	32.58	119.90200
		50-Sn-122	4.63	121.90300
		50-Sn-124	5.79	123.90500
51-Sb-	0	51-Sb-121	57.21	120.90400
		51-Sb-123	42.79	122.90400
54-Xe-	0	54-Xe-124	0.09	123.90600
		54-Xe-126	0.09	125.90400
		54-Xe-128	1.92	127.90400
		54-Xe-129	26.44	128.90500
		54-Xe-130	4.08	129.90400
		54-Xe-131	21.18	130.90500
		54-Xe-132	26.89	131.90400
		54-Xe-134	10.44	133.90500
		54-Xe-136	8.87	135.90700
63-Eu-	0	63-Eu-151	47.81	150.92000
		63-Eu-153	52.19	152.92100
64-Gd-	0	64-Gd-152	0.20	151.92000
		64-Gd-154	2.18	153.92100
		64-Gd-155	14.80	154.92300
		64-Gd-156	20.47	155.92200
		64-Gd-157	15.65	156.92400
		64-Gd-158	24.84	157.92400
		64-Gd-160	21.86	159.92700
72-Hf-	0	72-Hf-174	0.16	173.94000
		72-Hf-176	5.26	175.94100
		72-Hf-177	18.60	176.94300
		72-Hf-178	27.28	177.94400
		72-Hf-179	13.62	178.94600
		72-Hf-180	35.08	179.94700
74-W -	0	74-W -182	26.50	181.94800
		74-W -183	14.31	182.95000
		74-W -184	30.64	183.95100
		74-W -186	28.43	185.95400
80—Hg-	0	80-Hg-196	0.15	195.96581
		80-Hg-198	9.97	197.96675
		80-Hg-199	16.87	198.96826
		80-Hg-200	23.10	199.96831
		80-Hg-201	13.18	200.97028

		80-Hg-202	29.86	201.97063
		80-Hg-204	6.87	203.97348
82-Pb-	0	82-Pb-204	1.4	203.97300
		82-Pb-206	24.1	205.97400
		82-Pb-207	22.1	206.97600
		82-Pb-208	52.4	207.97700

Acknowledgement

I thank Dave Brown, LLNL, for translating the ENDF/B-VII.0 data from the ENDF-6 format to the Livermore ENDL format, which allowed it to be used to create TART nuclear data files.

References

[1] "**ENDF/B-VII.0**: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology", Nuclear Data Sheets 107 (December 2006) pp. 2931-3060, P.Oblozinsky and M Herman, Editors.

[2] **POINT 2007**: A Temperature Dependent ENDF/B-VII.0 Data Cross Section Library", UCRL-TR-228089 (February 2007), Lawrence Livermore National Laboratory, by Dermott E. Cullen.

[3] **TART05:** A Coupled Neutron-Photon 3-D, Combinatorial Geometry Time Dependent Monte Carlo Transport Code, UCRL-SM-218009 (November 2005), Lawrence Livermore National Laboratory, by Dermott E. Cullen.

Appendix A: Contents of ENDF/B-VII.0 (78 new + 315 old = 393 total evaluations)

1-H - 1	28-Ni- 60	44-Ru-100	**54-Xe-123**	63-Eu-155	**90-Th-227**
1-H - 2	28-Ni- 61	44-Ru-101	54-Xe-124	63-Eu-156	**90-Th-228**
1-H - 3	28-Ni- 62	44-Ru-102	54-Xe-126	63-Eu-157	**90-Th-229**
2-He- 3	28-Ni- 64	44-Ru-103	54-Xe-128	64-Gd-152	90-Th-230
2-He- 4	29-Cu- 63	44-Ru-104	54-Xe-129	**64-Gd-153**	90-Th-232
3-Li- 6	29-Cu- 65	44-Ru-105	54-Xe-130	64-Gd-154	**90-Th-233**
3-Li- 7	**30-Zn-Nat**	44-Ru-106	54-Xe-131	64-Gd-155	**90-Th-234**
4-Be- 7	**31-Ga- 69**	45-Rh-103	54-Xe-132	64-Gd-156	91-Pa-231
4-Be- 9	**31-Ga- 71**	45-Rh-105	54-Xe-133	64-Gd-157	91-Pa-232
5-B - 10	**32-Ge- 70**	46-Pd-102	54-Xe-134	64-Gd-158	91-Pa-233
5-B - 11	32-Ge- 72	46-Pd-104	54-Xe-135	64-Gd-160	92-U -232
6-C -Nat	32-Ge- 73	46-Pd-105	54-Xe-136	65-Tb-159	92-U -233
7-N - 14	32-Ge- 74	46-Pd-106	55-Cs-133	65-Tb-160	92-U -234
7-N - 15	32-Ge- 76	46-Pd-107	55-Cs-134	**66-Dy-156**	92-U -235
8-O - 16	**33-As- 74**	46-Pd-108	55-Cs-135	**66-Dy-158**	92-U -236
8-O - 17	33-As- 75	46-Pd-110	55-Cs-136	66-Dy-160	92-U -237
9-F - 19	34-Se- 74	47-Ag-107	55-Cs-137	66-Dy-161	92-U -238
11-Na- 22	34-Se- 76	47-Ag-109	**56-Ba-130**	66-Dy-162	**92-U -239**
11-Na- 23	34-Se- 77	**47-Ag-110M**	**56-Ba-132**	66-Dy-163	**92-U -240**
12-Mg- 24	34-Se- 78	47-Ag-111	**56-Ba-133**	66-Dy-164	**92-U -241**
12-Mg- 25	**34-Se- 79**	48-Cd-106	56-Ba-134	67-Ho-165	**93-Np-235**
12-Mg- 26	34-Se- 80	48-Cd-108	56-Ba-135	**67-Ho-166M**	93-Np-236
13-Al- 27	34-Se- 82	48-Cd-110	56-Ba-136	**68-Er-162**	93-Np-237
14-Si- 28	35-Br- 79	48-Cd-111	56-Ba-137	**68-Er-164**	93-Np-238
14-Si- 29	35-Br- 81	48-Cd-112	56-Ba-138	68-Er-166	93-Np-239
14-Si- 30	36-Kr- 78	48-Cd-113	56-Ba-140	68-Er-167	94-Pu-236
15-P - 31	36-Kr- 80	48-Cd-114	**57-La-138**	**68-Er-168**	94-Pu-237
16-S - 32	36-Kr- 82	48-Cd-115M	57-La-139	**68-Er-170**	94-Pu-238
16-S - 33	36-Kr- 83	48-Cd-116	57-La-140	71-Lu-175	94-Pu-239
16-S - 34	36-Kr- 84	49-In-113	**58-Ce-136**	71-Lu-176	94-Pu-240
16-S - 36	36-Kr- 85	49-In-115	**58-Ce-138**	72-Hf-174	94-Pu-241
17-Cl- 35	36-Kr- 86	50-Sn-112	**58-Ce-139**	72-Hf-176	94-Pu-242
17-Cl- 37	37-Rb- 85	**50-Sn-113**	58-Ce-140	72-Hf-177	94-Pu-243
18-Ar- 36	37-Rb- 86	50-Sn-114	58-Ce-141	72-Hf-178	94-Pu-244
18-Ar- 38	37-Rb- 87	50-Sn-115	58-Ce-142	72-Hf-179	**94-Pu-246**
18-Ar- 40	38-Sr- 84	50-Sn-116	58-Ce-143	72-Hf-180	95-Am-241
19-K - 39	38-Sr- 86	50-Sn-117	58-Ce-144	73-Ta-181	95-Am-242
19-K - 40	38-Sr- 87	50-Sn-118	59-Pr-141	73-Ta-182	95-Am-242M
19-K - 41	38-Sr- 88	50-Sn-119	59-Pr-142	74-W -182	95-Am-243
20-Ca- 40	38-Sr- 89	50-Sn-120	59-Pr-143	74-W -183	**95-Am-244**
20-Ca- 42	38-Sr- 90	50-Sn-122	60-Nd-142	74-W -184	**95-Am-244M**
20-Ca- 43	39-Y - 89	50-Sn-123	60-Nd-143	74-W -186	96-Cm-241
20-Ca- 44	39-Y - 90	50-Sn-124	60-Nd-144	75-Re-185	96-Cm-242
20-Ca- 46	39-Y - 91	50-Sn-125	60-Nd-145	75-Re-187	96-Cm-243
20-Ca- 48	40-Zr- 90	50-Sn-126	60-Nd-146	77-Ir-191	96-Cm-244
21-Sc- 45	40-Zr- 91	51-Sb-121	60-Nd-147	77-Ir-193	96-Cm-245
22-Ti- 46	40-Zr- 92	51-Sb-123	60-Nd-148M	79-Au-197	96-Cm-246
22-Ti- 47	40-Zr- 93	51-Sb-124	60-Nd-150	**80-Hg-196**	96-Cm-247
22-Ti- 48	40-Zr- 94	51-Sb-125	61-Pm-147	**80-Hg-198**	96-Cm-248
22-Ti- 49	40-Zr- 95	51-Sb-126	61-Pm-148	**80-Hg-199**	**96-Cm-249**
22-Ti- 50	40-Zr- 96	52-Te-120	61-Pm-148	**80-Hg-200**	**96-Cm-250**
23-V -Nat	41-Nb- 93	52-Te-122	61-Pm-149	**80-Hg-201**	97-Bk-249
24-Cr- 50	41-Nb- 94	52-Te-123	61-Pm-151	**80-Hg-202**	**97-Bk-250**
24-Cr- 52	41-Nb- 95	52-Te-124	62-Sm-144	**80-Hg-204**	98-Cf-249
24-Cr- 53	42-Mo- 92	52-Te-125	62-Sm-147	**82-Pb-204**	98-Cf-250
24-Cr- 54	42-Mo- 94	52-Te-126	62-Sm-148	82-Pb-206	98-Cf-251
25-Mn- 55	42-Mo- 95	52-Te-127M	62-Sm-149	82-Pb-207	98-Cf-252
26-Fe- 54	42-Mo- 96	52-Te-128	62-Sm-150	82-Pb-208	98-Cf-253
26-Fe- 56	42-Mo- 97	52-Te-129M	62-Sm-151	83-Bi-209	**98-Cf-254**
26-Fe- 57	42-Mo- 98	52-Te-130	62-Sm-152	**88-Ra-223**	99-Es-253
26-Fe- 58	42-Mo- 99	52-Te-132	62-Sm-153	**88-Ra-224**	**99-Es-254**
27-Co- 58	42-Mo-100	53-I -127	62-Sm-154	**88-Ra-225**	**99-Es-255**
27-Co- 58M	43-Tc- 99	53-I -129	63-Eu-151	**88-Ra-226**	**100-Fm-255**
27-Co- 59	44-Ru- 96	53-I -130	63-Eu-152	**89-Ac-225**	
28-Ni- 58	44-Ru- 98	53-I -131	63-Eu-153	**89-Ac-226**	
28-Ni- 58M	44-Ru- 99	53-I -135	63-Eu-154	**89-Ac-227**	

APPENDIX B: Elements, Isotopes, Atomic Weights and Per-Cent Abundances

The following table defines Elements, Isotopes, Atomic Weights and Natural Abundances for all elements, Z=1 through 100 [this data is available on-line at the NIST website]. These are included here as a convenience should the reader need to define isotopic abundances for any elements not covered by this codes automatic translation.

Elements, Isotopes, Atomic Weights and Per-Cent Abundances

1	H	1	1.0078250321	99.9885
		2	2.0141017780	0.0115
		3	3.0160492675	
2	He	3	3.0160293097	0.000137
		4	4.0026032497	99.999863
3	Li	6	6.0151223	7.59
		7	7.0160040	92.41
4	Be	9	9.0121821	100.0
5	B	10	10.0129370	19.9
		11	11.0093055	80.1
6	C	12	12.0000000	98.93
		13	13.0033548378	1.07
		14	14.003241988	
7	N	14	14.0030740052	99.632
		15	15.0001088984	0.368
8	O	16	15.9949146221	99.757
		17	16.99913150	0.038
		18	17.9991604	0.205
9	F	19	18.99840320	100.0
10	Ne	20	19.9924401759	90.48
		21	20.99384674	0.27
		22	21.99138551	9.25
11	Na	23	22.98976967	100.0
12	Mg	24	23.98504190	78.99
		25	24.98583702	10.00
		26	25.98259304	11.01
13	Al	27	26.98153844	100.0
14	Si	28	27.9769265327	92.2296
		29	28.97649472	4.6832
		30	29.97377022	3.0872
15	P	31	30.97376151	100.0
16	S	32	31.97207069	94.93
		33	32.97145850	0.76
		34	33.96786683	4.29
		36	35.96708088	0.02
17	Cl	35	34.96885271	75.78
		37	36.96590260	24.22
18	Ar	36	35.96754628	0.3365
		38	37.9627322	0.0632
		40	39.962383123	99.6003
19	K	39	38.9637069	93.2581
		40	39.96399867	0.0117
		41	40.96182597	6.7302
20	Ca	40	39.9625912	96.941
		42	41.9586183	0.647
		43	42.9587668	0.135
		44	43.9554811	2.086
		46	45.9536928	0.004
		48	47.952534	0.187
21	Sc	45	44.9559102	100.0
22	Ti	46	45.9526295	8.25
		47	46.9517638	7.44
		48	47.9479471	73.72
		49	48.9478708	5.41
		50	49.9447921	5.18
23	V	50	49.9471628	0.250
		51	50.9439637	99.750
24	Cr	50	49.9460496	4.345
		52	51.9405119	83.789
		53	52.9406538	9.501
		54	53.9388849	2.365
25	Mn	55	54.9380496	100.0
26	Fe	54	53.9396148	5.845
		56	55.9349421	91.754
		57	56.9353987	2.119
		58	57.9332805	0.282
27	Co	59	58.9332002	100.0
28	Ni	58	57.9353479	68.0769
		60	59.9307906	26.2231
		61	60.9310604	1.1399
		62	61.9283488	3.6345
		64	63.9279696	0.9256
29	Cu	63	62.9296011	69.17
		65	64.9277937	30.83
30	Zn	64	63.9291466	48.63
		66	65.9260368	27.90
		67	66.9271309	4.10
		68	67.9248476	18.75
		70	69.925325	0.62
31	Ga	69	68.925581	60.108
		71	70.9247050	39.892
32	Ge	70	69.9242504	20.84
		72	71.9220762	27.54
		73	72.9234594	7.73
		74	73.9211782	36.28
		76	75.9214027	7.61
33	As	75	74.9215964	100.0
34	Se	74	73.9224766	0.89
		76	75.9192141	9.37
		77	76.9199146	7.63
		78	77.9173095	23.77
		80	79.9165218	49.61
		82	81.9167000	8.73
35	Br	79	78.9183376	50.69
		81	80.916291	49.31
36	Kr	78	77.920386	0.35
		80	79.916378	2.28
		82	81.9134846	11.58
		83	82.914136	11.49
		84	83.911507	57.00
		86	85.9106103	17.30
37	Rb	85	84.9117893	72.17
		87	86.9091835	27.83
38	Sr	84	83.913425	0.56
		86	85.9092624	9.86
		87	86.9088793	7.00
		88	87.9056143	82.58
39	Y	89	88.9058479	100.0
40	Zr	90	89.9047037	51.45
		91	90.9056450	11.22
		92	91.9050401	17.15
		94	93.9063158	17.38
		96	95.908276	2.80

Elements, Isotopes, Atomic Weights and Per-Cent Abundances

41 Nb	93	92.9063775	100.0
42 Mo	92	91.906810	14.84
	94	93.9050876	9.25
	95	94.9058415	15.92
	96	95.9046789	16.68
	97	96.9060210	9.55
	98	97.9054078	24.13
	100	99.907477	9.63
43 Tc	97	96.906365	50.00
	98	97.907216	25.0
	99	98.9062546	25.0
44 Ru	96	95.907598	5.54
	98	97.905287	1.87
	99	98.9059393	12.76
	100	99.9042197	12.60
	101	100.9055822	17.06
	102	101.9043495	31.55
	104	103.905430	18.62
45 Rh	103	102.905504	100.0
46 Pd	102	101.905608	1.02
	104	103.904035	11.14
	105	104.905084	22.33
	106	105.903483	27.33
	108	107.903894	26.46
	110	109.905152	11.72
47 Ag	107	106.905093	51.839
	109	108.904756	48.161
48 Cd	106	105.906458	1.25
	108	107.904183	0.89
	110	109.903006	12.49
	111	110.904182	12.80
	112	111.9027572	24.13
	113	112.9044009	12.22
	114	113.9033581	28.73
	116	115.904755	7.49
49 In	113	112.904061	4.29
	115	114.903878	95.71
50 Sn	112	111.904821	0.97
	114	113.902782	0.66
	115	114.903346	0.34
	116	115.901744	14.54
	117	116.902954	7.68
	118	117.901606	24.22
	119	118.903309	8.59
	120	119.9021966	32.58
	122	121.9034401	4.63
	124	123.9052746	5.79
51 Sb	121	120.9038180	57.21
	123	122.9042157	42.79
52 Te	120	119.904020	0.09
	122	121.9030471	2.55
	123	122.9042730	0.89
	124	123.9028195	4.74
	125	124.9044247	7.07
	126	125.9033055	18.84
	128	127.9044614	31.74
	130	129.9062228	34.08
53 I	127	126.904468	100.0
54 Xe	124	123.9058958	0.09
	126	125.904269	0.09
	128	127.9035304	1.92
	129	128.9047795	26.44
	130	129.9035079	4.08
	131	130.9050819	21.18
	132	131.9041545	26.89
	134	133.9053945	10.44
	136	135.907220	8.87
55 Cs	133	132.905447	100.0
56 Ba	130	129.906310	0.106
	132	131.905056	0.101
	134	133.904503	2.417
	135	134.905683	6.592
	136	135.904570	7.854
	137	136.905821	11.232
	138	137.905241	71.698
57 La	138	137.907107	0.090
	139	138.906348	99.910
58 Ce	136	135.907140	0.185
	138	137.905986	0.251
	140	139.905434	88.450
	142	141.909240	11.114
59 Pr	141	140.907648	100.0
60 Nd	142	141.907719	27.2
	143	142.909810	12.2
	144	143.910083	23.8
	145	144.912569	8.3
	146	145.913112	17.2
	148	147.916889	5.7
	150	149.920887	5.6
61 Pm	145	144.912744	50.0
	147	146.915134	50.0
62 Sm	144	143.911995	3.07
	147	146.914893	14.99
	148	147.914818	11.24
	149	148.917180	13.82
	150	149.917271	7.38
	152	151.919728	26.75
	154	153.922205	22.75
63 Eu	151	150.919846	47.81
	153	152.921226	52.19
64 Gd	152	151.919788	0.20
	154	153.920862	2.18
	155	154.922619	14.80
	156	155.922120	20.47
	157	156.923957	15.65
	158	157.924101	24.84
	160	159.927051	21.86
65 Tb	159	158.925343	100.0
66 Dy	156	155.924278	0.06
	158	157.924405	0.10
	160	159.925194	2.34
	161	160.926930	18.91
	162	161.926795	25.51
	163	162.928728	24.90
	164	163.929171	28.18
67 Ho	165	164.930319	100.0
68 Er	162	161.928775	0.14
	164	163.929197	1.61
	166	165.930290	33.61
	167	166.932045	22.93
	168	167.932368	26.78
	170	169.935460	14.93
69 Tm	169	168.934211	100.0
70 Yb	168	167.933894	0.13
	170	169.934759	3.04
	171	170.936322	14.28
	172	171.9363777	21.83
	173	172.9382068	16.13
	174	173.9388581	31.83
	176	175.942568	12.76
71 Lu	175	174.9407679	97.41
	176	175.9426824	2.59

Elements, Isotopes, Atomic Weights and Per-Cent Abundances

72	Hf	174	173.940040	0.16
		176	175.9414018	5.26
		177	176.9432200	18.60
		178	177.9436977	27.28
		179	178.9458151	13.62
		180	179.9465488	35.08
73	Ta	180	179.947466	0.012
		181	180.947996	99.988
74	W	180	179.946706	0.12
		182	181.948206	26.50
		183	182.9502245	14.31
		184	183.9509326	30.64
		186	185.954362	28.43
75	Re	185	184.9529557	37.40
		187	186.9557508	62.60
76	Os	184	183.952491	0.02
		186	185.953838	1.59
		187	186.9557479	1.96
		188	187.9558360	13.24
		189	188.9581449	16.15
		190	189.958445	26.26
		192	191.961479	40.78
77	Ir	191	190.960591	37.3
		193	192.962924	62.7
78	Pt	190	189.959930	0.014
		192	191.961035	0.782
		194	193.962664	32.967
		195	194.964774	33.832
		196	195.964935	25.242
		198	197.967876	7.163
79	Au	197	196.966552	100.0
80	Hg	196	195.965815	0.15
		198	197.966752	9.97
		199	198.968262	16.87
		200	199.968309	23.10
		201	200.970285	13.18
		202	201.970626	29.86
		204	203.973476	6.87
81	Tl	203	202.972329	29.524
		205	204.974412	70.476
82	Pb	204	203.973029	1.4
		206	205.974449	24.1
		207	206.975881	22.1
		208	207.976636	52.4
83	Bi	209	208.980383	100.0
84	Po	209	208.982416	50.0
		210	209.982857	50.0
85	At	210	209.987131	50.0
		211	210.987481	50.0
86	Rn	211	210.990585	25.0
		220	220.0113841	50.0
		222	222.0175705	25.0
87	Fr	223	223.0197307	100.0
8	Ra	223	223.018497	25.0
		224	224.0202020	25.0
		226	226.0254026	25.0
		228	228.0310641	25.0
89	Ac	227	227.0277470	100.0
90	Th	230	230.0331266	
		232	232.0380504	100.0
91	Pa	231	231.0358789	100.0
92	U	233	233.039628	
		234	234.0409456	0.0055
		235	235.0439231	0.7200
		236	236.0455619	
		238	238.0507826	99.2745
93	Np	237	237.0481673	
		239	239.0529314	
94	Pu	238	238.0495534	
		239	239.0521565	
		240	240.0538075	
		241	241.0568453	
		242	242.0587368	
		244	244.064198	
95	Am	241	241.0568229	
		243	243.0613727	
96	Cm	243	243.0613822	
		244	244.0627463	
		245	245.0654856	
		246	246.0672176	
		247	247.070347	
		248	248.072342	
97	Bk	247	247.070299	
		249	249.074980	
98	Cf	249	249.074847	
		250	250.0764000	
		251	251.079580	
		252	252.081620	
99	Es	252	252.082970	
100	Fm	257	257.095099	

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