Status Report of Subgroup 19 to the NEANSC WPEC

May 2003

Activation cross-sections

Coordinator: A.J.M. Plompen, IRMM

The report covers the work that was carried out from May 2002 until April 2003.

This report is the last status report. The mandate of subgroup 19 was for two years starting January 2001. It therefore formally ended December 2002. To mark this ending a workshop was held January 13 and 14, 2003 at IRMM in Geel, Belgium. Below a brief account will be given of this workshop. The report starts with the usual account of progress by the participants for the above mentioned period and ends with the status and time schedule for the final report.

Progress

Progress is listed by the laboratory leading the activity. At the end a table is given that summarizes the status of measurements of the collaboration in the context of the subgroup.

ANL D.L. Smith

- D.L. Smith compiled the data of the IRMM measurement campaigns since 2000 in Exfor format. Files submitted last year to the NEA databank for all reactions on V and Tc99 have appeared with accession numbers 22656 and 22655. Files have been submitted for reactions on Ni and on Pb isotopes and files were prepared for the work on Co and on Cu. The Pb file has appeared as accession number 22680. Files on Co and Cu are on hold at IRMM/INRNE for final checks of the measurement data, the file on Ni is on hold at NEA and requires feedback from IRMM/INRNE.
- Provided data are delivered timely, exfor files will be compiled for the remaining reactions that were studied by the subgroup (ANL-IRMM-FZ-Juelich-INRNE-U.o.Debcrecen, collaboration). These primarily concern a large number of reactions on Mo and Zr isotopes and some recent measurements at Debrecen at 14 MeV.
- For the compilation of the Cr reactions a new error was found in entry 22406 subsection 003 line 34 and subsection 002 line 32. The reported energy of 21.7+/-0.5 MeV should be 21.07+/-0.5 MeV. This new error remains to be reported to NEA. The error that occurred in entry 22438 for the reaction specifier of the Cr-50 reaction was acknowledged by NEA (Mark Kellett) and a modified file was submitted by NEA for inclusion in Exfor. However, this file has not appeared yet.
- Papers were drafted for the January 2003 workshop on the compilation of activation data for exfor and on the method of correction for low energy neutrons for the IRMM measurements for 3 and in particular 4 MeV incident deuterons on solid Ti/T targets. These will appear in the proceedings. The table summarizing the status of measured cross sections in the context of the subgroup is added as an appendix in updated form.

IRMM/FZ-Jülich/ANL/INRNE/U.o.Debrecen, A.J.M. Plompen, P. Reimer, S.M. Qaim, D.L. Smith, V. Semkova, F. Cserpak

- Measurements on Pb isotopes were completed by V. Semkova and presented as a Jeff report at several workshops. As indicated above, the data were compiled in exfor format by D.L. Smith, submitted to NEA and have appeared in the Exfor data base.
- The effort for isotopes of Ni, Cu and Co was completed. The status is described in IRMM report GER/NP/1/2003/02/03, Geel, 2003 by V. Semkova that concerns the work she has done in her two years stay at IRMM. A publication is being prepared. A considerable addition was made to the knowledge of (n,xp) reactions, the production of ^{60}Co from Ni and Cu, and the knowledge of the isomer ratios of reactions leading to ^{58}Co and ^{60m,g}Co.
- The study of a considerable number of reactions on Zr isotopes was completed. Here, again the systematics of (n,xp) reactions could be studied with the aid of the enriched samples on loan from Drs. Y. Ikeda and Y. Kasugai. Results were reported by V. Semkova in the January workshop and at the recent Jeff meeting, see Jef-doc-963 and IRMM report GER/NP/1/2003/02/03, Geel, 2003.
- Three data points for the ^{58}Ni(n,x)^{56}Co have been completed by V. Semkova. The measurements have been presented in Jef-doc-963 and in
- The study of the I-129 sample was completed for the analysis of the iodine content and the I-127/I-129 mass ratio. There remains an uncertainty on the exact lead content that will hopefully be resolved later this year at the Budapest reactor based PGAA facility. Preliminary result for measurements on I-129, I-127, the Ag isotopes have been presented at the January workshop. A 14 MeV data point will be added for I-129 by measurements to be done at Debrecen. For Ag measurements have already been carried out at FZ-Jülich.
- For the study of the ^{14}N(n,p)^{14}C reaction cross section irradiations have been performed at IRMM for energies above 14 MeV, and at the Juelich reactor for the creation of a ^{14}C dilution series. A setup was constructed at FZ Juelich for the separation of ^{14}C from the AlN sample. The setup was tested and separations were carried out for the October-November measurement campaign. Additional irradiations are ongoing. Results are expected by the end of 2003.
- A paper is in preparation together with V. Avrigeanu and A. Filatenkov for the work that was reported in abbreviated form at the ND2001 conference for the Mo isotopes.
- A paper is in preparation for the work on Ni and Co isotopes.

NIPNE: V. Avrigeanu, M. Avrigeanu, and T. Glodariu

The modeling efforts at "Horia Hulubei", IFIN-HH (NIPNE), concentrate on the consideration of partial wave pre-equilibrium effects within the geometry dependent hybrid model, the angular momentum distribution of the nuclear level density, and the alpha-particle optical model. In addition, Gamma-ray strength functions have been given special attention for the reactions that were studied on isotopes of Mo, Ni and Co. These issues are addressed in the context of fully consistent nuclear physics modeling of the reactions with a unified use of parameters for all involved nuclides and the use of all experimental information that is relevant to fix all parameters involved. Work was supported by the Euratom-Nasti association contract and by a 3 month stay of VA at IRMM as scientific visitor.

- Analysis of fast-neutron induced reaction analysis for Mo isotopes: As reported last year, the comparison of the calculated and available experimental excitation functions has shown a good agreement in the limit of experimental errors for the reactions. This comparison with the Geel data at the ND2001 conference could be considered a blind exercise and thus proves the accuracy of the approach. In the reporting period the calculations were redone, while now taking the Geel measured data into account. In view of the cross sections with isomeric final states, the gamma-ray strength function was addressed. The energy-dependent Breit-Wigner was adapted using $F_{SR}=\Gamma_{\gamma 0}^{exp}/\Gamma_{\gamma 0}^{EDBW}$. This was checked by comparison with measured average capture cross sections for ^{93}Nb and $^{92,94-98,100}$Mo and the approach yielded good agreement with the data. For the activation cross sections, generally, the (n,2n), (n,p) and (n,a) reactions are well described, while the situation is more complicated for (n,np+pn+d) reactions.

- Modeling of reaction on isotopes of Ni and ^{59}Co: The approach described in the midterm report was further elaborated and has resulted in excellent description of the available measured activation cross sections. Additional attention was devoted to the study of (n,xα) reactions on ^{58}Ni and ^{60}Ni. Overall a good agreement was obtained. A paper is being compiled that describes the modeling together with the measurements that were done at IRMM.
- Double-folding method calculation of nuclear potential for complex particles.
  In the reporting period, the initial work described in the midterm report was extended to include additional nuclides in the A~100 region for energies between 13.5 and 35 MeV. Measured alpha-particle scattering data were included for ^{89}Y, ^{90,91}Zr, ^{92,94,96,98,100}Mo, ^{107}Ag and ^{116,122,124}Sn. In this work the real part of the α-OMP is determined by the double-folding approach and best agreement is obtained using the DDM3Y-Paris effective nucleon-nucleon interaction and the Tanihata density distribution for the alpha particle. The imaginary α-OMP is determined empirically with care to obtain a well-defined energy dependence. This energy dependence is used to correct the real potential via the dispersion relation. Good description of the data is obtained without renormalization of the real part of the potential. The approach to the real potential was also tested for Helium scattering. This and similar work by others for other mass regions indicates that a generally viable approach to the entire mass table could emerge, that would be a welcome addition to neutron data production codes. On the other hand it was also demonstrated in Bucharest that a purely phenomenological real potential can be obtained with the imaginary part fixed as above that result in an even better fit to the data.

University of Debrecen: S. Sudar, J. Csikai, R. Doczi, F. Cserpak

- Results of the measurement campaign at 14 MeV have been presented at the January workshop. The following reactions have been studied at 14.60±0.15 MeV at the Institute of Experimental Physics of the University of Debrecen: ^{19}F(n,p)^{19}O 21.5±1.1 mb, ^{31}P(n,α)^{28}Al 135.8±7.0 mb, ^{50}Ti(n,p)^{50}Sc 13.28±0.82 mb, 54Cr(n,p)54V 18.0±3.3 mb, ^{62}Ni(n,p)^{62}Co 21.92±2.5 mb, 208Pb(n,p)208Tl 0.90±0.15 mb. In addition, the following reactions were studied were studied with the cyclotron of the Institute for Nuclear Research (ATOMKI): ^{100}Mo(n,2n)^{99}Mo, ^{51}V(n,p)^{51}Ti, ^{45}Sc(n,α)^{42}K and ^{28}Si(n,p)^{28}Al using the DD reaction for neutron energies between 7.5 and 12.5 MeV. In addition, the dosimetry reaction ^{115}In(n,γ)$^{116m1+m2}$In was studied in the energy range from 25 keV until 12.4 MeV was studied using γ,n sources and the Li(p,n) and DD reactions at the ATOMKI cyclotron.
- S. Sudar has performed model calculations using Stapre and Empire-II for the reactions on I-127,129 and Ag-107,109 that have been studied experimentally by F. Cserpak at IRMM. Problem areas where data are required have been identified. Sensitivity of predicted cross sections to different parameter sets have been studied. Sometimes large differences between the Stapre and Empire-II calculations have been found the understanding of which would benefit from an

exchange of ideas with the author of Empire-II. A preliminary comparison with the data.

- Charged-particle induced activation cross sections for applications: In a collaboration between Tohoku University, the Insitute of Experimental Research and the institute of Nuclear Research, and the Free University of Brussels medium energy protons and deuterons are being used to study activation cross sections between 21 and 70 MeV on Ta, Pd, Zn, Pt, Fe, W. The stacked foil technique is used. First irradiations have been performed and method development is under way.

Tohoku University: M. Baba

- The work described in the midterm report is still in progress. In particular, attention must be devoted to the deconvolution of the contribution of low energy neutrons.
- Note the final bullet under "University of Debrecen". A considerable part of the work, notably in particular the irradiations, is being done at the Cyrix laboratory of the University of Tohoku.

JAERI: K. Shibata
The model calculations performed at JAERI by K. Shibata were communicated to the workshop in January 2003. The work concerns the following reaction cross sections from threshold to 20 MeV: $^{23}Na(n,2n)^{22}Na$, $^{27}Al(n,2n)^{26}Al$, $^{52}Cr(n,2n)^{51}Cr$, $^{60}Ni(n,p)^{60}Co$ and $^{186}W(n,2n)^{185}W$.

NRG: A. Koning
A. Koning has communicated a data base with Talys calculations using default parameters only for comparison with activation cross sections. This work was used for comparison with the Ni measurements mentioned above.

UKAEA: R. Forrest
R. Forrest has communicated a data base with EAF-03 evaluations for easy comparison with measured data. See below.

Workshop of the OECD-NEA WPEC subgroup 19 on Activation Cross Sections 13 and 14 January 2003 IRMM, Geel, Belgium

The contributors to subgroup 19 of the NEA-NSC WPEC were invited to present their achievements in the context of the subgroup. Since the subgroup's activities were to be finalized within 3 months following the meeting, the deliverables have been discussed as well as the form of the final contributions to the report.
The meeting brought together the participants and the interested parties (one subgroup monitor, evaluators and data file maintainers of the EAF and JEF library and nuclear reaction specialists). The meeting agenda is appended in annex.
All participants were able to get a complete overview of all the efforts that have taken place in the context of this subgroup. In addition, they committed to give their final contributions in time for completion of the final report. The schedule for the final report was foreseen to be end of August (see however the note below). The final report will be given on a CD together with the written contributions and the slide shows presented at the workshop. In addition the CD will contain the measured data

in the form of Exfor files submitted or to be submitted to NEA and in the form of tabular ascii files. In the same tabular format the modeling curves/evaluations will be presented, that have been carried out in the context of the workgroup. It was also concluded that it would be desirable to have a systematic graphical comparison between the newly measured data, Talys calculations, EAF-2003 and possibly also JENDL3.

At the workshop, the issues of sensitivity studies and predictability of reaction cross sections using model calculations were addressed in some detail. Participants to the subgroup showed their efforts in determining sensitivity curves for continuous variations of the most important parameters in the various model calculations. This primarily concerned level density parameters. Note that an earlier work of K. Shibata (OECD/GD(94)21, Paris 1994) addressed this procedure for optical model parameters. In particular, the use of uncertainty bands based on known parameter uncertainties allows to state which cross sections can be predicted within a given accuracy. The requested uncertainties would then indicate where additional measurements are required. The method presupposes the existence of a parameter data base with known uncertainties and is correct to the extent that continuous uncorrelated changes of model parameters are sufficient.

However, since essentially all issues in nuclear modeling are still under debate, one must also consider the impact of discrete model changes, e.g. those dependent on the choice of the formalism to handle optical models, level densities, pre-equilibrium treatment and gamma-decay widths. Here one also expects eventually advances in nuclear modeling will have an impact on the issue of predictability and uncertainties, in the sense that through physical guidance unphysical changes in the calculations will be reduced. Presentations by M. Avrigeanu, E. Bauge, S. Goriely, S. Hilaire, and A. Koning helped to shed some light on these issues. In conclusion, (semi-)microscopic modeling is needed for reliability of predictions far from the region where measured data exist. Uncertainties in that case can be 50% or worse. For nuclides, near the valley of stability where parametrizations can be benchmarked, global parametrizations should be better than that, typically from 20% for main channels such as (n,n), (n,2n), (n,p) reactions and well determined parameters to 50% in worse cases. Local parametrizations lead in favorable cases to predictions with accuracies on the 10% level. These statements can not be applied to complex particle emissions. There more work needs to be done, even if good results were obtained for alpha-particles by the Bucharest group. Although semi-microscopic optical models were shown to give promising results, local and global phenomenological optical models still yield better description of the experimental data. Accurate (semi-)microscopic nuclear level densities are still an active field of research, where now enhanced computing power allows to study the different aspects more elaborately, than before. Ultimately this will lead to more reliable and accurate nuclear level densities and a better understanding of which parametrizations should be used under which circumstances. However, at present this work is still in an exploratory phase.

Final report and schedule for completion

Originally the final report was foreseen by the end of August 2003. Participants were asked to hand in their final results by end of March 2003. Broadly speaking this deadline was achieved, with some exceptions. Some numerical measurement data are still lacking, therefore some data compilations could not be completed. The main problem is, however, the drafting of the final report and the compilation of the final CD. For the latter, the numerical tables have to be prepared as well as the systematic comparison with the new evaluations of EAF-2003, Talys and JENDL3.3. Here the subgroup coordinator has still a major job to do. His schedule has developed in such a way that December 2003 appears to be a more realistic deadline for the final report.

Annexes

1) Agenda of the meeting of January 13 and 14, 2003.
2) Summary table of compilation of measurements.

Annex I

Workshop of the OECD-NEA WPEC subgroup 19 on Activation Cross Sections

13 and 14 January 2003

IRMM, Geel, Belgium

time	Speaker	Title/Activity
		13 January ***Morning session***
8:30		Departure mini-bus Hotel Corbie - IRMM
9:00	E. Anklam	Opening
9:05	A. Plompen	Subgroup goals, activities and schedule
9:45	D.L. Smith (AP)	Compilation of measured activation cross sections
10:15		Coffee Break
10:30	R.A. Forrest	Using experimental data to improve EAF-2001
11:00	J. Kopecky	Integral experiments for EAF-2003
11:30	J.Ch. Sublet	EAF Decay Power Experimental Validation
12:00	P. Reimer	Excitation functions for neutron-induced reactions on Mo, Tc and Pb in the energy range from 0.5 to 20.4 MeV
12:30		Lunch Break
		13 January ***Afternoon session***
14:00	V. Semkova	Measurements of neutron-induced activation reaction cross-sections on different isotopes of Co, Ni, Cu, Zr, and Pb from threshold to 20 MeV
15:00	D.L. Smith (AP)	Corrections for low energy neutrons by spectral indexing
15:30		Coffee break
15:45	R. Dóczi J. Csikai	Validation of neutron reference activation libaries
16:15	F. Cserpák	Excitation functions of (n,2n), (n,p) and (n,a) reactions on iodine isotopes
16:45 45 min.	A. Filatenkov	Activation cross section measurements at KRI: Yesterday, Today and ...?
17:45		Departure mini-bus IRMM – Hotel Corbie
		14 January ***Morning session***
8:30		Departure mini-bus Hotel Corbie - IRMM
9:00	A. Fessler	Neutron activation cross-section measurements, calculations and parameter sensitivities for Chromium isotopes, - A review
9:30	V. Avrigeanu	Report on EAF related tools
10:00	S. Sudár	Model calculations and experimental data
10:30		Coffee Break
10:45	E. Bauge	A new model based evaluation of Europium isotopes
11:15	A. Koning	Predicting activation cross sections with Talys
11:45	S. Goriely	Microscopic models for practical applications
12:15		Lunch Break

14 January ***Afternoon session***		
14:00	S. Hilaire	Developments and prospects in level density modeling for nuclear applications
14:30	M. Avrigeanu	Semi-microcopic optical potentials for applications
15:00	J. Csikai	Proton activation cross sections measured at Tohoku University
15:30	A. Plompen	Summary of activities at JAERI and Tohoku University
15:45		Coffee Break
16:00		Discussion on Achievements
16:30		Discussion on Future
17:15		Closure
17:30		Departure mini-bus IRMM – Hotel Corbie

Annex II. Status of Subgroup 19 experimental data compilation activity

Reaction	Measured Quantity	Energy Range (MeV)	Data Status	Accession Number
19F(n,p)19O	*CS*	*16-20*	*j,x*	*22414.002*
23Na(n,p)23Ne	*CS*	*16-20*	*j,x*	*22414.003*
23Na(n,α)20F	*CS*	*16-20*	*j,x*	*22414.004*
25Mg(n,p)25Na	*CS*	*16-20*	*j,x*	*22414.005*
27Al(n,p)27Mg	*CS*	*16-20*	*j,x*	*22414.006*
28Si(n,p)28Al	*CS*	*16-20*	*j,x*	*22414.007*
29Si(n,p)29Al	*CS*	*16-20*	*j,x*	*22414.008*
29Si(n,np+d)28Al	*CS*	*16-20*	*j,x*	*22414.009*
31P(n,α)28Al	*CS*	*16-20*	*j,x*	*22414.010*
35Cl(n,2n)34Cl	*CS*	*16-20*	*j,x*	*22414.011*
37Cl(n,p)37S	*CS*	*16-20*	*j,x*	*22414.012*
46Ti(n,p)46Sc	*CS*	*16-20*	*j,x*	*22414.013*
50Ti(n,p)50Sc	*CS*	*16-20*	*j,x*	*22414.014*
51V(n,p)51Ti	*CS*	*16-20*	*j,x*	*22414.015*
51V(n,p)51Ti	CS	15.0-16.1	*j,x*	*22656.004*
51V(n,α)48Sc	CS	11.7-20.5	*j,x*	*22656.003*
NatV(n,xnα)47Sc	CS	11.7-20.5	*j,x*	*22656.002*
49Cr(n,x)49V	*CS*	*14-19*	*j,x*	*22483.002*
50Cr(n,np+d)49V	CS	14-19	*j,c,r,x*	*22465.002*
50Cr(n,np+d)49V	*CS*	*14-19*	*c,r,x*	*22406.009*
52Cr(n,2n)51Cr	*CS*	*14-19*	*j,c,r,x*	*22406.002*
52Cr(n,p)52V	*CS*	*9.3-21*	*j,c,r,x*	*22406.003*
53Cr(n,p)53V	*CS*	*12-21*	*j,c,r,x*	*22406.004*
53Cr(n,np+d)52V	*CS*	*16-20*	*j,c,r,x*	*22406.005*
54Cr(n,p)54V	*CS*	*16-20*	*j,c,r,x*	*22406.006*
54Cr(n,np+d)53V	*CS*	*16-20*	*j,c,r,x*	*22406.007*
54Cr(n,α)51Ti	*CS*	*16-20*	*j,c,r,x*	*22406.008*
55Mn(n,α)52V	*CS*	*16-20*	*j,x*	*22414.016*
54Fe(n,2n)53Fe	*CS*	*15-21*	*r.x*	*22440.002*
54Fe(n,np+d)54Mn	*CS*	*16-20*	*r,x*	*22440.003*
56Fe(n,p)56Mn	*CS*	*16-20*	*j,x*	*22414.017*
57Fe(n,p)57Mn	*CS*	*16-20*	*j,x*	*22414.019*
57Fe(n,np+d)56Mn	*CS*	*16-20*	*j,x*	*22414.018*
59Co(n,2n)58Co	CS	13.3-20.7	xs	*None*
59Co(n,2n)58Co	IR	15.3-19.3	xs	*None*
59Co(n,2n)58mCo	IR	15.3-19.3	xs	*None*
58Ni(n,p)58Co	CS	1.3-20.3	xs	*None*
58Ni(n,p)58Co	IR	0.7-19.3	xs	*None*
58Ni(n,p)58mCo	CS	0.7-19.3	xs	*None*
58Ni(n,np+d)57Co	*CS*	*14-19*	*j,x*	*22438.004*
58Ni(n,np+d)57Co	CS	14.8-20.3	xs	*None*
58Ni(n,2n)57Ni	CS	14.8-20.3	xs	*None*
58Ni(n,α)55Fe	*CS*	*13-19*	*j,c,r,x*	*22438.003*
58Ni(n,α)55Fe	*CS*	*5.4-9.5*	*j,c,r,x*	*22438.006*
58Ni(n,α)55Fe	*CS*	*7.5-19*	*j,c,r,x*	*22406.*
58Ni(n,αp+pα)54Fe	CS	14.2-19.4	j,r,x	*22465.004*
60Ni(n,p)60Co	CS	13.3-19.9	xs	*None*
60Ni(n,p)60mCo	CS	15.3-20.3	xs	*None*
60Ni(n,p)60Co	IR	15.3-20.3	r	*None*
61Ni(n,p)61Co	CS	14.8-19	r	*None*
61Ni(n,np+d)60mCo	CS	16.3-19.3	r	*None*
62Ni(n,np+d)61Co	CS	15.3-19	r	*None*
62Ni(n,α)59Fe	*CS*	*13-19*	*j,c,r,x*	*22438.005*

62Ni(n,α)59Fe	*CS*	*6.4-9.5*	*j,c,r,x*	*22438.007*
62Ni(n,α)59Fe	*CS*	*13-19*	*j,c,r,x*	*22438.012*
63Cu(n,α)60Co	CS	13.3-19.9	xi	*None*
90Zr(n,p)90mY	CS	18-20.6	r	*None*
90Zr(n,α)87mSr	CS	18-20.6	r	*None*
91Zr(n,p)91mY	CS	16.3-19	r	*None*
91Zr(n,np+d)90mY	CS	16.3-19	r	*None*
92Zr(n,p)92Y	CS	16.3-19	r	*None*
92Zr(n,np+d)91mY	CS	16.3-19	r	*None*
94Zr(n,p)94Y	CS	14.8-20	w	*None*
94Zr(n,α)91Sr	CS	14.8-20	w	*None*
93Nb(n,2n)92mNb	*CS*	*16-20*	*j,x*	*22414.021*
93Nb(n,α)90mY	*CS*	*16-20*	*j,x*	*22414.020*
92Mo(n,p)92mNb	CS	16.2-20.5	r,j	*None*
92Mo(n,2n)91mMo	CS	16.1-20.5	r,j	*None*
92Mo(n,α)89mZr	CS	16.1-20.5	r,j	*None*
94Mo(n,p)94Nb	CS	14.5-20.3	r,j	*None*
94Mo(n,2n)93mMo	CS	16.2-20.5	r,j	*None*
95Mo(n,p)95mNb	CS	16.2-20.5	r,j	*None*
96Mo(n,p)96Nb	CS	16.2-20.6	r,j	*None*
96Mo(n,np+d)95mNb	CS	16.2-20.6	r,j	*None*
97Mo(n,p)97mNb	CS	16.2-20.5	r,j	*None*
97Mo(n,p)97Nb	CS	16.2-20.6	r,j	*None*
97Mo(n,np+d)96Nb	CS	16.2-20.6	r,j	*None*
98Mo(n,p)98mNb	CS	16.2-20.5	r,j	*None*
98Mo(n,np+d)97mNb	CS	16.1-20.6	r,j	*None*
98Mo(n,np+d)97Nb	CS	16.2-18.0	r,j	*None*
100Mo(n,2n)99Mo	CS	16.2-20.5	r,j	*None*
100Mo(n,α)97Zr	CS	16.2-20.5	r,j	*None*
99Tc(n,n')99mTc	*CS*	*0.5-20.6*	*r,x*	*22655.004*
99Tc(n,p)99Mo	*CS*	*8.6-20.4*	*r,x*	*22655.003*
99Tc(n,α)96Nb	*CS*	*8.6-20.4*	*r,x*	*22655.002*
119Sn(n,p)119mIn	*CS*	*16-20*	*j,x*	*22414.022*
138Ba(n,2n)137mBa	*CS*	*16-20*	*j,x*	*22414.023*
natPb(n,xp)204Tl	CS	18-20.5	r,x	*22680.009*
204Pb(n,n')204mPb	CS	3.5-20.6	c,x	*22680.005*
204Pb(n,2n)203mPb	CS	16.1-20.3	c,x	*22680.006*
204Pb(n,2n)203Pb	CS	18.0-20.5	c,x	*22680.007*
204Pb(n,3n)202mPb	CS	18.1-20.5	c,x	*22680.008*
206Pb(n,α)203Hg	CS	16.2-20.5	c,x	*22680.003*
206Pb(n,3n)204mPb	CS	18.1-20.7	c,x	*22680.004*
208Pb(n,p)208Tl	CS	14.8-20.5	c,x	*22680.002*

CS: cross section
IR: isomer ratio
j: data published in a journal.
r: data available from a report.
c: data presented at a conference.
x: file archived in the EXFOR system.
xs: file submitted to NEA Data Bank but not yet archived in the EXFOR system.
xi: EXFOR file in preparation.
e: experimental work completed but results not yet reported.
w: experimental work in progress.