Correction of Capture Data from the ORELA 40 m Flight Station

(N. Otsuka, 2017-04-21, Memo 4C-3/407)

There was an error in the computer codes processing neutron capture yields measured at the ORELA 40 m flight station. Correction factors applied to their capture yields were published in 1981-1982 [1,2]. Though the capture kernel (resonance strength), resonance width and average capture cross section do not depend on the correction factors linearly, the authors mention that

> "Our experience so far indicates that for individual resonances the percentage correction to be applied to resonance capture areas can differ by as much as one-third of the percentage correction indicated in Table I. This implies that the factors shown in Table I can be used to correct resonance capture areas and radiation widths (except for the three extreme case mentioned above) with an uncertainty of not more than ~5%" [1]
>
> "The correction to resonance capture areas, radiation width, and average capture cross sections is in principle nonlinear because of sample thickness effects. However, an uncertainty of less than a few percent will result from the direct application of the correction factors. [2]".

Motivated by discussion with Dr. K. Shibata on the ~7% difference in the capture kernels between Macklin's data in EXFOR and JENDL-4.0 for ^{93}Nb (**Appendix 2**), I checked the general situation of the affected EXFOR entries (**Appendix 1**), and observer that:

1. The corrigendum is cited in all area 3 entries, but not cited in many area 1 entries.
2. Average group-wise capture cross sections in EXFOR are revised with the correction factors in Refs.[1,2] for all cases affected by the problem. The corrections have been done by the authors for ^{66,68}Zn, ^{104,105,106,108,110}Pd, ^{165}Ho and ^{232}Th by the authors, but by the centres for the other cases.
3. Resonance widths and capture kernels are not revised except for ^{232}Th for which the correction factor is large (1.1131) and the resonance parameters revised by the authors are in EXFOR.
4. Maxwellian spectrum averaged cross sections (MACS) are not revised except for ^{95,96,97,98}Mo for which NNDC found in 2012 that MACS obtained by reassessment of the capture yield data sets are published in 1987, and the revised MACS were added to the EXFOR entry by NNDC and NDS. (N.B. Karlsruhe evaluation [3] applies the corrections factors in Refs.[1,2] to the MACS in the original publications.)

Macklin mentions in Ref.[1] that "We are working with the Brookhaven National Center for Neutron Cross Section Data to have all cross sections and resonance parameters reported by us since 1972 brought up to date.", but we do not see its evidence in these EXFOR entries.

Compilation of data corrected by other than authors is allowed only when they are published in a peer-reviewed journal (NRDC2014 C30). Under this restriction, I think we should indicate the problem in the affected EXFOR entries more clearly, for example,

1. Addition of the corrigendum under REFERENCE.
2. Addition of STATUS=OUTDT to each data subentry.
3. Clear indication of the correction factors (*e.g.*, COMMENT, CRITIQUE, REL-REF) in each data subentry.

It would be useful for some users to have the correction factors in the EXFOR data correction system (see Viktor Zerkin's slides presented in NRDC 2015) so that the users can apply the correction factors easily. Addition of the correction factors to the correction system could be a task for evaluators rather than compilers because the relation between the capture yield (for which we have the correction factor from the author) and the quantities in EXFOR (e.g., average cross section, MACS, capture kernel, capture width) is not linear, and it is not trivial for compilers to judge if the correction factor is applicable to the EXFOR data set.

References

[1] R.L. Macklin, R.R. Winters, Nucl. Sci. Eng. **78** (1981) 110.
[2] B.J. Allen, J.W. Boldeman, R.L. Macklin, Nucl. Sci. Eng. **82** (1982) 230.
[3] R.L. Mackiln, Nucl. Sci. Eng. **59** (1976) 12.

Appendix 1: Summary of EXFOR entries compiling the ORELA data sets discussed in Refs.[1-2]

- Factor: Correction factors in Refs.[1,2]
- Ref: Reference numbers in Refs.[1,2]
- References: References cited in Refs.[1,2]
- Cite: x means the corrigendum is under REFERENCE of the EXFOR entry
- EXFOR: C following the entry number means that the comment on the correction is in the common subentry (001).
- $<\sigma_\gamma>$: Subentry numbers of group-wise capture cross sections
- Γ, $g\Gamma_n\Gamma_\gamma/\Gamma$: Subentry numbers of resonance widths and capture kernels
- MACS: Subentry numbers of Maxwellian spectrum averaged cross sections
- (!: no comment about correction, c: comment given, r: corrected by NNDC or NDS, R: corrected or reanalysed by authors (or corrected but not explicitly written who corrected it), o: no correction required, d: digitized data with comment but uncertain if corrected.)

[1] NSE,78,110,1981									
Target	**Factor**	**Ref**	**References**	**Cite**	**EXFOR**	**$<\sigma_\gamma>$**	**Γ, $g\Gamma_n\Gamma_\gamma/\Gamma$**	**MACS**	**Remark**
24Mg	0.9325	1	J,PR/C,14,1328,1976		10791		006!,007!	003cd	
25Mg	0.9325	1	J,PR/C,14,1328,1976		10791		008!	004cd	
26Mg	0.9325	1	J,PR/C,14,1328,1976		10791		009!	005cd	
32S	1.1131	2	J,PR/C,21,545,1980		10455		002!		
33S	0.9850	3	J,PR/C,12,1126,1975		10534C		002!		
51V	1.0360	4	J,PR/C,18,2092,1978		10813C		003!,004!,005!,006!	008!	
55Mn	0.9507	5	J,PR/C,18,2079,1978		10752	004r	003!		
63Cu	0.9507	6	J,PR/C,15,615,1977		10726C		002!		002.2: SF3: EL -> G
65Cu	0.9507	6	J,PR/C,15,615,1977		10726C		003!		003.2: SF3: EL -> G
64Zn	0.9850	7	J,PR/C,23,683,1981		10963		003!,004!		
66Zn	0.9507	8	J,PR/C,24,1922,1981		12719	003R	004!,005!,007!		

68Zn	0.9507	8	J,PR/C,25,1808,1982		10982	005R	002!,003!	006!	Citation wrong in Corrigendum. 006: AV -> MXW; EN -> KT
93Nb	1.0737	9	J,NSE,59,12,1976		10537	002r,003r,004r,005r	006!,007!		
92Mo	0.9507	10	J,PR/C,7,1532,1973		10748C		004!,005!		
100Mo	0.9507	11	J,PR/C,20,115,1979		10773C		002!		
100Ru	0.9850	12 13	J,NSE,73,174,1980 C,79BOLOGN,,103,1979		10875	012r	002!		Add C,79BOLOGN,,103,1979
101Ru	0.9850	12 13	J,NSE,73,174,1980 C,79BOLOGN,,103,1979		10875	013r	004!		Add C,79BOLOGN,,103,1979
102Ru	0.9850	12 13	J,NSE,73,174,1980 C,79BOLOGN,,103,1979		10875	014r	006!		Add C,79BOLOGN,,103,1979
104Ru	0.9850	12 13	J,NSE,73,174,1980 C,79BOLOGN,,103,1979		10875	016r	010!		Add C,79BOLOGN,,103,1979
103Rh	0.9507	12 13	J,NSE,73,174,1980 C,79BOLOGN,,103,1979		10875	015r	008!		Add C,79BOLOGN,,103,1979
104Pd	0.7999	13 14	C,79BOLOGN,,103,1979 J,NSE,71,182,1979	x	10868	007R	002c		Add C,79BOLOGN,,103,1979
105Pd	1.1131	13 14	C,79BOLOGN,,103,1979 J,NSE,71,182,1979	x	10868	008R	003c		Add C,79BOLOGN,,103,1979
106Pd	0.7734	13 14	C,79BOLOGN,,103,1979 J,NSE,71,182,1979	x	10868	009R	004c		Add C,79BOLOGN,,103,1979
108Pd	0.7480	13 14	C,79BOLOGN,,103,1979 J,NSE,71,182,1979	x	10868	010R	005c		Add C,79BOLOGN,,103,1979
110Pd	0.7480	13 14	C,79BOLOGN,,103,1979 J,NSE,71,182,1979	x	10868	011R	006c		Add C,79BOLOGN,,103,1979
159Tb	1.0737	15	J,PR/C,17,522,1978		10758		003!		
165Ho	1.1131	16	J,NSE,59,231,1976	x	10531	002R	006R		
169Tm	1.0737	17	R,LA-7479-MS,1978	x	10873	002r	005R		
186Os	0.8990	18	J,PR/C,21,563,1980		10882	002r			
187Os	0.9430	18	J,PR/C,21,563,1980		10882	003r			
188Os	0.9700	18	J,PR/C,21,563,1980		10882	004r			
197Au	1.0001	19	J,PR/C,11,1270,1975		10432	002r,003r	004!		
203Tl	0.9507	20	J,AJ,208,812,1976		10602	005r	002!,003!		

206Pb	1.0360	21	J,PR/C,19,335,1979		10842C		002!,004!		
207Pb	0.9655	22	J,PRL,39,598,1977		10700C		002!,003!		
209Bi	1.0360	23	J,PR/C,14,1389,1976		10610	006r	002!,003!		
232Th	1.1131	24	J,NSE,64,849,1977		10554	002R,003R,004R	005R,006R,009!		

[2] J,NSE,82,230,1982

Target	Factor	Ref	References	Cite	EXFOR	$<\sigma_\gamma>$	Γ, $g\Gamma_n\Gamma_\gamma/\Gamma$	MACS	Remark
23Na	1.0360	2	C,78HARWELL,,426,1978	x	30385		002!		
27Al	1.0000	2	C,78HARWELL,,426,1978	x	30414		002o		
28Si	1.0000	3 4	J,NP/A,252,62,1975 J,NP/A,334,269,1980	x	30330		002o,003o		
29Si	1.0000	3 4	J,NP/A,252,62,1975 J,NP/A,334,269,1980	x	30330		004o		
30Si	1.0000	3 4	J,NP/A,252,62,1975 J,NP/A,334,269,1980	x	30330		005o		
40Ca	1.0000	5	J,NP/A,259,365,1976	x	30395		002o	004o	Citation wrong in Corrigendum.
42Ca	1.0000	6	J,NP/A,279,317,1977	x	30356	003o	002o,004o		
43Ca	1.0000	6	J,NP/A,279,317,1977	x	30356	006o	005o,007o		
44Ca	1.0000	6	J,NP/A,279,317,1977	x	30356	009o	008o,010o		
45Sc	1.0737	7	J,AUJ,30,605,1977	x	30381	007r	002!,003!,004!	005!	
46Ti	0.9833	8 9	R,AAEC-E-402,1977 C,77GEEL,,447,1977	x	30359C	005r	002!,006!	003!	
47Ti	0.9833	8 9	R,AAEC-E-402,1977 C,77GEEL,,447,1977	x	30359C	010r	007!,011!	008!	
48Ti	1.0360	8 9	R,AAEC-E-402,1977 C,77GEEL,,447,1977	x	30359C	015r	012!,016!	013!	
49Ti	0.9833	8 9	R,AAEC-E-402,1977 C,77GEEL,,447,1977	x	30359C	020r	017!,021!	018!	
50Ti	1.0000	8 9	R,AAEC-E-402,1977 C,77GEEL,,447,1977	x	30359C	025o	022o,026	023o	
50Cr	1.0737	9	C,77GEEL,,447,1977	x	30393	006r	002!,003!,004!,005!	007!	

		10	R,AAEC-E-400,1977						
52Cr	1.0737	9 10	C,77GEEL,,447,1977 R,AAEC-E-400,1977	x	30393	012r	008!,009!,010!,011!	013!	
53Cr	1.0737	9 10	C,77GEEL,,447,1977 R,AAEC-E-400,1977	x	30393	018r	014!,015!,016!,017!	019!	
54Cr	1.0737	9 10	C,77GEEL,,447,1977 R,AAEC-E-400,1977	x	30393	024r	020!,021!,022!,023!	025!	
54Fe	1.0000	9 11	C,77GEEL,,447,1977 J,NP/A,283,37,1977	x	30355	007o	006o,010o	008o	
56Fe	1.0000	9 12	C,77GEEL,,447,1977 J,NP/A,269,408,1976	x	30355	003o	002o,005o	004o	
57Fe	1.0360	9 13	C,77GEEL,,447,1977 C,77GEEL,,476,1977	x	30424	004r	002!,003!	005!	005: SPA -> MXW
58Fe	0.9655	14	J,JP/G,6,381,1980	x	30486	004r	002!,003!	005!	
86Sr	1.0000	15	J,AUJ,35,267,1982	x	30487	002o	004o,008o	003o	
87Sr	1.0000	15	J,AUJ,35,267,1982	x	30487	005o	007o,009o	006o	
88Sr	1.0737	16	J,NP/A,269,397,1976	x	30369	005r	002!,003!	004!	
89Y	1.0360	17	J,NSE,64,744,1977	x	30391	006r	002!,003!	005!	
90Zr	0.967(16)	18	J,NP/A,246,1,1975	x	30329	004r	002!,003!	005!	STATUS of 005 incorrect
91Zr	1.0000	19	J,AUJ,30,391,1977	x	30423	005o	002o,004o	006o	
92Zr	0.9833	20	J,NP/A,269,31,1976	x	30358	007r	002!,004!	006!	
94Zr	0.9833	20	J,NP/A,269,31,1976	x	30358	013r	008!,010!	012!	
92Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	004r	002!,003!	028!	
92Mo	0.9833	22	J,PR/C,7,1532,1973		10748C		004!,005!		
94Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	007r	005!,006!	029!	
95Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	010r	008!,009!	024!,031R,035R	031 must supersede 024.
96Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	013r	011!,012!	025!,032R,036R	032 must supersede 025.
97Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	016r	014!,015!	026!,033R,037R	033 must supersede 026.
98Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	019r	017!,018!	027!,034R,038R	034 must supersede 027.
100Mo	0.9833	21	J,NP/A,270,108,1976	x	30357	022r	020!,021!	030!	

106Cd	0.9850	23	J,JP/G,5,771,1978	x	30453	005r	002!,003!	004!	004: SPA -> MXW
108Cd	0.9850	23	J,JP/G,5,771,1978	x	30453	009r	006!,007!	008!	008: SPA -> MXW
110Cd	0.9833	23	J,JP/G,5,771,1978	x	30453	013r	010!,011!	012!	012: SPA -> MXW
111Cd	1.2080	24	J,PR/C,7,780,1973		10746		002!		
111Cd	1.2080	25	C,78HARWEL,449,1978	x	30488	002r	004!	003!	
112Cd	1.0069	23	J,JP/G,5,771,1978	x	30453	017r	014!,015!	016!	016: SPA -> MXW
113Cd	1.0187	24	C,78HARWEL,449,1978	x	30488	005r	007!	006!	
114Cd	1.0187	23	J,JP/G,5,771,1978	x	30453	021r	018!,019!	020!	020: SPA -> MXW
116Cd	1.0187	23	J,JP/G,5,771,1978	x	30453	025r	022!,023!	024!	024: SPA -> MXW
134Ba	0.9833	26	J,NP/A,256,173,1975	x	30328	013r	002!,003!	004!	
135Ba	0.9833	27	R,AAEC-E-237,1974	x	30293	004r	002!,003!	005!	
136Ba	0.9833	26	J,NP/A,256,173,1975	x	30328	014r	005!,006!	010!	
137Ba	0.9833	28	J,AUJ,29,157,1976	x	30328	015r	011!,012!	017!	
138Ba	0.9833	29	J,AUJ,32,213,1979	x	30328	016r	007!,008!	009!	
139La	1.0737	30	J,AUJ,30,599,1977	x	30384	004r	002!,003!	005!	
140Ce	1.0000	29	J,AUJ,32,213,1978	x	30361	005o	002o,003o	004o	
141Pr	1.0737	31	J,AUJ,32,551,1979	x	30490	004r	002!,003!	005!	
142Nd	0.967(16)	32	R,AAEC-E-401,1977	x	30360	005r	002!,003!	004!	
143Nd	0.9507	32	R,AAEC-E-401,1977	x	30360	009r	006!,007!	008!	
144Nd	0.967(16)	32	R,AAEC-E-401,1977	x	30360	013r	010!,011!	012!	
145Nd	0.9507	32	R,AAEC-E-401,1977	x	30360	017r	014!,015!	016!	
146Nd	0.9833	32	R,AAEC-E-401,1977	x	30360	021r	018!,019!	020!	
148Nd	0.9833	32	R,AAEC-E-401,1977	x	30360	025r	022!,023!	024!	
204Pb	1.0737	33	J,PR/C,8,1504,1973		10155		007!,011!		
206Pb	1.0000	33	J,PR/C,8,1504,1973		10155		008o,013o		
206Pb	1.0737	34	P,AAEC-PR-46,16,1980	x	30386		002!	003!	003: SPA -> MXW; EN-DUMMY=45 keV ->

						KT= 30 keV
207Pb	1.0000	33 35	J,PR/C,8,1504,1973 C,71KNOX,2,764,1971	10155	009o,015o	
208Pb	1.0000	33 36	J,PR/C,8,1504,1973 P,AAEC-PR-43,36,1977	10155	010o,018o	
209Bi	1.0000	36	P,AAEC-PR-43,36,1977	30450	002o,003o	

Appendix 2:

Comparison of ^{93}Nb resonance parameters in ORELA [4], JENDL-4.0 and ENDF/B-VII.1

JENDL-4.0: $g\Gamma_n$ are from Table II of [4] (except for the 2641 and 5902 keV resonances), and the capture kernels are ~1.073 [1] times higher than those in Table I of [4].
ENDF/B-VII: $g\Gamma_n$ and Γ_γ are from Table II of [4] without any corrections (except for the 4069 eV resonance).

	ORELA [4]	JENDL-4.0						J4/ORELA	ENDF-B/VII.1						E71/ORELA
Er	gΓn Γγ/Γ	J	Γtot	Γn	Γγ	gΓn	gΓn Γγ/Γ	gΓn Γγ/Γ	J	Γtot	Γn	Γγ	gΓn	gΓn Γγ/Γ	gΓn Γγ/Γ
eV	eV		eV	eV	eV	eV	eV			eV	eV	eV	eV	eV	eV
2641	0.0914	4	2.785	2.547	0.239	1.146	0.0981	1.0737	4	3.549	3.356	0.193	1.510	0.0821	0.8985
2953	0.0565	4	0.704	0.522	0.182	0.235	0.0607	1.0736	4	0.669	0.522	0.147	0.235	0.0516	0.9136
3359	0.0560	5	0.447	0.191	0.256	0.105	0.0601	1.0737	5	0.429	0.191	0.238	0.105	0.0583	1.0404
3396	0.0683	4	1.268	1.076	0.192	0.484	0.0734	1.0749	4	1.234	1.076	0.158	0.484	0.0620	0.9077
3525	0.0743	4	1.092	0.869	0.223	0.391	0.0798	1.0736	4	1.051	0.869	0.182	0.391	0.0677	0.9113
3675	0.1157	5	2.067	1.809	0.258	0.995	0.1242	1.0737							
3763	0.0645	4	0.691	0.460	0.231	0.207	0.0693	1.0738	5	0.552	0.376	0.176	0.207	0.0660	1.0226
3977	0.1017	5	1.016	0.746	0.271	0.410	0.1092	1.0737	5	1.014	0.746	0.269	0.410	0.1088	1.0696
4069	0.0927	5	1.732	1.527	0.205	0.840	0.0995	1.0737	5	1.661	1.454	0.206	0.800	0.0992	1.0699
4557	0.1173	4	1.687	1.333	0.354	0.600	0.1259	1.0736	5	0.398	0.109	0.289	0.060	0.0436	0.3714
4599	0.0848	4	3.460	3.244	0.216	1.460	0.0911	1.0737	4	3.422	3.244	0.178	1.460	0.0759	0.8954
5153	0.1808	5	4.711	4.327	0.384	2.380	0.1941	1.0737	4	5.676	5.289	0.387	2.380	0.1623	0.8975
5550	0.0580	5	0.932	0.800	0.132	0.440	0.0623	1.0737	4	1.110	0.978	0.132	0.440	0.0523	0.9022
5659	0.0653	5	0.969	0.818	0.151	0.450	0.0701	1.0737	4	1.152	1.000	0.152	0.450	0.0594	0.9093
5691	0.0917	4	2.377	2.133	0.244	0.960	0.0985	1.0737	5	1.946	1.745	0.201	0.960	0.0991	1.0810
5902	0.0748	4	1.240	1.024	0.216	0.461	0.0803	1.0735	4	2.140	1.978	0.162	0.890	0.0674	0.9008

6003	0.1010	5	2.994	2.782	0.212	1.530	0.1084	1.0737	5	2.996	2.782	0.214	1.530	0.1093	1.0821
6051	0.0873	5	1.594	1.400	0.194	0.770	0.0937	1.0735	4	1.906	1.711	0.195	0.770	0.0788	0.9023
6114	0.0656	5	0.970	0.818	0.152	0.450	0.0704	1.0735	5	0.970	0.818	0.152	0.450	0.0705	1.0747
6412	0.0497	5	0.401	0.236	0.165	0.130	0.0534	1.0738	5	0.396	0.236	0.160	0.130	0.0525	1.0559
6427	0.0807								5	1.579	1.400	0.179	0.770	0.0873	1.0817
6532	0.0979	5	3.005	2.800	0.205	1.540	0.1051	1.0736	4	3.629	3.422	0.207	1.540	0.0878	0.8972
6571	0.0742	4	1.599	1.396	0.203	0.628	0.0797	1.0739	4	1.563	1.396	0.167	0.628	0.0671	0.9046
6634	0.1554	4	3.033	2.600	0.433	1.170	0.1669	1.0738							
6714	0.0922	5	1.134	0.909	0.224	0.500	0.0990	1.0736	4	1.335	1.111	0.224	0.500	0.0839	0.9098
7244	0.1433	5	2.592	2.273	0.319	1.250	0.1539	1.0737	5	2.593	2.273	0.320	1.250	0.1543	1.0766
Remark						**~ORELA**					**=ORELA**		**~ORELA**		