ciaaw Documentation

Release 0.2.0

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Mar 26, 2024

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CHAPTER

ONE

GETTING STARTED

Sources: https://github.com/MilanSkocic/ciaaw

1.1 ciaaw

ciaaw is a Fortran library providing the standard and abridged atomic weights, the isotopic abundance and the isotopes' standard atomic weights. It also provides a API for the C language. The formulas are taken from http://ciaaw.org.

1.1.1 How to install

A Makefile is provided, which uses fpm, for building the library.

On windows, msys2 needs to be installed. The MSVC compiler is only necessary for compiling the python wrapper. Add the msys2 binary (usually C:\msys64\usr\bin) to the path in order to be able to use make.

On Darwin, the gcc toolchain needs to be installed.

Build: the configuration file will set all the environment variables necessary for the compilation

```
chmod +x configure.sh
. ./configure.sh
make
```

Run tests

```
make test
```

Install

```
make install
```

Uninstall

```
make uninstall
```

If building the python wrapper is needed:

```
cd pywrapper
chmod +x configure.sh
. ./configure.sh
make
```

1.1.2 Dependencies

```
gcc>=10.0
gfortran>=10.0
fpm>=0.7
```

1.1.3 License

GNU General Public License v3 (GPLv3)

1.2 pyciaaw

Python wrapper around the Fortran ciaaw library. The Fortran library does not need to be installed, the python wrapper embeds all needed fortran dependencies. On linux, you might have to install *libgfortran* if it is not distributed by default with your linux distribution.

1.2.1 How to install

```
pip install pyciaaw
```

1.2.2 Dependencies

```

```

1.2.3 License

GNU General Public License v3 (GPLv3)

1.3 Examples

1.3.1 Example in Fortran

```
program example_in_f
    use ciaaw
    implicit none

    type(element_t) :: elmt

    print '(A)', '########### CIAAW VERSION ##########'
    print *, "version ", get_version()

    print '(A)', '########### CIAAW SAW ##########'
    elmt = H
    print '(A, A)', 'Element: ', elmt%element
    print '(A, A)', 'Symbol: ', elmt%symbol
    print '(A, I3)', 'Z: ', elmt%z
    print '(A, F23.16)', 'standard atomic weight max: ', elmt%saw_max
```

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```
    print '(A, F23.16)', 'standard atomic weight min: ', elmt%saw_min
    print '(A, F23.16)', 'standard atomic weight: ', elmt%saw
    print '(A, F23.16)', 'standard atomic weight uncertainty: ', elmt%saw_u
    print '(A, F23.16)', 'abredged standard atomic weight: ', elmt%asaw
    print '(A, F23.16)', 'abredged standard atomic weight uncertainty: ', elmt%asaw_u
    print '(A)', ''
    elmt = F
    print '(A, A)', 'Element: ', elmt%element
    print '(A, A)', 'Symbol: ', elmt%symbol
    print '(A, I3)', 'Z: ', elmt%z
    print '(A, F23.16)', 'standard atomic weight max: ', elmt%saw_max
    print '(A, F23.16)', 'standard atomic weight min: ', elmt%saw_min
    print '(A, F23.16)', 'standard atomic weight: ', elmt%saw
    print '(A, F23.16)', 'standard atomic weight uncertainty: ', elmt%saw_u
    print '(A, F23.16)', 'abredged standard atomic weight: ', elmt%asaw
    print '(A, F23.16)', 'abredged standard atomic weight uncertainty: ', elmt%asaw_u

end program
```

1.3.2 Example in C

```
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include "ciaaw.h"


int main(void){

    struct ciaaw_saw_element_t elmt;

    printf("%s\n", "########## CIAAW VERSION ##########");
    printf("version %s\n", ciaaw_get_version());

    printf("%s\n", "########## CIAAW SAW ##########");
    elmt = ciaaw_saw_H;
    printf("%s %s\n", "Element: ", elmt.element);
    printf("%s %s\n", "Symbol: ", elmt.symbol);
    printf("%s %d\n", "Z: ", elmt.z);
    printf("%s %23.16f\n", "standard atomic weight max: ", elmt.saw_max);
    printf("%s %23.16f\n", "standard atomic weight min: ", elmt.saw_min);
    printf("%s %23.16f\n", "standard atomic weight: ", elmt.saw);
    printf("%s %23.16f\n", "standard atomic weight uncertainty: ", elmt.saw_u);
    printf("%s %23.16f\n", "abredged standard atomic weight: ", elmt.asaw);
    printf("%s %23.16f\n", "abredged standard atomic weight uncertainty: ", elmt.asaw_
↪u);
    printf("%s\n", "");

    elmt = ciaaw_saw_F;
    printf("%s %s\n", "Element: ", elmt.element);
    printf("%s %s\n", "Symbol: ", elmt.symbol);
    printf("%s %d", "Z: ", elmt.z);
    printf("%s %23.16f\n", "standard atomic weight max: ", elmt.saw_max);
    printf("%s %23.16f\n", "standard atomic weight min: ", elmt.saw_min);
    printf("%s %23.16f\n", "standard atomic weight: ", elmt.saw);
```

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```
    printf("%s %23.16f\n", "standard atomic weight uncertainty: ", elmt.saw_u);
    printf("%s %23.16f\n", "abredged standard atomic weight: ", elmt.asaw);
    printf("%s %23.16f\n", "abredged standard atomic weight uncertainty: ", elmt.asaw_
↪u);

    return EXIT_SUCCESS;
}
```

1.3.3 Example in Python

```
import pyciaaw

print("########## CIAAW VERSION ##########")
print("version ", pyciaaw.__version__)

print("########## CIAAW SAW ##########")
elmt = pyciaaw.saw.H
print("Element: ", elmt["element"])
print("Symbol: ", elmt["symbol"])
print("Z: ", elmt["z"])
print("standard atomic weight max: ", elmt["saw_max"])
print("standard atomic weight min: ", elmt["saw_min"])
print("standard atomic weight: ", elmt["saw"])
print("standard atomic weight uncertainty: ", elmt["saw_u"])
print("abredged standard atomic weight: ", elmt["asaw"])
print("abredged standard atomic weight uncertainty: ", elmt["asaw_u"])
print()

elmt = pyciaaw.saw.F
print("Element: ", elmt["element"])
print("Symbol: ", elmt["symbol"])
print("Z: ", elmt["z"])
print("standard atomic weight max: ", elmt["saw_max"])
print("standard atomic weight min: ", elmt["saw_min"])
print("standard atomic weight: ", elmt["saw"])
print("standard atomic weight uncertainty: ", elmt["saw_u"])
print("abredged standard atomic weight: ", elmt["asaw"])
print("abredged standard atomic weight uncertainty: ", elmt["asaw_u"])
```

CHAPTER

TWO

USER GUIDE

2.1 Standard Atomic Weights

The standard atomic weights (or realtive atomic mass), $A_r(E)$, are extracted from table 1 in Prohaska *et al.* [1]. For the elements that feature an interval for the standard atomic weight, the mean value and the uncertainty are computed using formulas defined in van der Veen *et al.* [2]:

$$A_r(E) = \frac{a+b}{2}$$
$$u(A_r(E)) = \frac{b-a}{2\sqrt{3}}$$

The standard atomic weights are a dimensionless quantity and thus they need to be multiplied by the molar mass constant $M_u = 0.99999999965 \pm 0.00000000030 g.mol^{-1}$ in order to get the value in $g.mol^{-1}$.

CHAPTER

THREE

RELEASE NOTES

3.1 0.2.0

3.1.1 Summary

- All elements from the periodic table added for the saw module.
- They are implemented as parameter derived type.
- Fix error in phosphorus name.

3.1.2 Download

ciaaw

pyciaaw

3.1.3 Contributors

Milan Skocic

3.1.4 Commits

Full Changelog: https://github.com/MilanSkocic/ciaaw/compare/0.1.0...0.2.0

3.2 0.1.0

3.2.1 Summary

- All elements from the periodic table added for the saw module.
- They are implemented as parameter derived type.

3.2.2 Download

ciaaw

pyciaaw

3.2.3 Contributors

Milan Skocic

3.2.4 Commits

Full Changelog: https://github.com/MilanSkocic/ciaaw/compare/....0.1.0

CHAPTER

FOUR

API

4.1 ciaaw

Fortran and C API

4.2 pyciaaw

Standard Atomic Weights and Isotopes.

Standard Atomic Weights: the lattest values for are from 2021.

4.2.1 SAW (Standard atomic weights)

4.2.2 pyciaaw.saw

C extension for saw latest.

4.2.3 pyciaaw.saw_2021

C extension for saw 2021.

4.3 Raw data

4.3.1 Latest

```
Interpretation and use of standard atomic weights (IUPAC Technical Report): https://
↪doi.org/10.1515/pac-2017-1002
Standard atomic weights of the elements 2021 (IUPAC Technical Report): https://doi.
↪org/10.1515/pac-2019-0603
123456789_123456789_123456789_123456789_123456789_123456789_123456789_123456789_
↪123456789_123456789_123456789_123456789_
1         11        21        31        41        51        61        71        81  ␣
↪    91        101       111       121
Element             Symbol    z         saw                           saw_u         ␣
↪    footnote  asaw      asawu
------------------------------------------------------------------------------------
↪----------------------------------
hydrogen            H         1         [1.00784,1.00811]                           ␣
↪    m         1.0080    0.0002
```

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```
helium              He       2        4.002602                    0.000002
↪    g r       4.0026    0.0001
lithium             Li       3        [6.938,6.997]
↪    m         6.94      0.06
beryllium           Be       4        9.0121831                   0.0000005
↪              9.0122    0.00001
boron               B        5        [10.806,10.821]
↪    m         10.81     0.02
carbon              C        6        [12.0096,12.0116]
↪    m         12.011    0.002
nitrogen            N        7        [14.00643,14.00728]
↪    m         14.007    0.001
oxygen              O        8        [15.99903,15.99977]
↪    m         15.999    0.001
fluorine            F        9        18.998403162                0.000000005
↪              18.998    0.001
neon                Ne       10       20.1797                     0.0006
↪    g m       20.180    0.001
sodium              Na       11       22.98976928                 0.00000002
↪              22.990    0.001
magnesium           Mg       12       [24.304,24.307]
↪              24.305    0.002
aluminium           Al       13       26.9815384                  0.0000003
↪              26.982    0.001
silicon             Si       14       [28.084,28.086]
↪              28.085    0.001
phosphorus          P        15       30.973761998                0.000000005
↪              30.974    0.001
sulfur              S        16       [32.059,32.076]
↪              32.06     0.02
chlorine            Cl       17       [35.446,35.457]
↪    m         35.45     0.01
argon               Ar       18       [39.792,39.963]
↪              39.95     0.16
potassium           K        19       39.0983                     0.0001
↪              39.098    0.001
calcium             Ca       20       40.078                      0.004
↪    g         40.078    0.004
scandium            Sc       21       44.955907                   0.000004
↪              44.956    0.001
titanium            Ti       22       47.867                      0.001
↪              47.867    0.001
vanadium            V        23       50.9415                     0.0001
↪              50.942    0.001
chromium            Cr       24       51.9961                     0.0006
↪              51.996    0.001
manganese           Mn       25       54.938043                   0.000002
↪              54.938    0.001
iron                Fe       26       55.845                      0.002
↪              55.845    0.002
cobalt              Co       27       58.933194                   0.000003
↪              58.933    0.001
nickel              Ni       28       58.6934                     0.0004
↪    r         58.693    0.001
copper              Cu       29       63.546                      0.003
↪    r         63.546    0.003
```

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```
zinc                Zn        30        65.38                    0.02          ␣
↪     r         65.38     0.02
gallium             Ga        31        69.723                   0.001         ␣
↪                 69.723    0.001
germanium           Ge        32        72.630                   0.008         ␣
↪                 72.630    0.008
arsenic             As        33        74.921595                0.000006      ␣
↪     r         74.922    0.001
selenium            Se        34        78.971                   0.008         ␣
↪                 78.971    0.008
bromine             Br        35        [79.901,79.907]                        ␣
↪                 79.904    0.003
krypton             Kr        36        83.798                   0.002         ␣
↪     g m       83.798    0.002
rubidium            Rb        37        85.4678                  0.0003        ␣
↪     g         85.468    0.001
strontium           Sr        38        87.62                    0.01          ␣
↪     g r       87.62     0.01
yttrium             Y         39        88.905838                0.000002      ␣
↪                 88.906    0.001
zirconium           Zr        40        91.224                   0.002         ␣
↪     g         91.224    0.002
nobium              Nb        41        92.90637                 0.00001       ␣
↪                 92.906    0.001
molybdenum          Mo        42        95.95                    0.01          ␣
↪     g         95.95     0.01
technetium          Tc        43        nan                      nan           ␣
↪                 nan       nan
ruthenium           Ru        44        101.07                   0.02          ␣
↪     g         101.07    0.02
rhodium             Rh        45        102.90549                0.00002       ␣
↪                 102.91    0.01
palladium           Pd        46        106.42                   0.01          ␣
↪     g         106.42    0.01
silver              Ag        47        107.8682                 0.0002        ␣
↪     g         107.87    0.01
cadmium             Cd        48        112.414                  0.004         ␣
↪     g         112.41    0.01
indium              In        49        114.818                  0.001         ␣
↪                 114.82    0.01
tin                 Sn        50        118.70                   0.007         ␣
↪     g         118.71    0.01
antimony            Sb        51        121.760                  0.001         ␣
↪     g         121.76    0.01
tellurium           Te        52        127.60                   0.03          ␣
↪     g         127.60    0.03
iodine              I         53        126.90447                0.00003       ␣
↪                 126.90    0.01
xenon               Xe        54        131.293                  0.006         ␣
↪     g m       131.29    0.01
caesium             Cs        55        132.90545196             0.00000006    ␣
↪                 132.91    0.01
barium              Ba        56        137.327                  0.007         ␣
↪                 137.33    0.01
lanthanum           La        57        138.90547                0.00007       ␣
↪     g         138.91    0.01
```

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```
cerium              Ce        58        140.116                    0.001
↪    g         140.12    0.01
praseodymium        Pr        59        140.90766                  0.00001
↪              140.91    0.01
neodymium           Nd        60        144.242                    0.003
↪    g         144.24    0.01
promethium          Pm        61        nan                        nan
↪              nan       nan
samarium            Sm        62        150.36                     0.02
↪    g         150.36    0.02
europium            Eu        63        151.964                    0.001
↪    g         151.96    0.01
gadolinium          Gd        64        157.25                     0.03
↪    g         157.25    0.03
terbium             Tb        65        158.925354                 0.000007
↪              158.93    0.01
dysprosium          Dy        66        162.500                    0.001
↪    g         162.50    0.01
holmium             Ho        67        164.930329                 0.000005
↪              164.93    0.01
erbium              Er        68        167.259                    0.003
↪    g         167.26    0.01
thulium             Tm        69        168.934219                 0.000005
↪              168.93    0.01
ytterbium           Yb        70        173.045                    0.010
↪    g         173.05    0.02
lutetium            Lu        71        174.9668                   0.0001
↪    g         174.97    0.01
hafnium             Hf        72        178.486                    0.006
↪    g         178.49    0.01
tantalum            Ta        73        180.94788                  0.00002
↪              180.95    0.01
tungsten            W         74        183.84                     0.01
↪              183.84    0.01
rhenium             Re        75        186.207                    0.001
↪              186.21    0.01
osmium              Os        76        190.23                     0.03
↪    g         190.23    0.03
iridium             Ir        77        192.217                    0.002
↪              192.22    0.01
platinum            Pt        78        195.084                    0.009
↪              195.08    0.02
gold                Au        79        196.966570                 0.000004
↪              196.97    0.01
mercury             Hg        80        200.592                    0.003
↪              200.59    0.01
thallium            Tl        81        [204.382,204.385]
↪              204.38    0.01
lead                Pb        82        [206.14,207.94]
↪              207.2     1.1
bismuth             Bi        83        208.98040                  0.00001
↪              208.98    0.01
polonium            Po        84        nan                        nan
↪              nan       nan
astatine            At        85        nan                        nan
↪              nan       nan
```

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```
radon                Rn        86        nan                  nan          ␣
↪              nan       nan
francium             Fr        87        nan                  nan          ␣
↪              nan       nan
radium               Ra        88        nan                  nan          ␣
↪              nan       nan
actinium             Ac        89        nan                  nan          ␣
↪              nan       nan
thorium              Th        90        232.0377             0.0004       ␣
↪              232.04    0.01
protactinium         Pa        91        231.03588            0.00001      ␣
↪              231.04    0.01
uranium              U         92        238.02891            0.00003      ␣
↪     g m      238.03    0.01
neptunium            Np        93        nan                  nan          ␣
↪              nan       nan
plutonium            Pu        94        nan                  nan          ␣
↪              nan       nan
americium            Am        95        nan                  nan          ␣
↪              nan       nan
curium               Cm        96        nan                  nan          ␣
↪              nan       nan
berkelium            Bk        97        nan                  nan          ␣
↪              nan       nan
californium          Cf        98        nan                  nan          ␣
↪              nan       nan
einsteinium          Es        99        nan                  nan          ␣
↪              nan       nan
fermium              Fm        100       nan                  nan          ␣
↪              nan       nan
mendelevium          Md        101       nan                  nan          ␣
↪              nan       nan
nobelium             No        102       nan                  nan          ␣
↪              nan       nan
lawrencium           Lr        103       nan                  nan          ␣
↪              nan       nan
rutherfordium        Rf        104       nan                  nan          ␣
↪              nan       nan
dubnium              Db        105       nan                  nan          ␣
↪              nan       nan
seaborgium           Sg        106       nan                  nan          ␣
↪              nan       nan
bohrium              Bh        107       nan                  nan          ␣
↪              nan       nan
hassium              Hs        108       nan                  nan          ␣
↪              nan       nan
meitnerium           Mt        109       nan                  nan          ␣
↪              nan       nan
darmstadtium         Ds        110       nan                  nan          ␣
↪              nan       nan
roentgenium          Rg        111       nan                  nan          ␣
↪              nan       nan
copernicium          Cn        112       nan                  nan          ␣
↪              nan       nan
nihonium             Nh        113       nan                  nan          ␣
↪              nan       nan
```

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```
flerovium           Fl        114       nan                          nan          ␣
↪             nan       nan
moscovium           Mc        115       nan                          nan          ␣
↪             nan       nan
livermorium         Lv        116       nan                          nan          ␣
↪             nan       nan
tennesine           Ts        117       nan                          nan          ␣
↪             nan       nan
organesson          Og        118       nan                          nan          ␣
↪             nan       nan
```

4.3.2 2018

```
Interpretation and use of standard atomic weights (IUPAC Technical Report): https://
↪doi.org/10.1515/pac-2017-1002
Standard atomic weights of the elements 2021 (IUPAC Technical Report): https://doi.
↪org/10.1515/pac-2019-0603
123456789_123456789_123456789_123456789_123456789_123456789_123456789_123456789_
↪123456789_123456789_123456789_123456789_
1         11        21        31        41        51        61        71        81   ␣
↪    91        101       111       121
Element             Symbol    z         saw                          saw_u        ␣
↪    footnote  asaw      asawu
------------------------------------------------------------------------------------
↪----------------------------------
hydrogen            H         1         [1.00784,1.00811]                         ␣
↪    m         1.0080    0.0002
helium              He        2         4.002602                     0.000002     ␣
↪    g r       4.0026    0.0001
lithium             Li        3         [6.938,6.997]                             ␣
↪    m         6.94      0.06
beryllium           Be        4         9.0121831                    0.0000005    ␣
↪             9.0122    0.00001
boron               B         5         [10.806,10.821]                           ␣
↪    m         10.81     0.02
carbon              C         6         [12.0096,12.0116]                         ␣
↪    m         12.011    0.002
nitrogen            N         7         [14.00643,14.00728]                       ␣
↪    m         14.007    0.001
oxygen              O         8         [15.99903,15.99977]                       ␣
↪    m         15.999    0.001
fluorine            F         9         18.998403162                 0.000000005  ␣
↪             18.998    0.001
neon                Ne        10        20.1797                      0.0006       ␣
↪    g m       20.180    0.001
sodium              Na        11        22.98976928                  0.00000002   ␣
↪             22.990    0.001
magnesium           Mg        12        [24.304,24.307]                           ␣
↪             24.305    0.002
aluminium           Al        13        26.9815384                   0.0000003    ␣
↪             26.982    0.001
silicon             Si        14        [28.084,28.086]                           ␣
↪             28.085    0.001
phosphorus          P         15        30.973761998                 0.000000005  ␣
↪             30.974    0.001
```

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```
sulfur              S         16        [32.059,32.076]                          ␣
↪              32.06     0.02
chlorine            Cl        17        [35.446,35.457]                          ␣
↪    m         35.45     0.01
argon               Ar        18        [39.792,39.963]                          ␣
↪              39.95     0.16
potassium           K         19        39.0983                  0.0001          ␣
↪              39.098    0.001
calcium             Ca        20        40.078                   0.004           ␣
↪    g         40.078    0.004
scandium            Sc        21        44.955907                0.000004        ␣
↪              44.956    0.001
titanium            Ti        22        47.867                   0.001           ␣
↪              47.867    0.001
vanadium            V         23        50.9415                  0.0001          ␣
↪              50.942    0.001
chromium            Cr        24        51.9961                  0.0006          ␣
↪              51.996    0.001
manganese           Mn        25        54.938043                0.000002        ␣
↪              54.938    0.001
iron                Fe        26        55.845                   0.002           ␣
↪              55.845    0.002
cobalt              Co        27        58.933194                0.000003        ␣
↪              58.933    0.001
nickel              Ni        28        58.6934                  0.0004          ␣
↪    r         58.693    0.001
copper              Cu        29        63.546                   0.003           ␣
↪    r         63.546    0.003
zinc                Zn        30        65.38                    0.02            ␣
↪    r         65.38     0.02
gallium             Ga        31        69.723                   0.001           ␣
↪              69.723    0.001
germanium           Ge        32        72.630                   0.008           ␣
↪              72.630    0.008
arsenic             As        33        74.921595                0.000006        ␣
↪    r         74.922    0.001
selenium            Se        34        78.971                   0.008           ␣
↪              78.971    0.008
bromine             Br        35        [79.901,79.907]                          ␣
↪              79.904    0.003
krypton             Kr        36        83.798                   0.002           ␣
↪    g m       83.798    0.002
rubidium            Rb        37        85.4678                  0.0003          ␣
↪    g         85.468    0.001
strontium           Sr        38        87.62                    0.01            ␣
↪    g r       87.62     0.01
yttrium             Y         39        88.905838                0.000002        ␣
↪              88.906    0.001
zirconium           Zr        40        91.224                   0.002           ␣
↪    g         91.224    0.002
nobium              Nb        41        92.90637                 0.00001         ␣
↪              92.906    0.001
molybdenum          Mo        42        95.95                    0.01            ␣
↪    g         95.95     0.01
technetium          Tc        43        nan                      nan             ␣
↪              nan       nan
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ruthenium            Ru        44        101.07                    0.02          ␣
↪    g         101.07    0.02
rhodium              Rh        45        102.90549                 0.00002       ␣
↪              102.91    0.01
palladium            Pd        46        106.42                    0.01          ␣
↪    g         106.42    0.01
silver               Ag        47        107.8682                  0.0002        ␣
↪    g         107.87    0.01
cadmium              Cd        48        112.414                   0.004         ␣
↪    g         112.41    0.01
indium               In        49        114.818                   0.001         ␣
↪              114.82    0.01
tin                  Sn        50        118.70                    0.007         ␣
↪    g         118.71    0.01
antimony             Sb        51        121.760                   0.001         ␣
↪    g         121.76    0.01
tellurium            Te        52        127.60                    0.03          ␣
↪    g         127.60    0.03
iodine               I         53        126.90447                 0.00003       ␣
↪              126.90    0.01
xenon                Xe        54        131.293                   0.006         ␣
↪    g m       131.29    0.01
caesium              Cs        55        132.90545196              0.00000006    ␣
↪              132.91    0.01
barium               Ba        56        137.327                   0.007         ␣
↪              137.33    0.01
lanthanum            La        57        138.90547                 0.00007       ␣
↪    g         138.91    0.01
cerium               Ce        58        140.116                   0.001         ␣
↪    g         140.12    0.01
praseodymium         Pr        59        140.90766                 0.00001       ␣
↪              140.91    0.01
neodymium            Nd        60        144.242                   0.003         ␣
↪    g         144.24    0.01
promethium           Pm        61        nan                       nan           ␣
↪              nan       nan
samarium             Sm        62        150.36                    0.02          ␣
↪    g         150.36    0.02
europium             Eu        63        151.964                   0.001         ␣
↪    g         151.96    0.01
gadolinium           Gd        64        157.25                    0.03          ␣
↪    g         157.25    0.03
terbium              Tb        65        158.925354                0.000007      ␣
↪              158.93    0.01
dysprosium           Dy        66        162.500                   0.001         ␣
↪    g         162.50    0.01
holmium              Ho        67        164.930329                0.000005      ␣
↪              164.93    0.01
erbium               Er        68        167.259                   0.003         ␣
↪    g         167.26    0.01
thulium              Tm        69        168.934219                0.000005      ␣
↪              168.93    0.01
ytterbium            Yb        70        173.045                   0.010         ␣
↪    g         173.05    0.02
lutetium             Lu        71        174.9668                  0.0001        ␣
↪    g         174.97    0.01
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```
hafnium             Hf        72        178.486                    0.006          ␣
↪    g         178.49    0.01
tantalum            Ta        73        180.94788                  0.00002        ␣
↪              180.95    0.01
tungsten            W         74        183.84                     0.01           ␣
↪              183.84    0.01
rhenium             Re        75        186.207                    0.001          ␣
↪              186.21    0.01
osmium              Os        76        190.23                     0.03           ␣
↪    g         190.23    0.03
iridium             Ir        77        192.217                    0.002          ␣
↪              192.22    0.01
platinum            Pt        78        195.084                    0.009          ␣
↪              195.08    0.02
gold                Au        79        196.966570                 0.000004       ␣
↪              196.97    0.01
mercury             Hg        80        200.592                    0.003          ␣
↪              200.59    0.01
thallium            Tl        81        [204.382,204.385]                         ␣
↪              204.38    0.01
lead                Pb        82        [206.14,207.94]                           ␣
↪              207.2     1.1
bismuth             Bi        83        208.98040                  0.00001        ␣
↪              208.98    0.01
polonium            Po        84        nan                        nan            ␣
↪              nan       nan
astatine            At        85        nan                        nan            ␣
↪              nan       nan
radon               Rn        86        nan                        nan            ␣
↪              nan       nan
francium            Fr        87        nan                        nan            ␣
↪              nan       nan
radium              Ra        88        nan                        nan            ␣
↪              nan       nan
actinium            Ac        89        nan                        nan            ␣
↪              nan       nan
thorium             Th        90        232.0377                   0.0004         ␣
↪              232.04    0.01
protactinium        Pa        91        231.03588                  0.00001        ␣
↪              231.04    0.01
uranium             U         92        238.02891                  0.00003        ␣
↪    g m       238.03    0.01
neptunium           Np        93        nan                        nan            ␣
↪              nan       nan
plutonium           Pu        94        nan                        nan            ␣
↪              nan       nan
americium           Am        95        nan                        nan            ␣
↪              nan       nan
curium              Cm        96        nan                        nan            ␣
↪              nan       nan
berkelium           Bk        97        nan                        nan            ␣
↪              nan       nan
californium         Cf        98        nan                        nan            ␣
↪              nan       nan
einsteinium         Es        99        nan                        nan            ␣
↪              nan       nan
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fermium             Fm       100       nan                 nan                 ␣
↪             nan       nan
mendelevium         Md       101       nan                 nan                 ␣
↪             nan       nan
nobelium            No       102       nan                 nan                 ␣
↪             nan       nan
lawrencium          Lr       103       nan                 nan                 ␣
↪             nan       nan
rutherfordium       Rf       104       nan                 nan                 ␣
↪             nan       nan
dubnium             Db       105       nan                 nan                 ␣
↪             nan       nan
seaborgium          Sg       106       nan                 nan                 ␣
↪             nan       nan
bohrium             Bh       107       nan                 nan                 ␣
↪             nan       nan
hassium             Hs       108       nan                 nan                 ␣
↪             nan       nan
meitnerium          Mt       109       nan                 nan                 ␣
↪             nan       nan
darmstadtium        Ds       110       nan                 nan                 ␣
↪             nan       nan
roentgenium         Rg       111       nan                 nan                 ␣
↪             nan       nan
copernicium         Cn       112       nan                 nan                 ␣
↪             nan       nan
nihonium            Nh       113       nan                 nan                 ␣
↪             nan       nan
flerovium           Fl       114       nan                 nan                 ␣
↪             nan       nan
moscovium           Mc       115       nan                 nan                 ␣
↪             nan       nan
livermorium         Lv       116       nan                 nan                 ␣
↪             nan       nan
tennesine           Ts       117       nan                 nan                 ␣
↪             nan       nan
organesson          Og       118       nan                 nan                 ␣
↪             nan       nan
```

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