Report on Nuclear Data Section activities at IAEA

Arjan Koning

Head of Nuclear Data Section
Division of Physical and Chemical Sciences NAPC
Department for Nuclear Sciences and Applications
IAEA, Vienna

WPEC Meeting, June 27-28 2018, NEA, Paris
Nuclear Reaction Data Centres (NRDC)

13 centres from 8 countries and 2 international organisations
EXFOR: Extra effort in FY compilation

From: Shin Okumura

Fissile and reaction information were taken from CINDA.
### Statistics of the completeness

<table>
<thead>
<tr>
<th>Area</th>
<th>E-R’s list</th>
<th>Already in EXFOR</th>
<th>New entry</th>
<th>Another action</th>
<th>No action</th>
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<td>610</td>
<td>413</td>
<td>68</td>
<td>41</td>
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<td>2 OECD countries</td>
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<td>171</td>
<td>83</td>
<td>14</td>
<td>35</td>
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<tr>
<td>3 Others</td>
<td>155</td>
<td>103</td>
<td>24</td>
<td>8</td>
<td>20</td>
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<tr>
<td>4 Former Soviet Union countries</td>
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<td>69</td>
<td>15</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Not specified*</td>
<td>443</td>
<td></td>
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<td><strong>Total</strong></td>
<td><strong>1602</strong></td>
<td><strong>756</strong></td>
<td><strong>190</strong></td>
<td><strong>66</strong></td>
<td><strong>590</strong></td>
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<table>
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<th>Area</th>
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<th>Already in EXFOR</th>
<th>New entry</th>
<th>Another action</th>
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<td>248</td>
<td>26</td>
<td>17</td>
<td>30</td>
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<tr>
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<td>149</td>
<td>70</td>
<td>63</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>3 Others</td>
<td>82</td>
<td>53</td>
<td>22</td>
<td>3</td>
<td>4</td>
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<tr>
<td>4 Former Soviet Union countries</td>
<td>73</td>
<td>37</td>
<td>28</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Not specified*</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>645</strong></td>
<td><strong>409</strong></td>
<td><strong>139</strong></td>
<td><strong>34</strong></td>
<td><strong>64</strong></td>
</tr>
</tbody>
</table>

*Not specified due to private communications, Ph.D. theses, or classified reports. Also includes under checking.

**Only 924 articles are referred in the numerical data table used in the evaluation of ENDF/B-VI.

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**England-Rider’s list**

- Exist: 47%
- New: 12%
- Another action: 4%
- No action: 37%

**Mills’ list**

- Exist: 63%
- New: 22%
- Another action: 5%
- No action: 10%

**NSR (done by NNDC)**

- New entry: 212
- 44%

Including neutron-, photo- and spontaneous-fission

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From: Shin Okumura
Nuclear Structure and Decay Data

ICTP-IAEA Workshop on NSDD, 15-26 Oct. 2018
Evaluation of the Neutron Data Standards


1 National Institute of Standards and Technology, 100 Bureau Drive, Stop 8463, Gaithersburg, MD 20899-8463, USA
2 Pl. Atomsandart, State Corporation Rosatom, 117242, Moscow, Russia
3 NAPC-Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria
4 Los Alamos National Laboratory, Los Alamos, NM 87545, USA
5 Tsinghua University, Beijing, 100084, China
6 Universidad de Santiago de Compostela, Spain
7 EC-JRC-Directorate G, Unit G.2, B-2440 Geel, Belgium
8 Japan Atomic Energy Agency, Nuclear Data Center, Ibaraki 319-1195, Japan
9 Physikalisch-Technische Bundesanstalt, Org. 6.4, 38116 Braunschweig, Germany
10 Uppsala University, Uppsala, Sweden
11 SPRC/LEPh, CEA Cadarache, 13108 Saint Paul Les Durance, France
12 Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen, Germany
13 Argonne National Laboratory, Argonne, IL 60439, USA
14 China Nuclear Data Center (CNDC), China Institute of Atomic Energy, Beijing, China
15 Vera Laboratory, Faculty of Physics, University of Vienna, A-1090 Vienna, Austria
16 Dept. of Nuclear Physics, The Australian National University, Canberra ACT 0200, Australia

(Received 3 September 2017; revised received 30 October and 12 November 2017; accepted 20 November 2017)

With the need for improving existing nuclear data evaluations, (e.g., ENDF/B-VIII.0 and JEFF-3.3 releases) the first step was to evaluate the standards for use in such a library. This new standards evaluation made use of improved experimental data and some developments in the methodology of analysis and evaluation. In addition to the work on the traditional standards, this work produced the

Ongoing: Consultancy meetings on Uncertainty quantification for Standards
Photonuclear Cross Sections
Photon Strength Functions

- Radiation shielding
- Dosimetry

- Nuclear Structure
- Nuclear Astrophysics

- Reactor operation & safety
- Nuclear waste management

- Nuclear Forensics
- Homeland security
Updating the Photonuclear Data Library & Generating Reference Database for Photon Strength Functions (2016-2019)

Online database
ENDF library

Measurements
Recommendation
Compilation
Evaluation/Theory
Assessment
New results for $^{209}$Bi($\gamma$,xn)

New data: A.I. Gheorghe+ (2017)
New IAEA Photonuclear Data Library

- 200 nuclides – incl. for medical isotope production
- Energies up to 200 MeV
- New GDR parameters
- New evaluation methods – improved modelling
- Available in ENDF-6 format and user-friendly interface
- Publication in preparation

Y.-S. Cho *S370*  KAERI
D. Filipescu, I. Gheorghe  IFIN-HH
N. Iwamoto  JAEA
X. Ruirui, X. Tao *R172*  CNDC
V. Varlamov  Moscow University

Review:
R. Capote
T. Kawano
Y.-O. Lee
O. Iwamoto
Final output

Reference Database for Photon Strength Functions

S. Goriely 1, P. Dimitriou 2, M. Wiedeking 3, T. Belgya 4, R. Firestone 5, J. Kopecky 7,
M. Krtička 8, V. Plujko 9, R. Schwengner 10, S. Siem 11, H. Utsunomiya 12, S. Hilaire 13,
S. Péru 13, Y. S. Cho 16, D. M. Filipescu 15, N. Iwamoto 16, T. Kawano 6, V. Varlamov 18,
R. Xu 17

All the data will be made available from an online interactive database

…and are included in the next release of TALYS
Ongoing project

– R-matrix theory: theory to describe individual resonances in the scattering of A+B and the non-resonant background between them

– IAEA Project on inter-comparison of R-matrix codes

  (2015-present): verify codes, compare fit procedures, validate R-matrix data fits and perform evaluations

– Codes: AZURE2, AMUR, EDA, RAC, SFRESCOX, SAMMY

– Verification has concluded (European Physical Journal A, in press) – next step is comparison of evaluations
New CRP (2019-): Updating Fission Yield Data for Applications

- Objective: improve existing evaluated Fission Product Yields (FPY)
- Scope:
  - Compilation of all new FFY and FPY experimental data
  - Improve systematics and models
  - Incorporate new knowledge in FPY evaluations: correct errors and inconsistencies, update evaluations, provide reliable estimate of uncertainties
  - Agree on treatment of covariances, provide FPY covariance data and propose suitable format for inclusion in ENDF-6
  - Validation of new evaluations

- Participant countries: Belgium, China, Finland, France, Germany, India, Japan, Russia, Sweden, UK, USA
Positron Emitters

K. Gul et al., IAEA TECDOC 1211, Vienna, 2001

\[
\begin{align*}
11^C & \quad 14^N(p,\alpha)^{11}C \\
13^N & \quad 16^O(p,\alpha)^{13}N \\
18^O & \quad 15^N(p,n)^{15}O \\
13^O(n,d)^{15}O & \quad 18^F \\
18^F(n,\gamma)^{19}F & \quad \text{nat}^\text{Ne}(d,x)^{18}F \\
44^{\text{Se}} & \quad 44^{\text{Ca}(p,n)}^\text{Sc} \\
44^{\text{Ca}(d,2n)}^\text{Sc} & \quad 43^{\text{Ca}(d,n)}^\text{Sc} \\
45^{\text{Sc}(p,2n)}^\text{Ti} & \quad 45^{\text{Sc}(d,3n)}^\text{Ti} \\
52^{\text{mMn}} & \quad \text{nat}^\text{Ni}(p,x)^{52}\text{Fe} \\
55^{\text{Mn}(p,4n)}^\text{Fe} & \quad 50^{\text{Cr}(\alpha,2n)}^\text{Fe} \\
52^{\text{Cr}(p,n)}^\text{Mn} & \quad 52^{\text{Cr}(d,2n)}^\text{Mn} \\
52^{\text{Mn}} & \quad 52^{\text{Cr}(p,n)}^\text{Mn} \\
52^{\text{Cr}(d,2n)}^\text{Mn} & \quad 52^{\text{Cr}(d,2n)}^\text{Mn} \\
55^{\text{Co}} & \quad 58^{\text{Ni}(p,\alpha)}^\text{Co} \\
54^{\text{Fe}(d,n)}^\text{Co} & \quad 56^{\text{Fe}(p,2n)}^\text{Co} \\
61^{\text{Cu}} & \quad 61^{\text{Ni}(p,n)}^\text{Cu} \\
60^{\text{Ni}(d,n)}^\text{Cu} & \quad 64^{\text{Zn}(p,\alpha)}^\text{Cu} \\
62^{\text{Cu}} & \quad 63^{\text{Cu}(p,2n)}^\text{Zn} \\
62^{\text{Cu}(d,3n)}^\text{Zn} & \quad 62^{\text{Ni}(p,n)}^\text{Cu} \\
62^{\text{Ni}(d,2n)}^\text{Cu} & \quad 66^{\text{Ga}} \\
66^{\text{Zn}(p,n)}^\text{Ga} & \quad 66^{\text{Cu}(\alpha,n)}^\text{Ga} \\
68^{\text{Ga}} & \quad 68^{\text{Zn}(p,n)}^\text{Ga} \\
68^{\text{Cu}(\alpha,n)}^\text{Ga} & \quad \text{nat}^\text{Ga}(p,x)^{68}\text{Ge} \\
69^{\text{Ga}(p,2n)}^\text{Ge} & \quad 72^{\text{As}} \\
75^{\text{As}(p,4n)}^\text{Se} & \quad \text{nat}^\text{Br}(p,\alpha)^{72}\text{Se} \\
75^{\text{Br}(p,\alpha)}^\text{Ge} & \quad \text{nat}^\text{Ge}(p,x)^{72}\text{As} \\
73^{\text{As}(d,3n)}^\text{As} & \quad 76^{\text{Br}} \\
76^{\text{Se}(p,n)}^\text{Br} & \quad 77^{\text{Se}(p,2n)}^\text{Br} \\
76^{\text{As}(\alpha,3n)}^\text{Br} & \quad 82^{\text{mRb}} \\
82^{\text{Kr}(p,n)}^\text{Rb} & \quad 82^{\text{mRb}} \\
82^{\text{Kr}(d,2n)}^\text{Rb} & \quad \text{nat}^\text{In}(p,x)^{110}\text{Sn} \\
82^{\text{Kr}(p,n)}^\text{In} & \quad 108^{\text{Cd}(\alpha,2n)}^\text{In} \\
82^{\text{Kr}(d,2n)}^\text{In} & \quad 106^{\text{Cd}(d,2n)}^\text{In} \\
82^{\text{mRb}} & \quad 107^{\text{Ag}(\alpha,n)}^\text{In} \\
85^{\text{Rb}(p,4n)}^\text{Sr} & \quad 85^{\text{Rb}(p,4n)}^\text{Sr} \\
86^{\text{Sr}(p,n)}^\text{Y} & \quad 88^{\text{Sr}(p,3n)}^\text{Y} \\
86^{\text{Y}} & \quad 85^{\text{Rb}(\alpha,3n)}^\text{Y} \\
89^{\text{Y}(p,n)}^\text{Zr} & \quad 89^{\text{Y}(d,2n)}^\text{Zr} \\
89^{\text{Y}} & \quad 93^{\text{Nb}(p,x)}^\text{Nb} \\
89^{\text{Nb}} & \quad 89^{\text{Y}(\alpha,3n)}^\text{Nb} \\
94^{\text{mTc}} & \quad 94^{\text{mTc}} \\
92^{\text{Mo}(\alpha,x)}^\text{Tc} & \quad 94^{\text{Mo}(p,n)}^\text{Tc} \\
110^{\text{mIn}} & \quad 110^{\text{mIn}} \\
115^{\text{Sn}(\alpha,n)}^\text{Te} & \quad 116^{\text{Sn}(p,2n)}^\text{Te} \\
115^{\text{Sn}} & \quad \text{nat}^\text{Sb}(p,x)^{118}\text{Te} \\
115^{\text{Sn}(d,x)}^\text{Te} & \quad \text{nat}^\text{Sb}(p,x)^{118}\text{Te} \\
120^\text{I} & \quad 120^\text{Te}(p,n)^{120}\text{I} \\
122^\text{Te}(p,3n)^{120}\text{I} & \quad 122^\text{I} \\
124^\text{Xe}(p,x)^{122}\text{Xe} & \quad 127^\text{I}(p,6n)^{122}\text{Xe} \\
127^\text{I}(d,7n)^{122}\text{Xe} & \quad 128^\text{Cs} \\
133^\text{Cs}(p,6n)^{128}\text{Ba} & \quad 140^\text{Pr} \\
141^\text{Pr}(p,2n)^{146}\text{Nd} & \quad 141^\text{Pr}(d,3n)^{146}\text{Nd} \\
141^\text{Pr} & \quad \text{nat}^\text{Ce}(^{3}\text{He},x)^{140}\text{Nd}
\end{align*}
\]
Medical Isotope Browser
- Based on TENDL + IAEA medical isotope database
- Release: Oct 2019 at IAEA radiopharmaceutical symposium

- Product: TC 99m
- Projectile: p, D, α, T, 3He
- Target: MO 100
- Density [g/cm³]: 0 < 1, 1 < 100

- Thickness [cm]: 0 < 1, 1 < 10
- Exit energy [MeV]: 0 < 15, 15 < 200
- Incident energy [MeV]: 0 < 35, 35 < 200
- Incident energy scan [MeV]: from 10 to 30, ΔE = 1

- Current [μA]: 0 < 100, 100 < 10,000
- Irradiation time 1d: 0< 1 y, 1 d, 0< 1 h, 0< 1 m, 0< 1 s
- Post EOB time 1d: 0< 1 y, 1 d, 0< 1 h, 0< 1 m, 0< 1 s

Graph:
- Activity [MBq]
- Time [h]

- TC 99m
- Mo 97
- Mo 98
- Mo 99
- Mo 100
- Mo 101
- Tc 97m
- Tc 97g
- Tc 97
- Tc 98
- Tc 98g
- Tc 99
- Tc 99g
- Tc 99m
- Tc 100
- Tc 101
Status of INDEN evaluations

On behalf of the INDEN collaboration
Uranium-238 - Status

New information from integral testing since ENDF/B-VIII.0 release & publications

Criticality performance: any new/unexpected findings? No
Neutron transmission: any new/unexpected findings? PFNS 5-8 MeV
(n,xn) activations: any new/unexpected findings? No

Known deficiencies/gaps:
- Ongoing ChiNu experiments to precisely measure PFNS. The current set of data will be completed within a year or two, and should impact next ENDF
- An updated $^{238}$U resonance analysis (JRC EC Geel)
- (n,n’g) experiment & eval. – BNL/LLNL
- FPY, DN, Decay energy, PFGS, would benefit from various upgrades

An important ENDF/B-VIII.0/CIELO trend in $^{238}$U(n,inl) confirmed by CEA Cadarache adjustment studies (see G. Rimpault present., WONDER 2018)

Agreement in the plateau within quoted 7% uncertainties in ENDF/B-VIII.0 evaluation!!
IAEA Uranium-238 CIELO evaluation - Validation

CIAE benchmarks, slabs, 14MeV n + $^{238}$U

Excellent performance of U-238 evaluation confirmed!
Uranium-235 - Status

New information from integral testing since ENDF/B-VIII.0 release & publications

Criticality performance: any new/unexpected findings? No

Neutron transmission: any new/unexpected findings? No

\((n,xn)\) activations: any new/unexpected findings? No

Known deficiencies/gaps:

- Ongoing evaluations of ChiNu experiments to be used (low energy “scission” neutrons \(\sim 0.05n/fission \sim 2\%\) to be added as model defect to MN model??)

- New thermal PFNS exp. in agreement with \(\langle E \rangle\)

- Small 1% nubar fluctuations confirmed (Gook et al)

- Measured \((n,2n)\) SACS validated \(^{235}\text{U}(n_{th},f)\) PFNS (>8 MeV) \((n,2n)\) on \(^{169}\text{Tm}, ^{90}\text{Zr}, ^{89}\text{Y}, ^{127}\text{I}, ^{23}\text{Na}, ^{19}\text{F}, ^{59}\text{Co}, ^{55}\text{Mn}, ^{197}\text{Au}\) (Rez \(^{252}\text{Cf(sf)}+\text{LR0 reactor, on-going @ ILL reactor Grenoble})

- An updated URR evaluation of fission cross section (no criticality change)

\[^{235}\text{U}(n,f)\] URR

- RPI quasi-int/ exp. to verify fission, elastic/inelastic

- Inelastic and \((n,2n)\) discrepancies with CEA/DAM evaluation being further studied

- FPY, DN, Decay energy, PFGS, would benefit from various upgrades

\[ p_s(E) = p_0 \frac{E}{T_0} \exp \left( -\frac{E}{T_0} \right) \]

Excess neutrons from 2-FF models

\[ \langle \text{E}_{sc}^{PFNS} \rangle = 0.9 \text{ MeV} \]

\(^{239}\text{Pu}(n,f)\) PFNS

\[ n/\text{sr}/\text{fiss} \] En(MeV)
Other

- Yearly Technical meeting on nuclear data processing, including all ongoing processing code projects in the world
- INDEN on Light elements (in combination with R-matrix code development) and structural materials.
- FENDL library
- Technical Meeting on Nuclear Data Structure Network (NSDD)
- Technical Meeting on anti-neutrino spectra and their applications
- Technical Meeting on nuclear data for medical applications
Thank you!