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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

# Progress Report to The International Nuclear Data Committee

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May 1981

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# The International Nuclear Data Committee

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PROGRESS REPORT TO INDC

FROM AUSTRIA

May 1981

G. WINKLER, Editor

This report contains abstracts about work performed at

Institut für Radiumforschung und Kernphysik der
Österreichischen Akademie der Wissenschaften, Wien

Atominstitut der Österreichischen Universitäten, Wien

Institut für Experimentalphysik der Universität Wien

Institut für Radiumforschung
und Kernphysik der österr.
Akademie d. Wissenschaften,
Boltzmanngasse 3,
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INSTITUT FÜR RADIUMFORSCHUNG UND KERNPHYSIK DER
ÖSTERREICHISCHEN AKADEMIE DER WISSENSCHAFTEN, WIEN
Boltzmanng. 3, A-1090 Wien, Austria.

## 1. Precise absolute measurement of the $^{27}Al(n,\alpha)^{24}Na$ cross-section with 14.65 MeV neutrons

G. Winkler, V.D. Huynh *

The reaction $^{27}Al(n,\alpha)^{24}Na$ is in discussion as a potential candidate for a neutron cross section standard and fluence monitor, especially in the 14 MeV region. The cross section for this reaction has been remeasured in this energy region by activation with an accuracy of 0.9% (effective standard deviation) using the source reaction $^{3}H(d,n)^{4}He$ at an incident deuteron energy of 140 keV. The associated particle method was used to determine the neutron fluence. Corrections were applied for scattered alpha-particles, contamination of the alpha-spectrum by protons from the reaction $^{2}H(d,p)^{3}H$, and contributions from (n,α)- and (n,p)-reactions in the silicon surface barrier detector used for the detection of the associated alpha-particles. The absorption and scattering of neutrons by the target backing, the target holder, the beam line and the sample mounting system were taken into account. The induced $^{24}Na$ gamma-activity was measured using the $4\pi\gamma$-method with an absolutely calibrated 12.7 cm x 12.7 cm NaI(Tl) well-type detector. The result obtained is 112.2 $\pm$ 1.0 mb for an average neutron energy of 14.65 $\pm$ 0.02 MeV and a spread of about $\pm$ 0.14 MeV ($\pm$ FWHM/2) of the incident neutron energy distribution. It is planned to submit a detailed paper to Z. Physik for publication.

## 2. Precision measurement of the $^{27}Al(n,\alpha)^{24}Na$ cross section relative to the cross section of $^{197}Au(n,2n)^{196}Au$ in the energy range from 13.70 to 14.42 MeV

H. Friedmann

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* Bureau International des Poids et Mesures, Sevres, France

Using activation techniques the cross section for the reaction $^{27}Al(n,\alpha)^{24}Na$ was determined relative to the cross section of $^{197}Au(n,2n)^{196}Au$ with an accuracy of 0.3% in the energy region mentioned above. Normalizing these data to four absolute data of other authors, the excitation function could be determined to an accuracy of 0.7%. No Ericson fluctuations could be observed using the $^{3}H(d,n)^{4}He$ reaction as source reaction with its inherent neutron energy width. The work has been submitted for publication to Z. Physik.

## 3. Measurement of the average activation cross section for the reaction $^{63}Cu(n,\alpha)^{60}Co$ in the spontaneous fission neutron field of Californium-252 *

G. Winkler, V. Spiegel **, C.M. Eisenhauer **, D.L. Smith ***

The average cross section for the reaction $^{63}Cu(n,\alpha)^{60}Co$ has been measured absolutely in the $^{252}Cf$ spontaneous fission neutron field by activation in compensated flux geometry with an accuracy of $\sim$ 2.4% ($1\sigma$). A near-point source of $^{252}Cf$ and a light mass source-detector assembly in a low scattering environment was used. The resulting cross section value 0.709 $\pm$ 0.017 mb was compared with calculated values obtained by convoluting the spectral distribution of $^{252}Cf$ neutrons with existing energy-differential data for the reaction $^{63}Cu(n,\alpha)^{60}Co$. There is very good agreement (within 5%) between the experimental and the calculated average cross section if the results from a recent measurement of the $^{63}Cu(n,\alpha)^{60}Co$ excitation function are used [1]. Thus the reaction $^{63}Cu(n,\alpha)^{60}Co$, which is an important threshold reaction in reactor dosimetry, fulfills the conditions for a Category I neutron-dosimetry reaction for fission reactor applications. This work is to be published in Nucl. Sci. Eng.

[1] G. Winkler, D.L. Smith and J.W. Meadows, Nucl. Sci. Eng. 76, 30 (1980)

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* Work supported by the U.S. Department of Energy

** U.S. National Bureau of Standards, Washington, D.C.

*** Argonne National Laboratory, Argonne, USA

## 4. Precise measurement of cross sections for the $^{90}Zr(n,2n)^{89}Zr$ reaction from threshold to 20 MeV *

A. Pavlik, G. Winkler, H. Vonach

Work is going to be completed on measuring the excitation function for the reaction $^{90}Zr(n,2n)^{89}Zr$ from 12.3 MeV to 19.5 MeV in steps of 0.2 to 0.8 MeV using activation techniques. The reaction $T(d,n)^4He$ was employed as neutron source reaction. Neutron fluences were determined by means of a proton-recoil telescope at zero degrees and the differential neutron production cross sections. Additionally in the energy range 13.4 MeV to 14.8 MeV measurements were performed in smaller energy steps (0.04 to 0.15 MeV) relative to the well known cross sections for the reference reaction $^{27}Al(n,\alpha)^{24}Na$. Activity measurements were done with a 12.7 cm x 12.7 cm NaI(Tl) well-type detector. A final evaluation of the $^{90}Zr(n,2n)^{89}Zr$ excitation function in the above mentioned energy region is planned combining the new data with a recent evaluation of previously existing data.(1)

(1) S. Tagesen, H. Vonach and B. Strohmaier, Physics Data 13-1, (1979), ed. Fachinformationszentrum Karlsruhe, ISSN 0344-8401

## 5. Evaluation of the cross-sections for the reaction $^{27}Al(n,\alpha)^{24}Na$

S. Tagesen and H. Vonach

The cross-sections for the important dosimetry reaction $^{27}Al(n,\alpha)^{24}Na$ were evaluated in the neutron energy range from threshold to 20 MeV.
All data sets were critically reviewed and obviously erroneous data sets were disregarded. If necessary, the data were renormalized in order to take into account adjustments

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* In cooperation with the Central Bureau for Nuclear Measurements, Van de Graaff Laboratory, Geel, Belgium

in corresponding standard cross-sections and decay schemes.
Cross-section values were evaluated for energy groups between 0.1 MeV and 1.5 MeV wide, the width depending on both the slope of the excitation function and the density of the available data points.
For each evaluated cross-section also an uncertainty (on a 1σ confidence level)was derived taking into account the errors given by the experimentalists and the general consistency of the experimental data. In addition relative correlation matrices were derived for the evaluated excitation function describing the correlations between the uncertainties of the cross-sections at different energies. The results of this evaluation agree with the recent ENDF/B-V evaluation within the uncertainty limit given for the two evaluations. However, due to the considerably extended data base the uncertainties of the evaluated cross-sections for this work are much smaller than those given in the ENDF/B-V covariance file.
Strong arguments are presented, that in the energy range 13.5 - 14.7 MeV the $^{24}Al(n,\alpha)$ cross-section is known within an accuracy of about 0.5%. Therefore it can be recommended as the best cross-section standard for that energy region.

The results of the evaluation have been submitted to and accepted for publication by Physics Data and will be available from the Fachinformationszentrum Karlsruhe, 7514 Eggenstein-Leopoldshafen, Germany within about 3 months.

## 6. Evaluation of the cross sections for the reactions $^{19}F(n,2n)^{18}F$, $^{31}P(n,p)^{31}Si$, $^{93}Nb(n,n')^{93m}Nb$ and $^{103}Rh(n,n')^{103m}Rh$

B. Strohmaier, S. Tagesen and H. Vonach

This work described in the last progress report has been published in Physics Data: B. Strohmaier, S. Tagesen and H. Vonach, Physics Data No. 13-2 (1980), ISSN 0344 8401,

available at Fachinformationszentrum Karlsruhe, 7514 Eggenstein-Leopoldshafen 2, Germany.

## 7. Application of a small cylindrical multiwire proportional chamber for measurements of differential α-production cross-sections in the $^{50}Cr(n,x\alpha)$ and $^{93}Nb(n,x\alpha)$ reactions

C. Derndorfer, R. Fischer, P. Hille and H. Vonach

The final analysis of the measurements described in the last progress report has been completed and the results for $^{50}Cr$ have been submitted for publication to Zeitschrift für Physik. A publication on the Niobium results is being prepared. The final analysis of the data deviates slightly from the preliminary results reported in the last report.
Our final results concerning the total α-production cross-sections at 14.1 MeV are:

$$^{50}Cr(n,x\alpha) = 76.4 \pm 9.0 \text{ mb}$$
$$^{90}Nb(n,x\alpha) = 9.5 \pm 1.4 \text{ mb}$$

Measurements of the $^{56}Fe$ and $^{60}Ni(n,x\alpha)$ energy and angular distributions are planned for this summer.

## 8. Measurement of the $^{93}Nb(n,\alpha)^{90}Y$ and $^{93}Nb(n,n\alpha)^{89m}Y$ cross-section in the 14 MeV region

G. Winkler, H. Bak, R. Fischer

Work has been started to measure total alpha-production cross-sections for Niobium by activation techniques. The results are to be compared with differential alpha-production data to check normalization procedures (see also contribution No. 7 of this progress report). As the first step a technique is developed to measure the cross section for the reaction $^{93}Nb(n,\alpha)^{90g}Y$, which leads to a practically pure beta-emitter. A flow-through proportional counter will be used for the

quantitative determination of the beta-activity induced in Niobium foils with 20 mm diameter.

## 9. Measurement of the angle-integrated secondary neutron spectra from interaction of 14 MeV neutrons with medium and heavy nuclei

H. Vonach, A. Chalupka, F. Wenninger and G. Staffel

This work described in last year's report has been published in the proceedings of the Brookhaven Symposium on fast neutron cross-sections from 10-50 MeV: Symp. on Neutron Cross-Sections from 10 to 50 MeV, Brookhaven National Laboratory, Upton, N.Y., May 12-14,1980, Ed. M.R. Bhat and S. Pearlstein, Report BNL-NCS-51245, Vol. II of II, or INDC(USA)-84/L, p. 343 (1980).
The preliminary numerical values of the neutron production cross-sections given on page 8 of the last (1980) progress report have not been changed and are thus identical with those in the final publication.

## 10. Calculation of neutron induced cross-sections for $^{52}Cr$, $^{55}Mn$, $^{56}Fe$ and $^{58,60}Ni$ for energies up to 30 MeV

W.L. Reiter, B. Strohmaier and M. Uhl

The cross-sections are calculated within the frame of the statistical model taking into consideration preequilibrium decay. By simultaneously reproducing the available experimental data it is attempted to find a set of consistent model parameters which can be used to calculate unknown cross-sections in this mass region.

## 11. Calculation of the fission cross-sections for $^{237}Np$

H. Bak, B. Strohmaier and M. Uhl

First- and higher chance fission cross-sections for neutron energies up to 20 MeV are calculated by means of the computer code STAPRE.

## 12. Calculation of neutron induced cross-sections for $^{93}Nb$

B. Strohmaier

In connection with a recent (n,α) measurement (see contribution No. 7) at the IRK, neutron induced reaction cross-sections were calculated within the frame of the statistical model using a parameter set which reproduces the recent (n,α) measurement as well as other data from the literature.

## 13. Analysis of evaporation spectra from the reactions $^{64,66,68}Zn(p,\alpha)$ induced by 15 MeV protons

B. Strohmaier, M. Uhl, G. Staudt *, H.G. König *

Alpha-particle emission spectra from the reactions $^{64}Zn(p,\alpha)$, $^{66}Zn(p,\alpha)$ and $^{68}Zn(p,\alpha)$ have been measured between $30^{\circ}$ and $150^{\circ}$. The results were compared with the spin-dependent statistical model including rough estimates for isospin and preequilibrium effects. A parameter set was deduced which also describes the competing proton- and neutron emission reasonably well. The work has been published in Nucl. Phys. A349 (1980) 141.

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## 1. TRANSMISSION OF POLARIZED NEUTRONS THROUGH ORIENTED $^{165}$Ho AND $^{159}$Tb TARGETS

K.P.Schneider, H.W.Weber, C.Stassis[1)]

Single crystals of Ho and Tb were magnetized into saturation and cooled to mK-temperatures, in order to achieve significant nuclear orientations (∿80%). Transmission experiments of polarized neutrons allow then to deduce the spin-dependent neutron cross sections.
The results, which refer to thermal neutrons and were obtained at a neutron energy of 18 meV, are summarized in the Table, the definition of symbols agrees with the theoretical treatment given by Schermer /1/. A further evaluation of the data in terms of spin-dependent scattering lengths is in progress.

/1/ R.I. Schermer: Phys. Rev. 130, 1907 (1963)

Table of Results on Neutron Cross Sections (barn)

| | $\sigma_{oT}$ | $\sigma_{pT}$ | $\sigma_{ps,int}$ | $\sigma_T^+$ | $\sigma_T^-$ |
|---|---|---|---|---|---|
| Ho | 97±3 | -19.8±2.1 | 2.4±1.4 | 117±4 | 71.3±3 |
| Tb | 43.4±1 | 10.8±0.7 | 3.1±0.2 | 54.2±1 | 25.5±0.8 |

| | $\sigma_{coh}$ | $\sigma_{incoh}$ | $\sigma_{Ps}$ | $\sigma_{Pa}$ |
|---|---|---|---|---|
| Ho | 8.8±1.5 | (4±1) | -1.8±1.2 | 21.7±1.3 |
| Tb | 6.7±0.9 | (0.005) | - | - |

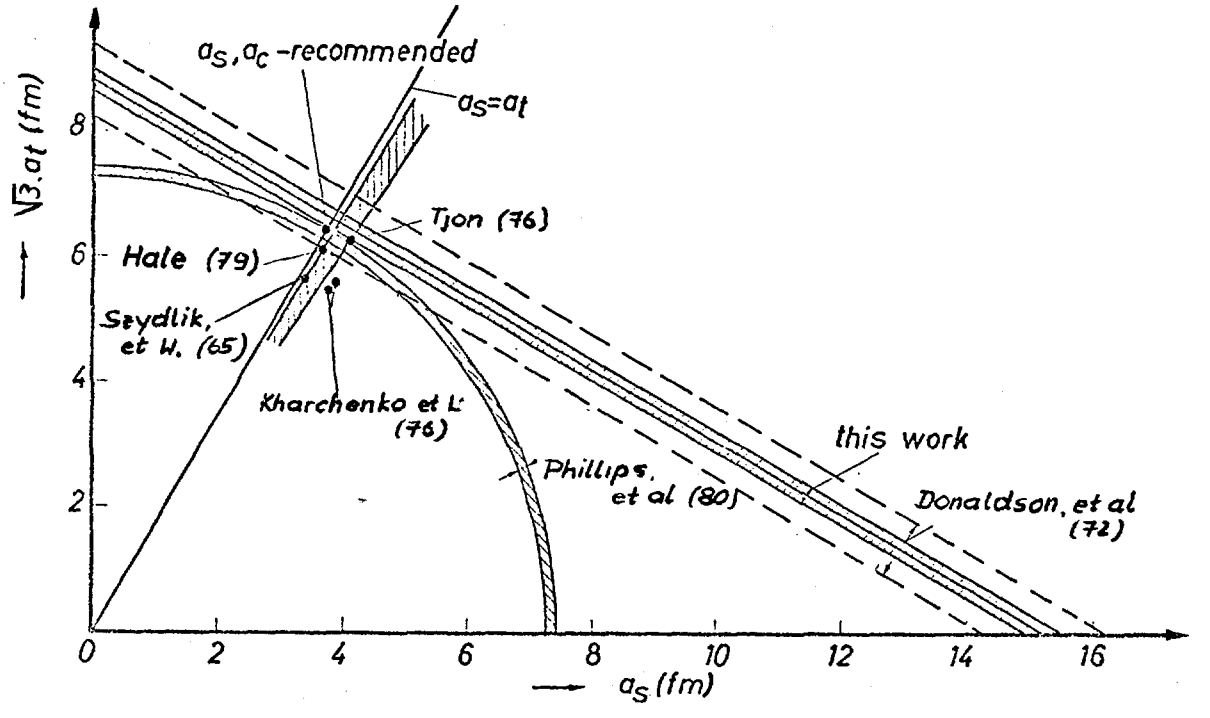
1) Ames Laboratory, Iowa State University, Ames, Iowa, U.S.A.

## 2. MEASUREMENT OF THE COHERENT NEUTRON-TRITIUM SCATTERING LENGTH AND ITS RELATION TO THE FOUR NUCLEON PROBLEM

S.Hammerschmied, H.Rauch, H.Clerc[x], U.Kischko[xx]

Using the neutron interferometer the bound coherent scattering length for the neutron-tritium system has been measured as $b_c = 5.10 \pm 0.10$ fm, which gives a value for the free scattering length of $a_c = 3.82 \pm 0.07$ fm. Together with the recently measured free cross section ($\sigma_s = 1.70 \pm 0.03$ b / Phillips et al. 80/) new recommended values for the singlet ($a_s$) and triplet ($a_t$) scattering lengths can be obtained. Due to the relations $a_c = \frac{1}{4} a_s + \frac{3}{4} a_t$, $\sigma_s = \pi(a_s^2 + 3a_t^2)$ the experimental situation for the determination of $a_s$ and $a_t$ is shown in the figure.

From the optimal fit-procedure the following values are obtained ($a_s = 3.70 \pm 0.62$ fm, $a_t = 3.70 \pm 0.21$ fm). These values are compared with theoretical estimates (points) based on recent four nucleon theories.

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x) Centre d'Etudes de Bryére le Chatel, F-92542 Montrouge, France

xx) Institute Laue-Langevin, F-38042 Grenoble and Institut für Physik, Universität Dortmund, D-46 Dortmund, Germany

## 3. SUMMARY OF NEUTRON SCATTERING LENGTHS[1)]

L.Koester[2)] and H.Rauch[3)]

All neutron scattering lengths of the elements and isotopes which are available from the literature are collected in a uniform way. More than 1000 values are listed and stored on magnetic tape. Spin-dependent scattering lengths are given as far as suitable measurement results are known in order to calculate these values. The values are given with their error bars and recommended values are given separately. A map of these recommended values provides an additional synopsis of these quantities.

## 4. PRECISION MEASUREMENTS OF HALF-LIFES AND GAMMA-RAY INTENSITIES OF SHORT-LIVED NUCLIDES AND ISOMERIC STATES.

R.Popp, G.P.Westphal, P.Schindler and F.Grass

By means of a virtually dead-time free and pile up free Ge(Li)-counting system a number of elements will be investigated after short activation periods with the TRIGA-reactor. A fast spectrum processing has been developed using four parallel storage areas for the gamma ray spectra. The fast read out of storage areas takes place parallel to the spectrum accumulation and enables a sequential registration of a large number of gamma spectra each one measured with a processing capability of 0.8 Mc. This way high statistical accuracies are acchived.

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1) IAEA-Contract No. 2517/RB

2) Reactorstation, TU-München, D-8046 Garching

3) Atominstitut und Institut für Festkörperforschung, KFA, D-517 Jülich

## 5. MEASUREMENT OF THE PROMPT NEUTRON EMISSION FOR $^{232}$Th($\alpha$,xnf) WITH $E_\alpha$ = 40 and 60 MeV

H.Cech, G.Eder, H.Jasicek, H.H.Müller[1], W.Reichart[1], P.Riehs, P.Schober, S.Steiner[1]

The energies of fragment pairs were measured in coincidence with the neutron time-of-flight spectra at 0° and at 90° with respect to the fragment flight direction. Preliminary results for the number of neutrons prior to the fission process $\bar{\nu}_{pre}$ show values of 2.9 ± 0.3 for $E_\alpha$ = 40 MeV and 5.2 ± 0.5 for $E_\alpha$ = 60 MeV. These results represent an upper limit since no corrections are applied for possible neutron contributions from the early stages of the fission process.

## 6. REEXAMINATION OF THE PROMPT NEUTRON EMISSION OF $^{252}$Cf(SF)

E.Mersits, H.H.Müller[1], H.Rauch, W.Reichart[1], P.Riehs, P.Schober, S.Steiner[1]

The decay on fission fragments by emission of prompt neutrons is investigated. Evaluations on the shape of $\bar{\nu}$(M) - the average neutron number as a function of fragment mass M - are continued (1). Again we apply an analysing approach (2) where neutrons from slowly moving fragments are taken into account. In the near future we intend to improve a split up of $\bar{\nu}$(M) into contributions from fully and partially accelerated fragments. In addition, we try to analyse data of a previous experiment, which was designed to measure the anticorrelation of neutron emission between the fragments.

(1) P.Riehs,R.Prasad,G.Eder,H.Jasicek,H.H.Müller,W.Reichart and S.Steiner, to be published in Helv.Phys.Acta

(2) P.Riehs, Acta Phys.Austr. in print

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1) Physik-Institut der Universität Zürich, Schönberggasse 9

Institut für Experimentalphysik, University of Vienna,
A-1090 Wien, AUSTRIA
(Experimental work done at Los Alamos Scientific Laboratory,
Los Alamos NM. 87545, USA).
Responsible scientist: Manfred DROSG.
Reporting date: February 26, 1981
General remark: Only those projects are mentioned that originated in Vienna and which are not included into LASL's Progress Report to INDC.

## I. Production of monoenergetic neutrons

### 1) Neutron production by the hydrogen isotopes.

The recent evaluation published in Nucl.Sci.Eng.67, 190(1978) was improved by including charged particle excitation functions of the reaction $^{3}H(d,\alpha)n$ between 4 and 11 MeV. These data did not change the evaluation of the $^{3}H(d,n)^{4}He$ reaction above 7 MeV, however, below that energy changes up to 5% were necessary by their inclusion. The maximum disagreement with Liskien's evaluation published in Nucl.Data Tables 11,569(1973) is 20% at 6.5 MeV for the 180° cross section. A paper on this subject has been submitted to Z.Physik.

In addition, the evaluation of the $^{2}H(d,n)^{3}He$ reaction was extended to 40 MeV deuteron energy.

### 2) Neutron production by the interaction of protons with $^{7}Li$.

The acceleration of the heavy partner restricts the neutron production into a forward cone thus im-

proving the background condition and gives, usually, higher intensities at $0^{o}$. A report has been prepared discussing the properties of a $^{1}H(^{7}Li,n)^{7}Be$ source. Although the neutron yield from this source is comparable or somewhat better than that from the generally used sources (p-Li,d-D,p-T) it cannot compete with the yield from the $^{1}H(t,n)^{3}He$ source.

II. $^{6}Li\ (n,t)^{4}He$ reaction (with D.M.Drake and R.Hardekopf, LASL)
New data of this neutron detection standard were obtained from its reciprocal reaction $^{4}He(t,n)^{6}Li$. The $0^{o}$ excitation function was measured between 0.079 MeV and 5.37 MeV neutron energy. In addition, angular distributions were measured at 0.236, 2.99 and 5.37 MeV neutron energy. At the lower energies the shape error in the angular distributions is less than 5%, at the highest energy 10% and more. In addition some data for the 1st and 2nd excited state of $^{6}Li$ were taken which will be valuable for the R-matrix analysis.

List of Recent Publications:

M.Drosg: "The $^{2}H(d,n)^{3}He$ Differential Cross Sections for Deuteron Energies between 20 and 40 MeV", Bericht LA-8538-MS, Los Alamos Scientific Laboratory (LASL) der Universität von Kalifornien (1980)

P.W.Lisowski, G.F.Auchampaugh, D.M.Drake, M.Drosg, G.Haouat, N.W.Hill, L.Nilsson: "Cross Sections for Neutron-Induced, Neutron Producing Reactions in $^{6}Li$ and $^{7}Li$ at 5.96 and 9.83 MeV", Bericht LA-8342 des LASL (1980)

M.Drosg: "Proposal of a Novel High Intense Neutron Source for Radiation Therapy", Z.Physik A 298, 297 (1980)

M.Drosg: "Improved Evaluation of the Differential Cross Sections of the $^{3}H(d,n)^{4}He$ Reaction for Deuteron Energies Between 3 and 7 MeV", Bericht LA-8532-MS des LASL (1980)

M.Drosg: "Properties of Monoenergetic Neutron Sources from Proton Reactions with Nuclei other than Tritons", p.241 Proc.IAEA Consultants' Meeting on Neutron Source Properties, Debrecen 1980, K.Okamoto, Ed., Bericht INDC (NDS)-114/GT (1980)

M.Drosg: "Production of Fast Monoenergetic Neutrons by Charged Particle Reactions among the Hydrogen Isotopes. Source properties, experimental techniques and limitations of the data", p.201 Proc.IAEA Consultants' Meeting on Neutron Source Properties, Debrecen 1980, K.Okamoto, Ed., Bericht INDC (NDS)-114/GT (1980)

M.Drosg: "The $^{3}H(p,n)^{3}He$ Differential Cross Sections Below 5 MeV and the n-$^{3}He$ Cross Sections", Bericht LA-8215-MS des LASL (1980)