NuDat 2.0: Nuclear Structure and Decay Data on the Internet

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Abstract. NuDat 2.0 is a software product developed by the National Nuclear Data Center. It provides an interface between web users and several NNDC nuclear structure and decay databases. NuDat 2.0 can be used to search for ground and excited states level properties, gamma-ray information, and decay radiation information. In addition to the search capabilities, an interactive chart of nuclei is displayed. Different examples highlighting NuDat 2 search capabilities and display options are presented.

INTRODUCTION

The program NuDat was first introduced by the National Nuclear Data Center (NNDC) [1] in 1986. Remote users were able to access via Telnet nuclear structure and decay databases and retrieve data according to a variety of search criteria. In 1997, access through the web was implemented using HTML forms that were processed by CGI scripts. The current version of NuDat [2] became public in April 2004. A relational database is used to store the data; the interaction between web users and the database is performed by a number of Java Server Pages files that communicate with the database server through Structured Query Language (SQL) commands.

NuDat searching capabilities include:

- Recommended nuclear level properties
  - Energy
  - Half-life
  - Spin and parity
  - Decay modes
- Recommended gamma-ray information
  - Energy
  - Intensity
  - Multipolarity
  - Coincidences
- Radiation information following nuclear decay
  - Energy
  - Intensity
  - Dose
  - Radiation type

Additionally, it is also possible to search for some neutron-induced reaction data from the BNL-325 book (thermal cross section and resonance integral). The information provided by NuDat can be seen in tables, level schemes and an interactive chart of nuclei.

<table>
<thead>
<tr>
<th>TABLE 1. Brief statistics on NuDat contents.</th>
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<tbody>
<tr>
<td>Number of nuclei</td>
</tr>
<tr>
<td>Number of levels</td>
</tr>
<tr>
<td>Number of levels with known $T_{1/2}$</td>
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<tr>
<td>Number of levels with known $J^P$</td>
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<tr>
<td>Number of $\gamma$ rays</td>
</tr>
<tr>
<td>Number of $\alpha$ transitions</td>
</tr>
<tr>
<td>Number of $\beta^-$ and EC/$\beta^+$ transitions</td>
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The sections of NuDat related to levels, gammas and decays are obtained from the Evaluated Nuclear Structure Data File (ENSDF) [3] and the Nuclear Wallets Cards [4]. NuDat is periodically updated to reflect changes in ENSDF. All the software used in NuDat to obtain information from ENSDF and the Nuclear Wallet Cards file was written in Java. A table with brief statistics on NuDat contents can be found in Table 1.

There are several ways of retrieving data from NuDat. At the front page, there is an interactive chart of nuclides, from which information for a given nucleus can be obtained. Additionally, three different forms allow searches for recommended levels, gamma information, and decay information.

INTERACTIVE CHART OF NUCLEI

Experimentally known nuclei are represented by a cell in a chart, with the number of neutrons on the horizontal axis and the number of protons on the vertical axis. The color of the cell is used to indicate the ground state half-life or the ground state predominant decay mode. An example of it can be seen in Fig. 1. It should be kept in mind, however, that there are nuclei with more than one decay mode, or having levels with a wide range of
FIGURE 1. Partial view of the Chart of Nuclei as obtained from NuDat, centered at $^{137}$Cs.

half-lives. As a result, the chart should be only used as a visualization tool. It is advised to use the full list of levels for complete decay mode and half-life.

The chart can be seen with 4 different zooming options. With the largest zoom value, the entire chart is displayed and the magic numbers 8, 20, 28, 50, 82 and 126 are indicated. For smaller zoom values, only a fraction of the chart is displayed. Ground and isomeric state information for a given nuclei can be obtained by clicking on a given nucleus. This information is displayed below the chart of nuclei. Links to a full list of levels and a level scheme are provided. Unless the zoom is at its largest value, clicking on a given nucleus also re-centers the chart. Further navigation possibilities can be obtained by using the arrows on the right-top corner of the window. The interactive chart of nuclides has proven to be the most popular NuDat retrievals, accounting for about 46% of them.

LEVEL SCHEMES

There are two types of level schemes that can be obtained in NuDat: adopted levels plot, that is all the levels that are known for a given nucleus, and Decay Schemes, i.e., only those levels that are populated following a particular nuclear decay. For the latter case, some extra decay information is also written in the plot. The level schemes are rendered in a single image. Most nuclei, however, have complex level schemes that can’t easily fit in an image. As a consequence, only selected parts of the level scheme should be plotted at a time using the interactive features provided: select lower and upper energy limits, write gamma energies, write level energies, write level half-lives, write level spin and parities, highlight specific levels or gammas, choose the image height in pixels, choose the level width in pixels, exclude or include bands and groups of levels, and write additional decay information. As an example, the low-energy part of the $^{136}$Nd level scheme is shown in Fig. 2.

SEARCH EXAMPLES

In this section, a few examples of NuDat search capabilities will be presented. In the first one, we will search for nuclear decay information for a given nucleus, for instance, that from the decay of $^{178}$Hf. This is achieved by using the Decay Radiation search page of NuDat and typing “$^{178}$Hf” in the Nucleus text box. An example of the search form can be seen in Fig. 3.

Two datasets are obtained, one for the 4-second isomer and another for the 31-year isomer. Links to interactive decay schemes are provided; the one for the 31-year isomer can be seen in Fig. 4. Decay information queries such this are the most popular among NuDat searches.

The same Decay Radiation search page can be used to get the isomers known to decay by gamma emission with a half-life larger than a given value, for instance one year. We simply have to select a parent $T_{1/2}$ larger than 1 year and “IT” as the decay mode. Nine different cases are returned, with $^{178m}$Hf having the largest energy release.

NuDat 2.0 allows searching for nuclei associated to specific gamma rays. For instance, if we are interested in finding a nucleus with a gamma ray in the 710 to 714 keV range connecting two of its levels, we use the Levels and Gammas search page of NuDat and type the energy limits in the Gamma condition energy text-boxes. Using the other Gamma condition, it is also possible to search for nuclei with two gamma rays; additionally, coinci-
FIGURE 2. $^{136}$Nd partial level scheme as obtained from NuDat.

FIGURE 3. NuDat’s decay radiation search form.
Decay scheme for $^{178m}$Hf as obtained from NuDat.

In summary, we have presented a short description of NuDat, a web-based tool to retrieve, search, and plot nuclear structure data. Like many other web-based products, we expect NuDat to undergo regular updates to reflect advances in programming technology and hardware. Additionally, we expect to expand NuDat reach, integrating it with the XUNDL (Experimental Unevaluated Nuclear Data List) database [5], as well as incorporating more features that are available in ENSDF.

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REFERENCES


nuDat also allows searching for gamma rays observed in nuclear decay. For instance, if we are interested in identifying a nucleus that following its decay, a gamma ray is observed with a given energy and time distribution, we use the Decay Radiation search page in NuDat, select Gamma in the Radiation Type Condition and type the corresponding values of energy and half-life.

FIGURE 4.