Nuclear Data Evaluation: why, what, where and who?

John H. Kelley
NCState & TUNL
Human Curiosity

- The theory of classical elements, held by the Hindu, Japanese, and Greek systems of thought, is that there are five elements, namely Earth, Water, Air, Fire,
- and a fifth element known as space, Idea, Void "quintessence" or Aether ("quintessence" derives from "quint" meaning "fifth").
Appended to J. Dalton
“On the Absorption of Gases by Water and Other Liquids”

This paper was already presented orally in 1803. It contains the first steps to the atomic hypothesis to explain the laws of definite and multiple proportions. The first table of relative weights is appended without explanation of the methods applied.

http://web.lemoyne.edu/~giunta/dalton52.html
John Dalton
A New System of Chemical Philosophy (1808)

http://www.archive.org/stream/newsystemofchemi01daltuoft

B. Pfeiffer
An ahead of time nucleosynthesis hypothesis?

In 1816, the physician Prout (and the chemist L. Meinecke) put forward the hypothesis that all relative weights of the elements are whole-number multiples of the weight of hydrogen. [It is generally assumed, that he did not base this assumption on contemporary measurements, but on natural philosophy. He set the πρωτή νή of the Greek philosophers synonymous with H.]

Some scientists in the 19th century assumed that “atoms” were composed of H atoms. Does anyone know, if they had speculated on nucleosynthesis by adding H on atoms?

In the following decades, chemists pushed the techniques to the limits in order to prove or disprove Prout’s hypothesis (and advanced many ad-hoc “improvements”). Around 1860, relative atomic weights for 57 elements had been determined and they were one essential ingredient for the establishment of the “Periodic System” by Mendeleev and Meyer.

Remark: Still in the 20th century, isotopic masses were calculated from isotopic abundances and chemically measured elemental relative weights.
THE PERIODIC TABLE

<table>
<thead>
<tr>
<th>Period</th>
<th>Group</th>
<th>Element</th>
<th>Atomic Number</th>
<th>Atomic Weight</th>
<th>Symbol</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IA</td>
<td>H</td>
<td>1</td>
<td>1.008</td>
<td>H</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>2</td>
<td>IIA</td>
<td>Na</td>
<td>11</td>
<td>22.99</td>
<td>Na</td>
<td>Sodium</td>
</tr>
<tr>
<td>3</td>
<td>IIIA</td>
<td>K</td>
<td>19</td>
<td>39.10</td>
<td>K</td>
<td>Potassium</td>
</tr>
<tr>
<td>4</td>
<td>IVA</td>
<td>Ca</td>
<td>20</td>
<td>40.08</td>
<td>Ca</td>
<td>Calcium</td>
</tr>
<tr>
<td>5</td>
<td>VA</td>
<td>Sc</td>
<td>21</td>
<td>44.96</td>
<td>Sc</td>
<td>Scandium</td>
</tr>
<tr>
<td>6</td>
<td>VIA</td>
<td>Ti</td>
<td>22</td>
<td>47.88</td>
<td>Ti</td>
<td>Titanium</td>
</tr>
<tr>
<td>7</td>
<td>VIIA</td>
<td>Cr</td>
<td>23</td>
<td>52.00</td>
<td>Cr</td>
<td>Chromium</td>
</tr>
<tr>
<td>8</td>
<td>VII</td>
<td>Mn</td>
<td>25</td>
<td>54.94</td>
<td>Mn</td>
<td>Manganese</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Fe</td>
<td>26</td>
<td>55.85</td>
<td>Fe</td>
<td>Iron</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Co</td>
<td>27</td>
<td>58.93</td>
<td>Co</td>
<td>Cobalt</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Ni</td>
<td>28</td>
<td>58.71</td>
<td>Ni</td>
<td>Nickel</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Cu</td>
<td>29</td>
<td>63.55</td>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Zn</td>
<td>30</td>
<td>65.38</td>
<td>Zn</td>
<td>Zinc</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Ga</td>
<td>31</td>
<td>69.72</td>
<td>Ga</td>
<td>Gallium</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Ge</td>
<td>32</td>
<td>72.63</td>
<td>Ge</td>
<td>Germanium</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>As</td>
<td>33</td>
<td>74.92</td>
<td>As</td>
<td>Arsenic</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Se</td>
<td>34</td>
<td>79.90</td>
<td>Se</td>
<td>Selenium</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Br</td>
<td>35</td>
<td>80.90</td>
<td>Br</td>
<td>Bromine</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Kr</td>
<td>36</td>
<td>83.80</td>
<td>Kr</td>
<td>Krypton</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Rb</td>
<td>37</td>
<td>85.47</td>
<td>Rb</td>
<td>Rubidium</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>Sr</td>
<td>38</td>
<td>87.62</td>
<td>Sr</td>
<td>Strontium</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>Y</td>
<td>39</td>
<td>88.91</td>
<td>Y</td>
<td>Yttrium</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>Zr</td>
<td>40</td>
<td>91.22</td>
<td>Zr</td>
<td>Zirconium</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>Nb</td>
<td>41</td>
<td>92.91</td>
<td>Nb</td>
<td>Niobium</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>Mo</td>
<td>42</td>
<td>95.94</td>
<td>Mo</td>
<td>Molybdenum</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>Tc</td>
<td>43</td>
<td>98.79</td>
<td>Tc</td>
<td>Technetium</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>Ru</td>
<td>44</td>
<td>101.07</td>
<td>Ru</td>
<td>Ruthenium</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>Rh</td>
<td>45</td>
<td>102.91</td>
<td>Rh</td>
<td>Rhodium</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>Pd</td>
<td>46</td>
<td>106.42</td>
<td>Pd</td>
<td>Palladium</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>Ag</td>
<td>47</td>
<td>107.87</td>
<td>Ag</td>
<td>Silver</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>Cd</td>
<td>48</td>
<td>112.41</td>
<td>Cd</td>
<td>Cadmium</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>In</td>
<td>49</td>
<td>114.82</td>
<td>In</td>
<td>Indium</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>Sn</td>
<td>50</td>
<td>117.61</td>
<td>Sn</td>
<td>Tin</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>Sb</td>
<td>51</td>
<td>121.76</td>
<td>Sb</td>
<td>Antimony</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>Te</td>
<td>52</td>
<td>127.60</td>
<td>Te</td>
<td>Tellurium</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td>I</td>
<td>53</td>
<td>126.90</td>
<td>I</td>
<td>Iodine</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td>Xe</td>
<td>54</td>
<td>131.29</td>
<td>Xe</td>
<td>Xenon</td>
</tr>
<tr>
<td>38</td>
<td></td>
<td>Cs</td>
<td>55</td>
<td>132.91</td>
<td>Cs</td>
<td>Cesium</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td>Ba</td>
<td>56</td>
<td>137.33</td>
<td>Ba</td>
<td>Barium</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>La</td>
<td>57</td>
<td>138.91</td>
<td>La</td>
<td>Lanthanum</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td>Hf</td>
<td>58</td>
<td>178.49</td>
<td>Hf</td>
<td>Hafnium</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>Ta</td>
<td>59</td>
<td>180.95</td>
<td>Ta</td>
<td>Tantalum</td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>W</td>
<td>60</td>
<td>183.85</td>
<td>W</td>
<td>Tungsten</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>Re</td>
<td>61</td>
<td>186.21</td>
<td>Re</td>
<td>Rhenium</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>Os</td>
<td>62</td>
<td>190.22</td>
<td>Os</td>
<td>Osmium</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>Ir</td>
<td>63</td>
<td>192.22</td>
<td>Ir</td>
<td>Iridium</td>
</tr>
<tr>
<td>47</td>
<td></td>
<td>Pt</td>
<td>64</td>
<td>195.08</td>
<td>Pt</td>
<td>Platinum</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>Au</td>
<td>71</td>
<td>196.97</td>
<td>Au</td>
<td>Gold</td>
</tr>
<tr>
<td>49</td>
<td></td>
<td>Hg</td>
<td>72</td>
<td>200.59</td>
<td>Hg</td>
<td>Mercury</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>Tl</td>
<td>73</td>
<td>204.38</td>
<td>Tl</td>
<td>Thallium</td>
</tr>
<tr>
<td>51</td>
<td></td>
<td>Pb</td>
<td>74</td>
<td>207.2</td>
<td>Pb</td>
<td>Lead</td>
</tr>
<tr>
<td>52</td>
<td></td>
<td>Bi</td>
<td>75</td>
<td>208.98</td>
<td>Bi</td>
<td>Bismuth</td>
</tr>
<tr>
<td>53</td>
<td></td>
<td>Po</td>
<td>76</td>
<td>209.0</td>
<td>Po</td>
<td>Polonium</td>
</tr>
<tr>
<td>54</td>
<td></td>
<td>At</td>
<td>77</td>
<td>210.0</td>
<td>At</td>
<td>Astatine</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td>Rn</td>
<td>86</td>
<td>222.0</td>
<td>Rn</td>
<td>Radon</td>
</tr>
</tbody>
</table>

**ALKALI METALS**

1. Lithium (Li)
2. Sodium (Na)
3. Potassium (K)
4. Rubidium (Rb)
5. Cesium (Cs)
6. Francium (Fr)

**ALKALI EARTH METALS**

1. Beryllium (Be)
2. Magnesium (Mg)
3. Calcium (Ca)
4. Strontium (Sr)
5. Barium (Ba)

**LANTHANIDES**

1. Lanthanum (La)
2. Actinium (Ac)
3. Thulium (Th)
4. Lawrencium (Lr)

**ACTINIDES**

1. Actinium (Ac)
2. Thorium (Th)
3. Protactinium (Pa)
4. Uranium (U)
5. Neptunium (Np)
6. Plutonium (Pu)
7. Americium (Am)
8. Curium (Cm)
9. Berkelium (Bk)
10. Californium (Cf)
11. Eka-radium (Es)
12. Flerovium (Fm)
13. Mendelevium (Md)
14. Nobelium (No)
15. Lawrencium (Lr)

**HALOGENS**

1. Fluorine (F)
2. Chlorine (Cl)
3. Bromine (Br)
4. Iodine (I)
5. Astatine (At)

**NOBLE GASES**

1. Helium (He)
2. Neon (Ne)
3. Argon (Ar)
4. Krypton (Kr)
5. Xenon (Xe)
6. Radon (Rn)
Origins of the elements


- Vanadium –
  the atomic number is 23 and the chemical symbol is V. The name derives from the “Scandinavia goddess of love and beauty”, Freyja Vanadis, because of its many beautiful multicolored compounds. It was discovered by the Swedish physician and chemist Nils-Gabriel Sefström in 1830. It had originally been discovered by the Spanish mineralogist Andres Manuel del Rio y Fernandez in 1801, who named it erythronium, after the plant of that name whose flowers have many beautiful colors. Del Rio later decided that it was really chromium in his lead sample, however his lead sample was later shown to have vanadium in it. Vanadium metal was first isolated by the English chemist Henry Enfield Roscoe in 1869.
Practical Uses

- [http://periodic.lanl.gov/default.htm](http://periodic.lanl.gov/default.htm)

Sources
- Vanadium is found in about 65 different minerals among which are carnotite, roscoelite, vanadinite, and patronite, important sources of the metal. Vanadium is also found in phosphate rock and certain iron ores, and is present in some crude oils in the form of organic complexes. It is also found in small percentages in meteorites.
- Commercial production from petroleum ash holds promise as an important source of the element. High-purity ductile vanadium can be obtained by reduction of vanadium trichloride with magnesium or with magnesium-sodium mixtures.
- Much of the vanadium metal being produced is now made by calcium reduction of V2O5 in a pressure vessel, an adaption of a process developed by McKechnie and Seybair.

Isotopes
- Natural vanadium is a mixture of two isotopes, 50V (0.24%) and 51V (99.76%). 50V is slightly radioactive, having a half-life of > 3.9 x 1017 years. Nine other unstable isotopes are recognized.

Properties
- Pure vanadium is a bright white metal, and is soft and ductile. It has good corrosion resistance to alkalis, sulfuric and hydrochloric acid, and salt water, but the metal oxidizes readily above 660°C.
- The metal has good structural strength and a low fission neutron cross section, making it useful in nuclear applications.

Uses
- Vanadium is used in producing rust resistant and high speed tool steels. It is an important carbide stabilizer in making steels.
- About 80% of the vanadium now produced is used as ferrovanadium or as a steel additive. Vanadium foil is used as a bonding agent in cladding titanium to steel. Vanadium pentoxide is used in ceramics and as a catalyst.
- It is also used to produce a superconductive magnet with a field of 175,000 gauss.

Handling
- Vanadium and its compounds are toxic and should be handled with care. The maximum allowable concentration of V2O5 dust in air is about 0.05 (8-hour time-weighted average - 40-hour week).

Costs
- Ductile vanadium is commercially available. Commercial vanadium metal, of about 95% purity, costs about $20/lb. Vanadium (99.9%) costs about $100/oz.
Now to the point.

Our curiosity drives us to characterize and catalog the stuff we understand.
Why?

The more that we know, the more that we can understand.
Our Home:  
Chart of Nuclides
Transition from Elements to Nuclides

A NEW METHOD OF POSITIVE RAY ANALYSIS.

A. J. DEMPSTER.

Phys Rev 4 (1917) 316

An apparatus for analyzing positively or negatively charged particles is described. Examples are given of the analysis of the ions from heated salts and of the positive rays obtained by bombarding various substances with electrons. The high resolving power obtainable with the method is also illustrated.

Ryerson Physical Laboratory,
Chicago,
October 20, 1917.

“When, among the light elements, we come across a clear case of large departure from an integral value, such as magnesium 24.32 and chlorine 35.46, we may reasonably suspect the elements to be a mixture of isotopes.” With the resolving power in the above examples this question can obviously be definitely decided, for, if the element is really homogeneous, the curve will lie entirely between two integral values, and if it is a mixture of elements differing by integers, the molecules will be completely separated. The only experimental difficulty is to get the rays, and this is the matter now under investigation. Magnesium has been ¹ Nature, 1917 also Scientific Monthly, p. 516, Dec. 1917.

The experiments described above are concerned chiefly with the development of the method, and they are published now only because the writer expects to be engaged in other duties for some time.

The writer wishes to express his appreciation of the kindness of Professor Michelson and Professor Millikan in placing the equipment of the laboratory at his disposal and in rendering every possible assistance.
Two isotopes identified in one Element

Bakerian Lecture:—Rays of Positive Electricity.

By Prof. Sir J. J. Thomson, O.M., F.R.S.

(Lecture delivered May 22,—MS. received June 4, 1913.)

The second sample from Sir James Dewar contained the lighter gases; the photograph (fig. 18) shows that, in addition to helium and neon, there is another gas with an atomic weight about 22. This gas has been found in every specimen of neon which has been examined, including a very carefully purified sample prepared by Mr. E. W. Watson and a specimen very kindly supplied by M. Claud, of Paris; the photograph of this specimen, fig. 19 (Plate 3), is remarkable, as it shows, in addition to this line and the helium line, a line corresponding to a substance with atomic weight 3, whose properties are discussed later on.

Fig. 18.
~3000 nuclei are predicted to exist

~6000 nuclei

~3000 the knowledge is very limited!
What do we want?

What can’t we do without?
What do we want?

• Everything that we need
• Varies from person to person

What can’t we do without?

• Organization
THE RADIOACTIVE CONSTANTS AS OF 1930

REPORT OF THE INTERNATIONAL RADIIUM-STANDARDS COMMISSION

By M. Curie, A. Debiener, A. S. Eve, H. Geiger, O. Hahn, S. C. Lind,
St. Meyer, E. Rutherford, and E. Schweidler

I. INTRODUCTION

Following the reorganization of the International Union of Chemistry
and of the International Atomic Weights Commission, the need has
arisen for the publication of special Tables of the Radioactive Constants.

This responsibility has been assumed by the International Radium
Standards Commission chosen in Brussels in 1910, which has expressed its
willingness to cooperate with the International Union.

Besides the members, M. Curie, A. Debiener, A. S. Eve, H. Geiger, O.
Hahn, S. C. Lind, St. Meyer, E. Rutherford, E. Schweidler, the following
have taken part as experts: J. Chadwick, I. Joliot-Curie, K. W. F. Kohlrausch,
A. F. Kovarik, L. W. McKeen, L. Meitner and H. Schlundt, to whom it is
desired to express especial obligations.

The following report will be simultaneously published* also in the Physikalische
Zeitschrift, in the Journal of the American Chemical Society, Philosophical
Magazine, and Journal de Physique et le Radium.

II. GENERAL REMARKS ON SYMBOLS AND TERMS

The symbols are provisionally retained as used in the texts of St. Meyer
and E. Schweidler, F. Kohlrausch and E. Rutherford, E. Chadwick and C. D
Ellis as well as in the Phys. Zeits. 19, 30 (1918), Zeits. f. Elektrochemie 24,

For the three radioactive gases the use of the terms radon (Rn), thoron
(Tn), and actinon (An) is recommended (Zeits. f. anorg. Chem. 103, 79, 1918),
and as general term for elements of atomic number 86 the retention of the
word "emanations" (Em) for the three isotopes. The words "emanate," "emanating
power," etc., are retained.

The designation "radio-lead" is restricted to the natural radio-active
mixture of lead isotopes in minerals and is not used to designate RaD.

RaG, ThD and AcD will be called uranium-lead, thorium-lead and actinium-
lead respectively. The mixture of RaG and AcD also will be designated
uranium-lead.

Instead of the designation "isotopic weight" (poids isotopique) as used in
the earlier Tables internationales des elements radioactifs for the whole-numbered
atomic weights or the number of hydrogen nuclei, the term "proton
number" is proposed.

* To facilitate desirable changes and additions in subsequent years it is requested that
data, notes and suggestions be sent to Prof. Dr. Stefan Meyer, Institut für Radiumforschung,
Boltzmanngasse 3, IX Vienna, Austria

427
## Table II. Ionium-Radium Family

<table>
<thead>
<tr>
<th></th>
<th>$T$</th>
<th>$\lambda$</th>
<th>$\tau$</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionium</td>
<td>io</td>
<td>$8.3 \cdot 10^{4}$yr</td>
<td>$8.3 \cdot 10^{-4}$yr$^{-1}$</td>
<td>7, 8, 8a</td>
</tr>
<tr>
<td></td>
<td>At. No. 90</td>
<td>$2.6 \cdot 10^{4}$s</td>
<td>$2.6 \cdot 10^{-1}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium</td>
<td>Ra</td>
<td>$5.02 \cdot 10^{4}$s</td>
<td>$1.38 \cdot 10^{-4}$s$^{-1}$</td>
<td>7, 8, 8a</td>
</tr>
<tr>
<td></td>
<td>At. No. 88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 226</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon</td>
<td>Rn</td>
<td>$3.825d$</td>
<td>$0.1812d^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 86</td>
<td>$3.305 \cdot 10^{3}$s</td>
<td>$2.097 \cdot 10^{-4}$s$^{-1}$</td>
<td>7, 8, 8a</td>
</tr>
<tr>
<td></td>
<td>P. No. 222</td>
<td>$3.823d$</td>
<td>$0.1813d^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Radium A</td>
<td>RaA</td>
<td>$3.03 \cdot 10^{2}$s</td>
<td>$2.908 \cdot 10^{-6}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 84</td>
<td>$3.05m$</td>
<td>$0.227m^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 218</td>
<td>$183s$</td>
<td>$3.78 \cdot 10^{-3}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Radium B</td>
<td>RaB</td>
<td>$26.8m$</td>
<td>$2.59 \cdot 10^{-17}$m$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 82</td>
<td>$1.61 \cdot 10^{4}$s</td>
<td>$4.31 \cdot 10^{-4}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 214</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium C</td>
<td>RaC</td>
<td>$19.7m$</td>
<td>$3.51 \cdot 10^{-2}$m$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 83</td>
<td>$1.18 \cdot 10^{3}$s</td>
<td>$5.86 \cdot 10^{-3}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 214</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium C' 99.96%</td>
<td>RaC'</td>
<td>$ca 10^{-4}$s</td>
<td>$10^{-4}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>(99.97%)</td>
<td>At. No. 84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 214</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium C'' 0.04%</td>
<td>RaC''</td>
<td>$79.2s$</td>
<td>$0.525m^{-1}$</td>
<td></td>
</tr>
<tr>
<td>(0.03%)</td>
<td>At. No. 81</td>
<td>$8.7 \cdot 10^{-4}$s</td>
<td>$1.00 \cdot 10^{-7}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium D</td>
<td>RaD</td>
<td>$22yr$</td>
<td>$0.0315yr^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 82</td>
<td>$6.94 \cdot 10^{3}$s</td>
<td>$1.00 \cdot 10^{-3}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium E</td>
<td>RaE</td>
<td>$4.9d$</td>
<td>$0.141d^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 83</td>
<td>$4.26 \cdot 10^{5}$s</td>
<td>$1.63 \cdot 10^{-4}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 210</td>
<td>$5.0d$</td>
<td>$0.139d^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Radium F</td>
<td>RaF (Po)</td>
<td>$4.32 \cdot 10^{4}$s</td>
<td>$1.61 \cdot 10^{-3}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Polonium</td>
<td></td>
<td>$140d$</td>
<td>$4.95 \cdot 10^{-3}$d$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Radium G</td>
<td>RaG</td>
<td>$1.21 \cdot 10^{3}$s</td>
<td>$5.73 \cdot 10^{-3}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>(uranium lead)</td>
<td>At. Wr. 206.016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>At. No. 82</td>
<td>$2.1 \cdot 10^{3}$s</td>
<td>$1.75 \cdot 10^{7}$s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. No. 206</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Earlier values still in use.
Evaluation History

Compilation:
Webster’s Dictionary defines “to compile” as “to put together, in a new form, out of materials already existing.”
In scientific fields it serves as a convenient source of detailed information.

Evaluation:
To evaluate means as “to appraise; to determine value”.
A good “evaluation” always involves “compilation”.

Filip Kondev - 6th Balkan School of Nuclear Physics, Trojan, Sept. 17-24, 2008
nuclear decay modes, half-life, decay energy, production
Professor G. T. Seaborg
Department of Chemistry
University of California
Berkeley, California

Dear Professor Seaborg:

I believe your suggestion of a revised list of radioactive isotopes for the April or July, 1942 issue of the REVIEWS OF MODERN PHYSICS is a very good one. By that time the rate at which such radioactivities are discovered may be reduced very considerably and the table would itself become "stable". I should be glad to have you prepare such a table.

I have the new edition and noted the tables in them. I am quite sure it is not worth taking any action, even though some evidence exists for a "case".

Sincerely yours,

J. R. Buchta
Assistant Editor

courtesy of E. Browne (LBNL)
What is Nuclear Data?

**Generally:** any result produced in a NP experiment can qualify

**Historically:** associated with neutron cross sections and fission like applications

... too applied to the basic physics ...too academic to the applied physics ...
Katherine Way, as a part of the Manhattan Project, collected nuclear data at Clinton Laboratory, today Oak Ridge National Laboratory (ORNL) in 1953 the Nuclear Data Project (NDP) moved under the US National Academy of Sciences-National Research Council in Washington, DC–published the first collection of data in loose-leaf pages called *Nuclear Data Sheets*.

In 1964, under the leadership of Katherine Way, NDP moved back to ORNL – NSR & ENSDF formats were developed.


In 1974 the International Nuclear Structure and Decay Data Network, under the auspices of IAEA was created – the main effort was shifted to NNDC.

Since 1981 the main editorial work has been carried out at NNDC (J. Tuly – the Editor).
ENSDF: only Nuclear Structure database updated continuously and comprehensively ALL nuclei and ALL nuclear level properties and radiations contributors are members of the Nuclear Structure and Decay Data Network, under the auspices of IAEA. Primary responsibility of NNDC; role of USNDP is indispensible!

No viable alternative exists in the world!

NSDD backbone – 6.7 FTE
✓ leadership, technical expertise and mentoring
✓ host and maintain ENSDF, NSR, network programs, manuals & references

Valuable contributions - 2.0 FTE
✓ issues: funding, retirements and replacements

Organize bi-annual meetings & technical workshops
NSDD coordination

Contributions to NSR & ENSDF
~0.25 FTE

Provide research grants ($4K/y)
developing countries
The main NSDD product - ENSDF

www.nndc.bnl.gov/ensdf

Contents: Evaluated nuclear structure and decay data for all known nuclei, organized in over 260 mass chains

ENSDF

Adopted
(best values)

Levels:
(E, J^\pi, T_{1/2}, \mu, Q, configurations)

Gammas:
(E_\gamma, BR, M, \delta, ICC)

Decays
\beta^-
\varepsilon + \beta^+
\alpha
\beta^-n
etc.

Reactions
(Hl,xn\gamma)
(p,p')
(n, \gamma), (n,xn\gamma)
Coul. Exc.
(\alpha, \alpha'), (\alpha,xn\gamma)
(d,p), etc.
www.nndc.bnl.gov/ensdf

Evaluated Nuclear Structure Data File (ENSDF)
Database version of August 29, 2008

Experimental Unevaluated Nuclear Data List (XUNDL)
Database version of August 29, 2008

The ENSDF database contains evaluated nuclear structure and decay information for over 2900 nuclides. The file is updated on a continuous basis. New evaluations are published in Nuclear Data Sheets.

The XUNDL database contains experimental data compiled from over 1700 recent nuclear structure papers.

Quick search: Retrieve all ENSDF datasets for a given nuclide or mass: Search (208Pb, pb-208, 144, etc.)

Browse datasets by element and mass.

Advanced search and retrieval options:

- Nuclide Search Retrieve datasets based on nuclide, charge, or mass.
- Reaction Search Retrieve datasets based on indexed reaction quantities.
- Decay Search Retrieve datasets based on indexed decay quantities.
- Recently added Retrieve recently added or modified datasets.

Database indices:

- Index to ENSDF Information on mass-chain evaluations and publication.
Datasets for $^{177}$Ta

Matching datasets in ENSDF:

- $^{177}$Ta
  - ADOPTED LEVELS, GAMMAS
- 177W EC DECAY
- 118(208Pb,XG)
- 170ER(118,4NG)
- 175LU(A,2NG)

Get selected ENSDF datasets: [HTML] [Download] [View ENSDF]
Get all ENSDF datasets: [HTML] [Download] [View ENSDF]

Data from AR_206722_1.ens

Download: [AR_206722_1.ens] View: Level schemes in the Nuclear Data Sheets style [JPEG] [PDF] [PS]

Published: 2003 Nuclear Data Sheets.

Type | Author | Citation | Cutoff Date
--- | --- | --- | ---

2000Da09.1994Da11: Produced using the $^{170}$Er($^{11}$B,4ny) reaction. Projectiles: $^{11}$B, E=55 MeV. Targets: isotopically enriched $^{170}$Er, 5.5 mg/cm² thick in the $\gamma\gamma(t)$ and $\gamma(t)$ experiments, which stopped most of the recoiling nuclei and a 1.5 mg/cm² thick during the conversion electron measurements. Detectors: six HPGe Compton-suppressed detectors and one (unsuppressed) planar germanium detector (LEPS) during the $\gamma\gamma(t)$ and $\gamma(t)$ experiments and a superconducting solenoid spectrometer with a Si(Li) detector and one HPGe Compton-suppressed detector during the conversion electron measurements. Pulsed beams of 1 ns on/1700 ns off ($\gamma\gamma(t)$), 2 µs on/103 µs off ($\gamma(t)$) and 1 ns on/900 ns off, and 80 µs on/720 µs off (conversion electron experiment) were used. Measured: $E_{\gamma}$, $I_{\gamma}$, $\gamma\gamma$ coin, $\gamma(t)$, $\gamma\gamma(t)$, $\gamma(\delta)$ and ce. Deduced: level scheme, lifetimes, transition multiplicities, $J_r$, $K$, and configurations. See also 1994Da11.

1995Ar18.1993Ri00: Produced using the $^{170}$Er($^{11}$B,4ny) reaction. Projectiles: $^{11}$B, E=55 and 60 MeV. Targets: $^{170}$Er, two self-supporting 1.0 mg/cm² thick foils. Detectors: five HPGe Compton-suppressed detectors (55 MeV) and ten HPGe Compton-suppressed detectors with a 28-element BGO multiplicity filter (60 MeV). Measured: $E_{\gamma}$, $I_{\gamma}$ and $\gamma\gamma$ coin. Deduced: level scheme, $J_r$, $K$, and configurations.
### Level Properties

<table>
<thead>
<tr>
<th>( E_{\text{level}} )</th>
<th>( J^\pi )</th>
<th>( T_{1/2} ) &amp;</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>7/2+</td>
<td>56.56 h 6</td>
<td>( J^\pi ): From adopted levels. ( T_{1/2} ): 69.3 ns 21 from 2000Da09.</td>
</tr>
<tr>
<td>70.59</td>
<td>5/2+</td>
<td>70.2 ns 19</td>
<td>( J^\pi ): From adopted levels. ( T_{1/2} ): 410 ns 7 (2000Da09).</td>
</tr>
<tr>
<td>73.36</td>
<td>9/2-</td>
<td>410 ns 7</td>
<td>( J^\pi ): From adopted levels. ( T_{1/2} ): 3.67 μs 14 from 2000Da09.</td>
</tr>
<tr>
<td>131.05</td>
<td>9/2+</td>
<td>3.62 μs 10</td>
<td>Additional documentation [3]</td>
</tr>
<tr>
<td>172.31</td>
<td>7/2+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>186.15</td>
<td>5/2-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Decay Properties

<table>
<thead>
<tr>
<th>( E \gamma )</th>
<th>( E_{\text{level}} )</th>
<th>( I \gamma )</th>
<th>( I \gamma )</th>
<th>( \text{Mult.} )</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.2</td>
<td>2832.7</td>
<td>132.32</td>
<td></td>
<td>E1</td>
<td>( \alpha(\exp)=3.0 \times 10^4 ) (2000Da09), ( \alpha(M1)=36.9 ), ( \alpha(E2)=1785.2 ) and ( \alpha(E1)=2.6 ).</td>
</tr>
<tr>
<td>86.1</td>
<td>4656.3</td>
<td>61</td>
<td></td>
<td>E2</td>
<td>( \alpha(\exp)=7.3 \times 10^9 ) (2000Da09), ( \alpha(M1)=6.4 ), ( \alpha(E2)=6.1 ) and ( \alpha(E1)=0.5 ). ( \alpha(L)\exp=4.0 \times 10^9 ) (2000Da09), ( \alpha(L)(M1)=0.8 ), ( \alpha(L)(E2)=3.8 ) and ( \alpha(L)(E1)=0.07 ).</td>
</tr>
<tr>
<td>101.8</td>
<td>172.31</td>
<td>67</td>
<td></td>
<td>M1+E2</td>
<td>( A_2=0.10 \times 17 ).</td>
</tr>
<tr>
<td>104.2</td>
<td>2956.9</td>
<td>211</td>
<td></td>
<td>E1</td>
<td>( A_2=0.02 ).</td>
</tr>
<tr>
<td>115.6</td>
<td>186.15</td>
<td>455</td>
<td></td>
<td>E1</td>
<td>( \alpha(\exp)=0.41 \times 10^9 ) (2000Da09), ( \alpha(M1)=3.9 ), ( \alpha(E2)=3.2 ) and ( \alpha(E1)=0.3 ). ( \alpha(L)\exp=0.05 \times 10^9 ) (2000Da09), ( \alpha(L)(M1)=0.52 ), ( \alpha(L)(E2)=1.77 ) and ( \alpha(L)(E1)=0.05 ). ( \alpha(M)\exp=0.03 \times 10^9 ) (2000Da09), ( \alpha(M)(M1)=0.12 ), ( \alpha(M)(E2)=0.44 ) and ( \alpha(M)(E1)=0.01 ).</td>
</tr>
<tr>
<td>128.6</td>
<td>300.89</td>
<td>157</td>
<td></td>
<td>[M1+E2]</td>
<td>( \alpha(\exp)=0.16 \times 10^9 ) (2000Da09) and 0.26 (1995Ar18), assuming K=5/2.</td>
</tr>
<tr>
<td>131.2</td>
<td>131.05</td>
<td>196</td>
<td></td>
<td>(M1+E2)</td>
<td>( A_2=0.09 \times 7 ). The value overlaps with that for the 131.9γ.</td>
</tr>
<tr>
<td>131.9</td>
<td>1737.40</td>
<td>100</td>
<td></td>
<td>(M1+E2)</td>
<td>( A_2=0.09 \times 7 ). The value overlaps with that for the 131.2γ.</td>
</tr>
</tbody>
</table>
Datasets for $^{177}$Ta

Matching datasets in ENSDF:

<table>
<thead>
<tr>
<th>$^{177}$Ta</th>
<th>ADOPTED LEVELS, GAMMAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>177W EC DECAY</td>
</tr>
<tr>
<td></td>
<td>118(208Pb, XG)</td>
</tr>
<tr>
<td></td>
<td>170ER(118, 4NG)</td>
</tr>
<tr>
<td></td>
<td>175LU(A,2NG)</td>
</tr>
</tbody>
</table>
### Adopted Levels, Gammas

Published: 2003 Nuclear Data Sheets.

$Q_\beta = 2001 \, SY \, S_n = 8.32 \times 10^3 \, \Gamma \, S_p = 4429 \, \alpha = 2740 \, \text{1995Au04}$

<table>
<thead>
<tr>
<th>Date</th>
<th>Type</th>
<th>Author</th>
<th>Citation</th>
<th>Cutoff Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-Jul-2007</td>
<td>Errata</td>
<td>J. Tuki</td>
<td></td>
<td></td>
<td>Fixed typo in comment</td>
</tr>
</tbody>
</table>

#### 177Ta levels

### Cross References (XREF) Flags

- **A** $^{170}$Er($^{11}$B,4$n$) $^{177}$W Electron Capture Decay
- **B** $^{175}$Lu($\alpha,2n\gamma$) $^{177}$B($^{208}$Pb,$\gamma\gamma$)

### Energy Levels and Transitions

<table>
<thead>
<tr>
<th>$E_{\text{level}}$</th>
<th>$J^{\pi}$</th>
<th>$T_{1/2}$</th>
<th>XREF</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>7/2+</td>
<td>56.56 h 6</td>
<td>ABC</td>
<td></td>
</tr>
<tr>
<td>70.59</td>
<td>5/2−</td>
<td>70.2 ns 19</td>
<td>AEC</td>
<td></td>
</tr>
</tbody>
</table>

### Notes
- **$J^\pi$:** $J^\pi$ of the atomic beam (1978Ru04); Strong $\sigma^+\beta^−$ feeding to the 7/2− and 9/2− levels in $^{177}$Hf. $J\pi$ systematics; band assignment.
- $T_{1/2}$: From 1961We11. Other values: 56.4 h 10 (1964Sa16) and 56 h 1 (1963Ra14).
- **$\mu$:** $\mu = 2.25$ (1981Ha06, 1984Ok07, 1989Ra17) using the nuclear magnetic resonance on oriented nuclei technique.
- **Configuration:** $\pi$ 7/2$^+$ Nilsson configuration. Based on the observed in-band properties, such as alignment and $g_{K}=\epsilon_{R}$ values ($\langle g_{K}=\epsilon_{R}\rangle Q_{0}=+0.0667$ 23 ($^{170}$Er($^{11}$B,4$n$))). Comparison between the measured $\mu$ with Nilsson model predictions and systematics of structures in neighboring nuclei.
- $J^\pi$: 70.5 $\gamma$ M1+E2 from $\alpha$($K$)exp, $\alpha$(L)exp, $\alpha$(M)exp and $\epsilon$(L1)$\epsilon$(L2)$\epsilon$(L3) exp ($^{177}$W $\gamma$ decay), and angular distribution data ($^{175}$Lu($\alpha,2n\gamma$)) to the 7/2$^+$ level; band assignment.
- $T_{1/2}$: Weighted average of 69.3 ns 21 in $^{177}$Er($^{11}$B,4$n$) (2000Da09), 73 ns 5 (1976Ac20), and 80 ns 10 (1973Sc20) in $^{175}$Lu($\alpha,2n\gamma$).
- **$\mu$:** $\mu = 4.75$ (1974Ac01, 1976Ac02, 1989Ra17) deduced using the perturbed polarization-angular correlation technique.
- **Configuration:** $\pi$ 5/2$^+$ ($^{40}$Ca) Nilsson configuration. Based on the observed in-band properties, such as alignment and $g_{K}=\epsilon_{R}$ values ($\langle g_{K}=\epsilon_{R}\rangle Q_{0}=+0.191$ 7 ($^{170}$Er($^{11}$B,4$n$))). Comparison between the measured $\mu$ with Nilsson model predictions and systematics of similar structures in $\gamma(177$Ta).
Nuclear Physics Databases & Services

ENSDF database plays a seminal role in scientific discoveries & many applications. ENSDF is the only Nuclear Structure database that is updated continuously – contains information for ALL nuclei and ALL nuclear level properties & radiations – currently contributed by members of the Nuclear Structure and Decay Data Network, under auspices of IAEA. It is maintained by NNDC and the NSDD role is indispensible!

No viable alternative exists in the world!

Applications

ENSDF

Basic NP Research

Simulations

Monte-Carlo Codes
MCNP, GEANT, EGS4
ORIGEN, CINDER90

ENDF, JEFF, JENDL ...

ORTEC & CANBERRA

MIRD

RIPL

PGAA

RNAL
Ground and isomeric state information for $^{132}$Sn

<table>
<thead>
<tr>
<th>$E$(level) (MeV)</th>
<th>$Jn$</th>
<th>$\Delta$(MeV)</th>
<th>$T_{1/2}$</th>
<th>Decay Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0+</td>
<td>-76.5542</td>
<td>39.7 s 8</td>
<td>$\beta^-$: 100.00 %</td>
</tr>
<tr>
<td>4.8485</td>
<td>(8+)</td>
<td>-71.7057</td>
<td>2.03 $\mu$s 4</td>
<td>IT: 100.00 %</td>
</tr>
</tbody>
</table>

A list of levels, a level scheme and decay radiation information are available.

**ADOPTED LEVELS, GAMMAS for $^{132}$Sn**

Author: YU. KHAZOV, A.A. RODIONOV AND S. SAKHAROV, BALRAJ SINGH

- $Q(\beta^-)$=3119 keV 9
- $S_n$= 7311 keV 25
- $S_p$= 15710 keV 30
- $Q_{ec}$= 11.08E3 keV 29

**References:**
- A: 132IN $\beta^-$-DECAY (0.207 S)
- B: 132SN IT DECAY (2.03 $\mu$s)
- C: 133IN $\beta^-$-N DECAY (165 MS)
- D: 248CM SF DECAY
- E: COULOMB EXCITATION

**ENSDF file for 132SN**

- ADOPTED LEVELS, GAMMAS
- 132IN $\beta^-$-DECAY (0.207 S)
- 132SN IT DECAY (2.03 $\mu$s)
- 133IN $\beta^-$-N DECAY (165 MS)
- 248CM SF DECAY
- COULOMB EXCITATION

---

<table>
<thead>
<tr>
<th>$E$(level) (keV)</th>
<th>KREF</th>
<th>$Jn$</th>
<th>$T_{1/2}$</th>
<th>$E_Y$ (keV)</th>
<th>$I_Y$</th>
<th>y mult.</th>
<th>Final level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>ABCDE</td>
<td>0+</td>
<td>39.7 s 8</td>
<td>$% \beta^-$ - 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4041.20</td>
<td>AES</td>
<td>2+</td>
<td>1.9 fs  $\neq$</td>
<td>4041.1</td>
<td>100</td>
<td>0.0</td>
<td>0+</td>
</tr>
<tr>
<td>4351.94</td>
<td>AE</td>
<td>(3-)</td>
<td>$&lt; 5.0$ ps</td>
<td>4351.9</td>
<td>11.0</td>
<td>(E1) [E3]</td>
<td>4041.20 2+</td>
</tr>
<tr>
<td>4416.29</td>
<td>AB</td>
<td>(4+)</td>
<td>3.95 ns  $J3$</td>
<td>4416.2</td>
<td>1.3</td>
<td>(E1) [E2] [E4]</td>
<td>4351.94 2+</td>
</tr>
</tbody>
</table>

Retrieve selected datasets  Retrieve all datasets
NuDat 2.4
Search and plot nuclear structure and decay data interactively. More

Levels and Gammas Search
Ground and excited states (energy, T1/2, spin/party, decay modes), gamma rays (energy, intensity, multipolarity, coinc.)

Nuclear Wallet Cards Search
Ground and isomeric states, neutron resonances and thermal cross sections

Decay Radiation Search
Radiation type, energy, intensity and dose following nuclear decay

Search forms

Interactive Chart of Nuclides
Click on a nucleus to obtain information

Chart, active area

Zoom
1
2
3
4

Nucleus: go

Color code Tooltips
Half-life On
Decay Mode Off

Uncertainties style
NDS Standard

> 10+15 s 10-01 s
10+10 s 10-02 s
10+07 s 10-03 s
10+06 s 10-04 s
10+04 s 10-05 s
10+03 s 10-06 s
10+02 s 10-07 s
10+01 s 10-15 s
10+00 s < 10-15 s
unknown

NNDC ENSDF NSR
Nuclear Wallet Cards
Nuclear Levels Properties - search

Nuclear Levels and Gammas Search

Specify Nuclei:
- Nucleus: [Blank]
- Z / Element: [Blank]
- ≤ Z ≤ [Blank]
- ≤ A ≤ [Blank]
- ≤ N ≤ [Blank]
  Even Z ▼
  Any A ▼
  Any N ▼

E(level) condition:
- enabled □
- disabled □
0 ≤ E_{level}(keV) ≤ 40000

Decay Mode condition:
- enabled □
- disabled □
Decay Mode ▼ ANY

J_{n}(level) condition:
- enabled □
- disabled □
J = 2 ▼ Order : 1st ▼ Parity : + ▼

T_{1/2}(level) condition:
- enabled □
- disabled □
0 fs ▼ ≤ T_{1/2} ≤ 1E10 Gy ▼
  No Upper/Lower limit values

γ condition #1:
- enabled □
- disabled □
0 ≤ E_{γ}(keV) ≤ 40000
  Multipolarity: ANY ▼ □ Not mixed

γ condition #2:
- enabled □
- disabled □
0 ≤ E_{γ}(keV) ≤ 40000
  Multipolarity: ANY ▼ □ Not mixed

γ condition #3:
- enabled □
- disabled □
0 ≤ E_{γ}(keV) ≤ 40000
  Multipolarity: ANY ▼ □ Not mixed

γ coincidence condition:
- any □
- coincident □
Coincidence gate ▼ ≤ 1 us ▼

γ reduced transition probability:
- enabled □
- disabled □
0 ≤ B(M_{γ},E_{γ})(Weisskopf units) ≤ 40000
  NEW

Ordering:
- Z, A, E(level), E(gamma) ▼

Output:
- Web Page □
- Formatted File □

Uncertainties:
- Nuclear Data Sheets style □
- Standard style □

Search ▼
Reset ▼

Levels and Gammas database version of 4/11/2008
Tool for systematic studies ....

Search for the first 2+ states in selected nuclides

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>$E_{\text{level}}$(keV)</th>
<th>Jπ</th>
<th>$T_{1/2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>136Te</td>
<td>443.1</td>
<td>10</td>
<td>(2+)</td>
</tr>
<tr>
<td>140Xe</td>
<td>376.658</td>
<td>15</td>
<td>2+</td>
</tr>
<tr>
<td>142Ba</td>
<td>359.597</td>
<td>14</td>
<td>2+</td>
</tr>
<tr>
<td>144Ce</td>
<td>397.441</td>
<td>9</td>
<td>2+</td>
</tr>
<tr>
<td>146Nd</td>
<td>453.77</td>
<td>5</td>
<td>2+</td>
</tr>
<tr>
<td>148Sm</td>
<td>550.255</td>
<td>8</td>
<td>2+</td>
</tr>
<tr>
<td>150Gd</td>
<td>638.045</td>
<td>14</td>
<td>2+</td>
</tr>
<tr>
<td>152Dy</td>
<td>613.82</td>
<td>7</td>
<td>2+</td>
</tr>
<tr>
<td>154Er</td>
<td>560.8</td>
<td>1</td>
<td>2+</td>
</tr>
<tr>
<td>156Yb</td>
<td>536.4</td>
<td>1</td>
<td>2+</td>
</tr>
<tr>
<td>158Hf</td>
<td>476.36</td>
<td>11</td>
<td>2+</td>
</tr>
<tr>
<td>160W</td>
<td>609.9</td>
<td>2</td>
<td>2+</td>
</tr>
<tr>
<td>162Os</td>
<td>706.7</td>
<td>3</td>
<td>(2+)</td>
</tr>
</tbody>
</table>

[Graph showing $E(2^+)$ vs. $Z$.]
Decay Radiation Search

Specify Parent Nuclei:
- Nucleus: 232th
- Z / Element: □ □ □
- A: □ □ □
- N: □ □ □

Parent T₁/₂ condition:
- enabled ○ disabled
- 0 fs □ ≤ T₁/₂ ≤ 1E10 Gy □
- No Upper/Lower limit value

Decay Mode condition:
- enabled ○ disabled
- Decay Mode □ ANY

Radiation Type condition:
- enabled ○ disabled
- Radiation Type □ ANY

Radiation Energy condition:
- enabled ○ disabled
- 0 □ ≤ Energy (keV) ≤ 10000

Radiation Intensity condition:
- enabled ○ disabled
- 0 □ ≤ Intensity (%) ≤ 100

Ordering:
- Z, A, T₁/₂, E □

Output:
- Web Page ○ Formatted File

Uncertainties:
- Nuclear Data Sheets style ○ Standard style

Search Reset

Decay Radiation database version of 4/11/2008
<table>
<thead>
<tr>
<th>Isotope</th>
<th>Energy (keV)</th>
<th>Intensity (%)</th>
<th>Dose (MeV/Bq-s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Th</td>
<td>3311.1 14</td>
<td>0.059 13</td>
<td>0.0026 5</td>
</tr>
<tr>
<td>Th</td>
<td>3947.2 20</td>
<td>21.7 13</td>
<td>0.86 5</td>
</tr>
<tr>
<td>Th</td>
<td>4012.3 14</td>
<td>78.2 13</td>
<td>3.14 5</td>
</tr>
</tbody>
</table>

### Electrons:

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Intensity (%)</th>
<th>Dose (MeV/Bq-s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auger L</td>
<td>9.09</td>
<td>8.7 5</td>
</tr>
<tr>
<td>CE K</td>
<td>36.958 15</td>
<td>0.0060 11</td>
</tr>
<tr>
<td>CE L</td>
<td>44.573 16</td>
<td>15.8 8</td>
</tr>
<tr>
<td>CE M</td>
<td>58.988 16</td>
<td>4.27 21</td>
</tr>
<tr>
<td>CE NP</td>
<td>62.602 16</td>
<td>1.53 8</td>
</tr>
<tr>
<td>Auger K</td>
<td>65.9</td>
<td>1.9E-4 4</td>
</tr>
<tr>
<td>CE L</td>
<td>121.643 16</td>
<td>0.031 6</td>
</tr>
<tr>
<td>CE M</td>
<td>136.058 16</td>
<td>0.0084 16</td>
</tr>
<tr>
<td>CE NP</td>
<td>139.672 16</td>
<td>0.0030 6</td>
</tr>
</tbody>
</table>

### Gamma and X-ray radiation:

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Intensity (%)</th>
<th>Dose (MeV/Bq-s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XR 1</td>
<td>12.3</td>
<td>7.1 5</td>
</tr>
<tr>
<td>XR 1</td>
<td>63.81 1</td>
<td>0.263 13</td>
</tr>
<tr>
<td>XR ka2</td>
<td>85.431</td>
<td>0.0017 3</td>
</tr>
<tr>
<td>XR ka1</td>
<td>88.471</td>
<td>0.0028 5</td>
</tr>
<tr>
<td>XR kβ3</td>
<td>99.432</td>
<td>3.4E-4 6</td>
</tr>
<tr>
<td>XR kβ1</td>
<td>100.13</td>
<td>6.4E-4 12</td>
</tr>
<tr>
<td>XR kβ2</td>
<td>102.499</td>
<td>2.4E-4 5</td>
</tr>
<tr>
<td>XR 1</td>
<td>140.88 1</td>
<td>0.021 4</td>
</tr>
</tbody>
</table>

### Alphas:

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Intensity (%)</th>
<th>Dose (MeV/Bq-s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Th</td>
<td>4082.8 14</td>
<td>228 88Ra</td>
</tr>
</tbody>
</table>
Interactive Decay Scheme

### 232-Th α decay

<table>
<thead>
<tr>
<th>Level</th>
<th>Energy</th>
<th>T1/2</th>
<th>Spin-parity</th>
<th>Final Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>&lt; E(level) &lt; 225.0</td>
<td>Level Energy</td>
<td>Level T1/2</td>
<td>Level Spin-parity</td>
</tr>
<tr>
<td>Highlight:</td>
<td>Level</td>
<td>Gamma Energy</td>
<td>Gamma Intensity</td>
<td>Gamma Multipolarity</td>
</tr>
<tr>
<td>Image Height:</td>
<td>Level Width:</td>
<td>Band Spacing:</td>
<td>Plot</td>
<td>Clear</td>
</tr>
</tbody>
</table>

- **232Th** → 0
- **90Th** 142
- **Q(gs) = 4082.8 keV** 14

\[
\alpha: 100\% \quad E\alpha: 14.05E+9 \quad I\alpha: 6
\]

\[
\alpha: 100\% \quad E\alpha: 3811.1 \quad I\alpha: 0.069 \quad HF: 16
\]

\[
\alpha: 100\% \quad E\alpha: 4012.3 \quad I\alpha: 78.2 \quad HF: 1.00
\]

\[
\alpha: 100\% \quad E\alpha: 228Ra 140 \quad 0+
\]

\[
\alpha: 100\% \quad E\alpha: 63.8 \quad I\alpha: 0.55 NS
\]

\[
\alpha: 100\% \quad E\alpha: 140.9 \quad I\alpha: 0.021 \%
\]
Horizontal Evaluations and Topical Reviews

- Log $ft$ values in $\beta\text{-}(EC+b+)$ decay
- Alpha-decay HF from even-even nuclei
- Nuclear Moments ($\mu$ and $Q_0$)
- Proton Radioactivity Decay Data
- many other applications oriented ...

Nuclear Data Sheets v. 97 (2002) 241

Table of Superdeformed Nuclear Bands and Fission Isomers* Third Edition (October 2002)

Balraj Singh†, Roy Zywna‡, and Richard B. Firestone‡
† McMaster University, Hamilton, Ontario L8S 4M1, Canada (bkhoro@mcmaster.ca)
‡ Lawrence Berkeley National Laboratory, Berkeley CA 94720, USA (Alf/Berger)
The rest is in the details
Nuclear Reactions

• Here is where the world splits
• In the US we have ENDF/B-7
  • CSEWG (Cross Section Evaluation Working Group)
  • Focus on neutron cross section data.
  • Input to MCNP

• Other developed nations have their own preferred cross section data bases.
  – Europe       JEFF 3.1
  – Japan        JENDL-3.3
  – Russia       ROSFOND
The NNDC traces its roots back to 1952, when the name Brookhaven Neutron Cross Section Compilation Group was adopted for a group in the Physics Department at BNL. This group published the first edition of the well-known reference book BNL-325 (Neutron Cross Sections) in 1955.

In 1960, the Sigma Center was moved to the Reactor Physics Division of the Nuclear Engineering Department (NE) to continue this work. The Cross Section Evaluation Group was formed in the same division at about the same time.

In 1967, the two groups were merged and the new Center was designated as the National Neutron Cross Section Center (NNCSC) by the Atomic Energy Commission. Early NNDC history is described by S. Pearlstein "The NNCSC: its history and functions" Nuclear News, November 1970, 73.
What can you get for cross sections

Evaluated Nuclear Data File (ENDF) Retrieval & Plotting

New in 3.1: ROSFOND library, fission yields, pre-calculated integral quantities, improved zooming.

Select first a library, then a sublibrary and finally click on a chemical element to obtain results.
Data are available for materials with a cyan background.

Library: ENDF/B-VII.0 (USA, 2006)  Sublibrary: Neutron reactions

Database Manager: Mike Herman, NNDC, Brookhaven National Laboratory
Web and Programming: B. Pritychenko, A.A. Sonzogni, NNDC, Brookhaven National Laboratory
Data Source: CSEWG and NEA-WPEC
What other cross section data is available?

• Data for Medical Doses (MIRD)
• (EXFOR / CSISRS)
  – Compiled Nuclear Reaction Data
  – Charged Particle Data
  – Photo-nuclear data
Why do Evaluation Efforts Matter?

- Isolated Universe
  - No Standards
  - Different Universes Use Different Values
  - Loss of comparability
If no central evaluation effort existed,

What would we need?

2007DO17


The decay of proton-rich nuclei in the mass $A = 36$-$56$ region

NUCLEAR REACTIONS Ni($^{38}$Ni, X), $E=74.5$ MeV/nucleon; measured fragments isotopic yields.

RADIOACTIVITY $^{36, 37}$Ca, $^{39, 40, 41}$Ti, $^{43}$V, $^{42, 43, 44, 45}$Cr, $^{46, 47}$Mn, $^{46, 47, 48, 49}$Fe, $^{50, 51, 52, 53}$Ni, $^{55}$Cu, $^{55, 56}$Zn($\beta^+$), (EC), ($\beta^+$p) [from Ni($^{58}$Ni, X)]; measured $T_{1/2}$, $\beta$-delayed proton and $\gamma$ spectra, branching ratios. $^{43, 45}$Cr, $^{46}$Mn, $^{46, 47, 48}$Fe, $^{50}$Co, $^{50, 51, 52, 53}$Ni deduced levels. Two-proton decay observed. Comparison with model predictions.

doi: 10.1016/j.nuclphysa.2007.05.004

Data from this article have been entered in the XUNDL database. For more information, click here.

Link to article (PDF), requires subscription
Keywords, which describe article’s content
Link to data in article
Too close for comfort
The original plan was to release the next Ame+Nubase evaluations in December 2008.
Since December 2003, discussions and meetings were held to prepare the future of the evaluation program.
Unfortunately they did not lead to a serious project.
No future could thus be established for these evaluations.

After the untimely death of A.H. Wapstra, the Ame+Nubase evaluation relies on one person alone. In the absence of any additional help, an evaluation of the same quality as the 2003 edition appears impossible.

I am therefore sorry to announce that the publication of Ame2008 and Nubase2008 is cancelled.

No other evaluation of masses is planned, since I have now moved to another domain of interest.
Institute of Modern Physics, Chinese Academy of Sciences
Lanzhou, China
Area for Improvement

• Nuclear Astrophysics
  – Merger of reaction $\sigma$ and structure
  – No adopted reaction rates
Nuclear Astrophysics

- Many factions/groups
  - Different preferred data sets
- Difficult to find consensus to form “Adopted Data Sets”
- Application requires heavy computation
  - Systematic effects
  - Resonance/Interference
  - Modeling
• **NUCASTRODATA.ORG** is your WWW resource for creating, accessing, and managing nuclear physics information for astrophysics studies

• **DATASETS** Hyperlinks to all online nuclear datasets, categorized and continually updated

• **REPOSITORY** Share nuclear astrophysics files with colleagues; upload via the Infrastructure

• **INFRASTRUCTURE** A suite of codes with a graphical user interface enabling researchers to
  – calculate thermonuclear reaction rates from nuclear physics input,
  – put them into rate libraries,
  – browse and plot the rates, and
  – manage and share rate libraries with the community
  – Calculate element synthesis occurring in astrophysical environments
Areas for Great Improvement

- Hadronic & QCD Physics
  - JLab
  - RHIC
What do we want?
- Everything that we need
- Varies from person to person

What can’t we do without?
- Reference Data base
  - Indexed for searching
- Certain “Horozontal Evaluations”
  - Mass excess

What makes us better
- A coordinated effort aimed at providing users the type of data that they need to efficiently continue in their research
Acknowledgements

• US DOE Office of Science
• USNDP & NSDD
  – Filip Kondev (ANL)
  – Balraj Singh (McMaster)

• B. Pfeiffer (GSI)
• Michael Thoennessen (NSCL)