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International Atomic Energy Agency

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

Needs of targets and samples for nuclear data measurements in the service area of the Nuclear Data Section

L. Hjärne

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IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

INTRODUCTION

Upon the recommendation of the International Nuclear Data Committee a systematic survey of targets and samples, needed for nuclear data measurements in countries within the service area of the IAEA Nuclear Data Section, was initiated. The preliminary results of the survey can be found in this report, and it should be understood that the needs, as listed here, are in most cases not to be regarded as formal requests from the respective Governments. A circular (annex I) was sent out to a number of physicists (annex II) in those countries where we know of facilities available for such measurements. In order to concentrate this effort on those countries which can be expected to have limited access to samples, the circular was not distributed to the US, the USSR or to OECD countries. Clearly, then, this survey was primarily aimed at the developing countries. The circular referred to all kinds of samples and targets; it was not limited, for example, to fissile isotopes, nor were non-neutron induced nuclear reactions excluded.

Answers have been received from more than a dozen countries, but in some cases the information has not been received in full, in spite of repeated reminders. Only one answer (from Thailand) was negative, while most answers emphasized that the problem was a very serious one. Most samples could be paid for, but only in local currency - the foreign exchange is extremely difficult in most developing countries.

BRAZIL

The question was forwarded to various institutions, and great interest has been announced, but no explicit response to the circular has been received as yet. It would seem that the seven Brazilian institutions concerned need still more time to formulate their needs in detail.

BULGARIA

The request for samples, which was presented in detail to the International Nuclear Data Committee at its 1968 meeting, is on its way to be filled. Here is given additional needs.

Correspondent:

E. Nadjakov, Institute of Physics, Nuclear Research Centre, Bulg.Acad.Sci., Sofia

Needs: ^{252}Cf $10^6 - 10^7$ spont. fiss./sec, 50 - 100 $\mu g/cm^2$ VYNS holder

Purpose:

The Cf source is needed for calibration in the following program: Correlation measurements on fission fragment distributions - energy, mass, angle. Thermal neutron fission of ^{235}U. Photo-fission (monoenergetic gammas) of ^{232}Th, ^{238}U, ^{239}Pu. Slowing down of fragments in various media and charge distribution of fragments.

Equipment:

2 MW Reactor IRT-2000 (water-water). Eleven horizontal and eleven vertical channels; one thermal column; fast chopper. One horizontal channel used to produce monoenergetic gammas by means of a combination of a large "target" and filters. Double pulse ionization chamber with semiconductor detectors (and computer data processing).

Financial arrangements:

Funds from the Academy of Sciences, local currency. Some photofission work (angular correlation of fragments) has been started on IAEA research contract 449. Californium source was not covered. This work has not yet been reported.

CHILE

Correspondent:

J. Luis Romero, University of Chile, Santiago.

Needs:

Four TiT targets ranging from 0.4 to 0.9 mils without backing. Diameter about 1 inch mounted in an annular copper ring. Maximum thickness for saturation of all Ti with T is about 10 mg/cm^2.

Purpose:

The targets shall be used for generation of neutrons in the range 14.1 – 21.1 MeV ($d + T \longrightarrow n + {}^4He$). Deutrons are accelerated up to 5 MeV in the cyclotron (see below). Further information is best given by the authors themselves:

> "The specific experiment we have in mind to begin with, is the measurement of the n-p differential cross section ratio $\sigma_{np}(165^\circ)/\sigma_{np}(90^\circ)$. The need of good measurements of this quantity in this energy region has been pointed out recently by M.H. MacGregor et al., Phys.Rev. 182 (1969) 1714 and by H.P. Noyes, Prog. Nuc. Phys.10 (1969) 357.
>
> "In the experiment we detect at the same time the protons at 5° and 45° using a thin $(CH_2)_n$ target. We use a DE-E combination to detect each proton, the DE being a thin solid state detector mainly to clean up the background and the E is a CsI detector coupled to a fast tube 56 AVP in order to get good timing and reasonable energy resolution. A time-of-flight signal is obtained between a deuteron beam pick off signal and the E detector to further reduce the neutron background."

The title of the article by MacGregor et al. mentioned above is "Determination of the Nucleon-Nucleon scattering matrix X. (p,p) and (n,p) Analysis from 1 to 450 MeV." In the abstract is stated: "Measurements of the ratio $\sigma(180^\circ)/\sigma(90^\circ)$for (n,p) scattering at 25 or 50 MeV to an accuracy of 1 % would help to remove the ambiguity in the ϵ_1 and ${}^1P_1$ phases". The relevant paragraph of the paper is reproduced in ANNEX IV.

Equipment:

22 inch cyclotron of Faculty of Sciences. Current more than 1 μamp. deuterons 1 – 5 MeV. About 85 % of the electronic equipment is already available, including a Nuclear Data Multichannel Analyser with accessories.

Financial Arrangements:

Application for funds has been made to the Nuclear Energy Commission of Chile. The funding of targets could be a problem; apparently it is expected that only two – at the most – of the targets will be paid for.

CHINA (Taiwan)

Correspondent:

Yu-Liang Yen. Institute of Nuclear Energy Research. Atomic Energy Council. Lung-Tan

Needs:

(a) Charged-Particle Reaction

Li	Nickel backing samples of 100 ~ 1000 $\mu g/cm^2$
^{9}Be	self-supporting samples of 20 ~ 200 $\mu g/cm^2$ or carbon backing in the thickness range of 10 ~ 100 $\mu g/cm^2$
C	self-supporting samples of 50 ~ 250 $\mu g/cm^2$
Mg	carbon backing samples of 10 ~ 250 $\mu g/cm^2$
^{27}Al	self-supporting samples of 15 ~ 1000 $\mu g/cm^2$
Cl	chlorine samples of NaCl, BaCl, & KCl can be made on carbon backings in the thickness range of 50 ~ 250 $\mu g/cm^2$
Ti	carbon backing samples of 10 ~ 250 $\mu g/cm^2$
^{55}Mn	carbon backing samples of 10 ~ 150 $\mu g/cm^2$
Fe	self-supporting samples of 50 ~ 200 $\mu g/cm^2$ & carbon backing targets of 10 ~ 100 $\mu g/cm^2$
^{59}Co	10 ~ 150 $\mu g/cm^2$ on carbon backings
Cu	self-supporting samples in the range of 50 ~ 500 $\mu g/cm^2$
Ge	10 ~ 150 $\mu g/cm^2$ on carbon backings
Zr	10 ~ 150 $\mu g/cm^2$ on carbon backing
Ag	self-supporting samples of 100 ~ 5000 $\mu g/cm^2$
Sn	self-supporting samples of 150 ~ 500 $\mu g/cm^2$
^{197}Au	self-supporting samples in the range of 25 ~ 250 $\mu g/cm^2$

(b) Targets used as Neutron-Source

ZrT 500 - 1000 $\mu g/cm^2$, atomic ratio 1:1, Pt backing, 1" dia active area

Tritium gas with gas handling and monitoring equipment.

Purpose:

The samples listed under (a) are intended for charged particle reaction and nuclear structure studies; (b) is for production of fast neutrons for neutron reaction studies.

Unfortunately, the information, which was supplied was of very general nature; a request for specific information on, for example, the nuclear reactions to be studied was sent in January, but no answer has been received.

Equipment:

Van de Graaff accelerator. No further information supplied.

Financial arrangements

No information.

FINLAND

Correspondent:

A. Palmgren. Reactor Laboratory, Technical University of Helsinki.

Needs: 100 kg ZrH on lease. Hafnium concentration 100 ppm.

Purpose:

To determine the diffusion parameters of thermal neutrons in Zirconium Hydride by the pulsed neutron method (Ref. e.g. Meadows and Whalen, Nucl. Sci. and Eng. 13, 320 (1962)) extending the measurements also to low temperatures (77° K).

Equipment:

TRIGA reactor. A good low temperature laboratory, with cryostats of their own construction, which they have made for, among others, CERN and Grenoble.

Financial arrangements

"We can arrange money from the budget of the Reactor Laboratory to rent the material for a fixed time. The funding of the samples presents a problem in the sense that we cannot get 7000 $ to buy 100 kg ZrH, if there is no chance of being able to sell back the material. We would like to rent it ...but we have not found suppliers willing to deal with us on such terms."

Negotiations with potential suppliers are under way, but the results of these are not certain.

HUNGARY

Correspondent I:

A. Lajtai. Central Research Institute for Physics. Hung. Acad. Sci., Budapest.

Needs: ^{252}Cf; 5 x10^5 - 10^6 spont. fiss./min; diameter 20 mm; Pt backing.

Two ^{234}U; 2 - 2,5 mg/cm^2; 10 mm by 12 mm; steel or Al backing;
Two ^{236}U; 2 - 2,5 mg/cm; 10 mm by 12 mm; steel or Al backing;
^{165}Ho, metallic; 30 mm height, 25 mm diam. cylinder; weight about 130 g.

Purpose:

Measurement and comparison of neutron energy spectra from thermal neutron fission of ^{235}U and from spontaneous fission of ^{252} Cf. (Reference given: J. W. Meadows, Phys. Rev. 157, 157, 1967)

Measurements of the angular distribution of fission fragments and the differential cross section of ^{234}U and ^{236}U at about the threshold energy of fission as a function of the bombarding neutron energy. (Reference given: Kh. D. Androsenko et al. Proc. 2nd Symp. Phys.Chem. Fiss. (Vienna, 1969) p.419)
This group has given a paper at the Helsinki Conference: IAEA/CN-26/4.

Study of inelastic excitation of the collective states of ^{165}Ho by 14 MeV neutrons.

Equipment

Research reactor and neutron time-of-flight spectrometer with fast-slow coincidence circuits. (Some electronic equipment here was developed locally with some limited IAEA financial support.)

220 keV Cockroft - Walton, 4,5 MeV van de Graaff, and fast neutron time-of-flight facility.

Financial arrangements

The holmium sample cannot be purchased and could only be taken on loan. Otherwise, financed by the Institute; currency restrictions are, however, very serious.

Correspondent II:

J. Csikai. Kossuth University, Debrecen.

Needs: All samples as oxides; diameter 10 mm; holder Al, 10 microns; tolerable inhomogeneity ± 10 %.

two ^{231}Pa; 1 mg/cm^2
two ^{231}Pa; 2 mg/cm^2
two ^{233}U; 5 mg/cm^2
four ^{235}U; 10 mg/cm^2 93 - 95 % enriched
two ^{237}Np; 10 mg/cm^2
two ^{239}Pu; 1 mg/cm^2 } other Pu isotopes less than 3 %
two ^{239}Pu; 2 mg/cm^2 }

Purpose:

Systematic investigations on the chain and independent yield of fission products as function of mass number of fissionable nuclei at 14 MeV neutron energy. The investigation is planned for a span of about three years. Measurements of delayed neutron-gamma coincidences, of angular distribution of fragments and of gamma ray spectra of fission fragments.

Equipment:

Activatron - 111 type TMC neutron generator. 30 cm^3 NEA Ge(Li) spectrometer (for gamma spectra of fission products) and a DIDAC-4000 Intertechnique analyser. Unfolding of gamma spectra will be carried out on a computer.

Financial arrangements:

The program is a part of a research contract with the IAEA. This financial support is limited to the free loan of some equipment, such as the neutron generator, which is owned by the IAEA.

INDIA

Correspondent I:

M. Balakrishnan. Bhabha Atomic Research Centre, Trombay. Several groups; all communicated through M. Balakrishnan.

Needs:

A general need for Tritium targets, for 14 MeV neutron work, was stated, but no specifics given.

Samples needed for proposed work;

(a) all roughly 0,5 by 7 inch; 1 - 3 mil Au, Pt or Ta backing:

^{26}Mg;	5 - 10 $\mu g/cm^2$
^{41}K	1 - 2 mg/cm^2
^{53}Cr	1 - 2 mg/cm^2
^{65}Cu	1 - 2 mg/cm^2
^{67}Zn	1 - 2 mg/cm^2
^{22}Ne, ^{40}A	absorbed in backing; alternatively contained in small cell.

Targets needed for future experiments;

(b) 10 - 15 μ/cm^2 on thin carbon films on 1 mil Ta backing with highest possible purity and enrichment.

^{28}Si	^{29}Si	^{30}Si
^{32}S		
^{37}Cl		
^{42}Ca	^{48}Ca	
^{50}Ti		
^{52}Cr	^{54}Cr	
^{64}Ni		

(c) Enriched isotopes.

^{41}K	10 - 15 $\mu g/cm^2$	with or without backing (Ta)
^{50}V	10 - 15 $\mu g/cm^2$	with or without backing (Ta)
^{36}S	30 mg	Targets to be prepared by evaporation.
^{42}Ca	50 mg	
^{46}Ti	50 mg	
^{50}Cr	50 mg	
^{54}Fe	50 mg	
^{58}Ni	50 mg	

Purpose:

(a)

^{67}Zn, ^{65}Cu, ^{53}Cr and ^{41}K for (p,n) work of the type reported in K.V.K. Iyengar et al., Nucl. Phys. A 96, 417 (1967) and L. Birstein et al., Nucl. Phys. A 113, 193 (1968).

Iyengar et al., title: "The study of the ^{51}V (p,n)^{51}Cr reaction". Measured σ(E, E γ), n - γ coincidences, angular correlation; energy range from 2.3 to 5.5 MeV.

Birstein et al., title: "The angular distributions of gamma rays following (α,n) and (p,n) reactions".
^{59}Co, ^{63}Cu, ^{68}Zn (p,n γ). Energy range from 3.1 to 5.2 MeV
^{56}Fe, ^{60}Ni, ^{65}Cu (α,n γ). Energy range from 6.5 to 9.3 MeV; measured σ(E γ, θ). ^{59}Ni, ^{63}Zn, ^{68}Ga deduced levels and spins. Enriched targets.

^{26}Mg for (α,n) and (α,n γ) work, similar to that reported in W.M. Deuchars and D. Dandy, Proc. Phys. Soc. 77, 1197 (1961).

Deuchars and Dandy, title: "Angular correlations in the reactions ^{18}O (α, n γ) ^{21}Ne and ^{22}Ne (α,n γ) ^{25}Mg". Measured ^{18}O, ^{22}Ne (α ,n γ). n - γ coincidences, angular correlation for the first excited state of ^{21}Ne and a brief study of the first excited state of ^{25}Mg.

^{22}Ne and ^{40}A for (α,n) studies; neutron yield measurements with 4π counter.

(b)

The eleven isotopes listed under (b) for total cross sections and level widths of (p,n) and (α ,n), and for elastic scattering of protons; absolute differential cross sections.

(c)

^{40}K and ^{50}V for (p,n) reaction studies, in order to obtain (n,p) cross sections.

^{36}S for the study of energy levels of ^{34}P by the (d,α) reaction

^{42}Ca, ^{46}Ti, ^{50}Cr, ^{54}Fe, ^{58}Ni for the study of energy levels of ^{44}Ti, ^{48}Cr, ^{52}Fe, ^{56}Ni and ^{60}Zn respectively, by (^{3}He, n) reaction.

Equipment:

Van de Graaff accelerator, model CN, 5.5 MeV; 3 port switching magnet .

Financial arrangements:

Difficulties with foreign exchange. In the past, IAEA has given some support in the form of research contract no 535.

Correspondent II:

A. M. Ghose. Bose Institute, Calcutta

Needs:

A comprehensive description of the plans for experiments during the next five years is given in ANNEX III. The tritium targets (40 pieces needed during five years) are extremely important, as the work is centred on neutron indu ed reactions.

(a) Tritium targets. Diameter 1 1/8 inch. Tritium absorbed in Ti on Cu backing, thickness 0.01 inch.
T content 3 or 5 $ci/inch^2$
Ti thickness 4 - 7 $mg/inch^2$

(b) Chemicals, 99.9 % purity in powder form. Rare earths and a few others. For details see ANNEX III, page 5.

Purpose: } see ANNEX III.
Equipment: }

Financial arrangements:

Foreign exchange of the order of $ 10.000 during the next five years for targets and target material will be needed. No solution to this problem has yet been found.

Correspondent III:

G.K. Mehta. Indian Istitute of Technology, Kanpur

Needs:

	Specification	Purpose of which target is needed
Er, Ce	Natural material Hollow Polycrystalline Cylinder 2" Long X2" OD x 1½" ID	Neutron Capture
^{54}Fe	Enriched Isotope as enriched as possible Form: Fe_2O_3 Quantity 50 mg	Proton-capture measurements

	Specification	Purpose of which target is needed
^{45}Sc	Enriched Isotope as enriched as possible, quantity - 50 mg	Proton-capture measurements
^{235}U	Size: 1" diameter .005" thickness 85 % enrichment	Neutron capture Fission and ternary alpha measurements
^{6}Li	As enriched as possible Form: LiO Quantity 50 mg	(P,P) (P, gamma)
^{10}B	As enriched as possible Form: B Quantity 50 mg	(P,P) (P,α) (P, gamma)
^{17}O	As enriched as possible Form-O_2 gas in a glass bulb or oxide of any heavy metal. Quantity: (?)	(P,P) (P,α) (P, gamma)
^{25}Mg ^{26}Mg	As enriched as possible. Form: Chloride Quantity 50 mg	(P,P) (P,α) (P, gamma)

Purpose: see above

Facility:

2 MeV van de Graaff

Financial arrangements:

Payments can be made, but only in local currency.

Correspondent IV:

E. Kondaiah. Tata Institute, Bombay

Needs:

Ten/year TiT targets, 1 inch diameter

Purpose:

Production of 14 MeV neutrons for the study of angular distributions. Reactions were not specified.

Equipment:

Electron linear accelerator, 3,5 MeV; Cockroft-Walton, 1 MeV.

Financial arrangements:

No information given.

Detailed information on a number of items was requested in January, but no answer has yet been received.

KOREA

Correspondent:

Moon-Kyu Chung. Atomic Energy Research Institute. Chongryangri

Needs:

^{149}Sm	10 g	Sm_2O_3	enriched in Sm^{149} to at least 90 %
Ti	100 g		
V	100 g		
Zr	100 g		

Purpose:

Samarium, for measurement of resonance parameters at 0.098 eV. Other elements for total cross section measurements in the thermal region.

Equipment:

TRIGA-2, 100 KW

Financial arrangements:

No information given.

PAKISTAN

Correspondent I:

M. Islam. Atomic Energy Centre, Ramna, Dacca (East P.)

Needs:

(a) For fission cross section measurements. Two samples of each, metallic preferred, otherwise oxide; diameter, backing, 3 cm, sample 2 cm.

	(thickness)	(enrichment)	(backing)	(weight, material, each)
^{240}Pu	0,3 mg/cm^2	95 % (or near)	Pt	1 mg
^{239}Pu	0,5 mg/cm^2	95 %	Pt	3,5 mg
^{239}Pu	5 mg/cm^2	95 %	Pt	35 mg
^{235}U	0,5 mg/cm^2	90 %	Pt	3,5 mg
^{235}U	5 mg/cm^2	90 %	Pt	35 mg
U	5 mg/cm^2	(Natural)	Pt	35 mg
^{235}U	50 μg/cm^2	90 %	VYNS	0,2 mg

(b) For neutron fission cross section measurements. One foil of each; thickness 0,02 mm; size 5 x 10 cm; 2,3 g each.

^{235}U	90 % enriched
^{239}Pu	95 % enriched
U	(Natural)

(c) For neutron total cross section measurement. One sample of each; metallic; cylinders 1,2 cm x 1,2 cm; appr. 30 g each; in stainless steel capsule (one empty capsule needed)

^{235}U	90 % enriched	
^{239}Pu	95 % enriched	
U	(Natural)	(Blank target)

(d) For neutron inelastic scattering cross section measurements. One of each; metallic; annular cylinders, height 1 cm, o.d. 2 cm, i.d. 1 cm.

^{235}U	90 % enriched	50 g	
^{239}Pu	95 % enriched	50 g	
U	(Natural)	50 g	(Blank target)
C	(Natural)	11 g	(Dummy target)

Purpose:

As indicated above, during two years.

Equipment:

3 MeV van de Graaff with accessories. Nanosecond pulsing facilities are being installed.

Financial arrangements:

Pakistan Atomic Energy Commission finances all projects, but only in local currency. Close to impossible to get foreign exchange for samples and targets.

Correspondent II:

Lahore. (Communicated by SKA Jafri, Pakistan AEC)

Needs:

^{235}U	80 - 90 % enriched;	cylinder, diam	2 cm,	height	1 cm
U	natural or depleted	"	4 cm,	"	7 cm
^{239}Pu	80 - 90 % enriched;	"	2 cm,	"	1 cm
^{240}Pu	80 - 90 % enriched;	"	2 cm,	"	1 cm

Purpose:

Elastic and inelastic differential and total neutron cross sections at 3 and 14 MeV; also planned inelastic gamma ray excitation measurements. The same experiments are being carried out on light and medium weight elements.

Equipment:

Cockroft-Walton accelerator and neutron generator.

Correspondents III:

T.A. Khan (heavy elements) }
M.A. Shaukat (medium and light elements) } PINSTECH, Rawalpinali

Needs

(a) Heavy elements for thermal fission measurements.

two	^{238}U	100 $\mu g/cm^2$	deposit diameter 3/4 inch; backing Ni 50 - 110 $\mu g/cm^2$
one	^{233}U	50 $\mu g/cm^2$	
two	^{235}U	100 $\mu g/cm^2$	
one	^{235}U	50 $\mu g/cm^2$	
two	^{239}Pu	100 $\mu g/cm^2$	
one	^{239}Pu	50 $\mu g/cm^2$	
two	^{252}Cf	$10^6 - 10^7$	spont.fiss./min; backing Ni. 0.1 and 0.5 mg/cm^2

3 grams of each, enrichment better than 92 %:

^{233}U, ^{235}U } as metal or oxide, metal preferred.

^{239}Pu as oxide

(b) Heavy elements for thermal neutron capture gamma ray measurements; enrichment better than 92 %:

^{233}U	3g	as metal or oxide, metal preferred
^{235}U	3g	
^{239}Pu	3g	as oxide
^{240}Pu	100 mg	

(c) Heavy elements for radioisotope production:

^{235}U 3g; enrichment 90 - 95 % for production of ^{99}Mo to prepare ^{99m}Tc generator for medical use

(d) Non-fissile materials for thermal neutron capture studies:

^{168}Yb	16 mg	
^{174}Yb	400 mg	
^{176}Lu	10 mg	
^{177}Hf	50 mg	
^{115}In	500 mg	
Na	100 g	(spec. pure)
Al	500 g	(spec. pure)
V	100 g	(spec. pure)
Mn	100 g	(spec. pure)
Mn	1 lb	60 mesh powder m 3N
Co	1 lb	50 mesh powder m 2N

La 200 g
Pr 100 g
Ho 25 g
Tb 10 g
Ta 100 g

(e) Materials for neutron resonance capture studies

Mg 20 x 15 x 5 cm (ca. 2600 g)
Si 15 x 10 x 2 cm (ca. 730 g)
Cr 15 x 10 x 2 cm (ca. 2 kg)
Mn 15 x 10 x 2 cm (ca. 2 kg)

(f) Targets for preparation of γ-ray calibration sources.

Cs 10 mg
^{138}Ce 10 mg
^{41}K 10 mg

Purpose:

(in addition to what is indicated above)

Fission group: Study of some rather unexplored regions of the fission process by double velocity and double energy measurements on fission fragments and later correlation measurements with prompt neutrons. Cf target will also be used for calibration.

Other groups: The program includes determination of energy levels, life-times, spin, parity by single and coincidence spectra, β-γ and γ-γ correlation.

Equipment

5 MW swimming pool reactor with six main beam tubes, one tangential through tube and one thermal column. One 35 000 Curie 60-Co source. A number of detectors including BF_3, 3-He, Ge(Li), NaI (Tl) and Si surface barrier detectors, and associated electronics, including several multichannel analysers and a 4096 channel analyser. A moderate (?) size IBM computer in Dacca, available. A facility for t-o-f work on fission fragments and prompt neutrons nearly completed.

Financial arrangements:

The research is financed by the Pakistan AEC, but the samples and sample materials are difficult to procure, because of foreign exchange difficulties, which at best cause very long delays.

POLAND

No renewed list was received as a response to the survey letter. The needs have already been presented to and discussed at the 1968 INDC meeting. Therefore we assume that the original request still stands, and the needs are given very briefly here.

Needs:

(a) Samples, fluorides; diameter 15 - 20 mm; 2 - 4 mg/cm^2; backing Ta or Pt 10 - 15 mg/cm^2, covering foil Ta or Pt 5 - 10 mg/cm^2, 'for ternary fission studies.

^{233}U

^{235}U

^{239}Pu

^{240}Pu

(b) Source, for ternary fission studies.

^{252}Cf 10^8 spont. fiss./min.

ROMANIA

Correspondent:

A. Berinde. Institute of Atomic Physics, Bucharest

Needs:

^{233}U, ^{234}U, ^{236}U, ^{241}Pu	0,5 - 1,5 mg/cm^2; 2,5 - 5,0 cm diam, Al backing
^{241}Pu, ^{241}Am	20 $\mu g/cm^2$; 2,5 cm diam, Al backing

Purpose:

The thin targets for fission cross section measurements at the reactor; the thicker ones for the study of fissioning isomers at the cyclotron.

Equipment:

2 MW WWR-C reactor with instrumentation for fission and neutron inelastic scattering measurements.
Cyclotron, 6,25 MeV (p), 12,5 MeV (d), 25 MeV (α). 500 μA internal beam; flux about 6 x 10^{13} part/cm^2 sec.; deflecting magnet permits measurements at three positions.

THAILAND

Correspondent:

P. Arrebhol. Office of Atomic Energy for Peace. Bangkok.

Because of lack of scientists and equipment no work is planned in the field of nuclear data.

UNITED ARAB REPUBLIC

Correspondent I:

M. El-Nadi. Nuclear Physics Dep., AEE, Cairo

Needs:

(a) Foils, size 4 cm x 10 cm

^{9}Be	1 - 2 mg/cm^2
^{27}Al	6 - 8 mg/cm^2
^{24}Mg	3 mg/cm^2
^{58}Ni	0,25 - 0,5 mg/cm^2
^{107}Ag	2,4,6 and 8 mg/cm^2

(b) Targets of about 0,1 - 0,2 mg/cm^2 on Ni backing:

^{4}He			
^{10}B	^{11}B		
^{13}C			
^{14}N	^{15}N		
^{17}O	^{18}O		
^{20}Ne	^{21}Ne	^{22}Ne	
^{30}Si			
^{42}Ca	^{44}Ca	^{46}Ca	^{48}Ca

(c) Enriched isotopes, materials only; 2 g each;

^{6}Li
^{7}Li
^{9}Be
^{24}Mg

Purpose:

Study of (p,γ), $(p,n\gamma)$, (p,α,γ), (d,p), (d,α) and (d,d) reactions in the energy range 1 - 2,5 MeV.

Equipment:

Van de Graaff accelerator.

Financial arrangements:

No information given

Correspondent II:

I. Hamouda, Reactor and Neutron Physics Dep. AEE, Cairo.

(a) Foils for neutron total cross section measurements.

Element	The thickness in cm for metallic samples in the form of plates of square area 4 x 4 cm^2	No. of Plates	Weight of the Element in the form of Powder if not available in Metallic form
Mg	4	4	500 gm
Ti	0,5	2	200 gm
	0,3	2	
	0,2	2	
	0,1	3	
Cr	0,50	4	250 gm
	0,25	2	
Mn	0,20	3	200 gm
	0,10	2	
	0,05	2	
Co	0,100	2	150 gm
	0,050	2	
	0,025	4	
Nb	4	4	200 gm
Ag	0,1	4	150 gm
	0,05	4	
	0,025	4	

(b) Samples for capture gamma spectrum measurements; cylinders, diameter 15 mm, height 20 mm. Solid or in plexiglass container.

Mg^{24}	Mg^{25}	Mg^{26}	
Cr^{50}	Cr^{52}	Cr^{53}	
Ni^{58}	Ni^{60}	Ni^{62}	
Cu^{63}	Cu^{65}		
Zn^{64}	Zn^{66}	Zn^{67}	Zn^{68}
Ga^{69}	Ga^{71}		
Ge^{70}	Ge^{72}	Ge^{73}	Ge^{74}

Purpose

(a) Total neutron cross section measurements at various temperatures in the range 0.002 - 1 eV.

(b) Prompt gamma ray spectra following thermal neutron capture.

Equipment:

2 MW Research Reactor; slow chopper. Gamma ray spectra will be measured with a Ge(Li) detector at the centre of an annular NaI (Tl) crystal to be operated as a pair spectrometer.

Financial arrangements:

IAEA support in the form of technical assistance. The detectors (including most accessories) mentioned above paid by the technical assistance program.

YUGOSLAVIA

Correspondent:

M. Potokar. Institute Jožef Stefan, Ljubljana

Needs:

Sample	Composition	Sample form	Quantity [g]
Sc	Sc_2O_3	powder	210
	metal		
Ga	natural metal some oxide	liquid	230
As	^{75}As	Amorphous form in powder or small grains	400
Sr	$SrCO_3$	powder	200
	metal	powder	300
Y	Y_2O_3	powder	260
Ru	metal	powder or small grains	450
Rh	metal	powder or small grains	450
Pd	metal	powder or small grains	450

Sample	Composition	Sample form	Quantity
Sb	^{123}Sb(enriched)		230 ?
La	^{139}La metal		230
	La_2O_3	powder	360
Pr	Pr_2O_3	powder	360
Ho	Ho_2O_3	powder	360
other rare earths	oxides	powder	360
Ta	metal (natural)	powder	200 - 550
W	^{186}W (enriched)		
	natural	powder	300 - 640
Ir	natural (metal)	powder	
Pt	"	"	

Purpose:

Investigation of (n, γ) reactions with 14 MeV neutrons; gamma ray spectra and integrated cross sections are measured by a special telescope scintillation pair spectrometer. In the centre of a sperical sample (2 - 4 cm radius) a tritium target is located as a neutron source. About fifteen elements have already been studied (see ref. below). The mass dependence of the obtained integrated cross sections shows some departure from the mass dependence of the (n, γ) cross sections obtained by activation techniques. The group wishes to get a better picture of this by completing the data with measurements on a number of other elements.

Because of the experimental geometry and the low (n, γ) cross sections the quantities needed are fairly large. As the primary purpose is gamma ray spectra, at least 90 % of the main isotope is needed. Elements in their natural composition, elemental or in some compound with light elements, would be welcomed; such samples would, however, be useful only for measuring integral cross sections.

References:

F. Cvelbar et al. Nucl. Instr. 44, 292 (1966)
F. Cvelbar et al. Nucl. Phys. A130, 401 (1969)
F. Cvelbar et al. Nucl. Phys. A138, 412 (1969)

Equipment:

Cockroft-Walton, 100 keV deuterons on Tritium targets.

Financial arrangements:

Funds from the Jugoslavian Federal AEC. The table given above presents only those elements which are too expensive to be purchased for the present experiment. It is hoped that some of the material could be, at least, borrowed for periods of a few months.

Some fraction of the cost for equipment is currently being paid in cash by IAEA research contract 536.

Summary and conclusions

Most of the first answers to our circular letter were incomplete. In some cases, the needed supplementing informations were received following a reminding letter. In the descriptions of the individual cases of samples and targets needs in this report, some details are still missing, such as:

1) Time schedule of the experiment; in other words, when and for how long the sample or target is needed.

2) In almost all cases no mention is made regarding the accuracy, which is aimed at. In a few cases no mention is made of the particular reaction, and the specific quantities to be measured.

3) Energy range.

4) Available equipment. In a number of cases, other sources of information have been used to supplement incomplete answers.

5) Financial arrangements. Only regarding those programs, which are supported by the IAEA, some further information could be added to what was supplied by the correspondent.

This report is now submitted to the International Nuclear Data Committee in its preliminary form, for evaluation. We should keep in mind that in contrast to the situation in industrialized countries, the aim of the IAEA support to nuclear data experiments should be at least twofold:

(a) to support measurements of data (primarily neutron nuclear data) needed in nuclear science and technology and

(b) to aid the scientific and technical development of research institutes in the developing countries (independently of whether the work is planned for neutron or non-neutron nuclear data).

Only the preliminary results of a survey are given here; the samples and targets needs should be regarded as needs, only, and not as requests. Only in the cases of Poland, India and Pakistan do the items reported here correspond to official request from Member States. Whether or not official requests shall be a prerequisite for action on the part of the IAEA or the INDC is, of course, a matter which shall depend upon the mechanism which can be established for implementation in the future.

Acknowledgement

The author has received valuable help in writing this report from J.J. Schmidt and J. Dolnicar.

10 December 1969

Dear

During recent years we have become increasingly aware of the fact that the procurement of targets and samples needed for nuclear (especially neutron) data presents a severe problem to physicists particularly in developing countries. We have had several individual cases, which have demonstrated the need for a streamlined procedure. In past meetings the International Nuclear Data Committee (INDC) has paid particular attention to this problem and recommended us to provide the Committee with more detailed information on this subject. Acting upon that recommendation, we are therefore in the process of surveying the present and near-future needs for and availability of samples.

As a first step, we want to compile a comprehensive list of sample needs in order to initiate a systematic approach to the problem. Such a list may also serve a secondary purpose: Those who have the means of supporting nuclear data measurements, by making targets available, may find cases where the sample problem could be dealt with directly on a bilateral basis.

Without committing ourselves at present for the actual success of our efforts, we nevertheless hope and believe that you will find it serving your interest to provide us with a list of targets and samples, which you will need at your institute, and which you cannot acquire locally. Such a list should give in detail:

1. The purpose for which the targets are needed. This should include a short description of the experiment, as planned, its time-scale and perhaps a reference to any related published work.

2. The type of facility at which the experiment will be performed.

3. The desired specifications and/or range of tolerable specifications of the required targets.

4. The financial arrangements made (funds granted or applied for) in support of the experiment. Indicate also specifically whether or not the funding of the samples is expected to present a problem.

As we intend to distribute the lists of specifications to those who might be in a position to supply targets and to the INDC members for them to prepare comments for the next INDC meeting, we would be grateful if you could send us your reply before the end of January 1970.

Sincerely yours,

J.J. Schmidt / L. Hjärne

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TARGETS AND CHEMICALS REQUIRED BY BOSE INSTITUTE NUCLEAR PHYSICS LABORATORIES.

We require some chemicals and targets which are not locally available for our investigations on the interaction of fast neutrons with matter and the study of generalised optical model parameters. The type of experiments we propose to do, the facilities available, the time scale, the list of chemicals with percentage of purity and the approximate cost are given below.

Types of experiments : The Nuclear Physics Laboratory of the Institute carrying out researches on various aspects of neutron induced reactions, of which the main line of thinking lies on the experimental investigations on the generalised optical model parameters for fast neutrons. From the experimental point of view, model parameters pertaining to the neutron induced reactions are not so easily available due to the lack of accurately measured total and differential cross-sections and polarisation measurements specially at high energies. It is our intention to undertake a systematic measurement of total and differential elastic and non-elastic cross-sections of a large number of nuclei covering a wide range of mass numbers using fast neutrons. The neutron energy will also be suitably varied so that necessary and sufficient data becomes available to fit various versions of optical model and to establish their validity on experimental grounds.

a) Measurement of total non-elastic cross sections.

Sphere transmission technique is the most direct method for the measurement of non-elastic cross sections of nuclei. Although the basic principle of the method is quite simple under ideal conditions, in practice the accuracy obtainable in this method is limited by multiple scattering in the absorber, energy loss suffered by neutrons in elastic encounters, finite size of the source and the detector, finite source-to-detector distance and other sources of error. Of these vitiating factors the first two are the most important ones. It has been shown by us that the multiple scattering can be corrected for by extrapolating the measured cross section through a polynomial formula of the type (Ghose, A.M., Nucl. Inster. and Methods 35, 45, (1965).

$$\sigma_x = \sigma(t) \; (1 + at + bt^2 + \ldots), \qquad (1)$$

Where σ_x is the required non-elastic cross section and $\sigma(t)$ is its apparent value, when the absorber thickness is t. In most cases a simple linear extrapolation is sufficient.

The effect of the energy degenaracy in elastic scattering is due to rendering the counting rate dependent on the energy loss suffered due to elastic encounters, so that in the conventional versions of the sphere transmission method, an accurate knowledge of the elastic neutron spectrum taking multiple scattering into account, is necessary. We have removed this limitation by developing a new technique the multiple bias method, which is intimately connected with the response of plastic scintillators towards fast neutrons. (A.Chatterjee and A.M.Ghose, Nucl. Inster and Methods 49,(1967),101). It has been shown that if σ_x, σ_{exp} and $\sigma_{exp'}$ represent respectively the true non-elastic cross section and its apparent values at two different bias b and b' in the discriminator, to discriminate elastic neutrons against non-elastic ones, then

$$\sigma_x = \frac{\sigma_{exp} - m\sigma_{exp'}}{1-m} \qquad (2)$$

where m is a function of b and b' but is independent of the energy spectrum of the elastic neutrons.

We have already reported measurements on nine elements for 14.8 + 0.1 MeV neutrons. (A.Chatterjee and A.M.Ghose, Phys.Rev. Sept.20,(1967). The results obtained by us indicate that the papameters of the non-local potential of Perey and Buck require reevaluation. We, therefore, propose to extend these measurements on several more nuclei and for different incident-neutron energies to get a reasonably complete picture of the variation of non-elastic cross sections with the mass number of the scatterer and with the neutron wavelength.

b) Measurement of total elastic Cross Section :

The total elastic cross section σ_{el} is easily obtained by subtracting the total non-elastic cross section σ_x determined as indicated above, from the total interaction cross section σ_t

$$\sigma_{el} = \sigma_t - \sigma_x \qquad (3)$$

The accuracy with which the total cross section can be measured is determined by the accuracy with which the inscattering due to small angle scattering is taken into account. By Using a heavily biased directional neutron counter as well as by taking measurements as a function of source-detector distance with scatterer placed midway between the two; correction factors which often involve optical model parameters themselves can thus be avoided altogether.

Another method by which the same object will be achieved is the measurement of incomplete total cross section $\sigma_{t'}$ given by

$$\sigma_{t'} = \sigma_x + \int_{\theta_0}^{\pi} \sigma(\theta)\, d\Omega$$

where θ_r is the largest angle through which the neutron might be scattered without going away from the beam entering the detector. The objective is achieved by using a "bad" geometry arrangement with conically perforated filter piece and extrapolating the data to vanishing absorption thickness.

c) Differential elastic scattering at large angles by the multiple bias method.

Differential elastic cross section are usually the basic experimental data which have been used to evaluate the optical model parameters. Unfortunately the cross sections for scattering at large angles, which are critically important for such evaluations (especially the spin-orbit part) have not been measured with desired accuracy. This is due to the fact that at large angles the differential cross section for scattering is several order of magnitude smaller than that at forward angles and hence the number of recorded scattered neutrons is very small. The only measure adopting which, the statistical accuracy can be increased is by using large amount of properly arranged scattered. However, the time-of-flight technique which is almost always used for discriminating elastically scatterer-detector distance be essentially constant and this is in direct contradiction with the above.

To obviate these difficulties, we propose to use the multipias method discussed in (b) for the measurement of differential elastic scattering cross sections. The basic equation for this purpose is

$$I_0 = \frac{m\, I(b)\, \xi(b') - I(b')\, \xi(b)}{(m-1)\, \xi(b)\, \xi(b')} \qquad (4)$$

where ξ's are efficiencies for primary neutrons for the two bias values b and b' while m is the parameter given in eq.(2). I_0 is the required intensity of the elastic neutrons while I(b) and I(b') are the measured intensities at the two biases. This method of discrimination of elastic neutrons from inelastic ones is directed and places on limitation on the geometry of the experimental arrangement. We therefore, propose to use large amount of scatterer arranged in the form of surfaces of revolution formed by rotating arcs of circles passing through the source and the detector. Multiple scattering will be taken into account by using a polynomial extrapolation formula of the type given in (1).

(d) Measurement of polarisation during elastic scattering.

Considerations given in (c) will allow us to attempt a determination of the polarisation during elastic scattering by the method of double scattering. The most important obstacle which has to be overcome in this connection is the loss of intensity after each scattering process. The proposed investigation will be directed towards developing suitable geometry of the experimental arrangement in which the effect of these losses is minimised. For obvious reasons only a few selected nuclei will be studied in these investigations.

e) Cross sections for the excitation of nuclear states at different angles.

The differential inelastic cross section for the excitation of the lowest available nuclear states will be measured during the measurements indicated in (c), if a multichannel recorder is used. The theory of the method is essentially the same as shown there with the niases now will within the range of the high energy spectrum of inelastically scattered neutrons.

f) A detailed study of the fast neutron response of organic scintillators.

The above investigations will allow a more detailed and accurate study of the response of organic scintillators towards fast neutrons. Montecarlo technique along with mathematical methods which have been developed to smooth out fluctuations in the computed data will be utilised for the purpose.

g) To determine optical model parameters of nuclei, and tostudy their variation with mass number and energy of the incident neutrons and thus establish their range of validity.

Finally the experimental data obtained in the manner indicated above will be utilised to evaluate various optical model parameters. Depending upon the availability of computer and programming facilities, the work will be carried out either independently or in collaboration with laboratories in possession of such facilities.

Facilities Available:

Bose Institute has a Cockcroft-Walton type Neutron generator. In addition normal counting systems including several single channel, one ten channel and multichannel analyser are available. Most of the electronic equipments have been constructed in the laboratory so that normal facilities for the servicing etc. are available. The

Institute is also in close touch with the Physics, Technical Physics and Electronics Division of the Dept. of Atomic Energy.

We intend to complete all these measurements within the next five years.

Targets and Chemicals:

As we use Cockcroft-Walton accelerator for producing neutrons using $T(d,n)\ He^4$ reaction, the tritium targets is the most important to us. Further as we use the scattering method as a means of our investigations, we require extrapure samples as targets.

a) Tritium Targets (Disc Type) :

Tritium absorbed in their layer of titanium on copper backing, thickness 0.01 in.

Tritium target diameter	- $1\frac{1}{8}$ in.
Tritium content	- 3 ci/ in^2 or 5 ci/in^2 .
Titanium thickness	- 4mg/in^2 to 7mg/in^2 .

We require 40 pieces of such targets for our next five year programme.

b) Samples:-

Chemicals, targets: (Natural Isotopes only).

All the rare earth elements each 400 gm.

Cesium	-	10 gms.
Gallium	-	400 " .
Germanium	-	10 " .
Technetium	-	10 " .
Iridium	-	5 " .
Palladium	-	10 " .
Ruthenium	-	10 " .
Rubidium	-	5 " .
Rheneum	-	10 " .
Yttrium	-	10 " .

All the elements in the form of elemental powder of their compounds with high percentage of purity about 99.9% pure.

Dept. of Atomic Energy, Govt. of India has sanctioned a block assistance of ₨ 1.00 lakh a year for the next five years. A PL-480 project has also been submitted to US office of Aerospace Research. However no Foreign exchange is available under these grants. It is therefore necessary to have 10,000 $ worth of foreign exchange for the targets and chemicals mentioned above.

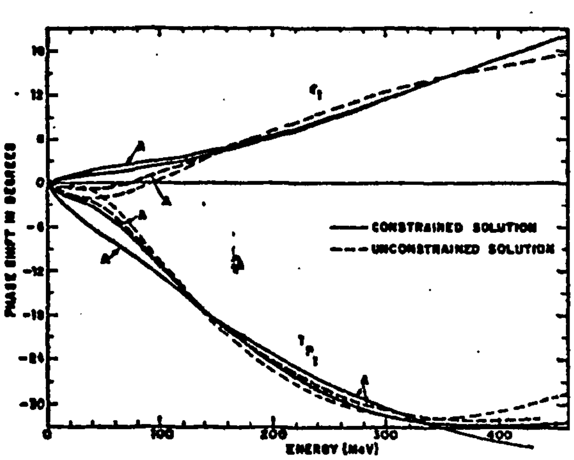

FIG. 1. ϵ_1 and $^1P_1$ phase shifts for the unconstrained and constrained isotopic-spin-0 solutions. The unconstrained solution has values for ϵ_1 and $^1P_1$ that are in disagreement with theoretical expectations at low energies. When we constrain ϵ_1 to remain positive at low energies, then $^1P_1$ also moves out to the larger (negative) values predicted from OPE. The curves labeled A are for the solutions given in Tables VI and VII; these are the results after the addition of the Wisconsin and Kyoto data, as discussed in the text. The other curves are the corresponding solutions before the addition of the Wisconsin and Kyoto data, as also discussed in the text.

Experiments needed to remove the ambiguity in the low-energy ϵ_1 and $^1P_1$ phases were investigated in detail by comparing predictions of the observables for the two energy-dependent solutions listed in Tables VI and VII. As we have shown in Fig. 1, the ϵ_1 and $^1P_1$ uncertainties at low energies are highly correlated. Comparing predicted observables for these two solutions, we found that the (n,p) P, D, R, A, R', A', C_{KP}, A_{ZX}, C_{NKP}, C_{PNP}, and C_{KNP} predictions are almost identical. The values predicted for C_{NN} at 25 MeV differ by a factor of 2 for the unconstrained and constrained solutions over the angular range 0°–∼90°. At the back angles, where (n,p) C_{NN} measurements exist,[19] the two solutions have very similar predictions. A measurement of the (n,p) C_{NN} observable at 45° c.m. to an accuracy of ± 0.02 would distinguish between the two solutions. This is not an easy experiment. The D_T, A_T, R_T', A_T', C_{KK}, C_{PP}, A_{ZZ}, and A_{XX} observables at 25 MeV all have differences in certain angular regions, but in each case an absolute precision of ± 0.02 to ± 0.04 is required to distinguish between solutions.

The one reasonable experiment to carry out in removing the (n,p) solution ambituity is the simplest one—a measurement of the $(n;p)$ differential cross section. A solution having a large (negative) $^1P_1$ phase (the constrained solution of Table VII) has a slightly more asymmetric (n,p) differential cross section than does a solution having a small (negative) $^1P_1$ phase (Table VI).[13] The effect is not large, but it is measurable. The recent Wisconsin measurement,[14] which has an accuracy of about 2%, and the Kyoto measurement,[15] with about the same accuracy, are helpful in reducing the solution ambiguity. Unfortunately these data are somewhat at variance with other (n,p) data, as indicated by the results of the phase-shift analyses. In this situation additional measurements of the 180°/90° ratio for (n,p) differential scattering below 60 MeV would be very useful. To have much influence on the analysis, these data would have to have an accuracy of at least 2%.

[19] J. J. Malanify, P. J. Bendt, T. R. Roberts, and J. E. Simmons, Phys. Rev. Letters 17, 481 (1966); and private communication from the authors.

This letter was received at the Nuclear Data Section on the 2 June (it was postmarked 23 May), when the rest of the report was already finished. Therefore it could be appended only this way.

24th March, 197o

Dear Dr. Schmidt,

In reply to your letter of 1oth December, 1969 and of 6th March, 197o we wish to inform you about the target outfit we need in the Cyclotron Department of the Institute for Atomic Physics of Bucharest and which is difficult to be obtained in the usual way. In fact, there is a group studying the isomer fission of transuranium nuclei. According to the research plan on 197o-1971, the isomer fission will be studied in the U, Np and Pu isotopes by means of nuclear reactions induced by fast neutrons, for estimating the double-humped potential barrier parameters in this region. Therefore, the isomer fission excitation functions are measured for (n,2n) and (n,γ) reactions, which allow a direct estimation of the excitation energy [G.N.Flerov et al., Nucl.Phys. A97 (1967) 444] and of the difference between the first and the second hump height of the potential barrier [I.Boca et al., Nucl.Phys. A1o2 (1967) 443].

For measuring the isomer fission in the nanoseconds range we use the natural modulation of the Cyclotron to pulse the fast neutron beam (the $^{7}Li(p,n)$ or the $^{2}H(d,n)$ reaction as source) and the time-analysis of the fission fragment pulses by means of a time-amplitude converter and a multichannel amplitude analyser. As a fission fragment detector we now use a nitrogen-filled spark counter (time resolution $\sim 3.1o^{-8}$sec), but a gaseous scintillation counter is intended for nearest future (time-resolution $\sim 5.1o^{-9}$sec). The device will be simultaneously used to measure the induced fission cross-sections within the same energy range E_n = o.3 - 15 MeV.

The following targets are required:

^{233}U, ^{234}U, ^{236}U, ^{241}Pu of 97% isotopically enriched. The targets are necessary under the form of deposit layers, 1-2 inch in diameter, o,5 - 1.5 mg/cm^2 thick, on thick alluminum backing.

We should prefer the targets to be delivered on a well defined period of time of about 1.5 - 2 years, but their purchasing would be also financially possible.

For further information, please adress your letters to Dr. N.Vîlcov, Cyclotron Department, Institute for Atomic Physics.

Yours sincerely,

D.Bally