**Nuclear Data Section**

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**Memo CP-D/1067**

**Date:** 9 January 2023

**To:** Distribution

**From:** N. Otsuka

**Subject: Dictionary 227 (Nuclides) converted from NUBASE2020**

**Reference** WP2003-4, WP2004-8, CP-D/0455

Dictionary 227 (Nuclides and natural isotopic mixtures) was updated with the Atomic Mass Evaluation (AME) file and Nuclear Wallet Cards (NWC) file as inputs. This Dictionary has been frozen many years since I do not receive an updated NWC file more than 10 years. Consequently, we sometimes receive an unnecessary error message from ZCHEX (e.g., superheavy element nuclides still defined by \* instead of NH, MV and TS).

Following Action XX of the NRDC 2022 meeting, I have written a program to convert the NUBASE2020 (F.G. Kondev et al., Chinese Physics C 45 (2021) 030001) file (nubase\_4.mas20) distributed from the Atomic Mass Data Center (AMDC <https://www.anl.gov/phy/atomic-mass-data-resources/>) to Dictionary 227.

A test dictionary generated with this new procedure is available as Dictionary 9927 in three formats (Trans, Archive and Backup) from the NDS open area: <http://nds.iaea.org/nrdc/ndsx4/trans/dictionaries/>. Note that all dictionaries other than 227 are equivalent to Dictionary 9127.

**Features of dictionary converter**

This converter

* adopts all ground states and metastable states with T1/2≥0.1 sec
* adds the spin/parity when a measured value without ambiguity is given
* adds the half-life after conversion to sec when a definite value from other than systematics is given (Consequently, the half-life flag field is abolished.)
* adds flag S for stable nuclide, flag U for unstable nuclide and P for particle-unstable nuclide
* adds the isomeric transition probability for unstable nuclides and the natural isotopic abundance for stable nuclides.

**Generation of lines for particle codes**

The information of “particles” (e.g., photon, meson, exotic baryon) as well as natural isotopic mixtures must be added from an additional input file. I introduced the following change in these additional dictionary lines:

* Addition of the corresponding particle code as its “A-symbol” when it is defined in Dictionary 33 (e.g., PI0, PIN and PIP for neutral, negative, and positive π mesons, respectively).
* Addition of 0 at the last column of the internal numerical equivalents of natural isotopic mixtures.
* Replacement of 0 or 1 with a unique negative integer for the internal numerical equivalent of particles other than γ.
* Correction of the position of the atomic masses of the natural isotopic mixtures (They were coded as the isotopic abundances.).
* Addition of the particle masses in amu which were converted from the masses in MeV compiled in the latest version of Review of Particle Physics (P.A. Zyla et al., Prog. Theor. Exp. Phys. **2020** (2020) 083C01).

**Use of -G, -M1 and -M2 in Dictionary 227**

So far, all metastable states were defined with -M and the corresponding ground state was defined without -G in the Dictionary 227:

*Example:*

TRA 201611 65-TB-156 156TB 651560 -3. 5.35 D 155924755.181

TRA 201611 65-TB-156**-M** 156TB 651561 24.4 H

TRA 201611 65-TB-156**-M** 156TB 651562 5.3 H

TRA 201611 65-TB-157 157TB 651570 +1.5 71. Y 156924033.028

TRA 201611 65-TB-158 158TB 651580 -3. 180. Y 157925420.947

TRA 201611 65-TB-158**-M** 158TB 651581 -0. 10.70 S

I believe it is more convenient for checking purpose to see -G for a ground state which has a metastable state, and -M1 or -M2 (instead of -M) when there are two metastable states.

*Example:*

TRA 202200 65-TB-156-**G** 156TB 651560 -3.0 4.6224E+05U 155.92475

TRA 202200 65-TB-156-**M1** 156TB 651561 1.9080E+04U 155.92485

TRA 202200 65-TB-156-**M2** 156TB 651562 8.7840E+04U

TRA 202200 65-TB-157 157TB 651570 2.2405E+09U 156.92403

TRA 202200 65-TB-158-**G** 158TB 651580 -3.0 5.6802E+09U 157.92542

TRA 202200 65-TB-158-M 158TB 651581 1.0700E+01U 157.92554

However, this new flagging creates the following side effects related with ZCHEX and DAN2X4:

Problem 1: Unnecessary error messages from ZCHEX

ZCHEX does not understand nuclide codes defined with M1 and M2.

*Example*: ZCHEX input and output for EXFOR D4370.006 to 008.

SUBENT D4370006 20170510 D4370006 1

BIB 3 5 D4370006 2

REACTION (65-TB-159(P,X)65-TB-158,,SIG) D4370006 3

DECAY-DATA (65-TB-158**-G**,180.YR,DG,944.189,0.439) D4370006 4

…

SUBENT D4370007 20170510 D4370007 1

BIB 3 3 D4370007 2

REACTION (65-TB-159(P,X)65-TB-156**-M2**,,SIG) D4370007 3

DECAY-DATA (65-TB-156**-M2**,5.3HR,DG,88.4,0.0115) D4370007 4

…

SUBENT D4370008 20170510 D4370008 1

BIB 3 3 D4370008 2

REACTION (65-TB-159(P,X)65-TB-156**-M1**,,SIG) D4370008 3

DECAY-DATA (65-TB-156**-M1**,24.4HR,DG,49.63,0.741) D4370008 4

…

ZCHEX (Ver-2021-05-14) run on 08-Jun-2022

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Input file: d4370.txt

…

ENTRY D4370 20170510

\*\* Illegal code in field 4

REACTION (65-TB-159(P,X)65-TB-156-M2,,SIG) D437000700003

^^^^^^^^^^^^

\*\* Illegal code in field 1

DECAY-DATA (65-TB-156-M2,5.3HR,DG,88.4,0.0115) D437000700004

^^^^^^^^^^^^

\*\* Missing independent variable NUCLIDE D4370007

\*\* Illegal code in field 4

REACTION (65-TB-159(P,X)65-TB-156-M1,,SIG) D437000800003

^^^^^^^^^^^^

\*\* Illegal code in field 1

DECAY-DATA (65-TB-156-M1,24.4HR,DG,49.63,0.741) D437000800004

^^^^^^^^^^^^

\*\* Missing independent variable NUCLIDE D4370008

Problem 2: Generation of TRANS dictionary by DAN2X4 with incomplete flags

It is not possible to convert the nuclide codes defined with M1 and M2 to the TRANS dictionary.

*Example*: -M1 and -M2 of 156Tb truncated to -M in the TRANS dictionary

65-TB-156-G 156TB 651560 -3.0 4.6224E+05U 30000227 2581C

65-TB-156-**M** 156TB 651561 1.9080E+04U 30000227 2582C

65-TB-156**-M** 156TB 651562 8.7840E+04U 30000227 2583C

65-TB-157 157TB 651570 2.2405E+09U 30000227 2584C

65-TB-158-G 158TB 651580 -3.0 5.6802E+09U 30000227 2585C

65-TB-158-M 158TB 651581 1.0700E+01U 30000227 2586C

**Format of Dictionary 227 produced by the newly developed code**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Line** | **Contents** | **Format** | **Archive** | **Trans** | **CHEX** |
| 1 | Code | A12 | 13-24 | 1-12 | x |
|  | A-symbol (e.g., 197AU) or particle code (e.g., PIP) | A6 | 44-49 | 14-19 |  |
|  | Internal numerical equivalent | I7 | 50-56 | 21-27 | x |
|  | Use flag  Z – not to be used in REACTION SF2,3,7 as well as in DECAY-DATA, DECAY-MON, EN-SEC, HALF-LIFE, MOM-SEC, PART-DET, RAD-DET (where the appropriate particle codes are to be used) | A1 | 57 | 29 | x |
|  | Spin/parity | A6 | 58-63 | 31-36 |  |
|  | State ordering flag  ~~Half-life flag~~  ~~~ about~~  ~~< less than~~  \* - state ordering uncertain | A1 | 64 | 38 |  |
|  | Half-life (in sec) | E11 | 65-75 | 39-49 |  |
|  | Decay flag ~~Half-life unit~~  S - stable  U - unstable  P - particle unstable | A3 | 76-78 | 50-52 | x |
|  | Isotopic abundance or isomeric transition probability | E11 | 79-89 | 54-64 |  |
|  | Atomic weight  (in amu, 1 amu=931.49410242 MeV) | E12 | 90-101 | N/A |  |
|  | Explanation | A21 | 102-122 | N/A |  |
| 2 | Explanation | A21 | N/A | 14-34 |  |

The **nuclide code** has the format *Z-S-A*(-X~~M~~)

where: *Z* = the charge number, up to 3 digits, no leading zeros;

*S* = the element symbol; 1 or 2 characters;

*A* = the mass number; up to 3 digits, no leading zeros; a single zero denotes natural isotopic composition.

*X=* G for the ground state when a metastable state exists

M for the metastable state if only one metastable state exists

M1 for the first metastable state

M2 for the second metastable state

The code is right adjusted on Z, *i.e.*, the Z ends in the 3rd position, and continuing with no blanks in the code. ~~All metastable states are labelled as –M.~~

The data associated with a nucleus are taken from the NUBASE Evaluation ~~Nuclear Wallet Cards and the Atomic Mass Evaluation (AME) Tables~~. All ground states and metastable states defied with half-lives longer than 0.1 sec ~~nuclides given in the Nuclear Wallet Cards~~ are included.

**Comparison of the Archive Dictionary 227 generated from the old procedure and new procedure for boron isotopes**

Original (generated from AME 2012 and NWC 2011)

----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8----+----9----+----0----+----1----+----2---

TRA 198202 5-B-0 B 5000 10.8110 Natural boron

TRA 201611 5-B-6 6B 50060 unbound. 47. 6050800.

TRA 201611 5-B-7 7B 50070 1.4 MEV 7029712.000

TRA 201611 5-B-8 8B 50080 +2. 770. MS 8024607.326

TRA 201611 5-B-9 9B 50090 -1.5 0.54 KEV 9013329.649

TRA 201611 5-B-10 10B 50100 +3. STABLE. 19.19.9 10012936.949

TRA 201611 5-B-11 11B 50110 -1.5 80.1 11009305.355

TRA 201611 5-B-12 12B 50120 +1. 20.20 MS 12014352.658

TRA 201611 5-B-13 13B 50130 -1.5 17.33 MS 13017780.166

TRA 201611 5-B-14 14B 50140 -2. 12.5 MS 14025404.012

TRA 201611 5-B-15 15B 50150 9.93 MS 15031087.680

TRA 201611 5-B-16 16B 50160 -0. <190. PS 16039841.663

TRA 201611 5-B-17 17B 50170 5.08 MS 17046989.906

TRA 201611 5-B-18 18B 50180 <26. NS 18055660.189

TRA 201611 5-B-19 19B 50190 2.92 MS 19063100.

TRA 201611 5-B-20 20B 50200 20072070.

TRA 201611 5-B-21 21B 50210 21081290.

New (generated from Nubase2020)

----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8----+----9----+----0----+----1----+----2---

TRA 202200 5-B-0 B 50000 10.8110 Natural boron

TRA 202200 5-B-6 6B 50060 P

TRA 202200 5-B-7 7B 50070 5.7000E-22U 7.02971

TRA 202200 5-B-8 8B 50080 7.7190E-01U 8.02461

TRA 202200 5-B-9 9B 50090 8.0000E-19U 9.01333

TRA 202200 5-B-10 10B 50100 +3.0 19.65 10.01294

TRA 202200 5-B-11 11B 50110 -1.5 80.35 11.00931

TRA 202200 5-B-12 12B 50120 +1.0 2.0200E-02U 12.01435

TRA 202200 5-B-13 13B 50130 1.7160E-02U 13.01778

TRA 202200 5-B-14 14B 50140 1.2360E-02U 14.02540

TRA 202200 5-B-15 15B 50150 1.0180E-02U 15.03109

TRA 202200 5-B-16 16B 50160 0.0000E+00U 16.03984

TRA 202200 5-B-17 17B 50170 5.0800E-03U 17.04694

TRA 202200 5-B-18 18B 50180 U 18.05560

TRA 202200 5-B-19 19B 50190 2.9200E-03U 19.06417

TRA 202200 5-B-20 20B 50200 0.0000E+00U 20.07450

TRA 202200 5-B-21 21B 50210 0.0000E+00U 21.08414

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