International Atomic Energy Agency

INDC(SEC)-61/LN

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

CONSOLIDATED PROGRESS REPORT FOR 1976

ON NUCLEAR DATA ACTIVITIES

IN THE NDS SERVICE AREA

Argentina

Bangladesh

Bulgaria

Hungary

India

Israel

Pakistan

Poland

Romania

South Africa

October 1977

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

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CORRIGENDUM

Please be advised that the "Progress Report on Nuclear Data Research in Poland" included in the "Consolidated Progress Report for 1976 on Nuclear Data Activities in the NDS Service Area", distributed in October 1977, as INDC(SEC)-61/LN, covers the time periods May 1975 - April 1976 and May 1976 - April 1977.

The heading correction on page 221 of INDC(SEC)-61/LN, including the original Polish report references, should read:

PROGRESS REPORT
ON NUCLEAR DATA RESEARCH IN
POLAND

May 1975 - April 1976 (INR-1642/I/PL/A)
May 1976 - April 1977 (INR-1702/I/PL/A)

Compiled by
A. Marcinkowski

INDC(SEC)-61/LN

CONSOLIDATED PROGRESS REPORT FOR 1976
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FOREWORD

This consolidated progress report for 1976 has been prepared for countries in the NDS service area. It is intended to encourage a closer relationship between Member States and provide for a wider circulation of unpublished progress reports from countries within the Nuclear Data Section service area. A second report INDC(SEC)-62/L covers countries outside the NDS service area.

The report is arranged alphabetically by country, and reproduces the content of each individual report as it was received by the INDC Secretariat. Also included in the Table of Contents is a list of each laboratory, institute and university referred to in the report.

As in all progress reports the information included here is partly preliminary and is to be considered as private communication. Consequently, the individual reports are not to be quoted without the permission of the authors.

Table of Contents

Progress Report on

Nuclear Data Activities in Argentina

ARGENTINE ATOMICA ENERGY COMISSION

Buenos Aires, Argentina

Spins of the 2350, 2516 and 2547 keV levels in ^{140}Ce determined from gamma-gamma directional and polarization-directional correlations.

G. Garcia Bermudez, A. Filevich and M. Behar
Departamento de Fisica Nuclear, Comision Nacional de Energia Atomica

Directional correlations and polarization-directional correlation have been measured for different gamma cascades in ^{140}Ce, populated from the decay of ^{140}La.

Combination of Ge(Li) and INa(Tl) detector were used in both experiments. For the polarization-directional correlation measurement a planar Ge(Li) detector was employed as the linear polarization analyser. Combination of the results of these measurements gives unique spin assignment of 5^-, 4^+ and 1^+ for the 2350 keV, 2516 keV and 2547 keV levels, respectively.

The determined mixing ratios are $\sigma(131) = 0.33 \pm 0.04$, $\sigma(267) \pm 0.39 \pm 0.05$, $\sigma(432) = 0.54 \pm 0.10$, $\sigma(868) = 0.034 \pm 0.007$ and $\sigma(951) = 0.10 \pm 0.$

Level structure of ^{74}AS from the ^{72}Ge(α,npγ) reaction

G. Garcia Bermudez, M. Behar, A. Filevich and M.A.J. Mariscotti
Departamento de Fisica Nuclear, Comision Nacional de Energia Atomica

States of ^{74}As, excited through the ^{72}Ge(α,npγ) reaction at E=30 to 55 MeV, were studied. Excitation function, gamma-ray angular distributions, gamma-gamma coincidences and gamma-time distributions with respect to the beam burst were determined. Three excited states are identified with states previously observed with the (p,n) reaction. In addition, six new levels are incorporated into the level scheme. The decay pattern of these levels is rather simple. The existence of two gamma-ray cascades showing quite similar energy spacings and possible sping sequences $J = 7 \rightarrow 6 \rightarrow 5 \rightarrow 4$ which mainly feed the known 3^- state at 183.0 keV state is observed. A half-life $T\ 1/2 = 28 \pm 2$ nsec of a level at 259.2 keV was determined. This is the state whose g factor was previously assigned to a level at 273.8 keV.

Level structure of ^{73}Se from the $^{72}Ge(\alpha,3n\gamma)$ reaction

M. Behar, A. Filevich, G. Garcia Bermudez, A.M. Hernandez and M.A.J. Mariscotti
Departamento de Fisica Nuclear, Comision Nacional de Energia Atomica

States of ^{73}Se, excited through $^{72}Ge(\alpha,3n\gamma)$ at E = 30 to 55 MeV, were studied; excitation function, gamma ray angular distribution and gamma-gamma coincidences were determined. Levels at the following energies in keV (spin-parity) are proposed: 151(3/2-), 505(5/2-), 804 (7/2-) and 1178(9/2-). These levels together with the hitherto known $1/2^-$ state at 25 keV, exibit a K = 1/2 quasi rotational structure as regards the energy spacing and branching ratios. A similar recent finding in ^{75}Se suggests that such a structure is not uncommon in this region of the periodic table. In spite of its spin, no decay into the 7/2 ground state, interpreted by Kuriyama et al as a deformed three dressed quasiparticle state, is observed although such a decay should be favoured in the present reaction.

Spin of the 1248 keV and 1958 keV levels in ^{124}Te determined gamma-gamma directional and polarization directional correlations.

M. Behar, G. Garcia Bermudez, A. Filevich and M.C. Cambiaggio
Departamento Fisica Nuclear, Comision Nacional de Energia Atomica

Directional correlations and polarization-directional correlation have been measured for the 643-603 keV cascade in ^{124}Te populated from the decay of ^{124}Sb. Ge(Li) detectors were used in both spectrometers, one of them a planar Ge(Li) detector as the linear polarization analyzer for the gamma radiation. Combination of the results of these measurements give unique spin assignments of 4^+ for the 1248 keV and 1958 keV levels. The determined E2/M1 mixing ratios are: $\sigma(646) = 0.00 \pm 0.01$ and $\sigma(709) = 0.02 {+0.06 \atop -0.07}$

Level structure of ^{72}As studied with the (α,xnp) reaction

M.A.J. Mariscotti, M. Behar, A. Filevich, G. Garcia Bermudez, A.M. Hernandez and C. Kohan
Departamento de Fisica Nuclear, Comision Nacional de Energia Atomica

States of ^{72}As, excited through the ^{70}Ge (α,np) and ^{72}Ge(α,3np) reactions at E 30 to 55 MeV, were studied. Excitation functions, gamma-ray angular distributions, gamma-gamma coincidences and gamma-time distributions with respect to the beam bursts, were determined. Five excited states are identified with levels previously observed with the (p,n) reaction. In additon seven new levels and their decay pattern are incorporated into a level scheme. A half-life of 17 $\pm$ 3 nsec was determined for the 309.8 keV state, and evidence for the existence of a long-lived state ($>$ 100 nsec) was obtained. A simple scheme based on simple particle shell-model configurations accounts for the gross properties of the low lying levels. While definite spin and parity assignment for the upper excited states require further measurements, tentative spin values up to 7 are obtained.

Two-Nucleon stripping reactions populating isobaric multiplets in the region $40 \geq A \geq 56$.-

O. Dragun, D.R. Bes and E.E. Maqueda
Comision Nacional de la Energia Atomica

A DWBA analysis accounts for the experimental results concerning the ratio between transitions populating isobaric multiplets in the region $40 \leqslant A \leqslant 56$, by using distorted waves of definite isospin.

The ^{135}Xe neutron cross section

J. Gil Gerbino and L. Cohen de Porto
Departamento de Reactores, Comision Nacional de Energia Atomica

The experimental determination of ^{135}Xe of neutron cross section has been made using the technique of ^{135}Xe depletion in a 10^{13} thermal neutron flux.

Comparation with previous recommended values indicates a 5 % higher value.

The determination of the ratio of U238 epithermal captures to U235 fissions and effective resonance integral in U238

G.H. Ricabarra, M.D.B. Ricabarra and H. Amato
Departamento de Reactores, Comision Nacional de Energia Atomica

An experimental determination has been undertaken of the epithermal neutron captures in the U238 in relatively thin samples to see how new resonance parameters of U238 (radiative width) describe effective resonance integral of U238.

Fission distribution in UO2 rods

M.D.B. Ricabarra, D. Waisman and R. Turjanski
Departamento de Reactores, Comision Nacional de Energia Atomica

Using mica and macrofol catchers the fission distribution in UO2 has been measured. The results between mica and macrofolagreeswithin their experimental error. The fission distribution has been compared with previous results and with theoretical models (diffusion, transport S-5 and THERMOS). The results of this experiment shows that the fission distribution is understimated by codes which do not take into account the neutron hardening in the reactor.

Progress Report

on

Nuclear Data Activities in

Bangladesh

1976

Compiled by

M. Mizanul Islam
Atomic Energy Centre,
Dacca.

Bangladesh Nuclear Data Committee

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ATOMIC ENERGY CENTRE, DACCA.

1. ENERGY DEPENDENCE OF FISSION FRAGMENT ANISTROPY IN FAST NEUTRON FISSION OF ^{235}U.

(M.M. Islam, A.H. Khan, M. Khaliquzzaman, M.A. Rahman, M. Enayetullah and D.A.M. Abdullah)

Studies of fission fragment anisotropy are important because such studies provide information about the nuclei at the saddle point. For each compound nucleus the two principal factors affecting the fission anisotropy are K_0^2 and the mean square orbital angular momentum $\langle l^2 \rangle_{av}$. The quantity K_0^2 is the standard deviation in the Gaussian distribution that is assumed for K, where K is the projection of the total angular momentum in the nuclear symmetry axis.

Below the second chance fission threshold, the expression for anisotropy[1] is given by

$$\frac{W(0^\circ)}{W(90^\circ)} = 1 + \frac{\langle l^2 \rangle_{av}}{4K_0^2} - \frac{\langle l^2 \rangle_{av} I_0^2}{36 K_0^4} \quad \text{..........(1)}$$

Here I_0 is the spin of the target nucleus.

From the studies of (d,pf) reaction, it was suggested[2] that the pairing energy gap ($2\Delta_0$) in the transition state spectrum of ^{240}Pu is considerably larger than the energy gap when it is at the equilibrium deformation. Nadkarni et.al[3] also reported such observation in ^{235}U (n,f). The quantity is determined from the fact that when the quantity ($E^* - E_f$) of the fissioning compound nucleus reaches $2\Delta_0$, there is a sudden decrease in anisotropy or corresponding step increase in K_o^2 value. The main interest of the present work is also the investigation of this phenomena in the case of $^{235}U(n,\gamma f)$ and the verification or otherwise of the previous observations.

<u>Experimental procedure and data analysis</u>

The anisotropy measurements were done by using 2 ORTEC heavy ion detectors, 25 mm in diameter and placed inside a thin walled brass vacuum chamber. The detectors, one at 0° and the other at 90° to the beam direction were used simultaneously to measure the fission yield. The distance between the target and the detectors were 3 cm in each case. The target was $\sim$200 $\mu g/cm^2$ enriched (99%) ^{235}U of 1 cm diameter. The backing material used for the target was 1 mil aluminium foil. The target was placed at 45° to the beam direction. Neutrons were produced by using T(p,n) and D(d,n) reactions with the beam from the 3 MeV Van de Graaff of the Atomic Energy Centre, Dacca. The spread in neutron energy were calculated from stopping power of protons in the target and also from the kinematic spread due to finite size of the target. Average beam current used was 40 μA. With such current it was necessary to have arrangements for target cooling. Both water cooling and compressed air cooling with wobling target were tried.

In the spectra obtained from the experiment, slight overlap were noticed between the α and fission peaks. So corrections were applied to fission yields by using an eye estimate tail to fit the fission peak. The corrections arising from such a procedure were of the order of 1-2 percent only and as such uncertainty involved in this correction was very small. Corrections were also applied for finite size of the detectors and for neutron flux variation across the surface of the target.

Results and Discussions

The values of anisotropy plotted against neutron energy as measured in this work are slightly lower than the values of others[3,4]. However, we plan to verify these data again with good statistical accuracy, and to measure anisotropies for a number of other neutron energies in order to investigate in detail the variation of K_o^2 with E_x^s. The present results also seem to indicate that the anisotropy is a smooth function of energy. But further measurements will be carried out to confirm as to whether or not the anisotropy has a break at $E_n \simeq 0.8$ MeV ($E^* - E_f \sim 2.0$ MeV) as observed earlier by Nadkarni et al[3].

Reference

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2. J.J. Griffin, Physics and Chemistry of Fission, 1, 23(1965)
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2. TWO PARAMETER STUDY OF FRAGMENT MASS-KINETIC ENERGY CORRELATIONS IN FAST NEUTRON FISSION.

(M.M. Islam, A.H. Khan, M. Khaliquzzaman, E. Husain, A. Rahman and P.K. Pal*)

Study of the details of the fragment mass and energy distributions and mass-energy correlations as a function of the compound nucleus excitation energy is important from the point of view of understanding the fission process. A programme has been taken up in our laboratory on this topic and some measurements have been performed with a ^{235}U target. Neutron beam was obtained from the 3 MeV Van de Graaff Accelerator using $D(d,n)^{3}He$ reaction.

Two parameter data in 64 x 64 channel configration were recorded by doing a double energy experiment with two detectors at 180° to each other. Preliminary analysis of data at thermal and 1 MeV neutron energy have been performed using the Grid method of Schimitt et al[1]. From qualitative considerations the results obtained appear satisfactory. Further analysis of data from measurements already done are in progress and further experiments are also planned.

Reference: 1) H.W. Schimitt et al, Phys. Rev. 141, 114(1966)

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* Department of Physics, Dacca University.

3. ANGULAR DISTRIBUTION STUDIES OF PROTON CAPTURE REACTIONS IN ^{44}Ca, ^{51}V AND ^{54}Fe.

(M.A. Awal, M.A. Rahman, H.M. Sen Gupta* and G.U. Din**)

The resonance spectra at E_p = 1644 and 1650 keV in the $^{44}Ca(p,\gamma)^{45}Sc$ reaction at 0°, 30°, 45°, 60° and 90° were studied with the help of a 2 MeV Van de Graaff Accelerator of the Australian National University, Canbera, Australia. Gamma rays were detected by a 30 cc Ge(Li) detector having a resolution of 5 keV for the 1332 keV gamma line of ^{60}Co source and were recorded with a Nuclear Data 4096 channel pulse height analyser.

The resonance spectra at E_p = 2329 keV in the $^{51}V(p,\gamma)^{52}Cr$ reaction at 0°, 30°, 55° and 90° and those at E_p=1730 keV in $^{54}Fe(p,\gamma)^{55}Co$ reaction at 0°, 30°, 45° and 90° were taken with the help of a 5.5 MeV Van de Graaff Accelerator of the Bhabha Atomic Research Centre, Bombay, India. Gamma rays were detected by a 20 cc Ge(Li) detector having a resolution of 5 keV for the 1332 keV gamma line of ^{60}Co source and were recorded with a 4096 channel pulse height analyser. The energies, relative intensities, probable transitions and branching ratios of the deexciting levels have been obtained.

The data of the above studies were analysed at the AEC, Dacca. The angular distribution fits for a number of gamma rays were obtained with the help of the relation

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$$W(\theta) = 1 + a_2 P_2(\cos\theta) + a_4 P_4(\cos\theta)$$

From the known knowledge of spin values of the low-lying levels, the possible spin values of the resonance levels were computed from a set of plots of χ^2 versus arctan δ. The values of χ^2_{min} and mixing ratios at 0.1% confidence level for different spin assignments in all the cases are shown in Table 3.1.

a) <u>The spin assignments of the 1644 and 1650 keV resonances in the $^{44}Ca(p,\gamma)^{45}Sc$ reaction</u>:

The spectra taken at 90° have been considered for the decay scheme in ^{45}Sc at the 1644 and 1650 keV resonances. The angular distribution fits and the χ^2 analyses of the 8490, 8127, 7565 and 7200 keV γ-ray transitions from the 1644 keV resonance to the 12.4, 376, 938 and 1303 keV levels and that of the 7568 keV γ-ray transition from the 1650 keV resonance to the 938 keV level have been obtained. From the analyses the spins of both the resonances are found to be 3/2. In the present analyses the spins of the 1555 and 2350 keV levels are confirmed to be ½ and 3/2 respectively.

b) <u>The spin assignment of the 2329 keV resonance in the $^{51}V(p,\gamma)^{52}Cr$ reaction</u>:

The angular distribution fits and χ^2 analyses of the 10415 and 9172 keV γ-ray transitions from the resonance level to the 2370 and 3613 keV levels have been obtained. From these analyses, the resonance spin has been assigned to be 4. This resonance is

Table 3.1

The values of χ^2 min and mixing ratios at 0.1% confidence level for different spin assignments.

E_p(Lab) (keV)	Primary transition	Branching ratio %	Spin sequences.	χ^2 (min)	Mixing ratio at confidence level 0.1%	min	0.1%	gΓ (eV)
	(a) $^{44}Ca(p,\gamma)^{45}Sc$							
	8490	9	3/2-3/2	0.43	0.3	0.30	-0.16	
						M2/E1		
					11.40	-3.27	-1.64	18.34
1644	8127	23	3/2-3/2	0.32	0.01	0.21	0.33	
						M2/M1		
	7565	6	3/2-1/2	0.24	-0.27	-0.10	-0.02	
						M2/E1		
				[illegible]	1.61	2.35	3.74	
	7200	7	3/2-3/2	0.44	-0.01	0.70	0.46	
						M2/E1		
1650	7568	38	3/2-1/2	0.10	0.066	0.17	0.10	
						M2/E1		
					1.37	1.66	2.04	
	(b) $^{51}V(p,\gamma)^{52}Cr$							
	10415	31	4-4	0.24	0.36	0.51	0.63	
						M2/E1		
2329					4.8	2.60	1.84	
	9172	25	4-5	0.56	0.11	0.92	4.91	
						M2/E1		
	(c) $^{54}Fe(p,\gamma)^{55}Co$							
1730	6755	90	7/2-7/2	0.32	0.35	0.46	0.57	
						E2/M1		

thus confirmed to be the analogue state in ^{52}Cr corresponding to the 1559 keV parent state in ^{52}V.

c) Spin assignment of the 1730 keV resonance in the $^{54}Fe\ (p,\gamma)^{55}Co$ reaction.

The χ^2 analyses and the angular distribution fits of the 6756 keV γ-ray transition from the resonance level to the G.S. were performed. From these analyses, it is observed that the spin of the resonance level is ought to be 7/2 since only the 7/2 transition lies fairly below the 0.1% confidence level.

4. THE LEVEL SCHEMES IN ^{55}Co AND ^{58}Co.

(M.A- Awal, H.M. Sen Gupta* and G.U. Din**)

The $^{54,57}Fe(p,\gamma)^{55,58}Co$ reactions were employed for constructing the level schemes in ^{55,58} Co nuclei from a number of singles spectra. Gamma rays were detected with a high resolution 34 cc Ge(Li) detector having a resolution of 2.3 keV for the 1332 keV gamma line of ^{60}Co source. The energies, intensities, probable transitions of the γ-rays and branching ratios of the deexciting levels were obtained. Four resonances at E_p = 1286, 1680, 1780 and 1747 keV in the $^{54}Fe(p,\gamma)^{55}Co$ reaction have been utilised to construct the decay schemes in ^{55}Co. New levels at 3885, 3906, 3950, 4240 and 4320 keV have been assigned. The agreement between the present work and others[1-3] is fairly good.

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The $^{57}Fe(p,\gamma)^{58}Co$ reaction has been studied at E_p = 1355, 1360, 1436, 1446 and 1583 keV resonances. The 1355, 1360, 1436 and 1446 keV resonances were studied for the first time. The decay schemes of the ^{58}Co nucleus are complex. It may be mentioned that the levels at 458, 1040, 1185, 1814, 1865, 2424, 2686, 2782, 3070, 3125, 3152, 3202, 3263, 3376, 3393, 3418, 3445 keV and these above 3512 keV have not been observed in the only other (p,γ) work of Erlandsson and MarchinKowski[4]. The 2105, 2642 and 3011 keV levels found by them however could not be assigned in the present work. The agreement between the present work and that of Schneider and Dachnick[5] is fairly good.

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2. D.J. Martin, J.R. Leslie, W. McLatchie, C.F. Monahan and L.E. Carlson, Nucl. Phys. A187, 337(1972)

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5. THE RELATIVE EFFICIENCY MEASUREMENTS OF A 30 CC Ge(Li) DETECTOR.
(M.A. Awal, M.A. Rahman and M. Zahur Ali)

The relative efficiency curves of a 30 cc Ge(Li) detector (type 5603 of philips, Holland) have been measured between 1 and 11 MeV. These curves have been obtained with the help of proton capture reactions in ^{27}Al. It was observed that the 992 keV resonance in the $^{27}Al\ (p,\gamma)\ ^{28}Si$ reaction was particularly suitable since it emits a number of strong gamma rays from 1.78 to 10.76 MeV and is formed mostly by s-wave proton capture (99% ℓ=0, 1% ℓ=2). Thus the angular distributions of the gamma rays are practically isotropic[1]. The resolution of the detector was found to be 3.2keV for the 1332 keV line of ^{60}Co source. The spectra of the resonance were stored in a 4096 channel Nuclear Data pulse height analyser. The efficiency is defined as the number of events counted in a peak in a gamma ray spectrum divided by the number of events actually produced by the monoenergetic source over 4π geometry. The efficiency ratio of two gamma ray energies is related to the ratio of their peak area and their relative intensities in the source, in the from:

$$\epsilon_1/\epsilon_2 = (N_1/N_2)\,(I_2/I_1)$$

where ϵ_1/ϵ_2, N_1/N_2 and I_1/I_2 are the ratios of the efficiencies, peak areas and intensities respectively for the two gamma rays. The "two line method" based on the measurement of ratios of efficiencies has be used in the present analysis. With the help of the known intensities of the 992 keV resonance[2], it was possible to build up relative efficiency curves for the full energy, single escape, double escape and for the ratio of double escape to full energy.

References

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6. STUDY OF REACTION MECHANISM AND LIFE TIME MEASUREMENTS.
(M. Sanaullah, M. Dilder Hossain and M. Khaliquzzaman)

The data taken from previous measurements on $^{54}Fe(p,\gamma)^{55}Co$ have been analysed. The results obtained are briefly discussed. The yield curve for the reaction are measured for E_p=1106-1747 keV. The resonance energies and the corresponding excitation energies are listed in Table 6.1. The decay schemes for the resonances at E_p=1747, 1721, 1679, 1666, 1653, 1474, 1286, 1224, 1161, 1106 keV were established by detecting the reaction γ-rays with high resolution co-axial Ge(Li) detectors. Decay schemes and branching ratios of the resonances were also obtained. For comparison, the low lying states observed in the present investigation are given along with those of others in Table 6.2. It can be seen from the table that the results of the present investigation are in general agreement with those of others[1-4].

References

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3) M. Hagen U.Janetzki and K.H. Maier, Nucl. Phys. A157, 177 (1970)
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Table 6.1

The $^{54}Fe(p,\gamma)^{55}Co$ resonance and the corresponding energy levels in ^{55}Co.

Proton Energy E_p (KeV)	Excitation Energy in ^{55}Co E_x (KeV)
1106	6150
1161	6204
1224	6266
1286	6327
1328	6368
1369	6408
1474	6511
1638	6672
1653	6687
1666	6700
1679	6712
1721	6754
1747	6780

Q - Value = 5064 ± 2 KeV.

Table 6.2

Energy levels below 5 MeV in ^{55}Co (E_x in MeV)

Present work	$^{54}Fe(p,\gamma)^{55}Co$ Ref.(1)	$^{54}Fe(^{3}He,d)^{55}Co$ Ref.(2)	$^{54}Fe(d,n)^{55}Co$ Ref.(3)	$^{54}Fe(p,\gamma)^{55}Co$ Ref. (4)
0	0	0	0	0
2.167	2.17 ± 0.02	2.162	2.16	2.166
2.566	2.57 ± 0.02	2.559	2.56	2.566
2.661	2.66 ± 0.02		2.70	2.660
2.918				2.920
				2.924
2.938		2.938	2.940	2.940
2.960	2.95 ± 0.02			2.976
3.302	3.31 ± 0.02			3.304
3.324			3.33	3.325
		3.37		
3.553				
3.564				3.563
3.640				3.644
		3.657	3.66	
3.725			3.72	3.726
3.860				
		3.87	3.87	
		3.97	3.98	(4.034)
4.164				4.165
4.176				4.177
		4.185	4.19	
				4.264
			4.29	
			4.39	
				4.472
			4.50	
4.548				4.550
4.590			4.58	
				4.629
		4.65	4.65	
4.722				4.722
		4.755	4.75	4.745
			4.94	
4.965				4.961
4.991	5.00 ± 0.05			4.990

7. STUDIES OF INTERACTIONS AND FISSION OF URANIUM BY FAST NEUTRON EMPLOYING NUCLEAR EMULSION.

(M.M. Kasim, Enayetullah Molla, A.R. Mollik and H. Nabi)

Five K1 emulsion plates were loaded with uranium. These plates were numbered as U-17-1, U-17-2, U-17-3, U-4 and U-5. Exposed plate no. U-17-3 to 17.4 MeV neutrons and then processed by usual procedure. Exposed plate no U-4 to 5.76 MeV neutrons from $D(d,n)He^3$ reactions using deuteron beam of Van de Graaff machine.. The plate U-4 has been scanned for fission events. 312 binary and four ternary fission events have been observed. Their angular distribution with respect to the incident neutron has been measured.

Six K1 and five K5 emulsion plates loaded with uranium were exposed to 4.7 MeV neutrons. Plate no U12 has been fully scanned and in this plate 671 binary and 29 ternary fission events have been observed. In plate no U15 about 200 fission events have been observed of which 2 were ternary fission events. In plate U13,180 fission events have been found.

8. PROTON-INDUCED X-RAY EMISSION (PIXE) ANALYSIS OF TRACE ELEMENTS.

(A.H. Khan, M.M. Islam, M.B. Zaman, M. Khaliquzzaman, M. Husain, F. Majid, A. Hussam*, M.A. Awal and M.A.Rahman).

During this reporting period, our main effort was to develop the experimental set-up for PIXE. Early in 1975, an X-ray spectrometer suitable for single element microanalysis was set-up and its properties studied. It consists of a 4" cube

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aluminum vacuum chamber, a gas-filled X-ray proportional counter with a FET preamplifier and a 512 channel pulse height analyzer (Nuclear Data). It is a very suitable system for inner-shell ionization cross section measurements but not for multi-element trace analysis, obviously due to the low resolution of proportional counters. The characteristis performance of the spectrometer has been reported else where[1].

Late in the same year (1975), all our efforts were concentrated on the development of a new X-ray spectrometer after we received a set of equipment including a Si(Li) X-ray detector, as a technical assistance from the IAEA.

The setting up of the new X-ray spectrometer and the detailed study of its characteristic features have been completed and reported elsewhere[2]. Essentially the spectrometer consists of the same aluminum vacuum chamber mentioned above, the Si(Li) detector with a cooled FET, an X-ray amplifier and a 4096 channel pulse height analyzer (Nuclear Data).

The vacuum chamber has the provision for loading twenty six targets at a time and it can also accommodate a charged particle detector. The X-ray detector is a 30 mm^2 Si(Li) crystal having the resolution of 175 eV at 5.9 keV. The X-ray amplifier has a built-in baseline restorer and a pile-up rejector. From the detailed study of its properties, it has been found that the system is capable of analyzing elements down to phosphorous.

The following problems have been studied with this spectrometer.

(i) Analysis of sulphur and phosphorous present in a system together.

(ii) Analysis of zircon for Hf and other trace elements,

(iii) Analysis of soil extract for micronutrients,

(iv) Determination of Uranium in a phosphate medium, etc.

References

1. Progress Report RC-1533/RB, 1975
2. Progress Report BAN/02/3, 1976

9. REDIOISOTOPE EXCITED X-RAY FLUORESCENCE ANALYSIS OF TRACE ELEMENTS

(A.H. Khan, M.M. Islam, M.B. Zaman, M. Khaliquzzaman M. Husain and F. Majid)

The equipment for this research were provided by the IAEA in 1975 under its technical assistance programme. This Analytical System obtained from Ortec consists of: (1) a 5 mCi ^{109}Cd X-ray source, (2) a stainless steel sample chamber with a capacity for four samples at a time, (3) the cooled Si(Li) detector used in PIXE and (4) other electronics necessary for energy dispersive X-ray analysis.

The experimental set-up of this X-ray spectrometer has been completed and its characteristic features have been studied. The system can be operated both unddr vacuum and atmospheric conditions. Samples both in the solid and liquid form can be used. Some of the applications of the technique so far studied are:

(i) Trace element analysis in beach sand minerals,

(ii) Trace element analysis in cow feed materials,

(iii) Trace element analysis in jute fibres etc.

The spectrometer is exceptionally suitable for mineral analysis. It would be still better if we could have a 10 m Ci ^{55}Fe source, most suitable for relatively light element excitation like S, P, Si, Cl, etc.

Quantitative measurements on the problems mentioned above are in progress.

10. INNER-SHELL IONIZATION CROSS SECTION MEASUREMENTS AND CALCULATIONS
(M. Sarkar*, S.M.M.R. Chowdhury, A.H. Khan and M. Hussain*)

After completing the basic studies of the existing three theories of inner-shell ionization cross sections, efforts were concentrated on the development of computer codes for these calculations. The original programme for PDP-15 computer was provided by Dr. Hans Mommsen of Bonn University. During his stay at the AECD (March-April, 1976), the programme was rewritten according to the input-output requirements of the IBM-1620 computer of the AECD.

The programmes for the semi-classical approximation (SCA) and the binary encounter approximation (BEA) have been tested for gold L-shell ionization with 1.0 MeV protons and found correct. The programming for the plane wave Born approximation is in progress.

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Dacca University.

11. EFFECT OF SHORT RANGE CORRELATION ON THE PHOTODISINTEGRATION OF ^{4}He

(S.A. Afzal, S.M.M.R. Chowdhury and S. Suhrabuddin*)

In the study of ^{4}He $(\gamma,p)^3$H reaction, investigation is mainly concentrated on the effect of strong short range correlation. Initially Jastrow type correlation has been introduced in the wave functions of ^{4}He and ^{3}H and reasonable agreement with experimental result has been obtained. Later on, the calculation has been further improved upon in another study by introducing modified density of states which is different from that of the free particle one, although the ejected proton will be represented by the plane wave asymptotically. This change in form is necessitated due to final state interaction between proton and triton. The ratio of modified density to the free particle density of states is taken to be of the form $(1 + AK + BK^2)^2$. The parameters A and B are obtained by a χ^2 fitting. By employing this procedure the result has been much improved.

12. PAULI PRINCIPLE IN THE ALPHA DEUTERON MODEL AND THE STRUCTURE OF ^{6}Li

(S. A. Afzal)

Various models have been employed to study the interesting nucleus of ^{6}Li. Among them shell model, collective model, optical model and cluster model are prominent. Cluster model works well in explaining many properties of ^{6}Li where other models fail to reproduce the desired results. In the cluster model study of ^{6}Li there are two approaches that are followed . In one case, effect

* Department of Mathematics, Dacca University.

of Pauli Principle through the introduction of antisymmetrization operator is taken into account while in the other case no antiymmetrization effect is taken. By the study of different works on charge form factor, quadrupole moment, bound state and alpha - deuteron phase shifts it has been shown that in both the approaches inclusion of Pauli Principle, that is the antisymmetrization operator, is very much a necessity to explain all the above nuclear properties consistently if one is to employ the cluster model calculation for ^{6}Li.

13. MORE CONSISTENT RESONATING GROUP CALCULATION OF α-α INTERACTION

(S.A. Afzal and S. Ali)

All previous resonating group calculations of the interactions have been made with α-particle wave functions, the parameters of which have been fixed not in the usual variational way as should have been the case, but rather from the r.m.s. radius of the α particle. The internal energy of the particle so determined has been used consistently in the subsequent calculations. But in the present calculation α- particle parameter has been determined from variational principle and the calculations have been made for s-, d-, and g- wave α-α scattering. The results point to a force mixture of N-N interaction different from that used in earlier calculations.

14. IMPROVEMENT OF SHELL MODEL WAVE FUNCTION OF TRITON IN THE LOWEST CONFIGURATION

(S.A. Afzal)

Shell model wave functions of triton have been constructed from the group theoretical point of view. In this study it has been observed that the wave functions of higher quantum number do not contribute much to the binding energy although the construction of the wave function involves huge amount of work. So it seems proper that the main contribution to the binding energy will come from the zero quantum number (for s-state) and two quantum number (for d-state) states. So main effort has been given to the improvement of these two states. This has been done by constructing additonal s and d states by introducing new parameters. The result has xx been much improged.

15. BINDING ENERGY CALCULATION OF TRITON WITH REALISTIC POTENTIAL

(I. Zakia* and S.A. Afzal)

The wave function of triton has been generated from the group theoretical formalism by emplåying the transformation properties of the partitions of the symmetric groups S_3 and in fact a set of space and spin-isospoin function is construcged by application of Young operators to some suitable generating functions. By applying a selection rule all the states including the states of higher configuration which make appreciable contribution to the binding energy of the ground state of triton have been taken into consideration. Then a series of nucleon - nucleon interactions including the soft core central and tensor potentials have been employed to calculate the binding energy of triton.

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16. A NEW METHOD FOR SOLVING COUPLED DIFFERENTIAL EQUATIONS IN BOUND STATE PROBLEMS

(S.A. Afzal and D. Clement*)

In calculating the binding energy of light particles like ^3H, ^4He, ^6Li and ^6He in group theoretical formalism one finally faces the problem of solving eigenvalues and eigenvectors for a large number of coupled differential equations of the form

$$\frac{d^2 f^i(x)}{dx^2} - \sum_{j=1}^{n} A_{ij}(x) f^j(x) = \epsilon f^i(x) \quad \text{with } i = 1, 2, \cdots n,$$

There is very limited scope of solving these equations in a small computer. So, a new method for solving these large number of coupled equations has been evolved in which an effective potential has been found out and with that potential a single differential equation is solved for eigenvalues and eigenvectors. Results a obtained with this method completely tally with those obtained from the basic parinciple. As a result, provision of massive storage capacity needed in a computer, which is a prerequisite for soàving such problems may be totally eliminated. Specific problems have been taken as examples and very good results have been obtained.

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* Institute of Physics, University of Tubingen, West Germany.

17. AN ANALYSIS OF $^{12}C(^{16}O,\alpha)^{24}Mg$ REACTION

(S.A. Afzal, A.A.Z. Ahmad and Habibul Ahsan)

A theoretical analysis of the nuclear reaction $^{12}C(^{16}O,\alpha)^{24}Mg$ is in progress. The nuclei ^{12}C, ^{16}O and ^{24}Mg are assumed as alpha clusters and their wave functions are taken to be of gaussain forms. Parameters appearing in the expressions for wave functions are found from the r.m.s. radii of the nuclei.

18. PHENOMENOLOGICAL α-α POTENTIAL AND THE GROUND STATE OF ^{8}Be

(S.A. Afzal and K.A. Motakabbir)

A series of α-α potentials that have been taken in the recent study of α-α phase shifts are being examined in the light of the ground state of ^{8}Be so that resonance energy E_r for $\ell = 0$ and the resonance width Γ can be evaluated. Finally from this study a more detailed information about the nucleon - nucleon interaction can be obtained.

Progress Report on Nuclear Data Activities in Bulgaria July 1975 - March 1977

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All the activities have taken place at the Institute mentioned above, some of them in collaboration with the Joint Institute for Nuclear Research (JINR), Dubna.

1. Neutron nuclear data

1. NEUTRON TOTAL CROSS SECTIONS OF Ag, In, Cu, Ni, Fe, Mo, N, Ar AND DRY AIR FOR NEUTRON VELOCITIES IN THE RANGE FROM 100 TO 250 m/s (N.T.Kashukeev, G.A.Stanev, V.T.Surdjiisky, E.N.Stoyanova)

The hereby given data for neutron total cross sections of some metals and gases have been measured at the following experiment conditions. As a source of neutrons with velocities in the range from 100 to 250 m/sec, we used a curved horizontal mirror neutron guide (electropolished tube of stainless steel), mounted at the IRT-2000 Reactor in Sofia. The detector was a proportional gas counter with ^{3}He and aluminium window. The neutron beam spectrum was analyzed with a very cold neutron time-of-flight spectrometer. Optimal operation conditions were obtained at a resolution of the facility in velocity approximately 8%, for neutron velocity of 100 m/sec. The maximum neutron beam intensity was obtained at the velocity of 160 m/sec. The neutron total flux in the given velocity range falling over the sample was 50 imp/cm^2 sec. The background of each analyzer channel was 1.5% at 160 m/sec and 3% at 100 m/sec. The investigations were carried out by transmission of the collimated neutron beam through the sample of the investigated substance.

The following results have been obtained:

Neutron total cross section in the velocity range from 100 to

250 m/sec of all investigated metals depends on the velocity according the 1/V law. Besides that it coincides with the absorption cross section, calculated by 1/V law, using data for thermal neutrons, for the metals: Ag, In, Cu, and is significantly greater for Ni, Fe and Mo. For the gases /N, Ar and dry air/ at 760 torr and 290 K, the neutron free path in the gas depends on the velocity by the A+B/V law.

In Table 1 the measured values of neutron total cross section are given for someinvestigated metals and gases at neutron velocity 100 m/sec; relative error in the results of about 10%. Dry air cross section was calculated with the assumption that the interaction at target length 0.5 m is realized effectively only with the N, which constitutes 78.08% of the air. The coincidence of the results with those of the N confirms the correctness of our hypothesis.

Table 1

Neutron total cross section /barn/ for neutron velocity 100 m/sec and relative error 10%

Ag	In	Cu	Ni	Fe	Mo	N	Ar	Dry air
1360	4100	85	140	92	195	140	16	140

2. REACTOR SHIELDING CALCULATIONS IN COMPLEX GEOMETRY (V.Christov, L.Alexandrov, M.Drenska, V.Gadjokov)

A series of reactor shielding calculations are being prepared. The necessary neutron cross-section data have been obtained in ENDF/B format from the nuclear Data Section of the IAEA. Results are expected for 1978.

2. Non-neutron nuclear data

1. NEW EXPERIMENTAL DATA ON THE $^{131}La \rightarrow {}^{131}Ba$ DECAY (Zh.Zhelev, Ts.Vylov, M.Enikova, T.Lebedev)

65 new gamma-transitions were observed in the decay of ^{131}La by means of high resolution Ge(Li)-detectors (with a volume of 11;38;50 cm^3), and about 70% of them were placed in the decay-scheme (Table 2). The new levels: 1105.0; 1154.3; 1291.6; 1475.6; 1873.0; 1981.0; 2271.0 keV are proposed on the basis of gamma-gamma coincidence - measurements and the intensity balance.

2. NANOSECOND ISOMERIC INVESTIGATIONS IN THE 89-NEUTRON ODD-ODD NUCLEI ^{152}Eu AND ^{156}Ho (W.Andrejtscheff, V.G. Kalinnikov[1)], N.S.Marupov[2)], T.M.Muminov[2)] and K.D. Schilling[3)])

Nuclei with 89 neutrons lie in a transitional region between well deformed and spherical nuclides. Isomeric investigations may reveal some interesting features of the nuclear structure in this region.

Using the Rossendorf research reactor, delayed gamma-gamma coincidences were performed in the reaction $^{151}Eu(n,\gamma)$ ^{152}Eu applying a NaI(Tl) scintillator and a Ge(Li) low-energy detector. Delayed gamma-ray spectra were recorded by means of the Ge(Li) detector in the region 40...350 keV with a time delay of 0, 4.5, 9 and 13.5 ns, respectively. Data processing is in progress.

In the decay of ^{156}Er(19 min), half-lives of excited states in ^{156}Ho have been determined using a plastic scintillator and a magnetic lens spectrometer. Following results were obtained: $T_{1/2}$(82 keV) = 1.25±0.20 ns and $T_{1/2}$(87 keV) = 58.3±3.0 ns.

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1) Joint Institute for Nuclear Research, Dubna (USSR)

2) Samarkand State University (USSR)

3) Zentralinstitut für Kernforschung, Rossendorf, 8051 Dresden (DDR)

Table 2

E (keV)	I	E (keV)	I
176.041(159)	0.114(70)	1455.045(251)	0.088(22)
209.269(27)	1.304(129)	1461.307(108)	0.172(22)
317.504(61)	1.224(113)	1475.983(156)	0.192(38)
352.075(147)	0.559(257)	1560.408(182)	1.101(19)
354.319(187)	0.683(167)	1564.217(183)	0.097(18)
413.303(231)	1.025(192)	1570.190(203)	0.079(17)
416.312(207)	2.376(735)	1664.606(251)	0.076(16)
483,867(81)	0.278(34)	1696.558(221)	0.141(18)
584.809(46)	0.263(28)	1706.876(240)	0.071(24)
609.134(74)	0.332(50)	1735.014(259)	0.113(38)
664.625(45)	0.595(25)	1754.386(136)	0.154(28)
694.625(143)	0.117(24)	1771.209(269)	0.062(20)
700.379(149)	0.109(23)	1779.397(265)	0.060(17)
703.707(345)	0.044(14)	1782.989(263)	0.062(19)
771.185(229)	0.173(48)	1789.390(381)	0.054(17)
837.861(109)	0.170(27)	1844.938(206)	0.110(28)
868,498(435)	0.206(71)	1849.804(213)	0.105(26)
869.403(310)	0.132(39)	1859.083(215)	0.072(27)
888.850(177)	0.055(16)	1873.653(172)	0.135(22)
924.347(164)	0.097(15)	1947.467(258)	0.170(30)
933.030(78)	0.175(20)	1994.015(470)	0.034(15)
944.127(143)	0.083(15)	1998.842(259)	0.069(18)
958.879(142)	0.101(22)	2005.035(356)	0.044(16)
969.724(306)	0.095(20)	2055.238(217)	0.069(11)
1154.228(198)	0.128(20)	2064.937(203)	0.032(8)
1158.011(491)	0.052(15)	2067.635(398)	0.014(5)
1168.970(557)	0.054(28)	2100.299(235)	0.079(18)
1209.448(150)	0.111(26)	2138.722(229)	0.029(9)
1212.852(216)	0.092(34)	2195.577(320)	0.050(14)
1227.742(99)		2238.605(246)	0.063(14)
1243.723(156)	0.083(18)	2263.927(352)	0.031(9)
1296.810(169)	0.098(14)	2271.227(198)	0.660(12)
1355.990(170)	0.119(20)		

3. FEEDING AND LIFETIMES OF YRAST LEVELS IN $^{166,168,170}HF$ AND $^{156,160}ER$ NUCLEI (B.Bochev, S.Iliev, R.Kalpakchieva, S.A.Karamian, T.Kutsarova, E.Nadjakov and Ts.Venkova)

High-spin yrast levels in $^{166,168,170}Hf$ and $^{156,160}Er$ nuclei were populated via the $^{122,124}Sn(^{48,50}Ti,4n)$ and $^{120,124}Sn(^{40}Ar,4n)$ reactions, respectively, using the external heavy ion beam of the Dubna U-300 cyclotron. The recoil - distance Doppler - shift method was applied and lifetimes as well as side - feeding intensities and times of the levels were measured.

The results of Hf and Er isotopes are presented in Tables 3 and 4 respectively. For the three Hf isotopes and for ^{160}Er the level lifetimes measured show the same trends of only small deviations from rigid rotor as in the known $_{70}Yb$ cases*), whereas in the case of ^{156}Er a considerable retardation of transitions seems to take place in the backbending region.

In addition to the fast feeding component, another type of slow feeding into the low spin ground state band levels in $^{166,168,170}Hf$ is observed, which can be associated with traps near to the yrast band.

The feeding times and intensities of yrast levels in $^{156,160}Er$ were measured at two bombarding energies corresponding to the left - hand side and to the right - hand side of the excitation function for (^{40}Ar,4n) reactions. In spite of a strong increase with energy of the angular momentum carried away by the gamma - ray cascade preceding the ground - state band population, the values of feeding times for both isotopes differ slightly at two ion energies. The observed considerable increase in feeding times as one goes from deformed ^{160}Er nucleus to transitional ^{156}Er could possibly be associated with effects due to a second minimum in the total energy of the rotating nucleus at large deformations.

*) B.Bochev et al., INDC (SEC) - 50/L, p.54, Vienna 1976;
Nucl. Phys. A267, 344 (1967)

April 1977

Table 3

Transition energies $E_{I\rightarrow I-2}$, side feeding intensities P_I, mean side feeding times φ_I and mean lifetimes τ_I (at spin I) of yrast bands of three Hf isotopes

Nucleus	Level	$E_{I\rightarrow I-2}$ (keV)	P_I (%)	φ_I (ps)	τ_I(ps) Experiment	τ_I(ps) Rigid rotor
$^{166}_{72}Hf_{94}$	2	158.7	0	-	717.4 ±33	717.4*)
	4	312.0	21±5	10.5±4.2	24.3 ±1.5	25.65
	6	426.9	18±5	14.1±5.3	5.11±0.68	5.053
	8	509.5	10±3	5.0±3.7	1.80±0.66	2.014
	10	564.0	7±3	16.4±13.3	0.95±0.70	1.185
	12	593.8	44±5	8.9±2.0	1.29±1.02	0.901
$^{168}_{72}Hf_{96}$	2	123.7	0	-	1278 ±54	1278*)
	4	261.5	0	-	51.5 ±5.2	49.57
	6	371.2	{ 0 { 11±4	- } 200 }	8.51±0.83	8.397
	8	456.6	6±3 7±4	3.0±2.4 200	2.86±0.27	2.898
	10	522.0	14±3	3.9±1.2	1.45±0.22	1.455
	12	569.8	12±3	9.2±3.2	0.75±0.26	0.925
	14	551.6	10±4	3.0±1.1	1.21±0.26	1.074
	16	452.9	40±8	3.2±0.5	2.62±0.29	2.845
$^{170}_{72}Hf_{98}$	2	100.3	0	-	1771 ±396	1771*)
	4	220.9	0	-	89.8 ±9.5	88.35
	6	320.4	{ 15+4 { 15±4	50 } 6000 }	15.6 ±1.3	13.88
	8	400.2	13±2	8.9±4.8	4.57±0.44	4.578
	10	462.0	6±3	2.7±2.2	2.19±0.27	2.196
	12	510.7	13±3	1.0±0.5	1.46±0.19	1.314
	14	550.6	8±3	0.8±0.7	0.95±0.21	0.894
	16	584.4	9±3	~0.2	~0.64	0.659
	18	614.1	5±2	~0.2	~0.50	0.511
	20	653.6	16±4	~0.8	~0.34	0.373

*) Normalized to experiment

Table 4

Side feeding intensities P_I and side feeding times φ_I obtained at two bombarding energies. The lifetimes τ_I of the g.s.b. levels are compared with the rigid rotor model. $E_{I \to I-2}$ are the transition energies

$^{156}_{68}Er_{88}$

Level	$E_{I \to I-2}$ (keV)	E_L = 150 MeV P_I(%)	φ_I(ps)	E_L = 168 MeV P_I(%)	φ_I(ps)	τ_I Experiment	Rigid rotor
2	344.2	0	-	0	-	50.05±1.81	50.05*)
4	452.7	10±2	65±39	0	-	7.25±0.73	9.062
6	543.3	15±2	15±9	{4±1, 6±2	{91±54, 31±18	2.93±0.45	3.329
8	618.5	35±4	29±21	36±4	22±15	2.35±0.85	1.678
10	674.4	10+2	17±12	15±2	17±13	2.25±1.00	1.061
12	682.1	8±2	8±6	10±2	10±7	4.26±2.60	0.986
14	522.7	22±4	11±5	25±4	11±7	8.1 ±4.8	3.665

$^{160}_{68}Er_{92}$

Level	$E_{I \to I-2}$ (keV)	E_L = 150 MeV P_I(%)	φ_I(ps)	E_L = 168 MeV P_I(%)	φ_I(ps)	τ_I Experiment	Rigid rotor
2	125.6	0	-	0	-	1326 ±45	1326*)
4	263.8	0	-	0	-	46.67±1.52	47.43
6	375.3	8±2	4.52±2.10	11±2	4.53±0.44	7.78±0.41	7.866
8	463.7	12±3	6.74±6.72	14±3	5.58±0.44	2.44±0.61	2.646
10	531.7	20±3	5.12±2.82	25±4	6.94±0.43	1.26±0.31	1.311
12	579.2	27±4	3.39±2.02	13±2	3.01±0.43	0.84±0.21	0.841
14	592.2	5±1	2.93±2.22	7±1	4.76±0.44	0.90±0.22	0.744
16	533.9	5±1	0.61±0.53	4±1	0.50±0.42	1.57±0.20	1.236
18	556.1	23±3	3.10±1.30	26±3	2.86±1.10	0.98±0.28	1.003

*) Normalized to experiment

P R O G R E S S   R E P O R T

Nuclear Data Programme

in

H U N G A R Y

1976

Central Research Institute for Physics of the Hungarian Academy of Sciences, Budapest

Institute of Experimental Physics, Kossuth University, Debrecen

Institute of Isotopes of the Hungarian Academy of Sciences, Budapest

Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen

Roland Eoetvoes University, Department for Atomic Physics, Budapest

Compiled by

G. Kluge

Central Research Institute for Physics
of the Hungarian Academy of Sciences
Budapest

CENTRAL RESEARCH INSTITUTE FOR PHYSICS
NUCLEAR PHYSICS DEPARTMENT, BUDAPEST

EXPERIMENTATION FACILITIES

1./ Van de Graaff-accelerator with the following parameters:

energy range: 0,8 - 5,0 MeV
accelerated ions: H^+, D^+, $^4He^+$
long-time energy stability: $\Delta E/E = 2 \times 10^{-4}$ FWHM
short-time energy stability: $\Delta E/E = 1,2 \times 10^{-4}$ FWHM
target places: 3
max. target current: 5 μA
working time: 4000 hours/year
type: EG-2R /home made/

2./ Neutron-generator:

max. voltage: 200 kV
working voltage: 150-180 kV
accelerated ions: H^+, D^+
max.ion current: 500 μA
neutronflux: 3×10^9 $n/cm^2 \cdot s$
/1 cm distance from the target at 10 μA deuteron current/
target places: 2
working time: 2500 hours/year
type: NG-200 /home made/

3./ A fast-slow coincidence unit for positron annihilation lifetime measurements with time resolution 0,6 ns /PAN/

4./ A setup for positron annihilation angular correlation measurements /PANNI/

5./ A fast-slow coincidence unit for the investigation of nuclear fission /gas-scintillation chambers, vacuum-system, etc./

6./ An automatically controlled three-detector system with fast-slow coincidence circuits for the differential and integral perturbed angular correlation /PAC/ measurements

7./ Three-axis goniometer for channeling and back-scattering experiments.

8./ 2 small computers /developped by the electronic department of CRIP/ with memory capacity 4k and 8k respectively /type TPA-1001/ for on-line measurements and for preliminary data analysis.

9./ 4096-channel analyser with matrix analog-digital converter.

10./ 1024-channel analysers /NTA-512 B/.

11./ 512 - channel analysers /NTA-512 A/.

12./ 2 Mössbauer-spectrometers, cryostats and furnaces

13./ Ge/Li/ semiconductor detectors /4 cm^3 - 80 cm^3/.

14./ Ge/Li/ X-ray detector /NE-5290/.

15./ Multiwire proportional chambers.

QUASIELASTIC SCATTERING OF 670 MeV PROTONS

J. Eroe, Z. Fodor, P. Koncz, Z. Seres

The kinematically complete measurement at the quasielastic scattering of 670 MeV protons on deuteron clusters in ^6Li was extended by registering in the $^6Li(p,pd)^4He$ reaction the backscattered protons at different angles. The angular dependence of the internal momentum distribution for the deuteron clusters could thus be extracted, found to be isotropic within the experimental error.

The experiment yielded the value $q = 40$ MeV/c for the width of the distribution. This is somewhat lower than the value found in a preliminary experiment, nevertheless, it is in accordance with an inter cluster wave function that has an exponential tail with decay constant corresponding to the binding energy of the deuteron in ^6Li, that is, 1.47 MeV.

This work was performed in cooperation with the Laboratory of Nuclear Problems of the Joint Institute for Nuclear Research, Dubna, USSR.

ISOBARIC ANALOGUE RESONANCES

Ilona Fodor, J. Sziklai

Excitation functions and spectra with Ge(Li) detector were measured in the case of the $^{56}Fe(p,\gamma)^{57}Co$ reaction. Some fragments of the $g_{9/2}$ and the $d_{5/2}$ isobaric analogue resonances were identified at E_p = 3723 and 3729 and 3768, 3788 keV, respectively. The spin assignments were proved by angular distributions.

On measuring the elastic scattering of protons several components of the $d_{5/2}$ analogue resonance were found in the ^{59}Cu nucleus at 4658, 4689, 4714, 4767, 4821, 4841, 4848 and 4870 keV proton energies.

The $^{92}Mo(p,\gamma)^{93}Tc$ nuclear reaction eas also studied with a Ge(Li) detector (75cc). The isobaric analogue of the ^{93}Mo ground state was found in the gamma ray excitation function and, simultaneously, in the $(p,p'\gamma)$ channel at E_p = 4370 keV bombarding energy. Excitation energies of many low-lying levels of the final nucleus were also determined to a high precision.

This work was performed in cooperation with the Zentralinstitut fuer Kernphysik, Rossendorf, GDR.

Paper

I. Fodor, I. Szentpetery, A. Schmiedekamp[x], K. Beckert[xx], H.U. Gersch[xx], J. Delaunay[xxx], R. Ballini[xxx]: Analogue resonances in the ^{64}Zn nucleus. J.Phys. G2(1976) 365

x University of Texas, Austin, Texas, USA

xx Zentralinstitut fuer Kernforschung, Rossendorf bei Dresden, GDR

xxx Centre d'Etudes Nucleaires, Saclay, France

LOW-ENERGY CROSS-SECTIONS OF SOME CHARGED PARTICLE REACTIONS OF LIGHT NUCLEI

I. Szentpetery

Certain charged particle reactions of light nuclei are relevant to controlled thermonuclear research. As regards the most interesting low-energy region, cross-section data are, however, for a number of reactions not at all available while, for other processes, the published values are contradictory. Motivated by these reasons, proton-induced reactions have been investigated at the 200 keV Cockroft-Walton facility of the Institute.

Measurements of the cross section have been completed for the ^{9}Be(p,α) and ^{11}B(p,α) reactions at 90° and 170° laboratory angle. Emphasis was put on the reliability of the results.

The summed S-factor for the ^{9}Be(p,d) and ^{9}Be(p,α) reactions varies slowly and monotonically from 22 to 70 MeV.b. in the 50-175 keV bombarding energy region. That for the ^{11}B(p,α) has an essentially constant value of 120 MeV.b between 75-190 keV apart from the resonance at 163 keV where the peak value is 1280 MeV.b. The estimated absolute error of the S factors is 15%.

MEASUREMENT OF THE ENERGY SPECTRUM OF PROMPT NEUTRONS FROM ^{235}U(n_{th},f) REACTION

J. Kecskemeti, Gy. Kluge, A. Lajtai

In cooperation with the Institute for Physical Energetics Obninsk, USSR the measurement of the energy spectrum of neutrons from the reaction ^{235}U(n_{th}, fission) has been continued in the 0.01-2 MeV energy region using TOF method and a gas scintillation detector as well as a glass scintillator detector of ^{6}Li content as fragment and neutron detectors, respectively. The preliminary results show a neutron excess in the number of low-energy neutrons compared to the Maxwellian spectrum of T = 1.315 MeV generally accepted for the description of the neutron spectrum above 0.5 MeV.

Paper

A. Lajtai, L. Jeki, Gy. Kluge, J. Kecskemeti, I. Vinnay, P.P. Dyachenko[x], N.N. Semenova[x], V.M. Piksaikin[x], B.D. Kuzninov[x]
Prompt neutron spectra in the 10 keV-1 MeV energy region from thermal fission of ^{235}U. Neutron Physics, Proc. Conf. on Neutron Physics, Vol. V.(Moscow, 1976) p. 146

[x] Institute for Physical Energetics, Obninsk, USSR

INVESTIGATION OF (n,γf) REACTION

J. Kecskemeti, Gy. Kluge, A. Lajtai

In cooperation with the JINR (Dubna), the energy spectra of gamma-rays from the thermal neutron induced fission reaction on ^{235}U have been investigated by delayed coincidence techniques in the prefission gamma-ray region. The ratio of the rate of isomeric fission events with prefission gamma-rays to the rate of prompt fission events was found to be less than 2×10^{-5}. In this measurement single lines of 428, 627 and 860 keV were identified as having a lifetime of 100 nsec which corresponds to that of the spontaneously fissioning isomer state.

Paper

Yu.P. Gangrsky[xx], A. Lajtai, B.N. Markov[xx]: Study of the spectra of gamma-rays emitted in the (n,gamma) reaction with production of spontaneously fissioning isomer ^{236}U.
Preprint JINR, P3-9274, Dubna, (1975)
Jadernaya Fizika 24 (1976) 880

[xx] Joint Institute for Nuclear Research, Dubna, USSR

INSTITUTE OF EXPERIMENTAL PHYSICS

KOSSUTH UNIVERSITY

DEBRECEN, HUNGARY

EXPERIMENTAL FACILITIES AND TECHNIQUES

A 0.3 mg ^{252}Cf/fission/neutron source /in 1977 Jan./, with remote control system.

180 kV/2/mA/ neutron generator/ home made/.

180 kv/1.2 mA/ Activatron-111 neutron generator: it can be pulsed, pulse period: down to 10 microsec.

Associated-particle system for ^{3}He and ^{4}He: this can be mounted onto any of the neutron generators.

Pneumatic transport system for quick /0.8 sec for 2-4 m/ automatic sample transfer.

Pu-Be neutron sources from 0.5 to 5 Ci.

40 cm^{3} Ge/Li/ detector with 2.6 keV FWHM at 1332 keV.

PLURIMAT-N/MULTI-20 / Intertechnique/ Computer-based data acquisition and processing system/ with 16K core memory, 16K 200 MHz ADC, fast punched tape I/O/

A 4000 channel DIDAC/ Intertechnique/ analyser: three 100 channel analysers.

Tally tape perforator, printer, tape, reader, X-Y plotter, spectrum-stabilizer.

Lorenz telex with tape-punching and punched tape reading units in five-hole CCIT code.

^{6}LiJ/Eu/ stilben and NaJ/Tl/ crystal spectrometers.

^{3}He, BF_3 proportional counters.

Low-background proportional counter for measuring weak beta and/or gamma 4 -beta counter.

Automatic expansion cloud chamber.

Time-off-flight system with associated particle and klystron bunching method for fast neutrons / under construction /.

Si/Li/X-ray spectrometer, resolution: 380 eV.

Fission chambers for neutron flux monitoring.

Proportional counter X-ray spectrometer.

FINE STRUCTURE IN THE MASS NUMBER DEPENDENCE OF RMS CHARGE RADII

I. ANGELI and M. CSATLÓS

A comprehensive study of experimental rms charge radii shows that the deviation from the rough $A^{1/3}$-dependence follows simple trends. For the isotopic sequence of an element, the values of rms radii normalized by an approximate $A^{1/3}$ law and plotted in the function of neutron number lie on or close to straight lines. The slopes of these lines vary systematically in the function of atomic number. There are discontinuities in the values of the slopes at elements that contain N=20, 28, 50, 82, 88, 90 and 126 neutrons as well as between Z=8 and 10; a significant change can be found also at the region of Z=76 /N=114/. These changes can be explained qualitatively by the shell model and by the effect of deformation. The "odd-even staggering" of the order of 6×10^{-4} has also been observed.

Fission neutron spectrum determination and average cross-sections for ^{252}Cf source

J.Csikai, Z.Dezső, M.Buczkó, Z.T.Bődy, S.Juhász, H.M.Al-Mundheri, G.Pető and M.Várnagy

A number of average cross sections have been measured for /n,α/, /n,p/, /n,2n/ and /n,γ/ reactions by the activation method[1]. On the basis of these data and the excitation curves of different reactions the Maxwellian temperature for the ^{252}Cf neutron spectrum has been deduced and a value of $T = 1.41 \pm 0.02$ MeV was found between 2.5 and 15 MeV[2]. The temperature has been determined also from the average energy which was deduced from the age of epithermal neutrons in water measured by gold foils. The high average cross section values obtained by the low threshold reactions and the age method confirm the assumption on the excess of neutrons in the low energy region of the spectrum [2].

Accepting the evaluated data for /n,2n/ cross-sections at 14.7 MeV and the shapes of /n,2n/excitation curves, average /n,2n/ cross-sections have been calculated for 48 nuclides [1].

Measurements were also made for the slowing down and diffusion of neutrons [3] and for different applications including an on--stream method to determine vanadium in crude oil [4], the determination of Ti, Fe and Mn in bauxite [5,6,7] and others [8] mentioned in abstracts of this Progress Report.

[1] M.Buczkó, Z.T.Bődy, J.Csikai, Z.Dezső, S.Juhász, H.M. Al-Mundheri, G.Pető, M.Várnagy, Average cross-sections for ^{252}Cf neutron spectrum. - Symposium International sur l'Utilisation du Californium - 252. Paris - 26-28 Avril 1976. France.

[2] J. Csikai, Z.Dezső, Annals of Physics /in press/ and Internat. Conf. on Interactions of Neutrons with Nuclei - July 6-9. 1976. Lowell, Massachusetts, PG1/J17

[3] Cs.M.Buczkó, M.H.Al-Mundheri, J.Csikai, Z.Dezső, Nucl. Instr. and Meth. 134/1976/ 101.

[4] S.M.Al-Jobori, S.Szegedi, J.Csikai, Radiochem. Radioanal. Letters 25 /1976/ 87.

[5] H.M.Al-Mundheri, Cs.M.Buczkó, Á.Pázsit, Radiochem.Radioanal. Letters 24 /4/ 299 /1976/

[6] Á.Pázsit, Cs.M.Buczkó, Radiochem.Radioanal. Letters, 27 /5-6/381/1976/

[7] Cs.M.Buczkó, S.Mukherjee, Z.Dezső, M.Hegedüs, M.Várady, J.Radioanal. Chemistry 29 /1976/ 295.

[8] M.Buczkó, J.Csikai, S.Daróczy, Z.Dezső, S.M.Al-Jobori, H.M.Al-Mundheri, G.Pető, P.Raics, K.Sailer, S.Szegedi, M. Várnagy: Some Application of ^{252}Cf neutron and fragment sources in technology - Symposium - International sur l'Utilisation du Californium-252. Paris - 26-28 Avril 1976. France.

Angular distribution of fragments in the fission on uranium, thorium and neptunium induced by ^{252}Cf neutrons

S.Juhász, J.Csikai and M.Várnagy

The angular distribution of fragments from neutron induced fission of natural uranium, natural thorium and Np-237 have been measured by means of polycarbonate solid-state nuclear track detectors. The neutrons were produced by a Cf-252 source. The experimental arrangement allowed us to measure the angular distribution of fragments in the interval of 0-180^{o}. The values of the anisotropy parameters measured for uranium and thorium are in good agreement with the calculated ones.

[1] M.Buczkó, Z.T.Bődy, J.Csikai, Z.Dezső, S.Juhász, H.M.Al-Mundheri, G.Pető, M.Várnagy, International Symposium on Californium-252 Utilization, April 26-28. 1976., Paris, France

[2] J.Csikai, IAEA-SR-3/23/1976/ p.29.

Some applications of a ^{252}Cf source and 14 MeV neutron generator for thermal and fast neutron activation analysis

K. Sailer, S. Nagy, S. Daróczy, P. Raics

The program on the analysis of the elements of aluminium alloys by thermal neutrons of a ^{252}Cf source [1] was continued 2,3 . The Hf content of the Al samples in the range of 5000-15000 ppm were determined by the ^{178}Hf $/n,\gamma/$ ^{179m}Hf reaction in addition to the previonsly published Mn contents. Using a 1 mg ^{252}Cf source the experimental sensitivity of 30 ppm was estimated for a quantitative determination with 10 % relative standard deviation at a timing of 2 min activation and 40 sec measurement without cooling time.

When measuring the thermal neutron flux by the activation of In we have found discrepancies with the relative intensities of the main gamma-lines given by the Nuclear Data Sheets [4]. The results of our relative measurements absolutized by accepting I = 84.8 % for the 1293.54 keV line from the recent paper of Helmer [5] are given in the table.

Absolute intensities of the main gamma-lines of ^{116}In usable for thermal neutron flux measurement

E_γ /keV	I_γ /%/
416.86	28.3
818.70	12.4
1097.30	57.0
1293.54	84.8
1507.40	10.2
2112.10	15.6

Plant samples /tobacco and coffe/ were analysed, too. Na, Cl, K, Mn and Br contents were determined by thermal neutron activation [6], while Al, Si, Cl, K, Fe and Zr contents by 14 MeV neutron activation.

[1] IAEA Progress Report, Hungary, 1974

[2] K.Sailer, S.Daróczy, S.Nagy, P.Raics, J.Csikai, L.Gergely, Atomnaya Energiya 39 /1975/ 288 /in Russian/

[3] K.Sailer, Diploma work, 1976. /in Hungarian/

[4] Nuclear Data Sheets 14 /1975/ 3, 278

[5] R.G.Helmer, BNL.-NCS-21501 ERDA /NDC-3/4 /1976. May/

[6] Gy. Batta, M.Bartha, K.Sailer, S.Daróczy, S.Nagy P.Raics, Mrs. S.Nagy, Izotóptechnika 19 /1976/ 140, /in Hungarian/.

Investigation of /n,t/ reaction at 14.7 MeV, ^{252}Cf fission and thermal neutrons

S. Sudár, J. Csikai, F. Cserpák, T. Biró

The measurement of tritium beta activity makes it possible to investigate the /n,t/ cross sections over the whole mass range and it can be applied to any target nucleus whether the residual nucleus is radioactiv or not. The method and first results have been published in [1]. Further /n,t/ cross sections have been measured for ^{27}Al, ^{93}Nb, ^{55}Mn, ^{203}Bi and Li elements at 14.7 MeV. Recently, measurements are under progress for the B element and ^{10}B with ^{252}Cf fission and thermal neutrons.

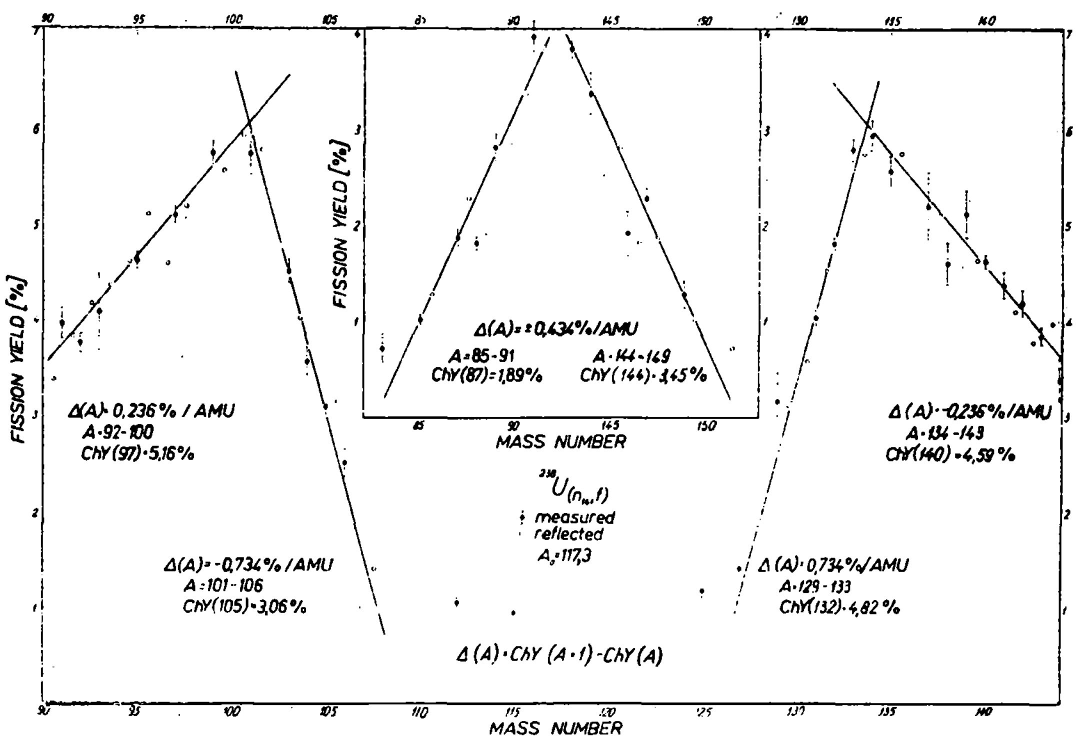
[1] T. Biró, S. Sudár, Z. Miligy, Z. Dezső and J. Csikai, J. Inorg. and Nucl. Chem. 37 /1975/ 1483.

Measurement of fission yields at 14 MeV neutron energy

S.Daróczy, S.Nagy, P.Raics

Measurements on mass-yield distribution of ^{238}U fission induced by 14.5 MeV neutrons were finished; 47 cumulative yields for 37 mass chains have been measured using direct gamma-spectrometric method as a variant of the instrumental neutron activation analyisis[1]. A general agreement was found, between our measured and the compilated data [2] although there are some remarkable differences, too. First, there is no fine structure in the peak regions. Second, the measured yields are systematically higher by about 20% than the compilated ones in the valley region. Third, our experimental data show a pronounced left-right symmetry to A_o = 117.3 in the mass-yield distribution. On the basis of our results the gross structure of the mass-yield distribution can be approximated fairly by straight lines in the mass regions of 85-106 and 129-149 /Fig.1/. The following unmeasured chain yield data were estimated - with about 5% relative standard errors - using the measured reference yields and the slopes of the straight lines given on the Fig. 1:

ChY/86/ = 1.46 %	ChY/102/ = 5.26 %
ChY/90/ = 3.19 %	ChY/130/ = 3.35 %
ChY/94/ = 4.45 %	ChY/136/ = 5.53 %
ChY/96/ = 4.92 %	ChY/145/ = 3.02 %
ChY/98/ = 5.40 %	ChY/148/ = 1.71 %
ChY/100/= 5.87 %	



A measurement of the fission product yields for half lives longer than 1 day in the ^{235}U fission induced by 14.6 MeV neutrons have been finished and its evaluation will be completed in 1977.

[1] S.Daróczy, P.Raics, S.Nagy, L.Kövér, I.Hamvas, E.Germán, ATOMKI Közlemények, 18 /1976/317

[2] M.E.Meek, B.F.Rider, Compilation of Fission Product Yields, NEDO-12154-1, Vallecitos Nuclear Center, 1974.

Measurements of /n,p/ /n,α/ /n,2n/ reaction cross sections by activation method at 14 MeV

S.Daróczy, S.Nagy, G.Pető, P.Raics, K.Sailer

A program is devoted to remeasure all the possible neutron cross sections on the isotopes of reactor materials ranging of $20 \leq Z \leq 50$.

The usual activation technique is applied with Ge/Li/ gamma spectrometry. The neutron flux is measured by foil activation /4πβ counter/ and fission chamber, simultaneously. Special attention is paid to the neutron energy distribution which is affected by the tritium target assemly.

Some prelimanary results at 14.8 MeV neutron energy are presented in Table I. The target materials are of natural abundance, the quoted errors are statistical only.

Table I.

Prelimanary reaction cross section values /mb/

at 14.8 MeV

^{50}Co /n,2n/^{49}Co	25.7 ± 0.8
^{52}Co/n,p/^{52}V + ^{53}Cr/n,np/^{52}V	70.3 ± 2.1
^{52}Co/n,2n/^{51}Co	350.9 ± 28.8
^{53}Co/n,p/^{53}V + ^{54}Cr/n,np/^{53}V	33.0 ± 5.0
^{54}Co/n, /^{51}Ti	12.4 ± 0.8
^{90}Zr/n,2n/^{89g}Zr	716.2 ± 14.8
^{90}Zr/n,2n/^{89m}Zr	102.5 ± 3.6
^{90}Zr/n,p/^{90m}Y + ^{91}Zr/n,np/^{90}Y	11.5 ± 0.3
^{90}Zr/n,α/^{87m}Sr + ^{91}Zr/n,nα/^{87m}Sr	3.74 ± 0.07
^{91}Zr/n,p/^{91m}Y ± ^{92}Zr/n,np/^{91m}Y	18.0 ± 0.5
^{92}Zr/n,p/^{92}Y	20.7 ± 0.6
^{94}Zr/n,p/^{94}Y	5.72 ± 0.20

Results and plans on the development of a pulsed neutron generator

T.Sztaricskai, L.Vasváry and G.Pető

In the last years, a good cooperation was founded on the field of neutron physics by regular meetings among the institutes in Dresden, Bratislava, Obninsk, Kiev and Debrecen. In addition, there are possibilities to make this cooperation stronger for common developments and utilizations of the common peculiarity, the use of neutron generators [1]. The study of neutron emitting reactions - on the basis of the neutron time-of-flight analysis - is well developed in Dresden [2], Kiev [3] and Obninsk [4]. An other method is used on the basis of activation technique since long time in Debrecen [1]. Measuring the prompt gamma rays, the time-of-flight technique gives a good possibility to decrease the background in the gamma spectrum. The possibility of the practical help of Salnikov's group from Obninsk in the construction of a pulsed neutron generator in Debrecen coincided with the plan to study the /n,n'/ and /n,2n/ reactions based on prompt gamma analysis. Finishing the common construction of the pulsed neutron generator this year, we start to investigate the above reactions by a Ge/Li/ spectrometer.

[1] J.Csikai: Atomic Energy Review 11/1973/415

[2] D.Hermsdorf, S.Sassonoff, S.Seeliger, K.Seidel: Kernenergie 17/1974/176,259

[3] M.E.Gurtovoj, A.S.Kuhlenko, B.E.Leshchenko, G.Pető, V.I.Shtrizak: Pribori Technika i Eksperimenta /1971/No.2,54

[4] O.A.Salnikov, G.V.Lovchikova, G.N.Kotelnikova, N.I.Fetisov, A.N.Trufjanov: Proc. 2nd Conf.Nucl.Data for Reactors, Helsinki 1970, T.2.359

Neutron fluence measurements with track detectors

M. Várnagy

The possibilities of utilization of a polycarbonate foil in neutron fluence measurements have been investigated. A commercially available polycarbonate foil - of 12 μm nominal thickness, Makrofól KG-was used as signal foil, Cf-252 as neutron source and Th-232 and natural U discs as converters. The arrangement of the materials guaranteed a tight contact between the foils and the converters and so a good 2π geometry was provided for the fission fragments to be counted. The irradiations were performed in free space at a distance of 97.5 mm from the Cf-source. All detectors were evaluated automatically by a jumping spark counter. The reproducibility of the fluence-measurement was between 3.2 and 4.5 % in the 400-2000 holes/cm^2 interval.

The sensitivities were 7.5×10^{-7} and 2.7×10^{-7} spark/cm^2 /neutron/cm^2 for U and Th, respectively. Composite Th and U-foil backgrounds were measured over a 70 day period and 0.007 spark/cm^2 day and 0.8 spark/cm^2 day determined for a neutron unexposed group of 10 samples. A background of 0.08 sparks /cm^2 was found on a group of foils exposed to Cf-252 neutrons for 15 hours. The effect of γ-doses have been investigated, too, and 0.7, 0.6 and 0.2 spark/cm^2 backgrounds were found on the 34.5 Mrad, 9.5 Mrad and 2.5 Mrad exposed foils, respectively, when 15 hour neutron irradiation were applied.

[1] M. Várnagy, L. Vasváry, E. Gyarmati, S. Juhász, T. Scharbert, T. Sztaricskai /to be published in Nucl. Instr. and Meth./

A jumping spark counter for counting etched holes in thin dielectric polymers

M.Várnagy, L.Vasváry, E.Gyarmati, S.Juhász, T.Scharbert, and T.Sztaricskai

A jumping spark counter /JSC/ has been constructed which is applicable /continuously or "step by step/ for counting of perforations in thin polymer foils. It is possible to vary the JSC-parameters and so to study their effect on the characteristics of counting. The JSC was combined with a DIDAC 4000 multi-channel pulse-height analyser and a two dimensional /time amplitude/ analyser to determine automatically the best parameters and procedure for the spark counting as well as to study the working mechanism of JSC. Investigations were performed on etched polymeric foils of various types and of different thicknesses irradiated with fission fragments, α-particles or neutrons and exposed to 0-35 Mrad gamma-rays. The track density interval studied was 0-100000 track/cm^2. The possibility of adopting the JSC for neutron dosimetric application, evaluation of angular distributions and for safeguards was tested. The possible consequences of the results were discussed.

[1] M.Várnagy, L.Vasváry, E.Gyarmati, S.Juhász, T.Scharbert and T.Sztaricskai to be published in Nucl. Instr. and Meth./

[2] E.Gyarmati, Prize Essay /Kossuth University, Debrecen, 1975/

[3] M.Buczkó, J.Csikai, S.Daróczy, Z.Dezső , S.M.Al-Jobori, H.M.Al-Mundheri, G.Pető, P.Raics, K.Sailer, S.Szegedi, M.Várnagy, Int. Symposium on. Cf-252 Utilization, April 26-28, 1976. Paris, France.

Track-etch radiography with thermal neutrons

S. Juhasz and M. Varnagy

Polymeric foils have been used for radiographic imaging studies on electric parts with thermal neutrons applying U-235 and lithium fluoride converters. A Cf-252 source combined with a collimator system was used as a thermal neutron source. Comparisons - made with X-ray film-detection method using Gd converter foil as well as NE-432 camera - show that the track-etch technique can give comparable results for spatial resolution, contrast and convenience.

[1] J. Csikai, IAEA-SR-3/23 /1976/ p. 29

On the possibility of the utilization of polycarbonates in γ-dosimetry using EPR technique

M. Varnagy

It was found that a group of free-radicals in γ-irraidated polycarbonate foils became very stable. There was no change in the concentration of free radicals after a time of about two months from the exposure, storing the foils at room temperature. Moreover, the concentration has been found to be dependent on the absorbed γ-dose. Therefore, a strip of a polycarbonate foil is excellent to record γ-dose distributions as well as to determine γ-dose with EPR.

[1] M. Varnagy, E. Gyarmati and T. Sztaricskai, Nucl. Instr. and Meth. 113 /1976/371.

On the possibility of the utilization of polymer plates in γ-dosimetry using UV-light

M. Varnagy, E. Rakosi

It was found that the electron, X-ray and γ-ray irradiation caused marked changes in the bulk etching rate of the polymers which depended on the absorbed doses [1]. Now, investigations have been performed on cellulose nitrate, acetate, acetate-butyrate, polycarbonate, and polyethylene terephthalate foils exposed to 2-5 - 34.5 Mrad γ-doses in order to search for dependence of the optical absorption variation on the absorbed γ-dose. A markable change was found in the absorbance of UV-light in the 275-325 um range with the absorbed γ-dose. Accuracy and reproducibility measurements by this method in 1-4 Mrad γ-dose interval are in progress. This dose range is interest in the sterilization of surgical instruments.

[1] M. Varnagy, J. Csikai, S. Szegedi, Nucl. Instr. and Meth. 119/1974/261.

INSTITUTE OF ISOTOPES
OF THE HUNGARIAN ACADEMY OF SCIENCES
BUDAPEST

THE EXCISTENCE OF THE 1180 keV LEVEL IN THE NUCLEAE LEVEL SCHEME OF ^{195}Pt.

A. Veres, I. Pavlicsek

The 1180 ± 10 keV level of ^{195}Pt was excited by photoactivation, and the excistence of the level was verified by the comparison of the integral activation cross-sections related to two different radiation sources. The $u = g \frac{\Gamma_o \Gamma_i}{\Gamma}$ partial level width was found to be $2.4 \cdot 10^{-6}$ eV. Excitation was carried out by ^{60}Co and ^{182}Ta radiation sources. For the intercalibration of the microspectra of the two radiation fields, the 1078 keV level of ^{115}In was utilized.

INSTITUTE OF NUCLEAR RESEARCH

OF THE HUNGARIAN ACADEMY OF SCIENCES

DEBRECEN

EXPERIMENTATION FACILITIES

1./ A Van de Graaff accelerator with 5 MV nominal voltage, used with proton - deuteron- alpha- and heavy ion beams. The measuring center of the accelerator is equipped with a Nuclear Data 50/50 data acquisition and handling system, coupled to a PDP 11/40 computer.

2./ A Van de Graaff accelerator with 1 MV nominal voltage.

The accelerators are used in fundamental nuclear reaction studies /reaction mechanisms, collection of nuclear data/ as well as in studying inner shell ionization phenomena, and in analytical applications.

3./ A Cockroft-Walton accelerator up to a voltage of 700 kV.

This accelerator is applied to generate proton- deuteron- and electron beams for reaction studies and for irradiation purposes.

4./ Neutron generator

to produce D+D neutrons at a voltage of 150 kV, with a maximal D^+ ion current of 500 μA /analysed beam/.

5./ Electrostatic electron spectrometers for ESCA studies.

6./ Computer facilities include a PDP 11/40 computer. Access to a CDC 3300 computer is made possible through a fully equipped UT-200 terminal.

7./ Beta-, gamma- and X-ray spectrometers of different types are available in the Institute to carry out investigations in different fields of nuclear spectroscopy and its applications, including research in other branches of science and practical applications.

X-RAY PRODUCTION CROSS SECTION MEASUREMENT AT LOW ENERGY HEAVY ION BOMBARDMENT

L. Sarkady, J. Végh, D. Berényi, E. Koltay and I. Kiss

Ti and Cu targets are bombarded by C, N, O heavy ions of 0,8 - 3 MeV region in a Van de Graaff accelerator. The X-rays are detected from the targets and the X-ray production cross sections are determined.

ORBIT-DEPENDENT PARTIAL HARTREE-FOCK REARRANGEMENT IN ELECTRON CAPTURE

E. Vatai

Experimental electron-capture ratios are compared with theoretical results calculated in different approximations. It is shown that the differencies can be explaned if the Hartree-Fock rearrangement is different for the capture of different /K_1, L_1, M_1 ... / electrons. The electron capture ratios are affected by the degree of rearrangement through the exchange and overlap corrections. To describe the radial wave functions for these final states a linear combination of the original /frozen-in/ and of the fully rearranged orbitals may be used. The coefficients characterize the degree of rearrangement. The regions and degree of rearrangement explaining the existing experimental data are estimated.

To be presented at the 27th All-Union Conference in Nuclear Spectroscopy and Nuclear Structure, 22-25 March 1977, Tashkent.

SOFT X-RAY SOURCE FOR ESCA STUDIES

L. Kövér, Gy. Mórik, D. Varga

The water-cooled X-ray tube was constructed and adjusted to serve as an excitation source for a double pass cylindrical mirror electrostatic electron spectrometer. There were measurements connected with the anode carbonisation during the working time of the tube.

In the case of aluminium anode, the typical working parameters are: 40 mA emission current at 5 kV anode voltage.

DETERMINATION OF THE K_α/K_β X-RAY RATIO FOR SEVERAL ELEMENTS AT ELECTRON BOMBARDMENT

S. Ricz, B. Schlenk, A. Valek and D. Berényi

The ratio of X-ray production cross sections at electron impact are determined for Fe, Co, Ni, Cu, Se, Y and Ag by the detection of the X-rays from the target using a Si/Li/ semiconductor detector. The bombarding electrons are accelerated in a Cockroft-Walton generator in the 300-600 keV region. For Cu and Se absolute K-shell ionization cross sections are determined too.

X-RAY PHOTOELECTRON SPECTROSCOPIC INVESTIGATION OF ELECTROLYTICALLY REDUCED AND OXIDIZED PLATINUM SURFACES

L. Kövér, Cs. Ujhelyi, J. Miller, D. Varga, I. Kádár
D. Berényi

The 4f photoelectron lines of smooth platinum and platinised platinum surfaces were investigated.

Surfaces reduced in Na_2SO_4 and H_2SO_4 solutions were compared with those treated in 36M H_2SO_4 and 12 M $HClO_4$ as well as with those heated in a Méker flame. Reduction in 3M H_2SO_4 gave appropriate results.

The oxidation state of the samples electrolysed in different solutions /Na_2SO_4, $NaClO_4$, $HClO_4$/ was investigated as a function of the time of the electrolysis. The $HClO_4$ concentration was changed up to 9M. The yield of oxidation was found to be maximal /90 %/ in a concentration region of 1-3M.

IN-DEPTH ANALYSIS OF CONCENTRATION PROFILE USING /p,X/ PROCESSES IN A VAN DE GRAAFF ACCELERATOR

D. Berényi, E. Koltay, I. Kiss, S.S. El-Nasr, L. Sarkadi
and J. Végh

In-depth composition profile determinations are carried out in aluminium samples for Zn as a function of sample annealing. The experimental procedure is the detection of X-rays coming out of the samples at the bombardment of protons of 0,8 - 2,5 MeV energy. The analysed depth is of 10 μ in orders of magnitude and the layer resolution is about 1 μ.

MEASUREMENT OF K-SHELL ELECTRON IMPACT IONIZATION CROSS-SECTIONS FOR Pd, Ag, In AND Sn IN THE ENERGY REGION OF THE BOMBARDING ELECTRONS FROM 300 TO 600 keV

B. Schlenk, S. Ricz, A. Valek and D. Berényi

Bombarding Pd, Ag, In and Sn targets in a Cockroft-Walton generator accelerating electrons, the absolute K-shell ionization cross sections were determined by the detection of the X-rays from the target in the energy region of the bombarding electrons from 300 to 600 keV.

ELECTRON IMPACT L-SHELL IONIZATION IN THE BOMBARDING ENERGY REGION FROM 300 TO 600 keV

B. Schlenk, D. Berényi, S. Ricz, A. Valek and G. Hock

The X-ray production cross-sections and yield ratios for the L-Lines and the total L-Shell measured in electron impact ionization in the region from 300 to 600 keV of the bombarding electrons are determined for Yb, Au, and Pb. The experimental data are compared with theoretical calculations.

INNER-SHELL IONIZATION BY ELECTRONS IN THE 300-600 keV REGION

B. Schlenk, D. Berényi, S. Ricz, A. Valek and G. Hock

A measuring set-up at a Cockroft-Walton accelerator is described for the determination of electron impact inner-shell ionization cross-section detecting the χ-rays by Si/Li/ solid-state detector. The K-shell electron impact ionization cross-sections for Ag in the region from 300 to 600 keV were determined and compared with the earlier experimental and theoretically calculated values.

A NEW CRITICAL STUDY OF THE INTERNAL BREMSSTRAHLUNG SPECTRUM FROM ^{35}S

S. Mészáros, Cs. Ujhelyi, D. Berényi and D. Varga

A new precise measurement has been carried out for the internal bremsstrahlung together with control measurements to clear up the probable reason of the deviations from the theory in the earlier studies. It is stated that under proper experimental conditions there is a good agreement between the most precise theories and the experiments for the IB spectrum of ^{35}S.

THE KLL AUGER SPECTRUM OF MAGNESIUM IN MgO

I. Kádár, F. Záborszky

The KLL Auger spectrum of Mg in MgO has been investigated using a cylindrical mirror type electrostatic spectrometer. The primary vacancy has been produced by Al K excitation. Branching ratios and energies of the diagram lines have been determined. Correction for charging was performed using the shift of the Carbon 1S photoelectron line. From the KLL Auger spectrum of a Mg + MgO sample, the value of bulk plasmon energy loss has been determined.

THE KLL AUGER SPECTRUM OF MANGANESE

I. Cserny, I. Kádár, Cs. Ujhelyi

The KLL Auger spectrum originating from the electron capture decay of ^{55}Fe has been investigated using a cylindrical mirror type electrostatic spectrometer. Branching ratios of the diagram lines have been determined by approximating the instrumental line shape with an analytical function /convolution of an exponential function and a Gaussian one/, and fitting the experimentally measured spectrum by a combination of such functions, taking into account the energy dependence of the exponential tail.

ADDENDUM TO THE "CORRECTION OF ELECTRON CAPTURE RATIOS MEASURED BY MULTI-WIRE PROPORTIONAL COUNTER" 1

E. Vatai

Submitted to Acta Phys. Hung.

The formulas for the calculation of the corrections of multi-wire proportional counters published in Acta Phys. Acad. Sci. Hung. 28, 103 /1970/ are explained, simplified and corrected.

GENERAL DESCRIPTION OF TIME-DEPENDENT DECAY IN NUCLEAR REACTIONS

L. Sarkadi

ATOMKI Közlemények 18 /1976/ 593-598.

A new phenomenological expression describing the equilibration process in nuclear reactions is presented. In time-independent case the formula leads to the compound decay probability. As an illustration, a simple calculation based on the Griffin-Blann exciton model is given. The form of the deduced energy spectrum is in good agreement with experimental one.

MULTIELEMENT ACTIVATION ANALYSIS WITH FAST NEUTRONS

P. Bornemisza-Pauspertl, P. Kovács, I. Uray

Investigations were carried out comparing the applicability of great size NaJ/Tl/ detector with that of Ge/Li/ detectors of different sizes. The results we have got in multielement analyses applying great sized semiconductor detectors and inner standardization are presented in the determination of concentrations: a/ of impurities in a spectral-pure Os sample; b/ of some microcomponents of given steel samples.

TRENDS IN THE /n,2n/ AND /n,p/ CROSS-SECTIONS OF Os ISOTOPES

P. Kovács, I. Uray

The cross-section of /n,2n/ and /n,p/ reactions of Os-isotopes was measured at 14,7 MeV neutron energy by a Ge/Li/ spectrometer. It has been found that the /n,2n/ cross-section decreases, while the /n,p/ cross-section strongly increases with the decreasing of the number of neutrons.

HALF-LIFE SYSTEMATICS OF THE RADIOACTIVE NUCLIDES.

L. Sarkadi, I. Török

ATOMKI Közlemények 18 /1976/ 609-615.

Half-life versus mass-number diagrams of all known radioactive nuclides were plotted in 28 figures, using the same scale. Each figure represents a certain class of nuclides of the same decay mode and type /even-even, e-o, o-e, o-o/ in a given mass range. The points representing isotopes, isotones or nuclides differing by two neutrons and two protons are connected by different kinds of lines. Three further figures, keeping the same mass and order-of-magnitude scales, give the abundaces of the stable and primordial radioactive nuclides.

NUCLEAR REACTIONS INDUCED BY 14 MeV NEUTRONS ON ^{209}Bi

I. Uray, I. Török, P. Bornemisza-Pauspertl

Submitted to Nuclear Physics.

A decay scheme was proposed for the ^{206m}Tl on the basis of the observed new transitions at 88.5; 117.9; 184,2; 289.0; 305.4; 368.4; 535.4; 583.1; 604.0; 616.3; 632.6; 704.2 and 837.0 keV. The life time of the 12^- /2642.7 keV/ isomeric state of ^{206}Tl is 3.77$\pm$0.02 m. At 14.7 MeV neutron energy the cross section of the ^{209}Bi/n,α/^{206m}Tl, ^{209}Bi /n,3n/^{207}Bi and ^{209}Bi/n,^{3}He/ ^{207}Tl reactions was found to be 7,3 μb, 0,72 mb and 5.8 μb respectively.

LEVELS OF ^{28}Si EXCITED IN THE REACTION $^{27}Al/p,\alpha/^{24}Mg$ AT E_p = 1540 - 2220 keV

L. Zolnai, E. Koltay, I. Hunyadi

Izvestiya Akademii Nauk SSSR, Ser. Fiz. 40 /1976/ 2119

The excitation function of nuclear reaction $^{27}Al/p,\alpha_o/^{24}Mg$ and $^{27}Al/p,\alpha_1/^{24}Mg$ has been measured for E_p= 1540-1930 keV at θ_{lab} = 80° and 150° with solid state track detectors and $^{27}Al/p,\alpha_o/^{24}Mg$ curves have been taken for E_p = 1900-2220 keV at θ_{lab} = 90°, 120° and 150° with surface barrier semiconductor detectors. The relative yield of γ-rays from the $^{27}Al/p,\gamma/^{28}Si$ has been recorded with NaJ/Tl/ crystal at θ_{lab} = 90°. Fourteen $/p,\alpha_o/$ and ten $/p,\alpha_1/$ resonances were observed. The angular distribution of α-particles was also measured for each of the observed resonances with track detectors in the angular range 20°-170° and with semiconductor detectors in the range 85°-165°. A single level search program has been written on the basis of the reaction theory of Wigner and Eisenbud for deducing formation parameters and population numbers as well as the most probable spin and parity values from the angular distributions.

INVESTIGATION OF THE REACTION $^{24}Mg/\alpha,\gamma/^{28}Si$

J.W. Maas, E. Somorjai

International Symposium on Nuclear Structure Balatonfüred, Hungary 1-6 September 1975. Proceedings, II., p. 577. Budapest 1976.

Results concerning the yield curve, γ-decay and strength of the resonances in the $^{24}Mg/\alpha,\gamma/^{28}Si$ are given from the first part of the investigation in process. Four new resonances were found at E_α = 3357.5$\pm$0.8, 3432.5$\pm$0.9, 3628.5$\pm$0.9 and 3662.5$\pm$2.5 keV. The γ-decay of 31 resonances was established, 15 of them had not been known yet. The branching ratio of the bound level at E_x = 10.59 MeV was determined. The strength of 30 resonances was measured and compared to earlier results.

INVESTIGATION OF ^{28}Si LEVELS WITH THE $/\alpha,\gamma/$, $/p,\gamma/$ AND $/\gamma,\gamma/$ REACTIONS

J.W. Maas,* E. Somorjai, H.D. Graber,* C. Vander Leun,* P.M. Endt*

In: "Investigation of ^{27}Al and ^{28}Si Level Schemes." Thesis of J.W. Maas, Utrecht, 1976.

Excitation energies of ^{28}Si levels have been measured with the $^{27}Al/p,\gamma/^{28}Si$ reaction; the reaction energy is Q = 11584.5 $\pm$ 0.4 keV. The width of the semi-bound level at E_x = 11.45 MeV has been determined as Γ = 9 $\pm$ 2 eV in a $^{28}Si/\gamma,\gamma/^{28}Si$ resonant absorption experiment; a $^{27}Al/p,\gamma/^{28}Si$ resonance provided γ-rays of the appropriate energy.
Of 33 resonances observed in the $^{24}Mg/\alpha,\gamma/^{28}Si$ reaction /E_α = 1.5 - 3.8 MeV/, energies, strengths and γ-ray decay have been measured; six of these resonances had not been reported previously. Gamma-ray angular distribution measurements at three resonances yield the resonance J^π values and the mixing ratios of the strongest transitions involved in the decay. A $J^\pi = 3^+$, T = 1 assignment to the 10.38 MeV level follows from considerations based on the observed transition strengths.
The arguments on which T-assignments can be based are critically reviewed. These arguments are used to assign T = 1 character to 19 states in ^{28}Si.

* Department of Physics, Utrecht University, Utrecht, The Netherlands

THE ANGULAR DISTRIBUTION OF α PARTICLES FROM THE REACTION $^{9}Be/p,\alpha/^{6}Li$ DETERMINED BY THE METHOD OF γ-LINE BROADENING.

Á. Kiss, E. Koltay and Gy. Szabó

Izv. Akad. Nauk SSSR Ser. Fiz. T.40 /1976/ 800.

As it is shown in earlier papers the shape of the Doppler broadened gamma lines γ_i emitted in the reaction $X/a,b_i/Y^*$ contains the same information as the $b_i - \gamma_i$ angular correlation curve. In isotropic case the angular distribution of b_i particles can be deduced by the analysis of the line shape. The possibilities of this method have been checked in the case of $^{9}Be/p,\alpha_2/^{6}Li$ reaction using the α_2 angular distributions and gamma spectra taken in the neighbourhood of the resonance at 2.567 MeV bombarding energy.

K-SHELL IONIZATION BY PROTONS FOR Cr, Cu, In AND BY ALPHA-PARTICLES FOR Cr, Cu

E. Koltay, D. Berényi, I. Kiss, S. Ricz, G. Hock and J. Bacsó

Z. Physik A278,299-302 /1976/

K-shell ionization cross sections have been determined for Cr, Cu and In at proton bombardment in the energy region from 0.9 to 2.5 MeV. The same cross sections were determined for Cr and Cu at alpha bombardment in the 0.9-4.0 MeV region. The experimental results are compared with five different theoretical calculations.

LEVELS OF ^{10}B FROM THE $^{9}Be/p,\alpha_2\gamma/^{6}Li$ AND $^{9}Be/p,p/^{9}Be$ REACTIONS AT E_p= 2.56 MeV

A. Kiss, E. Koltay, Gy. Szabó, L. Végh

To be published in Nuclear Physics

To determine J^{π} values of the pair of states at 8.89 MeV in ^{10}B given so far as 2^+ and $3^{/-/}$, we have investigated the $^{9}Be/p,\alpha_2\gamma/^{6}Li$ reaction, which selects the natural parity states. We have deduced the $/p,\alpha_2/$ angular distribution at 17 energy points from the measured Doppler broadened γ-line shapes. We have found a 2^+ and a 3^- resonance and determined their parometers by a multi-level multi-channel R-matrix fitting program. The energies and widths obtained are about the same as those coming from the $^{9}Be/p,n/^{9}B$ and earlier $/p,\gamma/$ measurements. On this basis the identity of the levels found in our $/p,\alpha_2/$ measurement and in the /p,n/ reaction has been assumed and the resonance parameters derived from them have been used to predict the $^{9}Be/p,p/^{9}Be$ elastic scattering cross-sections. The calculated curve reasonably agrees with our measured elastic excitation functions.

A STUDY OF THE $^{14}N/d,p/^{15}N$ REACTION AT LOW BOMBARDING ENERGIES

A. Valek, T. Vertse, B. Schlenk, I. Hunyadi

Nucl. Phys. A270/1976/200-210.

Absolute differential cross-sections of the proton groups p_0, p_1+p_2, p_3, p_4 and p_5 from the $^{14}N/d,p/^{15}N$ reaction have been determined at bombarding energies between 0.309 MeV and 0.638 MeV. The shape of the measured angular distributions are generally well reproduced by the incoherent sum of the contributions of direct and compound nucleus processes calculated

with the distorted wave Born approximation and the Hauser-Feshbach formula respectively. However, reliable value for the spectroscopic factor can be extracted only for the p_5 transition whose mechanism even at this energy is almost entirely direct.

INVESTIGATION OF THE $^{20}Ne/d,p/^{21}Ne$ REACTION AT LOW BOMBARDING ENERGIES

A. Valek and L. Végh

Angular distributions and excitation functions of the proton groups p_0, p_1, p_2 and p_3+p_4 from the $^{20}Ne/d,p/^{21}Ne$ reaction have been measured between 0.5 and 0.66 MeV deuteron energy. The excitation function of the proton group p_0 shows two pronounced resonances, which may be assigned to isolated levels of the compound nucleus ^{22}Na. Calculations to determine the spins and parities of these levels are in progress on the basis of R matrix theory. The averaged angular distributions of the proton groups p_1 and p_4 displaying direct features have been reproduced by DWBA calculations.

SEARCH FOR VIRTUAL ELECTRON CAPTURE IN THE INVESTIGATION OF THE INTERNAL BREMSSTRAHLUNG FROM THE DECAY OF ^{59}Ni

D. Berényi, G. Hock, A. Ménes, G. Székely, Cs. Ujhelyi and B.A. Zon

Nuclear Physics A256 /1976/ 77-92.

The internal bremsstrahlung spectrum from the non-unique second-forbidden pure electron capture decay of ^{59}Ni was studied in a limestone low-background chamber using a 20 cm^3 Ge/Li/ detector,searching for the effects of the virtual electron capture in the spectrum shape of internal bremsstrahlung. Comparing the experimental data with the Cutkosky, Zon-Rapoport and virtual capture theories, the best fit was found for the Zon-Rapoport theory and thus the virtual capture theory is not indispensable to the interpretation of the experiment. Some additional results are also obtained in the present study. Thus, the combination of the nuclear matrix elements λ has been determined, $\lambda = 0.028 \pm 0.006$, as well as the total disintegration energy Q/^{59}Ni-^{59}Co/= 1075.1±1.3 keV. The existence of a positive β-branch was proved with an estimated value of 1.5×10^{-7} for the branching.

ANALYSIS OF THE INTERNAL BREMSSTRAHLUNG SPECTRUM

G. Székely

ATOMKI Közlemények 18 /1976/ 51-72

The internal bremsstrahlung spectrum of ^{59}Ni measured with Ge/Li/ detector was analysed by a method depeloped by us.
Results of the analysis interesting from the physical point of view are published elsewhere, here we describe way of the analysis from the computational point of view. Main phases of the method are: construction of monoenergetic spectra, decomposition of the measured spectrum to the sum of monoenergetic spectra,corrections on the measured spectrum and fitting the corrected spectrum by functions based on different theories.

MICROSCOPIC AND PHENOMENOLOGICAL PARAMETERS OF THE ISOBARIC ANALOGUE RESONANCE

T. Vertse, B. Gyarmati, G. Tertychny, E. Yadrovsky

To be published in Isv. AN. USSR. /In Russian/

Two methods for calculating the elastic proton S-matrix in the region of the IAR are compared: the numerical solution of the coupled optical equations and the shell-model description of reduced width. In the case of ^{209}Bi good agreement could be achieved in the T $>$ channel. Conclusions are drawn to the isospin purity of the IAS in ^{209}Bi.

ON THE SELF-CONSISTENCY OF THE LANE MODEL

R.G. Lovas

Nuclear Physics A262 /1976/ 356-364.

The conditions for the self-consistency of the Lane potential are investigated by fitting the /p,p/, /p,$\bar{n}$/ and /n,n/ differential cross sections in pairs. It is concluded that the model is correct only for average potentials to the accuracy of average potentials. The Lane potential can only be found by fitting /p,p/ and /p,$\bar{n}$/ data, and its real and imaginary parts should not be allowed to vary independently.

This work was performed by the author at the Nuclear Physics Laboratory, Oxford.

IMPROVED COUPLED-CHANNEL TREATMENT OF THE /d,$\bar{n}$/ THRESHOLD EFFECT

R.G. Lovas

Submitted to Nucl. Phys.

Calculations for the ^{90}Zr/d,p/ excitation function in a charge-exchange coupling model suggest that the /d,$\bar{n}$/ threshold effect can be explained with the resonant solution of the Lane equations taken as the proton form factor.

ON THE COMPLEX OPTICAL POTENTIAL IN THE LANE-MODEL

B. Gyarmati, T. Vertse, G.Ya. Tertychiny*, E.L. Yadrovsky*

ATOMKI Közlemények 18 /1976/ 31-36

By comparing the total widths of the IAR's in ^{209}Bi calculated in a microscopic model to those obtained from the Lane model, it is shown that the decay of the ^{208}Bi/0^+/ core of ^{209}Bi in a few lowest-lying IAR's can be taken into account by assuming complex optical potential in the /closed/ $T_>$ channel.

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* Institute of Physics and Power Engineering, Obninsk, USSR.

ON THE DETECTION OF LOW-ENERGY ^{4}He, ^{12}C, ^{14}N, ^{16}O IONS IN PC FOILS AND ITS USE IN NUCLEAR REACTION MEASUREMENTS

G. Somogyi, I. Hunyadi, E. Koltay and L. Zolnai

To be published in Nuclear Instruments and Methods

It is shown that by using a proper etching reagent the registration sensitivity of polycarbonate foils can be enhanced and they prove to be very suitable track recorders for alpha-particles emitted from nuclear reactions. At 6 MeV an energy resolution of 0.2 MeV can be achieved when using the track diameters as a measure of the particle energy. A theoretical way to calculate the track parameters important in nuclear reaction measurements involving alpha-particles recorded in polycarbonate foils is given. For this purpose the track etch rate vs residual range curve was determined by a parameter optimization procedure. The energy resolution of the track-diameter method as a function of the particle energy was predicted. In our earlier studies the track--diameter method was mostly used in angular distribution measurements of $/d,\alpha/$ nuclear reactions. In this work it is shown that with polycarbonate foils it can be well applied to excitation function measurements, as well. Such studies are presented for the α_0 and α_1 groups of the $^{27}Al/p,\alpha/^{24}Mg$ reaction in an energy interval between 1540 and 1920 keV. Finally, preliminary results on the track etching properties of low-energy O^{+}, N^{+}, C^{+} and He^{+} ions accelerated with a 5 MV Van de Graaff generator are given.

INVESTIGATION OF THE STRUCTURE OF ^{45}Sc NUCLEUS

Dang H.U., Fényes T., Gulyás J., Kiss Á., Koltay E., Máté Z.

International Symposium on Nuclear Structure, Balatonfüred, Hungary, 1975. Proceedings, vol. II, p. 11, Budapest, 1976.

The scattered proton and γ-radiations of the $^{45}Sc/p,p'\gamma/^{45}Sc$ reaction have been studied with surface-barrier Si, and Ge/Li/ detectors at 2; 2.5; 3; 3.5 and 4 MeV bombarding proton energies. From the 48 gamma rays, associated with the decay of ^{45}Sc excited levels, 11 are new. The intensity of gamma-rays was measured as a function of the bombarding proton energy. In the proton spectrum 18 inelastically scattered proton groups were observed, which are connected with ^{45}Sc excited states. $p'\gamma$-coincidences and the γ-radiation of the $^{45}Ti \rightarrow ^{45}Sc$ decay were also investigated. On the basis of experimental results we propose a new level scheme of the ^{45}Sc nucleus. Gamma-ray branching ratios have been obtained for the excited levels. From the experimental results and different theoretical calculations conclusions are drawn on the structure of the ^{45}Sc nucleus.

4. FAST NEUTRON ACTIVATION ANALYSIS

S. Gueth, F. Deák, A. Kiss, Cs. Sükösd

Considerable activity is devoted to find simple and economical methods for the determination of trace elements in organic compounds. Fast sample carriing system, low-level measuring place with high resolution Ge/Li/ detector combined with an effective on-line evoluation method are used in these studies.

5. STUDY OF CHEMICAL BOND BY MÖSSBAUER SPECTROMETRY

L. Korecz, Abou-El Hassan Abd El Shaghier+, I. Király

The standard Mössbauer spectrometry method is used for the investigation of chelate complexes of iron and for the study of forwards and backwards donation. The same method is applied for the solution of structure problems of stannatrate complexes.

+on leave from Al-Ahzar University, Cairo, Egypt

6. INVESTIGATION OF H-BRIDGES BY NMR METHOD

L. Korecz, I. Király, I. Kurucz, I. Kövesdy, A. Csehi

The intramolecular H-bridges in some chelate complexes as well as the H-bridges connected with conjugated rings are studied by high resolution proton-resonance technique.

7. NQR STUDIES

P. Mag, L. Korecz

Considerable research work is devoted to the development of the NQR method in order to investigate the ^{14}N resonance.

ROLAND EOETVOES UNIVERSITY
DEPARTMENT OF ATOMIC PHYSICS
BUDAPEST

1. STUDY OF THE NEUTRON-GAMMA COMPETITION IN REACTION DEEXCITATION PROCESSES OF NUCLEAR STATES EXCITED IN 14 MeV NEUTRON REACTIONS

A. Kiss, F. Deák, V. Fajer+, S. Gueth and Cs. Sükösd

The energy spectra of the evaporated neutrons are investigated at 14,7 MeV incident neutron energy in order to learn about the energetically allowed neutron-gamma competition. The targets range from light to heavy nuclei. The results, available so far indicate that there are considerable gamma competitions for light nuclei while the gamma yields are negligible for the heavier ones.

+on leave from Nuclear Research Institute, Habana, Cuba

2. INVESTIGATION OF SHORT-LIVED ACTIVITIES EXCITED BY 14 MeV FAST NEUTRONS

F. Deák, S. Gueth, A. Kiss, Cs. Sükösd

The production of short-lived activities ranging from 10 usec - 10 μ sec is investigated by 14.7 MeV fast neutrons. A combined α-particle-pulsed-beam method is ised to measure the time distribution of γ -rays following the excitation process of some medium-weight nuclei. Properties of statistical nuclear processes are investigated and the half-lives of isomeric levels are deduced.

3. DEEXCITATION PROPERTIES OF ^{238}U FISSION PRODUCTS WITH HALF-LIVES OF SOME SECONDS

Cs. Sükösd, K. Hamid+, F. Deák, S. Gueth, Á. Kiss

Gamma yields with half-lives of some seconds are investigated after the fission of ^{238}U induced by 14,7 MeV neutrons. The aim of this work is to study the assymmetry of the fission mode. We hope to find a method to identify the fragments by their short-lived gammas.

+on leave from the Pakistan Academy of Sciences, Quetta, Pakistan

B.A.R.C. -

GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

B.A.R.C. -

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN INDIA - XII

Compiled by
M. Balakrishnan
Indian Nuclear Data Group
Nuclear Physics Division

BHABHA ATOMIC RESEARCH CENTRE
BOMBAY, INDIA

INTRODUCTION

The twelveth progress report on Nuclear Data Activities in India covers the work done during the calander years 1975 and 1976. Major part of the work reported here has been presented at the annual Nuclear Physics and Solid State Physics Symposium held at Gujarat University, Ahmedabad during December 1976. The major Nuclear Physics activity in the country is aimed at basic research , and except in case of fission studies, mostly involve charged particle reactions. However, purely nuclear data oriented activities have gathered momentum at the B.A.R.C. as can be seen from items numbered 1,2,3,23,24,25,26 and 27 under Section 1. The work reported from the R.R.C. is almost all related to nuclear data evaluation and prediction of neutron cross section.

The total number of CINDA entries sent to the Nuclear Data Section of IAEA during the period is 16. The liason activity with Computer Programme Library (CPL) of the NEA was continued.

The assembly of all the system at the Variable Energy Cyclotron being built at Calcutta is complete and tested. The full power RF testing has just started. The work on the 100 MeV research reactor project at Trombay has progressed satisfactorily. Plans for setting up an intense pulsed 14 MeV neutron source at B.A.R.C. are under discussion.

(M.K. Mehta)
Convener,
Indian Nuclear Data Group

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Institution	Page

1. BHABHA ATOMIC RESEARCH CENTRE, BOMBAY 400 085

1. On a new Semiempirical Nuclear Level Density Formula with Shell Effects. V.S. Ramamurthy, S.K. Kataria and S.S. Kapoor - A new semi-empirical nuclear level density formula is proposed, which takes into account the influence of nuclear shell structure on level densities and its excitation energy dependence. The ground-state shell and pairing correction energies enter directly into this formula, which involves two mass-independent parameters characterizing the average single particle level density near the Fermi level and the wave length of the shell oscillations. The present formulation is shown to give a good fit to the experimental data on resonance level spacings of spherical nuclei. The present analysis of the data for deformed nuclei also does not indicate an enhancement of the level densities of the magnitude suggestive of a rotation degree of freedom completely decoupled from intrinsic degrees at the excitation energy equal to neutron binding ener energies.

2. Cross-sections of Neutron Induced Reactions in Intermediate and Heavy Nuclei. S.B. Garg - Interaction of neutrons with the nuclides in the Mev energy range gives rise to binary and tertiary reactions. The various induced reactions are (n,n'), (n,2n), (n,3n), (n,p), (n,d), (n,t), (n,He^3), (n,α), (n,np), (n,nd), (n,nt), (n,nHe^3), (n,nα), (n,pn), (n,2p), (n, n), (n, p), (n,dn) and (n,pα). The cross-sections of these reactions can be predicted with the statistical theory. In the structural elements (n,p), (n,np), (n,pn), (n,2p), (n,α), (n,nα) and (n,αn) reactions are significant since they lead to the production of hydrogen and helium gases which cause swelling in them when they are exposed to high neutron fluences in nuclear reactors. The cross-sections of all these reactions have been evaluated in the energy range 0.5 Mev to 20 Mev for V^{51},Cr^{50}, Cr^{52}, Cr^{53}, Cr^{54}, Fe^{54}, Fe^{56}, Fe^{60}, Ni^{58}, Ni^{60}, Nb^{93} and Nb^{94}.

3. Prediction of Neutron Cross-sections of Pa^{231}, Pa^{233} and U^{232} in the MeV energy range. S.B. Garg - Thorium irradiation in nuclear reactors leads to the production of Pa^{231}, Pa^{232} and U^{232}. The nuclear cross-sections of these elements are thus needed to carry out the physics

studies of thorium fuel cycles. But the measured cross-section data of these elements are not sufficient in the Mev energy range. To fill this void optical, statistical and dipole radiation models have been used to evaluate the total, elastic scattering, inelastic scattering, level excitation and capture cross-sections of these elements in the energy range 0.1 Mev to 20 Mev. Contributions due to direct and collective effects have been taken into account in the estimation of capture cross-sections.

4. Intermediate Structure below the Analogue States in ^{73}As. C.V.K. Baba, M.G. Betigeri and V.M. Datar S.M. Bharathi* and A. Roy* - Earlier studies on the inelastic scattering of protons from ^{72}Ge showed several resonances in energy regions in between and even below the expected Isobaric Analogue states. The average separation of these levels is about 100 times that expected from the usual level density formulae. In order to establish that the observed structure are genuine resonances and not fluctuations, a Ge^{72}(p,) excitation function in the energy range of E_p from 3.0 to 3.4 MeV has been measured. Several resonances which are correlated with those observed in the inelastic scattering have been found. A possible origin for these resonances in terms of an excited deformed configuration of the nucleus, and the attempts to experimentally verify this explanation has been made.

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5. Total (p,n) Cross-section for the ^{48}Ca(p,n)^{48}Sc Reaction. Gulzar Singh*, S. Saini, S. Kailas, A. Chatterjee, M. Balakrishnan and M.K. Mehta - The total (p,n) cross-section excitation function for the ^{48}Ca(p,n)^{48}Sc reaction[1] has been measured from $E_p = 1.8$ MeV to 5 MeV, in 5 keV steps ($^{48}CaCO_3$ target, thickness $\sim$ 1 keV for 2 MeV proton) with a r4π neutron counter. The excitation function displays a large number of fine structures which could be attributed to fluctuations of the Ericson type. The Isobaric Analog Resonances (IAR) (^{49}Ca-^{49}Sc pair) at $E_p \sim 1.98$[2] and $\sim$ 3.9 MeV populated in this reaction have been studied in detail by the "energy scanning"[3] technique.

1. P. Wilhjelm, et al., Phys. Rev. 177, 1553 (1969).
2. K.K. Sekharan and M.K. Mehta, Proc. Int. Conf. on Properties of Nuclear States, 763 (1969).
3. P.J. Bhalerao et al., Nucl. Phys. Solid State Phys. (India) 17B (1974).

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6. Isobaric Analogue Resonance at E_p = 2.338 MeV in the $^{51}V(p,n)^{51}Cr$ Reaction. S. Kailas and M.K. Mehta - It has been shown[1] that from a detailed analysis of the Isobaric Analogue Resonance (IAR) in (p,n) reaction, the proton partial width Γ_p, the spreading widths W and the spectroscopic factor SF can be extracted. We have carried out this type of shape analysis for the strong IAR measured earlier by Sekharan and Mehta[2] at E_p = 2.338 MeV in the $^{51}V(p,n)^{51}Cr$ reaction. This IAR has been shown to be formed by l = 1 protons leading to a 4^+ level in ^{52}Cr at 12.8 MeV excitation and the corresponding parent level in ^{52}V is at an excitation energy of 1.559 MeV. In the Breit Wigner analysis of this IAR[2] it was assumed on adhoc basis that $\Gamma_p > \Gamma_n$ while extraction the partial widths. However, the present analysis including both Breit Wigner and Robson Johnson procedures has yielded the result that $\Gamma_n > \Gamma_p$. Using this value of Γ_p, the spectroscopic factor SF and the parameter insensitive reduced normalisation Λ have been determined.

1. S. Kailas et al., Nucl. Phys. Solid State Phys. (India) 18B, 8 (1975).
2. K.K. Sekharan and M.K. Mehta, Phys. Rev. C6, 2304 (1972)

7. Intermediate Width Structures in $^{50}Ti(p,n)^{50}V$ Reaction Excitation Function. S. Kailas and M.K. Mehta - The observation of intermediate width structures (IWS) in measured excitation function for the reaction $^{50}Ti(p,n)^{50}V$ was reported earlier.[1] A systematic analysis has been performed here to confirm their existence and to predict their energy positions in excitation function. An autocorrelation analysis of the fine structure data of this reaction has confirmed the presence of modulating structures of width $\sim$ 100-150 keV over and above the fine structures of width $\sim$3 keV (Coherence width). Calculation of the energy positions of IWS based on Izumo's partial equilibrium model[2] has been carried out. The theoretically predicted values of their positions agree fairly well with that of the experimentally observed gross structures[3].

1. S. Kailas et al., Phys. Rev. C12, 1789 (1975).
2. K. Izumo, Prog. The Phys. 26, 807 (1961).
3. S. Kailas, Ph.D. (Thesis), Bombay University, 1976 (unpublished).

8. Isobaric Analogue Resonances in the $^{80}Se(p,n)^{80}Br$ Reaction.
Y.P. Viyogi*, S. Kailas, S. Saini, M.K. Mehta, N.K. Ganguly*, N. Veerabahu*, T.K. Bhattacharjee* - The Isobaric Analog states in ^{81}Br populated in the $^{80}Se(p,n)^{80}Br$ reaction as compound nuclear resonances have been studied utilising the 4π neutron counter and thin target technique. The experiment involved the measurement of total (p,n) cross-section excitation function in 5 keV step from threshold to 5.1 MeV bombarding energy. The shapes of the observed IARs were determined with a resolution of about 3 keV which was less than the observed total widths. A detailed shape analysis following the procedure of Kailas et al.[1] of the IARs measured in this reaction has been carried out to extract the proton partial width Γ_p and spectroscopic factor SF. The SFs so extracted exclusively from (p,n) work agree better with that from (d,p) work as compared to that extracted from (p,p) work[2], for the same states.

1. S. Kailas et al., Nucl. Phys. Solid State Phys. (India) 18B, 8 (1975).
2. D.P. Balamuth et al., Phys. Rev. 170, 995 (1968).

*Members of VEC Project, BARC.

9. Unbound States in ^{36}Ar through Radiative Capture of α-particles in ^{32}S. D.R. Chakrabarty, M.A. Eswaran, N.L. Rangoowansi and H.H. Oza - In the region of excitation of 10.3 to 11.1 MeV in ^{36}Ar, seven energy levels have been established being observed as resonances in the reaction $^{32}S(\alpha,\gamma)^{36}Ar$, using an enriched (99.9%) isotopic target. The spin and parity of observed 10.33 and 10.65 MeV levels were uniquely determined as 2^+ and 1^- respectively from the angular distribution of the γ_0 originating from the deexcitation of the levels to the ground state, whereas for 10.49 and 10.78 MeV levels, which decay to the 1st excited state, angular distributions of γ_1, were consistent with the respective J^π assignment of 3^- and 2^+.

Resonance strengths of the resonances were calculated from the measurement of γ-yield of the levels. A 12.5 cm (ϕ) x 15 cm NaI(Tl) detector was used for the γ-detection in above measurements. A 30 cc Ge(Li) detector was used to establish quantitatively the γ-decay branching of the 10.49 MeV level to lower excited states.

1. Erne, Nuclear Physics, 84 (1966) 91.

10. A New Approach to the Calculation of Light Ion (Lion) Optical Potential. D.K. Srivastava, S. Mukhopadhyay and N.K. Ganguly - Optical potential for light ions (lions) has been calculated in terms of the optical potential for its constituent nucleons known a priori. In doing so, an extension of Feshbach's projection operator formalism for optical potential has been utilized in which the propagator for the lion has been approximated by the propagator for one of the nucleons in the projectile evaluated at an effective energy ($E-\sum' Ti-\sum' Vi^{00}$) where E is the incident energy of the lion, Ti is the kinetic energy of ith nucleon in the projectile, and V_i^{00} is the first order optical potential felt by it. The prime indicates the exclusion of one of the nucleons from the summation. The second order nucleon-nucleus optical potential depth, B, has been treated as a parameter. For the imaginary potential, a phenomenological shape has used. Good fits have been obtained to the elastic scattering data of triton (20 MeV), helion (20 MeV) and deuteron (12 MeV) scattered off ^{90}Zr, with nearly the same value of B, which is found to be attractive in nature. This result agrees fairly well with other microscopic results available in the literature. However, it may be noted that earlier attempt by Samaddar, Satpathy and Mukherjee for the calculation of lion optical potential yielded second order depth which was repulsive in nature in contrast to the physical expectations. The present method can be easily extended to the case of heavy ions.

11. Systematic Average Optical Potential for Protons. D.K. Srivastava, S. Mukhopadhyay, S. Pal and N.K. Ganguly - Quantities best determined in nucleon optical model analysis are the equivalent sharp radius (Rv) and equivalent root mean square radius (Qv) for the real pptical potential. These quantities calculated from best fit parameters available in literature are found to vary as $Rv = 1.13\ A^{1/3}+1.9$. Thus any physically valid systematic analysis of nucleon scattering data should ensure the consistency of the form factors of the real optical potentials with the above two quantities. We calculated Rv and Qv for potentials obtained by folding Green's strong density dependent force with the density distributions of a number of nuclei and obtained the same result as given above, which provides a microscopic justification to these relations. The geometrical parameters were determined in terms of Qv and Rv and the depth parameters were searched on to fit proton elastic scattering data globally for a large number of target nuclei in the energy range of 30 to 180 MeV. The average set of

optical model parameters obtained above fitted the data better than those hitherto available in the literature.

12. Nuclear Structure Calculations in ^{51}V. S. Saini and M.R. Gunye - Various attempts have been made to explain the recently accumulated data on the nuclear properties of odd Vanadium isotopes in terms of phenomenological rotation-particle coupling model. The results of such calculations depend very sensitively on the parameters employed, indicating the necessity of performing microscopic calculations with realistic nucleon-nucleon interactions. The calculations in ^{51}V reported here are carried out in the framework of Hartree-Fock projection formalism with the band-mixing between the lowest four intrinsic states. The effect of variation of the single particle energies in the pf-shell configuration space on the computed nuclear properties is also studied. The energy spectrum, static moments and the electro-magnetic transitions in ^{51}V are well accounted by the same set of single particle energies and the effective nucleon charges employed in our earlier calculations in $^{47,49}V$.

13. Studies of Fragment Kinetic Energy and Mass Correlations in Thermal Fission of ^{235}U using Gridded Ion Chamber. D.M. Nadkarni, R.K. Choudhury and S.S. Kapoor - With a view to study fragment mass and energy correlations, especially in the symmetric mass region, in thermal neutron fission of ^{235}U we have carried out a four parameter experiment using a back-to-back gridded ion chamber. A thin source ($\sim 25\mu g/cm^2$) of ^{235}U coated on a VYNS film formed the cathode of this ion chamber which was filled with pure argon gas. The pulse heights from grids and collectors were recorded on magnetic tape using the four parameter data acquisition system. The grid distributions were analysed for different fragment kinetic energies using the expression $V_g = kE(1+bR^* \cos\theta)$ where V_g is the grid pulse height, E and R* are the energy and range of the fragment and k and b are constants. With the determination of angle of the fragments with respect to the field directions, only those events were analysed which are emitted nearly perpendicularly to the plane of the fissile target thereby reducing dispersion in energy due to target thickness. The mass distribution of fragments has a peak to valley ratio of 350:1 which is comparable to the TOF data. Various mass-energy correlations are obtained, in particular $\bar{E}_k$ and $\sigma(E_k)$ versus fragment mass and these are analysed in terms of theories of mass division.

14. Cross Sections for Excitation of Shape Isomers in Uranium Isotopes. A. Chatterjee, A.L. Athougies*, S. Kailas and M.K. Mehta - The cross-sections for delayed fission resulting from 14 MeV neutron bombardment of ^{238}U and ^{235}U targets have been measured using annular plastic track detectors in a recoil geometry. The delayed fission yields are very small and there are uncertainties associated with the subtraction of background. We obtain a cross-section of $(91 \pm 28) \mu b$ for delayed fission in ^{238}U, as evaluated on the basis of several runs. This cross-section as well as other available data on the production of shape isomers in ^{238}U and ^{235}U have been compared with a statistical model calculation employing a semi-empirical level density formula with shell effects[1] as well as the conventional Gilbert and Cameron Level Density[2]. The calculation utilises the double humped fission barrier parameters which are consistent with Γ_n/Γ_f data.

1. V.S. Ramamurthy, S.K. Kataria and S.S. Kapoor, Preprint (1975).
2. A. Gilbert and A.G.W. Cameron, Can. J. Phys. 43 (1965) 1446.
*Research Student.

15. Charge Distribution in Spontaneous Fission of ^{252}Cf, determination of Fractional Cumulative Yields of ^{134}Te and ^{135}I. S.B. Manohar, Sarbjit Singh, Tarun Datta, Satya Prakash and M.V. Ramaniah - The fractional cumulative yields of ^{134}Te and ^{135}I in the spontaneous fission of ^{252}Cf are determined. The values of most probable charges (Z_p) for 134 and 135 mass chains are calculated. The data is compared with other fractional cumulative yields in the fission of ^{252}Cf to see the effect of fragment shells on the widths of charge distributions.

16. Time of Flight Studies of Fission Neutrons Passing through Lithium Hydride. N.N. Ajitanand and S.R.S. Murthy - The attenuation of the fission neutron spectrum passing through lithium hydride (Li^6H) was studied by the time-of-flight technique. The start pulse was obtained by detecting the fission with a shallow Xe filled ionisation chamber containing a ^{252}Cf source and the stop pulse was generated by the detection of the associated fission neutron in a plastic scintillator after a flight path of 78 cms. The time of flight spectrum with and without a definite thickness of lithium hydride interposed in the flight path was recorded. Using the known form of the fission neutron spectrum from ^{252}Cf fission and the

unattenuated time of flight spectrum the efficiency of the plastic scintillator was obtained as a function of neutron energy. The time of flight spectrum obtained with the lithium hydride was then folded with the efficiency function to obtain the attenuated fission neutron spectrum. The results obtained are analysed in terms of the neutron absorption and scattering processes in the lithium hydride.

17. Interpretation of Fission Fragment Anisotropies at Intermediate Excitation Energies. S.S. Kapoor and R.K. Choudhury - The fission fragment angular distributions measured at intermediate excitation energies have been analysed on the basis of the statistical theory to obtain the values of $K_0^2/(E_x^s)^{1/2} = J_{eff}/(\hbar^2 a^{1/2})$ characterising the shape of the transition state nucleus. The present analysis of the anisotropy data in the fission of ^{238}U and ^{233}U by 20-140 MeV ^4He ions incorporates the effect of direct interaction fission and the expected differences in the anisotropies of fissions following compound nucleus and direct interactions. The results of analysis are examined for various assumptions regarding the reaction mechanism of the ^4He ion induced fission of ^{238}U and ^{233}U. The results obtained support the earlier theoretical prediction[1)] that the transition state seen by the fissioning nucleus shifts from the second barrier at low energies to the liquid drop model (LDM) saddle point at high excitation energies. The present analysis has also suggested the need for experimental measurements of the fragment-fragment angular correlations at various angles to obtain experimental values of the fragment anisotropies for the individual direct interaction and compound nucleus fission components.

1. V.S. Ramamurthy, S.S. Kapoor and S.K. Kataria, Phys. Rev. Lett., 25, 386 (1970)

18. Investigation of Deuteron-Alpha Scattering Using n-Alpha interaction. Kiran Kumar* and A.K. Jain. - The D-α scattering has been investigated using n-α and p-α interactions. The N-α interaction used in this calculation does not reproduce the N-α S-wave phase shift. The S-wave part of the D-α scattering matrix element has therefore been obtained using the N-N interaction in 5-body N-α system. The S-wave component has been found to play an important role in determining the shape of the d-α scattering angular distribution. The N-α spin-orbit interaction has been found to influence the d-α scattering mainly at large angles.

Satisfactory agreement has been obtained with the experimental data.

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19. Finite Range Distorted Wave Calculations for D(d,t)H Reaction at 25.3 MeV. A.K. Jain and N. Sarma - Finite range distorted wave calculations have been performed for the reaction D(d,t)H at an incident energy of 25.3 MeV. All the six interactions between the four particles have been included explicitly in the evaluation of the transition matrix element. The interactions that we neglected by earlier workers are found to be most significant. The minimum in the differential cross section is obtained only with the inclusion of distortions and the absolute cross section is reproduced to within 30% at forward angles. The results indicate that better agreement with experimental data may result from the use of an expanded deuteron.

20. Pion absorption on ^{3}He. B.K. Jain - With a view to understand the dynamics of the Pion absorption on nuclei, a detailed calculation of the absorption of negative pions on ^{3}He has been done. The absorption of pion is assumed to occur on a pair of nucleons. The final state interactions are described in partial wave analysis using realistic nucleon-nucleon interaction. The results include the absorption rate for the n + d branch and the angular correlation and energy spectrum for the n + n + p branch. The effect of the final state interaction for n + d branch is found to be insignificant while for n + n + p branch it is large.

21. Investigation of the non-locality of nucleon optical potential. D.K. Srivastava and N.K. Ganguly - Origins of non locality in optical potential for nucleons are investigated. Expressions are derived for calculation of nucleon-nucleus optical potential starting from non-local nucleon-nucleon interaction and including antisymmetrization. Calculations are performed in first Born-approximation using Tabakin's nucleon-nucleon interaction for ^{58}Ni. The resulting optical potential is non local, separable and direct and exchange contributions are of equal magnitude. The non-locality is of "exponential type" unlike the "gaussian type" as used by Perey and Buck empirically. For the exponential shape, the range of non-locality is about 0.4 fm which corresponds to about 0.85 fm for the gaussian shape. Energy dependence of the equivalent local potential is in good agreement with the phenomenological value. The Perey-Buck effect is studied.

22. Study of Scission configuration by the entropy maximisation method. M. Prakash, S.K. Kataria and V.S. Ramamurthy - Studies of static scission configurations of fissioning nuclei based on potential energy minimisation have been made in the past to explain qualitatively many features of low energy fission of actinide nuclei, like features of low energy fission of actinide nuclei, like the dip in the total kinetic energy for symmetric division and the equilibrium deformation 6 of fragments etc. Also, it provides an answer to the question of the existence of a scission barrier during the descent from saddle to scission. However, quantitative calculations have revealed scope for improvement in the shape parametrization of the fragments, inclusion of shell effects and nuclear interaction between the fragments, etc. Also, the fragments at scission are not necessarily cold, with the result one has to take into account the washing out of shell effects with excitation energies.

In the present work, we have initiated a study to determine the scission point characteristics by maximising the entropy of the fragment system at scission instead of minimising the potential energy of the system. For a system of coaxial spheroids with quadrupole deformations, the nuclear and coulomb interaction energies are calculated for fragments with diffuse surface. The maxima in entropy are sought after a proper inclusion of shell and pairing effects.

23. Binary and tertiary reaction cross sections of structural elements. (S.B. Garg) - Interaction of neutrons with the medium and heavy nuclides in the MeV energy range gives rise to binary and tertiary reactions. The various possible induced reactions are (n,n'), (n,2n), (n,3n), (n,p), (n,d), (n,t), (n,^{3}He), (n,α), (n,np), (n,nd), (n,nt), (n,n^{3}He), (n,nα), (n,pn), (n,2p), (n,αn), (n,αp), (n,dn) and (n,pα). Measured cross sections for all these reactions are not available in the entire energy range of interest. It is therefore imperative to combine experimental data and theoretical techniques to reduce time and cost on cross-section generation. In the structural elements (n,p), (n,np), (n,pn), (n,2p), (n,α), (n,nα), and (n,αn) reactions are significant since they lead to production of hydrogen and helium

gases which cause swelling in them when they are exposed to high neutron fluences in nuclear reactors. Based on stastical-imperical model the cross-sections of all these reactions have been evaluated in the energy range 0.5 MeV to 20 MeV for ^{51}V, ^{50}Cr, ^{52}Cr, ^{53}Cr, ^{54}Cr, ^{54}Fe, ^{56}Fe, ^{58}Ni, ^{59}Ni, ^{60}Ni, ^{61}Ni, ^{93}Nb and ^{94}Nb.

24. Optical model based study of Pa^{231}, Pa^{233} and U^{232} cross sections. S.B. Garg - Thorium irradiation in nuclear reactors leads to the production of Pa^{231}, Pa^{233} and U^{232}. The nuclear cross sections of these elements are thus needed to carry out the physics studies of thorium fuel cycles. But the measured data of these elements are not sufficient in the MeV energy range. To fill this void optical and statistical models have been used to evaluate the total, elastic scattering, inelastic scattering and level excitation cross sections of these elements in the energy 0.1 MeV to 20 MeV.

25. Evaluation of Capture cross sections of Pa^{231}, Pa^{233} and U^{232}. S.B. Garg - In thorium fuel cycle studies capture cross section is the most important entity which results in either the production of fissile element or the parasitic loss of neutrons by absorption. This cross section is difficult to evaluate because of certain limitations in the calculation of level densities of nuclides. The Margolis extension of Hauser-Feshback theory, the dipole radiation theory of Weisskopf, the electric giant-dipole radiation theory of Axel and the direct, collective and cascade processes of Lane and Lynn have been used to calculate the capture cross sections of Pa^{231}, Pa^{233} and U^{232} in the energy range 0.1 MeV to 20 MeV.

26. Multiplegroup cross-sections and analysis of fast critical assemblies. S.B. Garg & V.K. Shukla - The 27 group Garg-cross-section set for eighteen elements and the 26 group modified ABBN-set the twentyfour elements have been stored in proper neutronic-code formats to carry out the reactor physics studies of nuclear reactors. A test of both these cross section sets has been carried out in the criticality studies of the Pu^{239}, U^{235} and U^{233} based metal, oxide and carbide fuelled fast critical assemblies. A total of twenty fast critical assemblies of different sizes and varying neutron spectra have been selected for analysis. The selected assemblies are JEZEBEL, ZEBRA-3,

SNEAK-7A, SNEAK-7B, ZPR-3-48, ZPR-3-49, ZPR-3-50, ZPR-3-53, ZPR-6-7, POPSY, VERA-1B, ZPR-3-11, ZPR-3-12, JEMIMA-1, JEMIMA-2, GODIVA, TOPSY, ZEBRA-2, ZPR-6-6A and U^{233} - SPHERE. Based on these analyses it has been observed that the Garg-set predicts well the criticality of plutonium- based dense and dilute assemblies and the uranium-based hard-spectra assemblies. This superior trend of the Garg-set compared to that of the modified ABBN-sett is slightly lost in the uranium-based dilute systems because of large differences in the capture cross sections of structural elements of these two sets.

27. <u>Preliminary measurements of neutron capture cross-section on ^{232}Th by activation method.</u> H.M. Jain, R.P. Anand, M.L. Thingan, R.N. Jindal, S.K. Gupta, V.C. Deniz, M.K. Mehta - A set of test measurements of ^{232}Th (n, γ) capture cross-section relative to ^{197}Au were performed at Van de Graaff usIng a liquid nitrogen cooled lithium metal target, at neutron energies of 350, 460, and 680 kev. The 459 and 670 kev gamma rays following from β -decay of ^{233}Th and the 412 kev gammas from ^{198}Au were measured using a 27 c.c. Ge(Li) detector. The absolute photopeak efficiencies of the detector were measured using IAEA standard calibrated sources. Least square polynomial fitting was done to these measured efficiencies and were used for calculating the cross section. Computer program SAMPO was used for finding photopeak areas. Total errors arising from uncertainties in the determination of efficiency, peak areas and ^{197}Au cross section were estimated to be 15%. These results are being used to improve the experimental arrangement in order to reduce the total error below $\pm$ 10%.

2. REACTOR RESEARCH CENTRE, KALPAKKAM

1. RRC Evaluated Nuclear Data File. M.L. Sharma, S. Ganesan, P. Bhaskar Rao, A.M. Manekar and R. Shankar Singh - The study of formats and procedures of different nuclear data files such as KEDAK, ENDF/B, UKNDL, etc., was undertaken with a view to establish one for the users at Reactor Research Centre. This system was designed for the storage and retrieval of the evaluated nuclear data from many different sources, that are required for neutronics and photonics calculations. The formats chosen for implementation are flexible in the sense that almost any type of mechanism of neutron interaction can be described accurately. The recommended formats are presented in an internal note[1)]. The formats chosen are the ones which are most convenient for our processing codes[2,3)]. All the data types of Pu^{239} chosen as a sample isotope, have been compiled and stored on the magnetic tape file in the required format. These include resolved and unresolved resonance parameters, total, elastic, non-elastic, total inelastic, inelastic cross section for excitation of discrete levels, fission, absorption, capture, (n,p), (n, α), transport amongst others. Further work of storing the data for other important fertile, fissile, structural and control materials is in progress.

1. M.L. Sharma, S. Ganesan, P. Bhaskar Rao and R. Shankar Singh Internal note no. FRG/01100/75/RP/78 (1975)
2. S. Ganesan, P. Bhaskar Rao and R. Shankar Singh, RRC-6 (1975)
3. M.L. Sharma and P. Bhaskar Rao, Internal Note no. FBTR/01100/73/ RP-32 (1974)

2. Generation of Legendre Polynomial Expansion Coefficients for the Treatment of Elastic Scattering Resonances. M.L. Sharma and R. Shankar Singh - The code ELMOE[1)] requires as input a library of Legendre polynomial expansion coefficients of the scattering cross sections of the light elements present in the fast power reactors as coolant or structural materials to deal with the scattering resonances of these nuclides.

With a view to improve upon the present library a program LEGC[2] was written to generate the Legendre scattering coefficients for all the important light elements present in the fast reactors.

The present ELMOE library available to us contains data only for the five nuclides viz. C,O,Na, Mo,Fe. We intend to update the data for these nuclides and add other nuclides such as Ni, Cr, Al, V, stainless steel etc. The work in these areas is in progress.

1) A.L. Rago and H.H. Hummel, ANL-6805 (1964)
2) M.L. Sharma and R. Shankar Singh, Internal note no. FRG/01100/ RP-91 (1975)

3. <u>Generation of Inelastic Scattering Matrices</u>. M.L. Sharma and R. Shankar Singh - Considering the importance of inelastic scattering in energy degradation of neutrons in fast reactors and the availability of the more precise values of the parameters in the formulas for nuclear temperatures, a program was written based on the evaporation model to carry out the computations of inelastic scattering group transfer cross sections for the fissile, fertile, and structural materials using the group averaged nuclear temperatures. The results obtained are compared with the previously available data and are reported in an internal note[1].

These calculations are made only for the high energy neutrons (> 1 MeV). For the low energy neutrons a different routine is being developed which would take into account the discrete level data.

1) M.S. Sharma and R. Shankar Singh, Internal Note no. FRG/01100/75/ RP-63 (1975)

4. <u>Evaluation of Mean Fission Width for U235 in the energy region 0.1 to 25 keV.</u> S. Ganesan - The energy dependent mean fission width for U235 in 0.1 to 25keV energy region has been evaluated[1] corresponding to the latest recommended[2] fission cross-sections. The sensitivity of the evaluated mean fission width to the uncertainties in other mean resonance parameters, especially the s wave strength function used in the evaluation process is investigated. It is found that the magnitude of the fission width is very sensitive to the assumed value of s wave strength function.

There is a structure in energy space for the mean fission width so evaluated for U235 isotope. Work on determining the impact of these evaluations of mean fission width in predicting the central Doppler worth for U235 is in progress.

1. S. Ganesan, Nucl. Phys. & Solid State Phys. 18B, 35 (1975)
2. M.G. Sowerby et. al., Ann. Nucl. Sci. Eng., 1, 409 (1974)

5. Evaluation of statistical Resonance Parameters for U238 using ADDJA code in the Unresolved Resonance Region. S. Ganesan - A computer program ADDJA has been developed for evaluations of statistical resonance parameters in the unresolved resonance region for a fissile or fertile nuclide. This code has options to make adjustments of fission widths or capture widths for one or more spin states or strength function for s- or p-waves to reproduce the given recommended capture or fission cross-sections or alpha values as a function of energy. Using this code, we obtain an adjusted set of mean resonance parameters for U238[1] corresponding to the capture cross-sections recommended by Sowerby et. al.[2] The extent to which uncertainties in the evaluated mean resonance parameters affect the calculated magnitude of the temperature derivative of the selfshielding factor is illustrated[1] with sample calculations.

1. Ganesan, Atomkernenergie 29, 14 (1977)
2. M.G. Sowerby et. al., Ann. Nucl. Sci. Engg., 1, 409 (1974)

6. Evaluations of statistical resonance parameters for Th232 in 4 to 50 keV energy region. S. Ganesan - The neutron-induced reaction rates in the unresolved resonance region are of fundamental importance in the calculation of important integral parameters such as k_{eff}, breeding ratio and reactivity coefficients of large fast power reactor systems. For thorium fueled fast reactors, the evaluation of statistical resonance parameters for Th 232 is thus a great importance. We evaluate (based on the statistical approach) the p wave strength function as a function of energy for a broad group structure corresponding to the cross-sections recommended in the ENDF/B-IV library

using the code ADDJA[1]. A compilation of the mean resonance parameters reported by different evaluators and users for Th 232 has been presented and the effect of these different sets of mean resonance parameters on the infinite dilution cross-sections has been investigated[2]. We study the sensitivity of the adjusted p wave strength function corresponding to the uncertainties in the values of s wave strength function, s and p wave level spacings and the nuclear radius. After evaluating a set[2] of mean resonance parameters for use in reactor calculations, we recommend[2] that the thick sample transmission and self indication measurements[3] be performed for Th 232 in order to determine experimentally the mean resonance parameters in the unresolved resonance region.

1) S. Ganesan, Atomkernenergie 29, 14 (1977)

2) S. Ganesan, "Evaluations of Statistical Resonance Parameter for Th 232 in 4 to 50 keV Energy Region" (To be published)

3) T.Y. Byoun and R.C. Block and T. Semler, CONF-720901 1115 (1972)

7. Helium Production Cross Sections for Use in Irradiation Damage studies in LMFBR - S. Ganesan - We attempt to present[1] the status of the helium production cross section as compiled at our centre from various available sources for all the major and minor constituents of stainless steel. We discuss, for certain important isotopes like nickel, boron etc. the lack of reliable differential cross-section data that has lead to significant discrepancies in the amounts of helium calculated as being generated from the known (n,α) reactions and that estimated on the basis of irradiation measurements. The production rate of helium in certain elements like boron-10 and stainless steel 316 in the various locations of Fast Breeder Test Reactor are presented and discussed.[1] We present the status of $^{59}Ni\ (n,\alpha)^{56}Fe$ thermal cross section[2]. We evaluate[2] the cross section for this reaction to be 13.62 barns by fitting the formula for the two-step reaction in nickel to Weitman's experimentally measured helium production data.

1) S. Ganesan "Reactor Physics Considerations in Irradiation Damage Studies - I On Prddiction of Gas Production Rates for use in Irradiation Damage Studies in LMFBR" Internal Note no. FRG/01100/RP-113 (Sep. 1976)

2) S. Ganesan "A note on Two-step reaction in Nickel" J. Nucl. Mats 62, 329-332 (1976)

8. <u>Lumped Fission Product Data for Neutronics Calculations -</u> M.L. Sharma, K.P.N. Murthy and R. Shankar Singh - For understanding the problems in processing fission product (FP) cross section data and also to improve upon the gross FP cross section data available to us we decided to produce a set of group constants with latest FP cross section data in the group structure of Cadarache cross section library.

The individual multigroup cross section of 192 nuclides generated by using XSAVG[1] code were weighted with their concentrations computed using the code CHANDY[2] for the FBTR composition at different burnup stages to obtain the lumped microscopic fission product capture cross section data in 25 energy groups.

The variation of the gross FP capture cross section with irradiation time was also studied. It was found that the changes in the relative fission product concentrations contribute to 7% variation in the one group lumped cross section.

The effect of this variation of lumped microscopic data on the static neutronic parameters was also studied.[3]

1. M.L. Sharma and P. Bhaskar Rao, Internal Note no. FBTR/01100/73/RP-32 (1974)

2. K.P.N. Murthy and R. Shankar Singh, RRC-15 (1976)

3. M.L. Sharma, K.P.N. Murthy and R. Shankar Singh "Fission Product Group Constants for Fast Reactors", Paper presented at Reactor Physics Symposium, BARC, Bombay, March 1-3 (1976)

9. Generation and Evaluation of self shielded cross sections for nickel. S. Ganesan, M.L. Sharma, A.M. Manekar, R. Venkatesan, S.M. Lee and R. Shankar Singh - Updating of nickel cross sections was taken up at this centre because certain discrepancies were noticed in these cross section data in the analysis of critical assemblies. Another reason was conspicuous lack of self shielding factor data for this material in the Cadarache cross section library which is available at RRC. Latest resonance parameter data for all the five isotopes of nickel Ni 58, Ni 60, Ni 61, Ni 62 and Ni 64 were compiled[1,2]. These data were then processed with code DOPSEL[3] to generate temperature and composition dependent self shielding factors and infinite dilution cross sections in a suitable format[4] for further analysis and testing and were stored on a magnetic tape.

To evaluate this data, analysis of integral experiments has been taken up. Two reactors have been chosen for this analysis. ZPR-6-6A and RAPSODIE-FORTISSIMO. The integral parameters considered are k_{eff}, central worths and reflectivity worths. It should be noted that both the reactors chosen have predominant Ni reflectors. Analysis of the correlations of calculated integral parameters against their measured values is in progress.

1. M.C. Moxon, AERE-R-7568 (1974)
2. S.F. Mughabghab and D.L. Garber, BNL-325 (1973)
3. S. Ganesan, P. Bhaskar Rao and R. Shankar Singh, RRC-6 (1975)
4. R. Venkatesan, A.M. Manekar and S. Ganesan, Internal note FRG/01100/RP-102 (1976).

10. Generation of selfshielded cross sections for Fe, Cr, Ni and the study of their contribution to Doppler Effect in Fast Power Reactors. M.L. Sharma and S. Ganesan - The Doppler coefficient of reactivity is the only prompt reactivity coefficient in the considerations of the safety aspects of large fast power reactors during rapid power transients. Recently the delayed negative reactivity feedback due to Doppler broadening of the structural material resonances has been found to be of some importance relative to the contribution of fissile material present in the reactor. The present study aims at assessing this effect quantitatively for typical fast systems.

Latest basic data pertaining to the description of the resonances for all the important structural elements like Fe, Cr, Mo etc. were compiled and processed to generate the temperature and composition dependent self shielded cross sections using intermediate resonance approximation to improve upon the existing Cadarache cross section library in which self shielding factors were conspicuously absent for all these nuclides.

The important resonances that contribute to the Doppler coefficient substantially are identified[1] and the scope for further work is briefly mentioned.

1. M.L. Sharma and S. Ganesan, Paper submitted to the National Symposium on Radiation Physics, June 1976.

11. Improvements to Resonance self shielding corrections in the code EFFCROSS - M.L. Sharma - A detailed study of the heterogeneous resonance self shielding was made. More accurate algorithms for computing collision probabilities for accounting heterogeneity and for computing Dancoff correction in modified Sauer's approximation as suggested by Bonalumi have been incorporated in the code EFFCROSS[1,2]. The modifications made were tested for successful implementation and gave a difference of 150 pcm with earlier and new method for the sample problem of FBR-500 core.

Various interpolation schemes used in the generation of self shielding factors were studied with a view to select the best ones for incorporation in the code EFFCROSS. A code INTERPOL has been written incorporating the earlier schemes used in the code EFFCROSS and the latest schemes[3] suggested by Kidman[3]. Studies pertaining to these schemes have been reported in an internal note[4]. Efforts are being made to incorporate the new schemes in the code EFFCROSS to study the overall effect on the integral parameters.

1. M.L. Sharma, "EFFCROSS-A code for generating effective cross sections from Cadarache cross section library" Report under preparation
2. J. Damieus and A. Ravier, Report DRP/SETR no. 67/746 (1967)

3. R.B. Kidaman, HEDL-TME-71-40, Hanford Engineering Development Laboratory (1971)

4. M.L. Sharma, R. Venkatesan and R. Shanker Singh, Internal note no. FRG/01100/RP-121.

12. Analysis of Critical Assemblies and Data Testing. M.L. Sharma R. Shankar Singh and V. Gopalakrishnan - Integral parameters for a series of fast reactor benchmark assemblies covering a wide range of energy spectra have been calculated with the reference Cadarache cross section library to assess the utility of the available data together with the processing codes and computational algorithms. The parameters considered in this study include k_{eff}, spectral indices, β_{effs} and central reactivity worths. Results of these calculations[1] indicate that some of the important neutron cross section data for U 238, Pu 239, Ni, Fe and Cr need re-evaluation.

1. M.L. Sharma, R. Shankar Singh and V. Gopalakrishnan "Analysis of Selected Fast Critical Assemblies" (RRC report to be published).

13. The effect of using the statistical approach to the unresolved resonance region on the reliability of the calculated Doppler Constant as a function of sodium voiding in a fast critical assembly. S. Ganesan and M.M. Ramanadhan - The calculations of isotopic and groupwise break down of Doppler constant, made using IGDOP program[1], for ZPR-6-7 assembly for the cases of no sodium voiding and full sodium voiding show[2] that the region of importance in the calculation of Doppler constant shifts from the resolved to the unresolved resonance region for all the fissile and fertile isotopes present in the reactor. Not only the plant safety factor goes down in the case of sodium voiding but also the magnitude of the calculated Doppler constant becomes less reliable. While the former effect is well known to be due to the spectral hardening, the latter effect arises because of the statistical representation of neutron induced cross section data in the unresolved resonance region. High resolution cross section measurements for the fertile and fissile isotopes as recommended by

de Saussure and Perez[3] are necessary to alleviate this problem.

1. S. Ganesan and M.M. Ramanadhan, "The calculation of Isotopic and Groupwise Breakdown of Doppler Constant For Fast Systems" Internal Note: FRG/01100/76/RP-103 (July 1976)

2. S. Ganesan and M.M. Ramanadhan, "On The Reliability of the Calculated Doppler Constant as a Function of Sodium Voiding in LMFBRS" (To be published)

3. G. de Saussure and R.B. Perez, CONF-750303 (1975) P. 371

3. TATA INSTITUTE OF FUNDAMENTAL RESEARCH, BOMBAY 400005

1. Combined use of blocking and DSR method for the compound nuclear life time measurement. R.P. Sharma - The life time of the 7.38 MeV 2^+ excited state in ^{28}Si in the reaction ^{27}Al $(p,\gamma)^{28}$Si at E_p = 774 keV, has been measured by a new method in which the two techniques, Doppler shift recoil distance and charged particle Blocking are combined. A well collimated (0.5 mm x 0.5 mm) beam of protons from a 5 M.V. Van de Graaff Machine at Harwell was allowed to fall on an Al single crystal at an angle of $\sim 2°$ which is more than the critical angle for channelling, with respect to the $\langle 100 \rangle$ direction of the crystal. At this angle of incidence the recoiling compound nuclei following the above reaction move almost parallel to the row of atoms and get blocked or deflected through 90° with respect to the incident direction due to Coulomb interaction with the next consecutive nuclei in the row. The recoil distance in this way is reduced to one lattice spacing which in the present case is ~ 4 A°. The emitted gamma rays are detected in a 80 cc Ge(Li) detector (resolution 1.8 keV at 1330 keV) placed behind the crystal. From a measurement of the unshifted and Doppler shifted peaks the life time has been estimated to be 2×10^{-15} sec.

2. Impact parameter dependence of channelling dips for M-shell X-rays in ^{280}U. K.G. Prasad, R.P. Sharma and M.B. Kurup - Axial channelling of 2, 2.5 and 3.0 MeV alpha particles is observed in $\langle 110 \rangle$ direaction of UO_2 single crystal by simultaneously measuring the M-shell x-ray yield and the Rutherford back scattering yield. The measurements are carried out at two temperatures 300°K and 100°K. The minimum yield and the half width of the channelling dip are compared for both the processes at each incident α-particle energy. The observed difference in the minimum yield and the widths in the two cases are correlated with the impact parameter dependence of the M-shell ionization probability. Such studies are expected to yield important information which is useful in the analysis of compound nuclear life time measurements using Blocking technique.

3. <u>Structure of some odd-A nuclei in f -p shell and unified vibrational model.</u> Amit Roy and B.P. Singh - In the last decade the f-p Shell has been a region of special interest in nuclear structure studies: both theoretical and experimental. Informations obtained from host of varied techniques have made it possible to understand the dynamics of the nuclei in this region. The structure of odd-A Ni-isotopes from A = 59 to 65 can be described by coupling quasi-particle states j = 3/2, 1/2 and 5/2 to the anharmonic vibrations of the (A-1) core. Vibrations up to 2-phonons are included in the calculations. The model quite well describes the energy spectra, spectroscopic factors and transition probabilities. The j-dependence of interaction strength and inclusion of Pauli principle do not significantly alter either the energy spectrum or the transition rates. None of the calculations, however, reproduce the second 3/2 state in all the four nuclei. Similar calculation in Zn also misses the second 3/2 state and Fe the second 7/2 state, though no such limitations are noticed in the calculations of odd-A Cu-isotopes. The results indicate that when valence nucleons in the core are same as the extra-core particle being coupled and if the core shows large anharmonicity, the proper description of the odd-A nuclei should include three quasi-particle base.

4. SAHA INSTITUTE OF NUCLEAR PHYSICS, CALCUTTA

1. (n,p) Reaction at 14 MeV and the pre-equilibrium exciton model. A.K. Ganguly - The total cross-sections of the (n,p) reaction at 14 MeV have been calculated according to the pre-equilibrium exciton model for all stable target nuclei in the mass range $9 \leq A \leq 238$. It is observed that the agreement between the theoretical calculations and the experimentally determined cross-section values is very close (within experimental uncertainties in many cases) over the entire mass region (heavy as well as light) providing a firm support to the view that the (n,p) reaction in the 14 MeV range proceeds predominantly through pre-equilibrium emission.

2. Calculation of spreading width. K. Krishan and D. Pal - A rigorous calculation of the spreading width of a resonance is very hard because the complicated states responsible for the sprading width phenomenon are numerous. Spreading width of an IAR, which is essentially the measure of isospin mixing, i.e., coupling of the analogue state to the complicated states with isospine $T_>$ and $T_<$ respectively, is usually defined through energy averaging of the S-matrix over an interval less than the total width of the resonance but larger than the level spacings. This averaging procedure eliminates the necessity of counting of these numerous states. We have attempted to calculate the spreading width of IAR (width 8 KeV) excited in the reaction $^{51}V(p,n)^{51}Cr$ with 2.34 MeV protons. In the present case the averaging procedure does not seem to be justified as the 2-hole - 2-particle configurations, termed as complicated states, are not very many within the specified energy interval. An order of magnitude estimate of the spreading width is made with several approximations and the calculated numbers are fairly reasonable.

3. Quadrupole two phonon states in ^{205}Pb. P. Mukherjee, R. Majumdar and I. Mukherjee. - A recent reaction data on $^{206}Pb(p,d)^{205}Pb$ is interpreted in terms of the neutron holes coupled to the quadrupole one and two-phonon oscillation of the ^{206}Pb core. Good arrangement is obtained between the observed spectroscopic strengths and the calculated single particle amplitudes. The experimental observation of four $f_{7/2}$ states around an excitation of 1.8 MeV is interpreted in terms of the quadrupole two phonon coupled hole states. Similar situation in ^{207}Pb are cited, where d5/2 neutron particle state is strongly mixed with the two phonon-particle states.

4. <u>Gamma ray uoppler shift measurements in ^{85,87}SR.</u> S.K. Basu and A.P. Patro - The meanlives of a number of levels in ^{85}Sr and ^{97}Sr have been measured using the centroid shift technique in DSA measurements and the reaction ^{85,87}Rb(p,n γ) ^{85,87}Sr at E_p = 3.8 MeV. The lifetimes are: $>$ 125fs., 743.1 keV ($3/2^-$); $>$ 180fs, 767.5keV($5/2^+$); 195^{+80}_{-40}fs, 1152.7keV($1/2^-$,$3/2^-$); 300^{+120}_{-80} fs, 1220.6keV($7/2^+$-$11/2^+$); 265^{+135}_{-75}fs., 1262.1keV($11/2^+$); $>$185fs, 1355.0keV ($5/2^+$); $>$ 155fs, 1555.5keV($5/2^+$) for ^{85}Sr and $>$ 300fs, 1228.5keV ($5/2^+$); 365^{+335}_{-125}fs, 1253.8keV($5/2^-$); $>$ 270 fs, 1770.5keV ($5/2^+$); 185 $\pm$40fs, 1920.5keV ($7/2^+$); 125^{+40}_{-30}fs, 2110.8keV($1/2^-$, $3/2^-$); $>$ 210fs, 3169.3keV ($1/2^+$), 290^{+170}_{-80}fs, 2414.7keV ($5/2^-$) for ^{87}Sr. The results are discussed in the light of recent theoretical calculations which are in favour of a collective interpretation for the positive parity states.

5. <u>Decays of ^{95}Zr, ^{95m}Nb and ^{95g}Nb.</u> V.K. Tikku, H. Singh and S.K. Mukherjee - The decays of ^{95}Zr(65d), ^{95m}Nb(87h) and ^{95g}Nb(35d) have been investigated with a high resolution large volume Ge(Li) detector and 4096 channel analyzer. The ^{95}Zr - ^{95}Nb equilibrium source was produced by irradiating enriched ^{94}Zr(92.8%) with thermal neutrons. The energies in keV and relative intensities of the γ-rays observed for a ^{95}Zr - ^{95}Nb equilibrium source are: 204.1$\pm$0.5(2.3$\pm$0.3), 234.7$\pm$0.7 (0.40$\pm$0.05), 561.7$\pm$1.0(0.03$\pm$0.01), 582.1$\pm$0.7(0.3$\pm$0.1), 724.2$\pm$0.3(82.0$\pm$1.0), 756.7$\pm$0.3(100), 765.8$\pm$0.3(220$\pm$5) and 786.2$\pm$1.0(0.10$\pm$0.05). The new γ-rays at 582.1 and 786.2 keV, and 561.7 keV have been confirmed and assigned to ^{95m}Nb and ^{95g}Nb decays, respectively, on the basis of their time decays. A new level at 786.2($1/2^+$)keV is proposed in ^{95}Mo to accommodate 582.1 and 786.2 keV γ-rays. No evidence is found for the reported transitions of 762.5 and 840 keV in ^{95}Nb. Based on our measurements modified decay schemes of ^{95}Zr, ^{95m}Nb and ^{95g}Nb have been proposed. The present results have been compared with the predictions of various theoretical approaches. The framework of unified model seems to give a better fit to the experimental level scheme in ^{95}Mo.

6. <u>5.9 Min isomer of ^{108}Rh.</u> P. Bhattacharya, R.K. Chattopadhyay, B. Sethi, A. Basu and S. Mukherjee - The assignment of a 5.9 min activity to ^{108}Rh has been reported in the literature[1)] from the observation of this activity in the fast neutron activation of natural Pd. This assignment has been verified in the present work by fast neutron activation of enriched ^{108}Pd target, so that the interfering activities due to the other Pd isotopes were eliminated. Ten γ-rays of ^{108}Pd have been identified viz. 404.3, 434.2, 497.5, 581.1, 616.2, 724.0, 901.2, 932.0, 947.9 and 1092.8 keV, using a 32 c.c. Ge(Li) detector. In addition to these a new intense γ-ray of energy 2102.2 keV (Int. $\sim$50% of 434.2 keV) has been identified as belonging to the 5.9 min decay of ^{108}Rh. A decay scheme of ^{108}Rh (5.9 min decay of ^{108}Rh. A decay scheme of ^{108}Rh(5.9 m) is proposed showing that a level at 2536.4 keV in ^{108}Rh is also populated in addition to the others reported previously. The cross-section for the reaction ^{108}Pd(n,p) ^{108}Rh (5.9 m)for 14 MeV neutrons has been measured for the first time. The result obtained is σ (n,p) = 7.5 $\pm$ 1.5 mb.

1) J.A. Pinston et. al., Nucl. Phys. <u>A133,</u> 124 (1969)

7. <u>Decay of the 83 Min ^{75}Ge and energy levels and -transitions in ^{75}As.</u> P. Bhattacharyya, R.K. Chattopadhyay, B. Sethi, A. Basu and J.M. Chatterjeedas - The present study of the decay of the 83 min ^{75}Ge, produced by (n,2n) reaction on enriched ^{76}Ge target, using a 32.2 c.c. Ge(Li) detector for γ-spectroscopy, shows the presence of a 270.169 keV γ-ray confirming a recent report[1)] but does not show any 136 keV γ-ray (Int. $<$ 0.007) and hence rules out the recently proposed[1)] β-feeding (unique Ist forbidden) to the 400.5 keV level of ^{75}As. Two new γ-rays have been found with energies 279.685 $\pm$0.060 and 338.014 $\pm$0.060 keV having intensities of 0.053 $\pm$ 0.006 and 0.042$\pm$0.005, relative to 100 for the 264.615 keV γ-ray. In all 10 γ-rays have been observed and a revised decay scheme of the 83 min ^{75}Ge is proposed. The results are compared with those known from the 120 d ^{75}As should be placed only between the 821.85 and 617.60 keV levels of ^{75}As, thus removing the ambiguity about its placing. Also the isomeric (n,2n) cross-section ratio for the production of the 46.6 sec and 83 min isomers

of ^{75}Ge has been determined from the growth and decay characteristic of the intensities of ^{75}As γ-rays and the result obtained is σ_m/σ_g = 2.47 ± 0.03.

1) S. Venkataratnam et al., Nuov. Cim., 23A, 390 (1974)

8. <u>The decay scheme of the 284.3D ^{144}Ce and energy levels and transitions in ^{144}Pr.</u> J.M. Chatterjee-Das, R.K. Chattopadhyay, P. Bhattacharya, B. Sethi and S.K. Mukherjee - The decay scheme of the 284.3d ^{144}Ce has been studied with the help of high resolution X-ray Ge(Li) and 32.2 c.c. Ge(Li) detectors, and $\beta-\gamma$, $\gamma-\gamma$ coincidence experiments using scintillation and Ge(Li) detectors. The γ-ray energies (intensities) obtained are: 33.622(2.62), 40.892(3.59), 53.432(0.86), 80.106(10.20), 99.963(0.35) and 133.544 (100.00). Gamma-rays with energies 43.0, 66.0, 86.5, 91.0, 146.0 and 166.0 reported in the literature, have not been observed in the ^{144}Ce decay. The 40.892keV γ-ray which is very close to the 40.67 keV k_{β} f X-ray of Pr has been studied by careful comparison of high resolution X-ray spectra of the Pr X-rays emitted in the decay of ^{144}Ce with those from the X-ray fluorescence of spectroscopically pure praseodymium sample. The assignment of an isomer ($T_{1/2}$ = 6.6 ± 1.0 min) to ^{144}Pr has been confirmed by producing this activity through the reaction $^{144}Nd(n,p)^{144}Pr$ with 14 MeV neutrons.

9. <u>Energy levels of ^{100}Ru.</u> S. Bhattacharya and B. Basu - The level scheme of ^{100}Rh has been investigated using high-resolution Ge(Li) detectors in singles and two-parameter coincidence configuration. Altogether 45 γ-rays have been observed in the decay and these are placed in 18 levels below 3.5 MeV excitation on the basis of accurate energies and relative intensities of the observed γ-rays and their coincidence relationships. The log ft-values for the proposed levels are deduced from intensity balance and probable spin-parity assignments are made. The level scheme is discussed in the light of earlier investigations.

10. Excited states of ^{109}Ag. M.B. Chatterjee and B.B. Baliga - The excited states of ^{109}Ag has been investigated from the decay of Pd - 109 ground state. Spectroscopic study has been carried out by observing the gamma-ray singles with a high resolution Ge(Li) detector. Two parameter analysis has been done by observing the gamma-gamma coincidence with the Ge(Li) detectors. A level scheme has been constructed on the basis of accurate gamma-ray energies, intensities and coincidence results. Tentative spins and parities of the excited stages have been proposed.

11. Investigation of levels in ^{59}Ni by means of (p,n) reaction. D. Basu - The level structure of ^{59}Ni has been investigated by studying the γ-rays from (p,nγ) reaction on ^{59}Co at proton energy E_p = 4.5 MeV obtained from the Van-de-Graaff machine at Trombay. The γ-ray spectrum was studied using a 30 c.c. Ge(Li) detector. Evidences regarding the existence of the controversial levels at 1748 keV and 1778.8 keV have been obtained. The new 1768 keV level reported recently from ^{56}Fe(α,n)^{59}Ni reaction has been detected for the first time from the (p,nγ) reaction. Accurate excitation energies as well as bramching ratios have been obtained. A level scheme summarising the results is proposed.

12. Setting up a collective numerical Hamiltonian for O^{18}. Nandita Rudra - Kinetic energy of collective motion consists of vibrational and rotational part. Moment of inertia due to rotation is computed using cranking model formula. Vibrational mass parameter is computed following Pal's prescription using RPA technique and retaining two-body potential dependent terms, which is an improvement over Willet's expression for mass parameter. The collective potential energy is taken to be liquid drop energy plus shell correction term. Liquid drop energy is computed from advanced form of mass formula, assuming the drop to be a spheroid. Shell correction term is computed following Strutinsky prescription. The final solution of the Schrödinger equation for this Hamiltonian is in progress.

13. <u>Odd parity spectrum of ^{16}O with centre of mass correction using the Cornell interaction.</u> J. Dey, J. Mahalanabis - The Hamiltonian to be used in the independent pair approximation is

$$H = \sum_i \frac{p_i^2}{2m}\left(1 - \frac{1}{A}\right) - \sum_{ij} \frac{\vec{p}_i \cdot \vec{p}_j}{Am} + \sum_{i,j} V_{ij}$$

In case of two-particle spectrum e.g. ^{18}O and ^{18}F the second term does not contribute in first order. For p-h spectrum involving "cross-shell" matrix elements this term contributes in an important way.

For the potential V_{ij} we use the Cornell interaction deduced by Negele from the Reid-potential in nuclear matter. Irvine et. al[1] obtained reasonable agreement to the experimental spectrum with this interaction only when the p-h gap is treated as a parameter. We find better agreement without any adjustment of the p-h gap with the $p_i\, p_j$ term.

1) Irvine et. al., Nucl. Phys. <u>A173</u> (1971) 129, Adv. in Phys. <u>20</u> (1971) 661.

14. <u>Fragment excitation and prompt fission neutron spectra from the R G M Model</u>. Harashit Majumdar and Aparesh Chatterjee - In our RGM formulation of fission, the fragment excitation energy is partitioned into two parts: U^{PES}, the energy coming from shape distortion of the fragment F, and U^{RGM}, coming from RGM structural configurations. At scission, the RGM energy ∂E_Z of the fissioning nucleus I goes to U^{RGM}. The previous assumption that $U_F^{RGM} = \partial E_F - \frac{1}{2}\partial E_Z^F$ is replaced by the improved weighted relation $U_F^{RGM} = \partial E_F - (x_F - \eta_F)\partial \epsilon_Z$ where x_F and η_F are the two parameters arising from (i) fragment composition and (ii) odd-even and pairing effects, respectively. Microscopic calculations were done for the fission of ^{235}U + th n, ^{239}Pu + th n, ^{237}Np + fast n, 231 Pa + fast n and 252Cf, using a more realistic shape distortion of the fragments. A common neutron binding energy was assumed along with Kluge - Lajtai prescription. Results are in good agreement with those of others.

15. Stability of light superheavy elements in nature. S.K. Ghosh, S. Ray and A. Chatterjee - We have tested a coulomb criterion for beta-stability of known elements as neutron-proton Fermi gas ensembles and have combined this tested criterion with our predicted nuclear single particle densities of superheavy elements to study their natural relative stabilities. We find that $A = 274, 276$ ($Z = 104, 106$, $N = 170$), $A = 300 - 310$ ($Z = 114$, $N = 186$ to 196) and $A = 338, 340$ ($Z = 124, 126$ $N = 214$) are expected to have long half-lives against the usual modes of decay. The relative stabilities are roughly in the order shown, the last two species giving relatively the most stable superheavy nuclei.

16. Odd-mass Ruthenium isotopes in the quasi-particle phonon coupling model. S. Bhattacharya - The low energy nuclear properties of ^{99}Ru and ^{101}Ru nuclei have been calculated in a semi-microscopic model in which the neutron quasi-particle motion in 2d5/2, 3s1/2, 1g7/2, 2d3/2 and 1h11/2 orbitals in the $N = 50$-82 shell is coupled to the quadrupole vibrations of the corresponding even Ru-core. The calculated energy spectra, electromagnetic moments and transition rates are compared with the limited experimental data existing for these nuclei.

17. Structure of the Odd-A Nb isotopes. K. Krishan and S. Sen - The level schemes and electromagnetic properties of odd-A Nb isotopes from $A = 93$ to 97 are calculated in a semi-microscopic model which couples the proton quasiparticle motion to the quadrupole and octupole vibrations of the corresponding Mo core. The occupation and non-occupation probability factors for different single-particle orbitals are calculated from recent stripping and pick-up reaction data. The quasiparticle energies and the quasiparticle-phonon interaction strength are treated as adjustable parameters. The calculated energy levels, spectroscopic factors and B(E2) values are found to be in good agreement with recent experimental data. The inclusion of octupole vibration is found to be necessary to get a good agreement with observed spectroscopic factors of different negative parity levels.

18. Scattering at large angles. S.K. Sharma and S. Debi - A number of attempts have been made recently to extend the Glauber version of eikonal approximation to large angles. In this work a systematic study has been made to investigate the validity of large angle theory of Chen and Hoock. A considerable improvement over the Glauber eikonal formula is achieved. But this improvement is less compared to that obtained by including the Wallace corrections to the Glauber formula. The extension to the multiple scattering theory is also discussed.

19. Effect of pairing correlation in light nuclei. D. Pal and S. Devi - In order to fit the high energy ($\sim$1 GeV) proton scattering data from ^{4}He, ^{12}C, ^{16}O, we generated the nuclear ground state wave-functions variationally by treating the oscillator parameters as the variational parameter and could produce the elastic scattering as well as the nuclear binding energies reasonably well. However, our wave-functions failed to produce the electromagnetic form-factors. Here we have investigated the effect of short-range pair correlation in the nuclear interior with a view to reproduce the form-factors and the binding energies simultaneously. The results are interesting and the fits to the experimental formfactors have improved a lot.

20. Elastic scattering of intermediate energy pions by ^{4}He, ^{16}O and ^{40}Ca. J. Mahalanabis and A. Choudhury - We have analysed the elastic scattering data on ^{4}He, ^{16}O and ^{40}Ca using the Kisslinger and Laplacian potentials and also the high energy approximation for the pion-nucleus scattering, with different forms of density distribution for the nucleus. The effects of higher order waves and fermi motion was also taken into account. It is found that the Laplacian model gives better fit to the experimental data. The effects of density distribution on σ- Total was found to be negligible.

21. On the Single particle Schroedinger fluid. Mira Dey, Gautam Ghosh and Binayak Dutta-Roy - The coherent state basis is employed to obtain, in the semi-classical limit, the Euler equation of hydrodynamics, corresponding to the single particle Schroedinger eqqation. By introducing unobserved modes the concept of viscosity is extracted. The motivation for the study resides in the increasing use of macro-concepts and of hydrodynamical ideas in nuclear physics, particularly in the context of the liquid drop model and in the description of heavy ion reactions, and

4.A ALIGARH MUSLIM UNIVERSITY, ALIGARH

1. Angular correlation studies in $^{28}Si(\alpha, \alpha\gamma)^{28}Si$ for the investigation of enhancement in backward α-particle scattering.

Rajendra Prasad - Alpha-gamma angular correlations have been measured for the reaction $^{28}Si(\alpha, \alpha\gamma)$ in the energy range 15.00 to 16.20 MeV in steps of 200 keV to provide energy averaged results. The scattered α-particle were detected for lab angles θ_α = 115° to 178° in a multidetector arrangement. The coincident γ-rays were detected with a Ge(Li) detector placed at 90° in the reaction plane. It was found that the double differential cross section for the 1 0 correlation can be described very well with the Hauser-Feshbach theory. Double differential cross sections for the 2 → 1,3 → 1, and also for the 4 →1 (unnatural parity state) correlations give reasonable agreement with the prediction of compound nucleus theory. It is concluded that the double differential cross sections are more sensitive to the reaction mechanism than the single differential cross section measurements and the CN processes are responsible for the rise in backward α-scattering in $Si(\alpha, \alpha\gamma)^{28}Si$ at the energy studied.

5. ANDHRA UNIVERSITY, VISAKHAPATNAM

1. Some neutron activation cross sections in barium isotopes at 14 MeV. N. Lakshmana Das, C.V. Srinivasa Rao, B.V. Thirumala Rao and J. Rama Rao - Descripancies were noticed in the reported values of experimentally determined activation cross sections induced by 14 mev neutrons in Barium isotopes in a few cases like ^{138}Ba $(n,\alpha)^{135m}$Xe, ^{138}Ba(n,2n) ^{137m}Ba. Using mixture powder technique and a large volume Ge(Li) detector, activation cross section have been determined in some Barium isotopes using the 14 MeV neutron facility available at the cascade accelerator of Andhra University. The present values are compared with the reported values (wherever available) and with theoretical predictions.

2. Anomalous conversion of high multipole transitions. S. Bhuloka Reddy, K. Venkata Ramaniah and V. Lkashminaraya - The best conversion coefficient data available for about thirty high multipole transitions in the region $30 \leq Z \leq 52$ are compared with the theoretical interpolated Hager and Soltzer values. In all cases the experimental values are found to be lower than the theoretical values, the discrepancy varying between 3 and 20%. In some cases, however, the experimental errors are considerably large. The deviations in the conversion data are studied as a function of atomic number and an attempt is made to correlate these deviations with the hindrances in the transition probabilities.

3. Conversion of the 61 keV transition in Sb-122. D. Sudhakara Reddy, K.L. Narasimham, B.V. Thirumala Rao and V. Lakshminarayana - The 4.2 m ^{122m}Sb is produced by (n,2n) reaction with 14 MeV neutrons on the cascade accelerator of the Andhra University. The resultant gamma spectrum is recorded with the 35 cc Ge(Li) detector. From the relative intensities of the 61 keV-75 keV gamma-gamma cascade, the total conversion coefficient of the 61 keV transition is estimated to be 0.86(3) assuming the corresponding theoretical E21 value for the 75 keV transition. The value is nearly 20% greater than the theoretical E1 value. The gamma transition probability shows a hindrance of 4.0×10^6. Higher observed conversion together with the hindrance in the gamma transition probability are consistant with the assumed shell model configurations for the converting states.

4. <u>On the parity of the ground state of ^{192}Ir.</u> K. Venkata Ramaniah, S. Bhuloka Reddy and K. Venkata Reddy - To determine the parity of the ground state of Ir-192 unambiguously through the study of the nature of the beta transitions, the 535 and 666 keV beta
decay of Ir-192 have been analysed for theirs beta spectral shapes employing a thoroughly tested and suitably modified beta ray spectrometer of Intermediate Image Type and a conventional slow-fast coincidence system. The spectral shapes strongly support the negative parity to the ground state in accordance with the beta-gamma correlation data, the log ft values and with the recent assumption of -Vc parity to the ground state by Hiroso et al (Nucl. Phy. A164, 1970.220).

5. <u>A note on the symmetry properties of the resultant angular momentum function in the jj-coupling shell model.</u> A. Satyanarayana Rao - A previous note[1)] mentions that the reciprocal of the resultant angular momentum function for J = 0 in the jj-coupling shell model is a solution of the ultrahyperbolic equation of the second order for the case of two identical particles and other related results. In this note we study the Symmetry properties of the component single particle wave functions through circulant matrices and obtain new results in the case of several identical particles.

6. BANARAS HINDU UNIVERSITY, VARANASI

1. Activation cross sections for (n,2n), (n,p) and (n,α) reactions at 14 MeV. Lakshman Chaturvedi, C.N. Pandey and S.K. Bose - Neutron activation cross sections (in mb) for the following reactions at an incident neutron energy of 14 MeV will be reported:

$^{96}Ru(n,2n)^{95}Ru$, $^{97}Mo(n,p)^{97g}Nb$, ^{102}Pd (n,2n)^{101}Pd,

^{106}Pd (n,p)^{106m}Rh, ^{112}Cd (n,p)^{112}Ag and $^{142}Ce(n,\alpha)^{139}Ba$

The present work is to remove the existing disagreement in the available data of the above cross sections by measuring the same employing the mixed powder technique together with a high resolution Ge(Li) and a well type NaI(Tl) gamma ray detector incorporated with 512 channel analyser.

2. The decay of ^{75}Se. Rajendra Prasad - Gamma transitions following the decay of ^{75}Se have been studied using Ge(Li) detector and NaI(Tl) -Nai(Tl) sum-coincidence technique. Two new gammas of energy 373.6 and 556.2 keV have been observed and placed suitably in the decay scheme. Ambiguous gamma transitions of 249.4, 468.8, 542.8 and 821.8 keV energies, previously reported on the basis of Coulomb-excitation and singles Ge(Li) spectrum studies, have also been confirmed. However, no evidence was found for the existence of 269, 293 and 308 keV transitions. Relative intensities of all the observed transitions have been calculated and compared with those available in literature.

3. Angular distribution of fragments in the fission of ^{238}U induced by neutrons in the range 2 - 14 MeV. C.N. Pandey and S.K. Bose - The angular distribution of fragments from neutron-indūced fission of ^{238}U have been measured by means of solid state track detectors in the range 2.6 MeV $< E_n <$ 14.1 MeV. The behaviour of the angular anisotropy is analysed and the contribution of the (n, 2n'f) process is discussed. An attempt is made to get information about the parameter K_0^2 characterizing fragment anisotropies.

4. On divergent integrals in stripping and break-up reactions into the continuum. R. Shyam and S.N. Mukherjee - An alternative method to ensure fast convergence of the radial integrals appearing in the deuteron stripping and break-up reactions to the continuum has been suggested. The overlap integrals appearing in the DWBA calculation are expressed in the form $\int_R^\infty \phi(x)\, e^{-ikx}\, dx$, where $\phi(x)$ is an asymptotic series in powers of $\frac{1}{x}$. Then the integrals of the type $\int_R^\infty x^{-b}\, e^{-ikx}\, dx$ are expressed in terms of a fast convergent series of the form $R^{-b+1}\, e^{ikR}$ U(1,2-b, ikR) if kR $\leq$ 1 and U(1,2-b, ikR) is the confluent hypergeometric function defined by Abramowitz and Stegun (1). For kR $\geq$ 1 a suitable analytic continuation for the above series is used.

1) M. Abramowitz and I.A. Stegun, Handbook of Mathematical functions (N.B.S. Washington D.C. 1964).

5. Construction of the Half-shell function from the phase-shifts and the two-body bound state wavefunction. V.S. Mathur and Reeta Vyas - In our scheme, a rank one separable potential constructed from the given two-body bound state, is used for the model potential V_M envisaged by Haftel (P.R.L. 25 (1970) 120) for the off-shell continuation of the two-body t-matrix in the presence of the bound state. Then, in terms of the 'model' half shell function $\phi_M(k,k')$ and Haftel's function $\phi_W(k,k')$ $\langle \chi_k | V - V_M | \psi_k \rangle$ ($|\chi_{k'}\rangle$ and $|\psi_k\rangle$ being the scattering states for the model and actual potentials, respectively), the actual half shell function ϕ (k,k') can be determined. We have obtained an analytic form for $\phi_W(k,k')$ in which the only unknown is the 'free scattering defect', $\Delta^0(k,r) = \psi_k^0(r) - v_k^0(r)$, v_k^0 being the phase shifted free wave function. So to start with we make a rough guess for this viz. $\Delta^0(k,r) = -(2/\pi)^{1/2} \sin\delta_0(k)\, e^{-\beta r}$ and compute ϕ (k,k'). This in turn determines $\Delta^0(k,r)$ hence $\phi_W(k,k')$ more accurately. The iterative process is found to converge for the test potentials we have used viz. the exponential and square well potentials with an without hard cores. The computed half shell functions are found to agree well with the exact ones.

6. Reduction of coriolis matrix elements in light nuclei.

P.C. Joshi and P.C. Sood - In the particle plus rotor model studies in medium heavy deformed nuclei it has been invariably found that the strength of the Coriolis matrix elements has to be renormalized. We have undertaken investigations to determine whether such renormalization is also necessary in light deformed nuclei. Here we report the results on studies of the Coriolis perturbation of the $3/2^+$ (211) based rotational levels in 31p due to admixture of various K 1 1/2 band levels. The 'experimental' value of the band mixing parameter is obtained by fitting the observed level energies. This parameter has also been calculated theoretically using the Nilsson model single particle wave functions. We find that the agreement of the experiment with the theory requires the strength of the Coriolis matrix elements corresponding to 'favored' cases to be reduced by a factor of about one half which is comparable with the results of similar investigations in rare earth nuclei.

7. B.N. CHAKRAVARTHY UNIVERSITY, KURUKSHETRA

1. Analysis of reduced widths and size. H.C. Sharma, Ram Raj and N. Nath - Recent data on S-wave neutron reduced widths for a large number of nuclei have been analysed nucleus-wise and the calculations for the degree of freedom of the associated χ^2-distribution have been made using the Porter and Thomas procedure. It is noted that a number of nuclei can be fitted by a χ^2-distribution with degree of freedom one, while there are few which are identified to follow a χ^2-distribution with degree of freedom two and even more than two. The present analysis thus contradicts the usual presumption according to which the degree of freedom is taken to be always unity. An analytical attempt has also been made to ascertain the suitability of the data on reduced widths to be used for the analysis. These considerations are likely to modify the neutron cross-section evaluations.

8. BOSE INSTITUTE, CALCUTTA.

1. Optical model parameters of neutrons in the 14 MeV region.
B. Pal, A.K. Chatterjee and A.M. Ghose - Optical model analysis of experimental data on the non-elastic and differential elastic cross sections of 14 MeV neutrons for several nuclei ($12 \leq A \leq 207$) has been made. An average mass independent parameter set, using a criteria function Δ^2, different from generally accepted χ^2 function, has been derived. Relative merits of both the functions have been compared. The parameter set obtained, reproduces the experimental data fairly well in the mass region considered.

2. Absolute (n,2n) cross section of some closed shell nuclei at 14.8 MeV. S. Nath, S.C. Roy, Arun Chatterjee and A.M. Ghose - Absolute (n,2n) cross section of some closed shell nuclei and also some nuclei with high threshold value for (n,2n) reaction have been measured. The neutron flux has been measured by using a method developed in our laboratory. The activity of the irradiated samples have been measured by using a coincidence spectrometer. The data so obtained will be presented together with other experimental values. The empirical formalism of Sigg and Kuroda [J Inorg Nucl. Chem. 37 (1975) 631] for reaction of high threshold will also be rechecked by using our data. The controversial idea that (n, 2n) reaction cross section will show shell structure effect will also be explained by using the present data.

9. BURDWAN UNIVERSITY, WEST BENGAL

1. High energy phase shifts and half-off-shell reaction matrix elements for local and non-local nucleon-nucleon potentials.

B.C. Samanta, J. Dey and P.K. Banerjee - Phase shifts and half-off-shell-reaction matrix elements in $^1S_0$ state for Reid soft-core potential and Tabakin two term separable potential for nucleon-nucleon interaction have been calculated by the matrix-inversion method in the energy range 330 MeV-750 MeV. The phase shifts obtained with the Reid soft core potential give better agreement with those of Arndt and Mac Gregor. The plot of half-off-shell reaction matrix elements ($\langle k' | R | k_0 \rangle$) against momentum (k') for Tabakin potential shows almost the same structure upto bombarding energy of 750 MeV. For Reid soft core potential the plot of $\langle k' | R | k_0 \rangle$ against k' shows a hump at 4 fm^{-1} at lower energies but at a bombarding energy of 750 MeV it shows a second hump at a lower value of k'.

10. CALCUTTA UNIVERSITY, CALCUTTA

1. Shell model calculation of ^{58}Ni. D. Banerjee and L.K. Chakraborty - Employing $^{56}_{28}Ni28$ as the inert core, the structure of ^{58}Ni is studied in the framework of a conventional shell model. A pairing - plus - surface - tensor interaction is used as the effective two body interaction. The configurations with valence neutrons in the $p_{3/2}$, $f_{5/2}$, and $p_{1/2}$ shells are considered. Low-lying energy levels are calculated and a satisfactory agreement with experimental values is obtained. We also estimated the B(E2) values for transitions between low-lying levels.

2. A nuclear matter calculation for some non local $^1S_0$ potentials. S. Bhattacharyya and M.K. Roy - Kermode and McKerrell[1] have recently proposed some non-local $^1S_0$ p-p potentials which, while reproducing the experimental phase shifts to a high degree of accuracy, tend to reduce (or even completely remove) the height of the knoll that appeared in their purely local p-p potentials. We have used Tabakin's[2] method for these nonlocal potentials to make nuclear matter calculations and compare the results with those calculated from the purely local $^1S_0$ p-p potentials[3].

1) M.W. Kermode and A. McKerrell, J. Phys. G: Nucl. Phys. (1975) 6, 140; J. Phys. G: Nucl. Phys. (1976), 6, p375.

2) F. Tabakin, Ann. Phys. (NY), (1964) 30, p51.

3) S. Bhattacharyya and M.K. Roy, Proc. Nucl. Phys. and Solid State Phys. Symposium, Calcutta, (1975) V 18B, p108.

11. DIBRUGARH UNIVERSITY, ASSAM

1. Nuclear matter properties with a finite charge-dependent N-N Potential. A.K. Deka and P. Mahanta - Recently we used[1] a charge dependent N-N Potential to explain the energy level shift in the mass A=18 nuclei. In the present work we report the results of a detailed nuclear matter calculation within the framework of Brueckner formalism for the same N-N potential which introduces the charge dependence in the singlet even states. The wound integrals, binding energy, compressibility, contribution of tensor as against the central force, higher partial wave contributions give a first estimation for the influences of charge dependence of nuclear forces on nuclear matter binding energy.

Our conclusion is that of the two versions of the potentials RHEL 1 and RHEL 2 only RHEL 1 is suitable for nuclear matter calculation; RHEL 1 GIVING -17.37 MeV for binding energy two-body approximations. In ISO state the proper inclusion of charge dependence leads to a gain of about .25 MeV at normal density. In the 1D2 state the charge dependence is very small but shows a different variation than the 1SO state.

1. A.K. Deka and P. Mahanta, Phys. Rev. C13 (1976) 2044.

2. Neutron matter in Jastrow theory. Tapash Chakraborty - The energy per particle in neutron matter is calculated with the lowest-order variational method as developed by Clark and Ristig. A mononotonic correlation function which allows "overshoot" was used. It is found that a gain in energy can be obtained at high density, with an appropriate choice of the subsidiary condition.

12. GUJARAT UNIVERSITY, AHMEDABAD

1. Determination of r_0 and the overlap parameter from the measured fragmentation cross-section. S.D. Verma - A study of the total fragmentation cross-section of nuclei in different targets could be used to study various nuclear parameters. In the present work nuclear radius of hydrogen 'r_0' and the Bradt - Peters overlap parameter 'b' have been obtained using the total fragmentation cross-section σ_f, of relativistic oxygen ions in various targets of differing values of atomic weights. The values obtained are

$$r_0 = (1.42 \pm .02)\ 10^{-13}\ cm^2$$

$$b = (1.97 \pm .034)$$

The implications of the Bradt-Peters formulation are discussed. Data of σ_f for oxygen ions was taken from work carried out using mono-energetic (2.2 GeV/nucleon) oxygen ion beam of University of California, Bevatron, Berkeley, Cal., U.S.A.

13. H.P. UNIVERSITY, SIMLA

1. Phase shifts for electron scattering from a spheroidal potential.
Sham S. Chandel and S. Mukherjee - The spheroidal phase shifts for electron scattering from a two-centre coulomb potential have been calculated by a semiclassical method, first suggested by Miller and Good[1] and developed further by Lu et al.[2] The exact solution of the coulomb equation provides the basis function for the approximation. The spheroidal phase shifts for small ℓ are found to differ considerably from the spherical case, whereas the phase shifts for higher ℓ tend to the corresponding spherical phase shifts. For the S-wave phase shift, a slight variation of the method has been found useful. The method will be applicable to the high energy electron scattering from the molecules and deformed nuclei like Er^{166}, Yb^{176}, which have been observed[3] to cluster into two centres.

1) S.C. Miller and R.H. Good, Phys. Rev. 91, 174 (1953)
2) S.S. Wald, M. Schardt and P. Lu, Phys. Rev. D. 12
3) W. Bertozzi, High Energy Physics and Nuclear Structure (1975)

14. INDIAN ASSOCIATION FOR CULTIVATION OF SCIENCE, CALCUTTA

1. On higher order Eikonal approximation. S. Sarkar and S. Khatun. We propose some improvements of Yennie's work on high energy approximation for electron-nucleus scattering by making calculations more rigorously.

We have evaluated both amplitude and phase of eikonal wave function, retaining higher order correction terms which are functions of inverse momentum transfer and interacting potential.

Second order term of phase is retained.

In the process of reducing 6-D integration to 3-D one for scattering amplitude, we have retained some correction terms neglected before.

Angular integration has been done exactly.

For positron nucleus scattering these have led to a better agreement with phase shift analysis than obtained by Yennie.

Another method due to Resenfelder, derived from eikonal approximation of scattering T-matrix, is not satisfactory at large scattering angle while our method is. We have further applied eikonal approximation to the detailed study of elastic and inelastic processes and their dependence on the polarisation states of electrons and nuclei.

15. INSTITUTE OF PHYSICS, BHUBANESWAR

1. On the shape of zirconium and molybdenum nuclei. C.R. Praharaj - We have done Hartree-Fock calculation (a) for $Zr^{96,98,100,102}$ nuclei by placing active neutrons in the $3S_{1/2}$, $2d_{3/2,\ 5/2}$, $1g_{7/2}$, $1h_{11/2}$ single-particle orbits and assuming a Zr^{90} core and (b) for $Zr^{96,98,100,102}$ and Mo^{98} nuclei with active protons in the $1f_{5/2}$, $2p_{1/2,\ 3/2}$, $1g_{9/2}$ orbits and active neutrons in the $3S_{1/2}$, $2d_{3/2,\ 5/2}$, $1g_{7/2}$, $1h_{11/2}$ single-particle orbits. A surface Delta residual interaction is used in the Hartree-Fock calculation.

These nuclei seem to prefer the Prolate shape to the Oblate shape, the Prolate H.F. minimum being consistently lower than the Oblate H.F. in these nuclei. In the Zr^{96} calculation with active neutrons only there is no Oblate H.F. solution and the lowlying spectrum of this nucleus is dominated by the Spherical and the Prolate shapes. The first excited 0^+ state of Zr^{96} occurs at a lower excitation energy than the 2^+ state, in agreement with experiment.

Angular momentum projected spectrum (also taking into account the mixing of different shapes) for some of these nuclei is being calculated.

2. On the anomaly of high spin states. A. Ansari and L. Satpathy - The phenomena of backbending and forward bending have been critically examined. It is shown that the backbending effect, i.e., the rise of moment of inertia with the associated decrease of angular frequency, which has been considered very anomalous and challenging is a very normal and natural feature of the spectrum arising out of a single intrinsic axially symmetric many-body wave functions. Such a spectrum has no forward bending. These contentions have been proved analytically and illustrated through microscopic calculations in the rare-earth region. Thus backbending is a very normal feature and there is nothing anomalous about it. The seemingly anomalous feature is due to the use of classical definition of moment of inertia and angular frequency. The real problem is the forward bending which appears to need non-axialdegrees of freedom for its description.

16. INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

1. Gamma decay of analogue resonances in ^{56}Fe. S.N. Chaturvedi, H.R. Prabhakara, G.K. Mehta and S. Sen. - The resonances in the ^{55}Mn $(p,\gamma)^{56}Fe$ reaction at incident proton energies 1678, 1687 and 1697 keV have been studied. From the similarity of their decay characteristics, these resonances were interpreted as the fine structure components corresponding to the 334 keV parent analogue state in ^{56}Mn in an earlier investigation.[1)] It is now known that there exists a doublet in ^{56}Mn at energies 335.5 and 341 keV and thus a reinvestigation of the corresponding analogue resonances is of interest. In the present investigation it is found that the decay characteristics of these resonances are not similar in contradiction with the results of the earlier study. The angular distribution of the primary γ-rays from these resonances have also been investigated.

1) Friedrich et al. Ann. Der. Phy. 23 (1969) 168.

2. Study of analogue states in ^{52}Cr. H.R. Prabhakara, S.N. Chaturvedi and G.K. Mehta - Gamma decay of analogue states of ^{52}V at 146, 431, 787 and 837 keV were reported earlier*. The angular distribution studies of the primary gamma rays from the resonant states have been completed. The spin assignments of the resonant states and some of the bound states, and the electromagnetic transition rates from the analogue to the lowlying states have been obtained.

* Nuclear Physics and Solid State Physics Symposium Calcutta 1975

3. Calculation of transition rates for electromagnetic decay of analogue states in ^{52}Cr. M. Prakash and G.K. Mehta - Available effective interactions are employed to deduce the wave functions of low-lying states in ^{52}Cr and ^{52}V nuclei in $f_{7/2}\ p_{3/2}$ space. Analogue state wave functions in ^{52}Cr are generated from ^{52}V states and electromagnetic transition rates to low-lying ^{52}Cr states are calculated. Proper isospin character of final states has been taken into consideration. The analogue states considered are the ground state analogue (3^+ : 11.263 MeV) and the 4^+ analogue at 12.113 MeV. Calculated numbers are compared with experimental ones.

4. <u>Long range charged particle emission in keV neutron fission of ^{235}U.</u> B. Krishnarajulu, G.K. Mehta, R.K. Choudhury, D.M. Nadkarni and S.S. Kapoor - Although long range charged particles LCP (mostly alpha particles) are known to be emitted with small probability from fissioning nucleus close to scission stage, very little is known about the factors which influence their emission probability (P_{α}). In the present work we have investigated whether P_{α} and $N(E_{\alpha})$ are dependent on the characteristics of the transition states accessible at the saddle point and, in particular, due to the change in the parity of the available states in going from S-wave fission to p-wave fission. P_{α} and $N(E_{\alpha})$ were measured in the fission of ^{235}U induced by neutrons of energies E_n = 120, 180, 500, 800 and 1020 keV and are compared with those in thermal neutron fission. Fast neutrons were generated with $^7Li(p,n)^7Be$ and T(p,n) reactions using the 2 MeV Van de Graaff accelerator at IIT, Kanpur. LCP were detected by a semiconductor detector and the fissions were detected by a small ionisation chamber. A low energy component ($E < 12$ MeV) was observed in the energy spectrum which is attributed to tritons emitted in fission. P_{α} is found to increase around $E_n \sim 200$ keV and the extracted triton yield P_t shows a marked increase around $E_n \sim 500$ keV. The results on P_t, P_{α}, E_{α} and $\sigma_{\beta\alpha}$ are analysed in terms of transition state level characteristics.

5. <u>Bound Pion absorption followed by emission of two unequal energy nucleons</u>. R.S. Bhalerao and Y.R. Waghmare - Angular distributions for the reaction ^{12}C (bound π^-, pn) are calculated without assuming energies of the two outgoing nucleons to be equal, Hartree-Fock wave functions used for the pion-capturing nucleon pair in the initial state, incorporate some effects of the short-range nucleon-nucleon correlations (SRC). In the final state, nucleon-nucleon scattering is taken into account while that between each of the two nucleons and the residual nucleus is neglected. Contribution of low-lying excited states of the residual nucleus is also taken into account. Results are compared with the recent data of Lee et al (Nucl. Phys. A <u>182</u> (1972 20). A very good agreement is obtained, which is better than that of many old calculations which employ different approaches to introduce SRC between nucleons and/ or take energies of the two outgoing nucleons to be equal.

6. Distorted-wave calculation of (π^+, p) reaction on ^{4}He, ^{6}Li and ^{12}C. N. Chandrasekhar, R.S. Bhalerao and Y.R. Waghmare - The process of free-pion absorption (T_π = 70 MeV) leading to a single-proton emission is studied by using Hartree-Fock wave functions which take into account some effects of the short-range nucleon-nucleon correlations. The reaction is studied according to the single-nucleon mechanism for π -absorption and both the pion - and proton waves are taken to be distorted. Excited states of the residual nuclei are taken into account in a simple shell model calculation. Results are found to be quite satisfactory. In particular, minimum in the cross section for ^{6}Li (π^+, p) ^{5}Li has, for the first time, been reproduced at the experimentally observed angle. Predictions are made for ^{12}C (π^+, p) ^{11}C.

We have also studied this reaction on ^{4}He. Here the pion is represented by a plane wave while the final-state interaction is taken into account in two different ways. In one the proton wave function is determined according to the Glauber prescription and in the other it is derived starting with N-N interaction. The two results are compared.

17. KASHMIR UNIVERSITY, SRINAGAR

1. Angular correlation measurement of gamma ray transitions in the decay of ^{207}Bi. N.N. Raina and Ayub Thuker - Gamma-gamma directional correlation measurements have been carried out for the following cascades in ^{207}Pb using fast-slow coincidence system, and the expansion coefficients are:- (1063.62-569.67) keV: $A_2 = +0.209 \pm 0.001$, $A_4 = -0.022 \pm 0.004$ (1770.22-569.67) keV: $A_2 = -0.0048 \pm 0.0021$, $A_4 = +0.0102 \pm 0.0054$. Our A_2 value for the (1063.62 - 569.67) keV cascade appears to be attenuated as compared to the A_2(Theo.) = +0.232, assuming (E5/M4) =[illegible]0.03 for the 1063.62 keV transition: This is confirmed from the recent time differential correlation measurements of Kumar et al*, who have established the existence of extra nuclear perturbation, Mixing ratio and the reduced transition probability for the 1770.22 keV transition have also been calculated after allowing for the extra nuclear perturbation of the (1770.22 - 569.67) keV cascade.

* Ashok Kumar, S.K. Soni, S.C. Pancholi and S.L. Gupta Nucl. Phys. and Solid State Physics (India) 18 B, 278 (1975)

18. MARATHWADA UNIVERSITY, AURANGABAD

1. The study of levels in ^{64}Cu by $^{64}Ni(p,n\ \ )\ ^{64}Cu$ reaction.
R.G. Kulkarni, P.N. Patrawale and V.U. Patil. - In beam gamma-ray singles from the $^{64}Ni(p,n\gamma)^{64}Cu$ reaction have been measured with the Ge(Li) detector varying the proton energy from 2.5 to 4.5 MeV in steps of 500 keV using BARC Van de Graaff accelerator. Angular distribution of gamma ray transitions were measured at 3.0 MeV proton energy. A decay scheme consisting of ten levels is proposed on the basis of measured energies and intensities of gamma transitions. Three new levels of 574, 875 and 927 keV have been observed in this work. The branching ratios for the proposed levels are deduced and the possible spin assignments are made for some of the levels.

2. The positive parity states in ^{121}Sb.* P.N. Patrawale and R.G. Kulkarni - Low lying positive parity levels in ^{121}Sb were Coulomb excited with 3.0 to 4.5 MeV protons to test the 2p - 1h states predicted by the detector used
to measure the gamma ray yields. The levels at 946, 1406 and 1412 keV in ^{121}Sb were Coulomb excited for the first time. Gamma ray angular distribution measurements established spin values of 9/2, 3/2, 5/2 and 3/2 or 5/2 for the 946, 1380, 1406 and 1412 keV states respectively. The E2 and M1 reduced transition probabilities were determined for the seven states and the 573, 946,1024 and 1037 keV levels have electromagnetic properties consistent with the interpretation of 2p - 1h states.

* Experimental work was carried out at BARC Van de Graaff Laboratory.

3. The decay of ^{124}Sb. D.P. Navalkele, K. Andhradev, R.G. Kanitkar and R.G. Kulkarni - Through the beta decay of ^{124}Sb - ^{124}Te, the gamma rays, beta-rays, and conversion electrons have been observed using NaI (Tl) detector and β-ray spectrometer. The K and L conversion electrons have been found for the first time for the gamma rays at 185, 386, 663, 817 and 1301 keV. A new gamma ray at 511 keV has been observed along with its K and L conversion electrons. The results are analysed in the light of theory.

19. PHYSICAL RESEARCH LABORATORY, AHMEDABAD

1. Skyrme's interaction and nuclear spectroscopy. V.B. Kamble and S.B. Khadkikar - Band averaged density dependent Skyrme's interaction has been used to study the spectroscopic properties of some op-shell nuclei. Individual contributions of the various terms of this interaction to the ground state band have been evaluated. Projected Hartree-Fock calculations are performed in the configuration space of first four major shells treating all the nucleons on equal footing. The interaction used is the variant SIV of Beiner et al. (Nucl. Phys. A238 (1975) 29). It is found that most of the contribution to the spectrum comes from the s-state attractive (to) and the s-state repulsive (5 (t_1) terms and that these two terms are the ones which decide the overall nature of the spectrum, while in case of 12 C, the two-body spin-orbit term (W_0) also plays an important role in deciding the total spectrum.

2. Structure of ^{20}Ne with Skyrme's interaction. V.B. Kamble and S.B. Khadkikar - Ground state band of the nucleus ^{20}Ne has been obtained using the density independent and band averaged density dependent Skyrme's interactions. These are the variants SV, SIV and SIV-d. Projected Hartree-Fock calculations are performed in the configuration space of first four major shells treating all the nucleons on equal footing. The calculations are compared with the Cranked Hartree-Fock (CHF) calculations of Passler and Mosel (Nucl. Phys. A257 (1976) 242). The set SV gives compressed spectra in both the cases. The set SIV gives good agreement in our projected HF calculation while CHF gives a compressed spectrum. The variant SIV-d which provides a good agreement with CHF gives a highly spread out spectrum in Projected HF formalism.

3. On the quadrupole polarizabilities of the nuclei Ge(70,72) and Kr(80). S.K. Sharma - Quite recently the lifetime measurements for the low-lying, positive parity states in As(71,73) as well as in Rb(81) have been reported by B. Heits et al. (Physics Letter 61B (1976) p.33). These measurements enable us to extract the effective quadrupole deformations (β) for these nuclei. From a comparison of these values of β with those obtained empirically for the nuclei Ge(70,72) and Kr(80), it turns out that whereas the change in β in going from Ge(70) to

As(71) is about 22 percent, that in going from Ge(72) to As(73) is only about 14 percent. Further, practically no change in deformation is observed in going from Kr(80) to Rb(81). We have first carried out the constrained Hartree-Fock-Bogoliubov(CHFB) calculations for these nuclei (with the value of the Q taken as a constraint) employing the Kuo's effective interaction in the 2p-1f-0g valence space. The CHFB calculations have enabled us to obtain the "E( ) versus plots. Similar curves for the even-odd nuclei were next obtained by coupling the appropriate Nilsson orbits for the odd protons to the energy-versus-deformation curves for the corresponding even-even nuclei. The calculations are quite successful in explaining qualitatively the observed trends concerning the changes in deformations induced by a proton in the nuclei Ge(70,72) and Kr(80).

4. Effective charges and E2 transitions in 1f-2p shell nuclei. A.K. Dhar and K.H. Bhatt - The proton and neutron effective charges needed to reproduce the observed E2 data on the transitions between the ground state bands of the isotopes of Ti(A=44-50), V(A=47-51), Cr(A=48-52) and Fe(A=52,54) are found to be $e(p) = (1.33 \pm 0.09)e$, $e(n)=(0.64 \pm 0.10)e$. These charges were obtained by a least squares fit between the deformed configuration mixing shell model calculated and the observed B(E2) values for the transitions in these nuclei. These values support the charges e(p)= 1.25e, e(n) = 0.47e obtained recently by Kuo and Osnes in a microscopic calculation and the charges e(p) = 1.21e, e(n) = 0.79e obtained on the basis of macroscopic estimates of Bohr and Mottelson.

5. Deformed shell-model calculations of V-47 and V-49. A.K. Dhar and K.H. Bhatt - Deformed configuration mixing shell model calculations of the spectra and electromagnetic properties of V-47, 49 have been performed. Agreement between the calculation and available observations is good. On the basis of the correspondences between the calculated and observed decay properties we suggest the spin assignments J = 1/2 to the 2.21 MeV level in 4-47 and J = 1/2, 9/2, 7/2, 11/2 and 13/2 to the levels at 1.64, 2.35, 2.41, 2.67 and 2.73 MeV respective in V-49. Modified Kuo-Brown effective interaction and microscopically obtained effective charges e(p)=1.25e, e(n)=0.47e are used in the calculations.

6. Binding energy of ^6Li with velocity dependent potentials and importance of saturation. D. Mahanti and B.K. Srivastava - We make variational calculations of the ground state energy of ^6Li with two central velocity-dependent potentials derived differently - the parameters in one are obtained by fitting the relevant two-body data (the potential of Herndon[1] et al) while those in the other are obtained primarily by fitting the saturation properties of nuclear matter (the potential of Davies[2] et al). The variational wave functions are further used to compute the r.m.s. charge radius of the nucleus. We find that, of the two potentials, only the potential obtained from a good fit to the saturation properties of nuclear matter gives results for the binding energy and the r.m.s. radius of ^6Li consistent with experiments.

1 R.C. Herndon et al., Nucl. Phys. 42, 113 (1963)
2 K.T.R. Davies et al., Nucl. Phys. 84, 545 (1966)

7. $d^{-1}_{3/2}$ hole states in $f_{7/2}$ shell nuclei. U.P. Ahalpara and K.H. Bhatt - Bansal and French successfully explained the systematics of hole states" in the Sc and Ti isotopes in a semiempirical way. They assumed a simple $\{(f_{7/2})^{n+1}_{J_0,T_0} \times d^{-1}_{3/2}\}$ structure for the hole states, where $J_0 = 0$ or 7/2 and $T_0 = T_>$ of the $f_{7/2}$ nucleons. They further took the empirical binding energies of the nuclei to calculate the excitation energies of the "hole states" relative to the ground states of these nuclei.

The recent determinations of the effective interactions for nucleons in the $d_{3/2}$ and $f_{7/2}$ orbits makes it possible to check the validity of these two assumptions.

We have used the empirical $\langle d^2_{3/2} | V | d^2_{3/2} \rangle$ $\langle d_{3/2} f_{7/2} | V | d_{3/2} f_{7/2} \rangle$ and $\langle f^3_{7/2} | V | f^3_{7/2} \rangle$ interaction matrix elements and the empirical $d_{3/2}$ $f_{7/2}$ single particle energies to calculate the energies and the structure of the the $(d^2_{3/2})$ $(f^n_{7/2})$ ground state and $d^{-1}_{3/2}$ $(f^{n+1}_{7/2})$ hole states of Ca, Sc, Ti and V isotopes. Contrary to the tacit assumption of Bansal and French it is found that the empirical intersections do not reproduce well the binding energies and the observed "hole states" systematics of these nuclei.

8. Spectral averaging for single nucleon transfer sum-rules.
V. Potbhare - Spectral averaging methods have been used to calculate the linear-energy weighted sum-rules for the single-nucleon transfer in various s-d shell spaces using the Preedom-Wildenthal interaction. Width of the strength distribution has also been evaluated. This quantity is very useful in determining how high in energy one should look to exhaust enough strength for single-nucleon addition and removal processes.

9. Influence of the lower SU(3) representation on the spectral properties of heavy deformed nuclei. V.K.B. Kota - Although the pseudo SU(3) model in its extremely simplified version, by taking only the leading pseudo SU(3) representation, explains well the ground state properties of the heavy deformed nuclei (Ratna Raju et al. N.P. A202 (1973) p.403), it fails completely in accounting for the large hinderance factors observed in certain interband M1 transition probabilities. There are notable discrepancies in the spectra of Eu and Tm isotopes, predicted by this model. The influence of the lower SU(3) representations in removing these anomalies is studied by analysing Dy^{160} nucleus. We have included one lower SU(3) representation and allowed for a limited amount of mixing of proton and neutron spaces. It is found that the calculated spectra comes near to the experimental spectra only when the lower representation (20 0) is included. It is observed that the interband transition probabilities strongly depends on the lower representations, unlike the intraband transition probabilities.

10. Unitary groups and Hartree-Fock (HF) approximation.
V. Satyan and J.C. Parikh - The question to what extent the HF procedure converts the two-body interaction into an effective one-body operator has been studied. For this purpose the interaction is classified according to its tensor parts under the unitary groups U(N) and its direct sum subgroup U(m) +U(N-m) where N is the total number of HF single particle (s.p.) states of which m are occupied. The sizes of these tensor parts in m-particle spaces are determined by evaluating their Euclidean norms. Next a polynomial expression is derived for the norm of the effective one-body operator resulting from the

decomposition of the interaction under U(m)+U(N-m). In terms of this norm and also the U(N) norms a ratio is defined which provides a measure of the conversion efficiency of HF procedure and also provides a global measure of the goodness of the HF s.p. basis. This ratio is evaluated for some N=Z even even nuclei in 0d-1s and 0f-1p shells using realistic two-body interactions. Our results show that the HF conversion efficiency is low and that the HF s.p. basis is not a globally good basis.

11. Independent particle model approach to nuclear mass formula and mass relationships. J.C. Parikh - A mass formula based on the notion of independent particle motion in the presence of residual two-body interaction is suggested. The expression for the bidning energy $E(A,T_z)$ of a nucleus having A particles and charge T_z turns out to be

$$E(A,T_z) = aA + bA^2 + cT_z + dT_z^2 + eAT_z + f s_p(s_p+1) + g s_n(s_n+1)$$

where a,b,c.d,e,f,g. are parameters. Here s_p (s_n) is zero if the number of protons (neutrons) is even and is $\frac{1}{2}$ if it is odd.

A fit to the empirical bidning energies of nuclei is made with this seven parameter expression. Very good fits are obtained.

The mass-formula has also been used to study Kelson-Carvey and Franzini-Radicati mass relationships.

12. Potential for scattering of two non-identical heavy ions in two-centre shell model. D. Mahanti - In a model which describes the scattering of heavy ions by the relative distance between the two nuclei and collective degrees of freedom, we derive the interaction potential for the scattering of two non-identical heavy nuclei depending on the collective coordinates and the relative distance. In our formalism, we employ the two centre shell model and treat excitation in terms of surface vibration which is regarded as a perturbation.

20. PUNJAB UNIVERSITY, CHANDIGARH

1. Level structure studies of ^{169}Tm. H.R. Verma, A.K. Sharma Nirmal Singh, B.K. Arora and P.N. Trehan - Precise measurements of energies (overall error $\lesssim$ 0.05 keV) and relative intensities of gamma rays emittäd in the electron capture of ^{169}Yb have been made using a 64.1 c.c. Ge(Li) detector (energy resolution $\lesssim$ 2.2 keV at 133 2 keV), Ge(Li)-NaI(Tl) fast coincidence set-up and a 4096 channel analyser. The existence of 117.3, 295,328,355,371 and 600keV γ-rays have been confirmed whereas our data clearly excludes 140.0, 156.7, 160.0, 207.0, 218.0, 229.0, 285.0, 304.0,316.0,320.0 and 335.0 keV γ-rays reported by some authors. γ- γ angular correlation measurements with good precision were performed for the 198-110, 198-118, 261-110 and 177-(21)-110 keV cascades in ^{169}Tm using Ge(Li)-NaI(Tl) set-up. Out of these, the 261-110 keV cascade has been attempted for the first time. The multipole admixtures in 110.0, 177.0, 198 and 261 keV transitions have been found to be M1+(2.5$\pm$0.5)%E2,M1$\pm$ 0.5%E2, M1+ $(4.5^{+2.5}_{-2.0})$% E2 and E1+ (1.5$\pm$0.5)%M2 respectively. The experimental transition probabilities have been compared with single particle estimates. The large enhancement and hindrance factors for E2 and M1 components for these transitions suggest a collective rather than single particle behaviour of ^{169}Tm.

2. Study of ^{131}Ba decay. A.K. Sharma, H.R. Verma, B.K. Arora and P.N. Trehan - The decay of ^{131}Ba has been investigated using co-axial Ge(Li) detector of active volume 64.1 c.c. and energy resolution of $\lesssim$ 2.2 keV at 1339 keV and Ge(Li)-NaI(Tl) fast coincidence set-up. The data was recorded on a 4096 channel analyser. Precise measurements of energies (errors generally 0.05 keV) and intensities of 31 gamma rays have been made by analysing single spectra using computer codes. The existence of gamma rays of energies 351.84 and 797.78 keV has been confirmed whereas previously reported gamma rays of energies 82.43, 137.3, 323.9, 462.9, 508, and 563 keV were not observed in our measurements. In addition, the presently existent discrepancy in the spin assignments for the 215 keV level has been removed by carefully performing the - angular correlation measurements for 832-215 keV level has been assigned the spin of $3/2^+$. The multipàle admixture in the 832 keV transition has been found to be of M1$\pm$ (98.5 $\pm$ 0.5)% E2.

3. Weak-coupling model for equivalent sub-systems; Ashwani Kumar, and R.K. Bansal - According to this model, the eigenstates of a large system of n (= $n_1 + n_2$) particles can be approximated by weekly coupling the low-lying eigenstates of two sub-systems consisting of n_1 and n_2 particles, respectively. This approach is very useful where the magnitude of the exact n-particle shell model calculation may be prohibitively large. By selecting a suitable set of low-lying states of n_1- and n_2-particle systems (for which the exact problem can be solved), it is possible to achieve significant reduction in the dimensionality of the n-particle problem.

This model has been applied to repeat the calculation[1)] of ^{20}Ne spectrum in a basis formed by weakly coupling the low-lying states of ^{18}F to themselves. As a test case, the spectrum of ^{59}Ni has been obtained by weakly coupling the ^{57}Ni spectrum to that of ^{58}Ni. Similar calculations for other Ni isotopes are being carried out.

1) S.K.M. Wong and A.P. Zuker, Phys. Lett. 36 B, 437 (1971)

4. Mixed-configuration shell model calculations of electromagnetic moments and transition rates in nickel region. R.K. Bansal and S.K. Gandhi. - Magnetic moments, quadrupole moments and transition rates in nickel isotopes have been studied assuming the neutrons outside ^{56}Ni core to be spread over the entire f-p vector space. These calculations have been done using Kuo-Brown, Yale, Reid and Modified surface Delta interactions. Multishell codes for doing these calculations have been made and perfected at Chandigarh.

5. Even parity states of ^{41}Ca and ^{41}Sc. R.K. Bansal and Ashwani Kumar - The even parity states of ^{41}Ca and ^{41}Sc are considered to be arising from the coupling of $d_{5/2}$, $s_{1/2}$, $d_{3/2}$ hole states to the relevant $f^2_{7/2}$ configuration. This is, in a way, an extension of the Bansal French Model (1), which explained for the first time, the existence of even parity states in Scandium isotopes. The present calculation explains the entire fine structure of the even parity states.

We plan to extend the application of this generalization to explain the occurrence of fine structure in natural as well as unnatural parity states in other parts of the periodic table as well.

1) R.K. Bansal and J.B. French, Phys. Lett. 11, 145 (1964)

6. Energy centroids in transfer reactions on complex target states.

R.K. Bansal and S.K. Gandhi - Energy weighted monopole sum rules of Bansal[1] have been applied earlier for prediction of isospin centroids of residual nuclei obtained in transfer reactions on complex but non-configuration-mixed target states. These sum rules could not be applied to the situations involving mixed-configuration target states because of non-availability of the partial shell occupancy (this being one of the inputs in the Bansal sum rules) of the target state.

Recently, doing a mixed-configuration calculation using the multishell codes developed at Chandigarh, we have calculated the partial shell occupancies of target states in nickel isotopes and then applied the Bansal sum rules to obtain much better values for the centroids of residual nuclei with mass=A+1, where A is the target mass number. These calculations will be extended to nuclei in other parts of the periodic table.

1) R.K. Bansal, Phys. Lett. 40B, 189 (1972)

21. PUNJABI UNIVERSITY, PATIALA.

1. Production cross-sections for some millisecond activities.
K.C. Garg and C.S. Khurana - The automatic electronic programmer (AEP) constructed by us[1] for handling the millisecond isomer activities with pulsed beam technique has been utilised to measure the reaction cross sections for the production of some activities through (n,p), (n,α), (n,n') and (n,2n) reactions with 14.7 MeV neutrons, from the 400 keV Van de Graaff accelerator. The deflected deuteron bursts used to generate neutron bursts of millisecond widths[2] have been found to be very useful in reducing significantly the long-time background to initial counts ratio in the obtained decay curves. As a result better accuracies have been achieved in present reaction cross section measurements. A calibrated $1^3/4$" x 2" NaI(Tl) crystal mounted onto a 53 AVP Philips photomultiplier tube and coupled to the NTA-512B, 1024 channel analyser has been employed as a gamma-ray scintillation detector. This technique has also been extended to handle the pure beta-activities of millisecond half-lives.

1) K.C. Garg and C.S. Khurana
Indian J. Pure and Appl. Phys. 14 (1976) 154.
2) K.C. Garg and C.S. Khurana
Indian J. Pure and Appl.Phys. 14 (1976)738.

2. Directional Correlation studies in ^{75}As and ^{133}Cs. V.S. Puri, H.S. Sahota and C.S. Khurana - The multipolarities of the weak 24 keV and 53 keV gamma rays in ^{75}As and ^{133}Cs respectively have been determined from the 24 γ -279 γ and 53 γ - 382 γ directional correlation measurements. These correlations have been attempted for the first time. The 24 keV gamma ray was taken in the Si(Li) detector. The interference from the degraded photons of the high intensity 121 and 136 keV gamma rays coincident with 279 and 264 gamma rays in ^{75}As was determined by measuring the combined (121 + 136) - (264 + 279) directional correlation. The corrected A2 (24 γ) coefficient yields δ 24 = 0. 18 + 0.02.

In the 53 γ -382 γ directional correlation the high intensity (356 γ -81 γ) directional correlation will have its contribution due to the iodine escape peak of the 81 keV gamma rays at 53 keV as well as its degraded photon contribution under the 53 keV peak. This contribution has been determined under the experimental conditions and the corrected A2(53γ) yields 0.09 $\lesssim \delta^2 \lesssim$ 0.16.

3. <u>Effects of single and double coriolis couplings and triaxiality on spectra, static moments and transition probabilities of some odd nuclei.</u> S.D. Sharma and V.P. Garg - According to extended version of Davidov and Filippov's non-axial rotor model for odd-odd nuclei, K-mixings occur either due to triaxiality (i.e. due to asymmetry for states with $\Delta k = \pm 2$) or coriolis couplings (due to intrinsic spin projection(s) of single or both the valence nucleon(s) for states with $\Delta k = \pm 1$). The effects of these mixings are studied for $Tm^{162,164,166,168,170 \,\&\, 172}$ and some other odd-odd deformed nuclei.

Computed spectra are compared with the available experimental reports. K-mixing effects are found to improve the results. The magnetic dipole moments for K =±, 1 ± are studied and the coriolis coupling effects are analysed. The coriolis and triaxeility effects are found to improve also the estimates for BM1 and BE2 transition probabilities.

4. <u>Competition between nuclear forces and core rotation.</u> S.D. Sharma - Nuclear forces have a strong tendency to keep valence nucleons in parallel alignment of their intrinsic spins, while centrifugal force under core rotation has a tendency to flip their spins off. This competition is studied using extended version of axial rotor model with 1.s, Γ^{34} and δ-type n-p interaction in the Hamiltonian. The analysis is carried on for spectra and other properties of conjugate bands (with band heads K2 + K1 and $K_2 - K_1$) in case of some deformed odd-odd nuclei. The competition is found to affect static moments etc. and results into weakening of intensity in the band with parallel alignment and finally into its termination due to prominence of centrifugal and coriolis forces under core rotation. It is realized that the analysis of this competition will be quite useful for the study of strength and nature (Tenorial or central etc.) of nucleon forces.

22. SAMBALPUR UNIVERSITY, BURLA

1. A simple effective interaction for nuclear matter and finite nuclei. B. Behera and R.K. Satpathy - A simple three-parameter density-dependent effective interaction is used to study the properties of symmetric and asymmetric nuclear matter, neutron matter and some bulk properties such as ground state energies and rms charge radii of three double-closed-shell nuclei ^{4}He, ^{16}O and ^{40}Ca in first order perturbation theory. The three parameters of the effective interaction are fixed by requiring a fit to energy per particle and density in symmetric nuclear matter as well as the ground state energy of ^{16}O.

This interaction gives correct saturation and compressibility as 276.04 MeV in symmetric nuclear matter. The energy per particle in asymmetric nuclear matter compare well with the semiempirical results of Sjoberg. The symmetry coefficient at saturation density is 33.53 MeV. The energy per particle in neutron matter at various densities are in good agreement with those of Nemeth and Sprung. Ground state energies of ^{4}He, ^{16}O and ^{40}Ca, calculated by using oscillator eigen functions as single particle wave functions, are in good agreement with empirical values. The rms charge radii are better than those obtained by Moszkowski with the MDI.

2. Ground state energies and rms radii of even-even nuclei with energy density formalism. N.M. Guru, B. Behera and R.K. Satpathy - Energy density formalism (EDF) has been used to calculate the ground state energies and rms charge radii of some even-even light nuclei using a density dependent effective interaction. This interaction gives good results for various properties of symmetric and asymmetric nuclear matter as well as ground state energies and rms charge radii of three double-closed-shell nuclei, ^{4}He, ^{16}O and ^{40}Ca.

It is found that ground state energies and rms charge radii of eleven nuclei between ^{4}He and ^{40}Ca are in excellent agreement with the empirical results and are better than the results of Krieger and Moszkowski, obtained from HF calculations. We further find, in cases of ^{12}C, ^{20}Ne and ^{24}Mg, where HF calculations do not give satisfactory results for rms charge radii, the present calculations give results quite close to the empirical values.

23. SOUTH GUJARAT UNIVERSITY, SURAT

1. Simulation of Hartree-Fock field by one-body operators for O^{18} and F^{18}. S.G. Trivedi and B.I. Sheth - We have constructed simple phenomenological interaction which contains one-body operators Q_o^2 and Q_o^4. Our calculations show that the entire HF fields for O^{18} and F^{18} can be very well simulated by our phenomenological interaction. The strength of Q_o^2 interaction required to simulate the HF fields is larger than that of Q_o^4 interaction.

Wave functions obtained using phenomenological interaction are projected out. Energy values of low-lying levels of O^{18} and F^{18} are calculated using projected wavefunctions. For O^{18} projected energy spectrum agrees well with the experimental spectrum as well as the spectra obtained using HF and shell model calculations. For F^{18} agreement is not very good and band-mixing calculations are carried out.

24. UNIVERSITY OF BANGALORE, BANGALORE

1. Isobaric analogue resonances in ^{71}As. C.R. Rameswamy, N.G. Puttaswamy and M.G. Betigeri - Excitation functions for the elastically scattered protons off ^{70}Ge at 90, 125, 149 and 165° lab angles have been measured in the incident proton energy range of 3.9 - 5.3 MeV in steps of 2 keV. The resonances in the excitation function have been identified as isobaric analogues of low lying bound states in ^{71}Ge. The excitation functions at different angles at each of the resonances have been analysed using ANSPEC to evaluate E resonance, ℓ, Γ and Γ_p. The proton reduced widths are compared with the neutron single particle spectroscopic factor as obtained in $^{70}Ge(d,p)^{71}Ge$ reaction[1]. The coulumb energy for ^{71}As - 71Ge is found to be (10.16) MeV.

1) L.H. Goldman, Phys. Rev. 165 (1968) 1203.

25. UNIVERSITY OF DELHI, DELHI

1. Time differential directional correlation of the (450.6-27.8) keV Gamma-gamma cascade in ^{129}I. Ashok Kumar, S.K. Soni, S.L. Gupta and S.C. Pancholi - The time differential angular correlation measurements of the $5/2^+$ (459.6 keV) $5/2^+$ (27.8 keV)$7/2^+$ gamma-gamma cascade in ^{129}I have been performed with a NaI-plastic detector system using a $^{129m+g}Te$ source in HCl solution. A plot of $A_2(t)$ vs. t revealed the presence of a time - dependant electric quadrupole perturbation of the correlation. Preliminary analysis of the data yields the unperturbed expansion co-efficient (solid angle uncorrected) $A_2(0) = -(0.056 \pm 0.002)$ and the relaxation parameter $\lambda_2^{el} = (0.2 \pm 0.0\ ) \times 0^9$ sec. The results are analysed in the light of the theory of Abragam and Pound.

2. Lifetime measurements of the 80.2-, 341.1-, 364.5- and 404.8 keV Levels in ^{131}Xe. Suvra Sanyal, S.C. Pancholi and S.L. Gupta - Lifetime measurements of the 80.2-, 341.1-, 364.5- and 404.8-keV levels in $^{13.1}Xe$ populated in the β^- decay of ^{131}I have been carried out by the delayed coincidence method. Analysis of the data by the slope method gave the following values:

$T_{1/2}$ (80.2 keV level) = 416 ± 10 ps

$T_{1/2}$ (341.1 keV level) = 1.34 ± 0.04 ns

$T_{1/2}$ (364.5 keV level) = 67.6 ± 1.4 p s

and $T_{1/2}$ (404.8 keV level) $<$ 75 ps.

Using the measured half-life values the experimental absolute and reduced transition probabilities are calculated and discussed in the light of the single particle model and the intermediate coupling approach of the unified model.

26. UNIVERSITY OF MADRAS, MADRAS

1. A Statistical approach to shell corrections. M. Rajasekaran, G. Shanmugam, P.R. Subramanian and V. Devanathan - A redistributing statistical function of the Gaussian type is used to smear out the entire single-particle energy spectrum of different heavy nuclei. The residual effect due to non-uniformity in the single-particle energy distributions was extracted to obtain the shell corrections. The relative displacement of the statistical means of the original and the redistributed energy spectrum is a measure of the shell corrections. The redistributing function used is

$$y(x) = \left(N e^{-(x-\bar{x})^2/2\sigma^2}\right) \Big/ \sigma\sqrt{2\pi}$$

A comparative study of this method with the well known Strutinsky's method is made.

2. Partial Muon capture rates in ^{16}O from the generalised helm model. V. Devanathan and P.R. Subramanian - Partial capture rates in the reaction

$$\mu^- + {}^{16}O(0^+) \longrightarrow {}^{16}N(2^-, 3^-, 2^-) + \nu_\mu$$

are calculated using the generalized Helm model. The results are in good agreement with the recent experimental data. Helm model parameters[1] extracted from electron scattering at low, medium and high momentum transfer have been used in the calculations. Our results are compared with some versions of the shell model such as Gillet and Vinh Mau wave functions and Migdal's wave functions and the phenomological model of Donnelly and Walecka[2].

1) R.D. Graves et al., to be published

2) T.W. Donnelly and J.D. Walecka, Phys. Lett. 41B (1972) 275

27. UNIVERSITY OF MYSORE, MYSORE

1. Recoil deuteron polarization in $\gamma + d \rightarrow \pi^0 + d$

G. Ramachandran and M.V. Nagaraja Murthy - The spin state of the recoil deuteron in $\gamma + d \rightarrow \pi^0 + d$ is studied taking into consideration the Fermi motion and also the deuteron D-state. The vector and tensor polarization of the recoil deuteron are sensitive to the type of deuteron wave function used and the percentage admixture of D-state. The study is also of interest to resolve ambiguities in photo production amplitudes at low and intermediate energies where our model is expected to be valid.

28. UNIVERSITY OF INDORE, INDORE

1. Study of Effective Interactions in sd shell. K.P. Joshi - The Kuo, and Predom and Wildenthal (PW) interactions have been studied in terms of the spin-tensor structure of the two-body matrix elements and the relative matrix elements (RME). These interactions have been employed by the Glasgow group for their untruncated shell model calculations. The RME give a detailed information about the interaction nature. Same features of the PW interaction are found to be contrary to the general belief.

2. Effective Interactions in shell nuclei. G.K. Upadhyaya and K.P. Joshi - The spin-tensor structure of the various effective interactions in the p-shell region is done and an extensive comparison is made. In general, a wide variation is seen in TBME involving odd state interactions while even state TBME show less divergence. This is consistent with the general belief that even state interactions are comparatively well determined. However the comparison in terms of Radial Integrals (RI) does not support the above view. In fact the largest variation among interactions is seen for the combination of Singlet. Even $RI(I_{eS} + I_{\lambda' S})$. The comparison in terms of RI and their combinations gives a hint that the radial shape should be different from a single Yukawa or Gaussian shape.

29. UNIVERSITY OF ROORKEE, ROORKEE

1. Multipolarity of 1487-KeV Gamma-Transition in Nd-144
I.V.S. Rathore and B.P. Singh, - 2186 KeV level in Nd^{144} state had been identified as 1^- to be a quintuplet formed by coupling an octupole phonon to a quadrupole phonon. The multipolarity of this transition is important in order to understand this state. This has been done by beta-gamma-gamma angular correlation method[1]. The results obtained are discussed and compared with the theory.

1) B.P. Singh et al., Phys. Rev. C4, 1510 (1971)

2. A constraint on the T-matrix of a local potential. C.S. Warke and M.S. Srivastava - We have obtained a constraint on t-matrix elements in the case of a local potential. By a local potential we mean locality in the usual sense. For example, we admit spin-orbit or dependent interactions which are local in any partial wave. It is well known that for a local potential the Wronskian of the Jost solutions and the regular solution is independent of r and the Fredholm determinant of the regular solution is unity. These conditions are not very useful as they involve quantities which are not physically observable.

Consider trace $G_k V$. One can easily see that it vanishes for a local potential. Writing it in momentum space, expressing V in terms of t-matrix and using optical theorem and principal value integrations, leads to

$$I(k) = \mathrm{Trace}\ G_k V = \mathrm{Im}\int dk' \int dq\, k' q^2 \frac{t(q\, q,\, k'^2) - t(k\, q,\, k'^2)}{(q^2-k^2)(k'^2-k^2+i\epsilon)}$$

This is the desired result. If the interaction is local, the t-matrix elements are constrained to make I(k) vanish identically.

3. Off-shell generalization of Jost-pais theorem. C.S. Warke and M.K. Srivastava - It is well known[1] that the Jost function f(k) can be expressed as the ratio of the Fredholm determinants of the integral equations corresponding to outgoing wave scattering solution and regular

solution respectively.

$$j(k) = \det|1 - G_k^+ V| \,/\, \det|1 - G_k V|$$

We have generalized this theorem. It now states that the off-shell Jost function[2] is the ratio of a generalized Fredhom determinant of the integral equation for the off-shell outgoing scattering wave solution to that of the on-shell regular solution.

$$f(k, q) = \det|1 - G_k V - F_{kq} V| \,/\, \det|1 - G_k V|$$

$$F_{kq}(r, r') = -\frac{1}{k}\left(\frac{q}{k}\right)^{l} e^{-il\pi}\, u_l(kr)\, \omega_l^+(q r')$$

Where $u_l(x) = x\, j_l(x)$ and $\omega_l^*(x) = i\, e^{il\pi} x\, h_l^{(1)}(x)$

1) C.S. Warke and R.K. Bhaduri, Nucl. Phys. A162 (1971) 289

2) M.G. Fuda and J.S. Whiting, Phys. Rev. C8 (1973) 1255

30. VISWA BHARATI UNIVERSITY, SANTINIKETAN

1. A generalized approach to the Phase-amplitude method.

B. Talukdar, D. Chattarji and P. Banerjee - A generalized formulation of the phase-amplitude method is given for scattering by a complex non-local potential. It is shown that the constraint on the derivative of the wave function introduced by earlier workers is redundant to the development of the approach. The cases of real local and non-local potentials as well as a complex local potential can be obtained in a straight forward manner.

2. L-wave off-shell Jose function for the Morse potential.

D. Chattarji, M.N. Sinha Roy and B. Talukdar - The Van-Leeuwen and Reiner equation for the l-th partial wave is solved for the Morse potential by transforming to a rotating coordinate frame with uniform angular velocity ω depending on l and the parameters b and d of the potential. An analytic expression is derived for the off-shell Jost function.

LS-270

NUCLEAR DATA AND LOW ENERGY NUCLEAR RESEARCH IN ISRAEL

Progress Report

compiled by

SHIMON YIFTAH

Israel Atomic Energy Commission
April 1977

The Israel Nuclear Data and Low Energy Nuclear Research relevant to the International NUclear Data Committee was continued in the various institutions listed in previous Progress Reports [Report for 1974, INDC (SEC) - 42/L, December 1974, Report for 1975, INDC (SEC) - 50/L, January 1976].

The major experimental facilities consist of:

1. A 5 Megawatt swimming pool enriched uranium reactor at the Soreq Nuclear Research Centre.

2. A 26 Megawatt heavy water tank-type natural uranium reactor at the Negev Research Centre.

3. A 6-million volt EN tandem accelerator at the Weizmann Institute of Science, Rehovot.

4. The new most modern high energy 14 UD pelletron accelerator manufactured by the National Electrostatic Corporation of Middleton, Wisconsin, installed inside the Koffler Accelerator Tower at the Weizmann Institute of Science, Rehovot.

Brief abstracts of the research work, both published and unpublished, listed according to the various laboratories, are reported in the following pages.

Israel Atomic Energy Commission Laboratories

ETGAR - INFORMATION SYSTEM FOR ABNORMAL OCCURRENCES IN NUCLEAR POWER PLANTS[1]

J. Baram, M. Nagar and G. Pultorak

Extensive information on the systems and components of a nuclear power plant are needed early in the planning stage, during the building of the plant, and during the licensing process. Another type of information helps preventive maintenance during the operating life of the plant. In the case of abnormal occurrences additional information on the possible consequences and ways of handling them is essential.

To cover these needs, the ETGAR system collects and evaluates information on abnormal occurrences in nuclear power plants. The information is coded, using a three-level coding scheme for systems and components, and put on magnetic tape. A search program permits the retrieval of any pertinent information from the data base. At present the ETGAR scope covers mostly PWR and BWR type nuclear power plants.

REFERENCE:

1. Baram, J., Nagar, M. and Pultorak, G., Trans. Joint Annual Meeting of the Israel Nucl. Soc. and Israel Health Phys. Soc., Haifa, Nov. 30, 1975. 3, p. III-15, 1975.

PRACTICAL FORMALISMS FOR NUCLEAR DATA REPRESENTATION IN EVALUATED NUCLEAR DATA FILES IN THE UNRESOLVED RESONANCE ENERGY REGION[1]

Y. Gur and S. Yiftah

The currently used formalism for basic data representation in the unresolved resonances energy range is based on the statistical parameters of the population of Breit-Wigner resonances. The present work suggests new practical formalisms, based on parametric representation of the shielding factor curves, by which the values of effective cross sections may be obtained simply and quickly in the unresolved range. These formalisms were shown to be useful in existing codes to improve the accuracy and efficiency of the calculation of effective cross sections. Observed spatially dependent self-shielding factors were transformed into pseudo-background cross-section-dependent self-shielding factors, enabling the evaluator to use this experimental information. Numerical values of the transformation for U-235 and Pu-239 self-shielding factors were determined. Finally, as an example, Pu-239 basic data were represented in the unresolved range by one of the new formalisms.

REFERENCE:

1. Gur, Y. and Yiftah, S., Nucl. Sci. Eng., in press.

A SURVEY OF CROSS SECTION EVALUATION METHODS FOR HEAVY ISOTOPES[1]

M. Caner and S. Yiftah

Evaluation methods and neutron nuclear reaction theories applicable to heavy isotopes were considered. A compilation was made, in tabular form, of the most recent evaluations of the transactinium isotopes, with the exception of the main fissile and fertile isotopes (^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{238}Pu). The evaluations were examined in terms of the formalisms and models used in the different energy ranges.

Of the 18 isotopes for which evaluations are available, 11 were evaluated using optical model and statistical theory calculations (^{231}Pa, ^{233}Pa, ^{232}U, ^{236}U, ^{237}U, ^{238}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{244}Cm, ^{252}Cf) and the other 7 (mentioned below) were evaluated using systematic methods of varying degrees of sophistication. We checked the experimental data now available on these 7 isotopes in order to ascertain for which of them an optical model and statistical theory calculation has become feasible. The data needed are: excited energy levels, their spins and parities; fission cross sections; average capture widths and average level spacings. Of the 7 isotopes, enough data for the above calculations are available for ^{234}U, ^{237}Np, ^{241}Am, ^{243}Am and ^{245}Cm, but not enough for ^{238}Np and ^{236}Pu.

The next point considered was which isotopes, for which there are requests in WRENDA[2], have not been evaluated. These isotopes are: ^{239}U (σ_γ, σ_f requested), ^{239}Np (σ_γ requested) and ^{237}Pu (σ_γ, σ_f requested). However, there are not enough data available for any of these to perform optical model and statistical theory calculations. Only preliminary evaluations, based on systematics and the limited experimental data, are possible.

REFERENCES:

1. Caner, M. and Yiftah, S., "A Survey of Cross Section Evaluation Methods for Heavy Isotopes", contributed paper for the IAEA Advisory Group Meeting on Transactinium Isotope Nuclear Data, Karlsruhe, 3-7 November 1975.
2. WRENDA 74, INDC (SEC)-38/U (1974)

NEUTRON CROSS SECTIONS FOR PLUTONIUM-238[1,2]

M. Caner and S. Yiftah

An evaluation of ^{238}Pu neutron data was performed. All significant cross sections in the neutron energy range 10^{-3} to 15×10^{6} eV were considered.

The experimental data were complemented by spherical optical model and statistical theory calculations, and by systematics. The evaluated data were compared with those in the ENDF/B-IV file.

REFERENCES:

1. Caner, M. and Yiftah, S., IA-1301, 1975, and IAEA distribution code INDC (ISL) - 2/L (July 1974, rev. Jan. 1975)
2. Caner, M. and Yiftah, S., Nucl. Sci. Eng. 59, 46 (1976)

STATUS OF TRANSACTINIUM ISOTOPE EVALUATED NEUTRON DATA IN THE ENERGY RANGE 10^{-3} eV TO 15 MeV(1)

S. Yiftah, Y. Gur and M. Caner

Large amounts of transactinium elements will be produced in the next 25 years in thermal power reactors, fast breeders, fast reactors, special purpose reactors, thermonuclear explosions and improved heavy-ion accelerators. In order to be able to evaluate, predict, compute and judge the effects and uses of these elements, the nuclear community needs fully evaluated nuclear data to be used as nuclear input for all computations and evaluations.

The sixteen transactinium elements and two hundred isotopes known to data were divided into three groups, and eight main areas of application were considered from which needs can be derived for new measurements and evaluations. Existing evaluations were tabulated and analyzed. From "WRENDA minus CINDA" descriptive equation, nine main conclusions and recommendations were presented, including a "world transactinium nuclear data evaluation program" and other specific items for future IAEA action in this field.

REFERENCE:

1. Yiftah, S., Gur, Y. and Caner, M., "Status of Transactinium Isotope Evaluated Neutron Data in the Energy Range 10^{-3} eV to 15 MeV", Invited paper presented at the IAEA Advisory Group Meeting on "Transactinium Isotope Nuclear Data", Karlsruhe, Germany, November 3-7, 1975.

SENSITIVITY OF THE LUMPED FISSION-PRODUCT MODEL TO DIFFERENT FISSION-PRODUCT CROSS SECTION LIBRARIES(1)

D. Ilberg, D. Saphier and S. Yiftah

The extent to which the use of different fission-product cross sections (FPCS) affects the neutron multiplication factor k_{eff} in high burnup cores of fast reactors was evaluated. It was found that discrepancies of the order of 2.5% exist when different FPCS are used to calculate k_{eff} in the same core. These discrepancies are due to the absence of data on a number of fission-product isotopes present in some of the nuclear data libraries on the one hand, and large differences in the capture cross sections of some of the isotopes on the other. A list of fission-product isotopes was proposed that, when used, reduces discrepancies in k_{eff} to <1%. The important isotopes for fast-reactor burnup and k_{eff} calculations in which large discrepancies exist were identified, and it is suggested that they be subjected to further evaluation to close the discrepancy gap.

REFERENCE:

1. Ilberg, D., Saphier, D. and Yiftah, S., Nucl. Sci. Eng. 58, 445 (1975)

ENERGY SPECTRA OF SECONDARY NEUTRONS FROM THE ^{238}U (n,2n) AND (n,3n) REACTIONS

M. Caner, M. Segev* and S. Yiftah

A consistent compound nucleus theory of (n,2n) and (n,3n) neutron emission was applied to ^{238}U in order to obtain the energy spectra of the second and third secondary neutrons. The evaluation was based on inelastic level excitation and evaporation data for ^{238}U, ^{237}U and ^{236}U. The ^{238}U and ^{236}U data were retrieved from ENDF/B-IV files; the ^{237}U data were evaluated by us using experimental information and statistical reaction theory codes.

At reaction energies E_o just above the (n,2n) threshold energy B_2, the energy E of the second inelastic neutron has a spectrum of (E_o-B_2-E); just above the (n,3n) threshold B_3, the third neutron energy has a spectrum of $(E_o-B_2-E)^3$. At energies E_o well above the thresholds the second and third neutron spectra approach the evaporation form.

A secondary neutron spectrum for any given reaction energy E_o is approximated by the composite form

$$P_i(E_o \to E) = \left[\frac{2(i-1)\beta_i(E_o)}{E_o-B_i}\right]\left(1-\frac{E}{E_o-B_i}\right)^{2i-3} + \left[\frac{1-\beta_i(E_o)}{T_i^2(E_o)}\right] E \exp\left(-\frac{E}{T_i(E_o)}\right)$$

where $i=2,3$ for the second and third neutrons, respectively. The temperatures T_i and blending coefficients β_i were calculated for several energies in the range from threshold up to 15 MeV for $i=2,3$; in addition, $\beta_1 \equiv 0$ and $T_1 \equiv T_{U-238}$ (ENDF/B-IV).

*Presently at Argonne National Laboratory, Argonne, Ill. U.S.A.

We compared the experimental effective temperature for all secondary neutrons from ^{238}U (n,n'), (n,2n) and (n,3n) at 14 MeV with the value we calculated (by performing a least squares fit to our data). Our results were found to be consistent with the experimental data.

COMPARISON OF METHODS FOR THERMAL REACTOR LATTICE CALCULATIONS

A. Schneider, W. Rothenstein* and E. Greenspan

The computer codes HAMMER[1] and WIMS-D[2] for solving the transport equation in thermal lattice cells were investigated. The values of the effective multiplication constant (k_{eff}) calculated by HAMMER are about 2% below the experimental values for both heavy and light water-moderated lattices. The k_{eff} calculated by the WIMS-D code are about 1.0% below and less than 0.5% above the experimental values for heavy water and light water lattices, respectively.

The approximations to the transport equation used by the two codes were investigated. Detailed comparisons of the group cross sections used by the codes and of the values of the average lattice parameters calculated by them were performed.

It was found that the discrepancies between calculated and experimental results are due mainly to inaccuracies in the cross section data, especially in the energy region of the resonances.

REFERENCES:

1. Suich, J.E. and Honech, H.C., DP-1064, 1967.
2. Roth, M.J., AEEW-M845, 1969.

STUDY OF A TEMPERATURE DISTRIBUTION IN THE COOLANT MEDIUM OF A LIQUID METAL FAST BREEDER REACTOR[1]

M. Tilman

An analytical method of determination of a temperature distribution in the coolant medium in a fuel assembly of a liquid-metal fast-breeder reactor (LMFBR) was developed. The temperature field obtained was applied to a constant velocity (slug flow) fluid flowing parallel to the fuel pins of a square and hexagonal array assembly. The coolant subchannels contain irregular boundaries. The geometry of the channel due to the rod adjacent to the wall (edge rod) differs from the geometry of the other channels.

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The governing energy equation was solved analytically, assuming se -e solutions for the Poisson and diffusion equations, and the total solution w.s a superposition of the two solutions. The boundary conditions were specified by symmetry considerations, assembly wall insulation and a continuity of the temperature field and heat fluxes. The initial condition is arbitrary.

The method satisfies the boundary conditions on the irregular boundaries and the initial condition by a least squares technique.

Computed results were given for various geometrical forms, with the ratio of rod pitch-to-diameter typical for LMFBR cores. These results are applicable to various fast-reactors, and thus the influence of the transient solution (which solves the diffusion equation) on the total depends on the core parameters.

REFERENCE:

1. Tilman, M., NRCN-387, 1975.

THE EFFECT OF FUEL BURNUP ON THE DYNAMIC BEHAVIOR OF FAST REACTORS

D. Ilberg, D. Saphier and S. Yiftah

Performance of an accident analysis taking burnup (BU) changes into account requires fission product (FP) nuclear data of relatively small uncertainty, suitable BU calculation models, and point kinetics and dynamic computer programs. These were prepared and used in the present study(1) with the following results:

a) Significant changes in static and dynamic parameters were observed when investigating the effect of BU. These changes were found to be larger than differences introduced by the uncertainty of the FP nuclear data.

b) A one-dimensional BU computer program was prepared. It was found that a BU model based on the generalized radioactive decay scheme is most suitable for accurate fast reactor calculations.

c) Kinetic and space-time dynamic calculations of fast reactors having different BU levels were performed. The stability difference between "clean" and high BU cores is greater when local rather than uniform perturbations are inserted along the entire core length. The magnitude by which the "end-of-life" core increases the transient excursion over that of the "clean" core depends on the particular region in which the perturbation is inserted. The "end-of-life" core will magnify the transient excursion more than the "clean" core whenever the perturbation is inserted into a region having a higher adjoint flux level than that of the "clean" core. It is suggested that the analysis of local perturbations be performed for "end-of-life" cores as well as for "clean" cores in the safety evaluation of fast reactors.

REFERENCE:

1. Ilberg, D., Saphier, D. and Yiftah, S., Nucl. Sci. Eng. (1976), in press.

METHODS FOR THE OPTIMIZATION OF NUCLEAR SYSTEMS

D. Gilai, E. Greenspan, P. Levin and T. Tabak*

The maximum principle of Pontryagin for the optimization of one-dimensional systems has been extended to multidimensional systems[1]. Table 1 summarizes the generalized formalism and compares it with the conventional one-dimensional principle. In the generalized formulation, $\underline{\underline{E}}$ is a matrix operator of first order partial derivatives. The resulting optimality conditions are found to be the same as those obtained from the perturbation theory approach[2]. Using the generalized maximum principle, an algorithm for the optimization of the enrichment distribution in power reactors was developed and successfully tested using the diffusion approximation. The solution of a two-dimensional shield optimization problem was also illustrated.

TABLE 1

Comparison between the generalized and one-dimensional maximum principle

	One-dimensional	Generalized
State equation	$\frac{d\underline{\phi}}{dx} = \underline{F} = \frac{\partial H}{\partial \underline{P}}$	$\underline{\underline{E}}\,\underline{\phi} = \underline{F} = \frac{\partial H}{\partial \underline{P}}$
Adjoint equation	$\frac{d\underline{P}}{dx} = -\frac{\partial H}{\partial \phi}$	$\underline{\underline{E}}^T \underline{P} = -\frac{\partial H}{\partial \underline{\phi}}$
Hamiltonian	$H = \pm g + \underline{P}\cdot\underline{F}$	$H = \pm g + \underline{P}\cdot\underline{F}$
Optimum condition	$H(\underline{U}^*, \underline{\phi}^*, \underline{P}^*) \geq H(\underline{U}, \underline{\phi}^*, \underline{P}^*)$	$H(\underline{U}^*, \phi^*, \underline{P}^*) \geq H(\underline{U}, \underline{\phi}^*, \underline{P}^*)$

*Ben-Gurion University of the Negev, Beer-Sheva

Efforts are currently being made to extend the range of applicability and efficiency of the perturbation theory-based transport code SWAN designed for the optimization of source driven systems.

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1. Gilai, D. and Tabak, T., An extension of the maximum principle to multidimensional systems and its application in nuclear engineering problems, IEEE Trans. Automat. Contr., in press.
2. Lewins, J. and Babb, A.L., Optimum nuclear reactor control theory, in: Advances in Nuclear Science and Technology, Vol. 4, Academic Press, New York, 1968, p. 251.

A GENERALIZED SOURCE-MULTIPLICATION METHOD FOR DETERMINING REACTIVITY AND A SOURCE-MULTIPLICATION REACTIVITY

E. Greenspan

A source-multiplication method, capable of providing subcritical reactivities without the need for intercalibration against another independent reactivity measurement method (or against calculations) has recently been proposed(1). Such calibration is required by other source-multiplication (SM) methods. Instead, this method, designated the SMR method(1), calls for the measurement of the rate of linear power increase of the source-driven reactor when it is at a reference critical state. As previously derived(1) the SMR method can be applied only to slightly subcritical reactors; that is, to the determination of small reactivities. The reason for this restriction is that in the derivation we have expanded the subcritical reactor flux into normal modes and assumed that (a) the fundamental mode has the dominant contribution to the detector reading and (b) the fundamental mode of the subcritical reactor is similar to that of the critical one.

In a recent work(2) the SMR method is rederived in a general form [to be referred to as the generalized source-multiplication (GSM) method] that makes it applicable for the determination of absolute reactivities for any degree of reactor subcriticality. This is accomplished by relating the reactivity to the actual flux distribution in the source-driven subcritical reactor rather than to the fundamental mode. The resulting reactivity is referred to as the "source-multiplication (SM) reactivity." The relationship between the SM and other definitions of reactivity in common use was also established(3).

Several aspects of the practical implementation of the GSM method were discussed(2). The GSM method was compared(2) with the modified source multiplication (MSM) and other methods for reactivity measurement. The fundamental difference between the GSM and the MSM methods is in the calibration of the reactivity scale; the MSM method requires intercalibration against an independent reactivity-determination method. The two methods may also differ in the definition of the correction factors needed. These depend on the definition of the calibrating reactivity (in the MSM method) and of the reactivity to be determined[3].

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ENERGY-DEPENDENT FINE-STRUCTURE EFFECTS ON MATERIAL AND DOPPLER REACTIVITY WORTH

E. Greenspan and Y. Karni

The effects of perturbations in the fine-structure of the neutron spectrum on the reactivity worth of resolved resonances were investigated, using a simple, space independent model, amenable to analytic solution. It was found[1] that these spectral fine-structure effects can contribute significantly to the reactivity worth of resonances. The multigroup perturbation theory methods commonly used do not adequately take these effects into account. Consequently, the reactivity worth associated even with an infinitesimal change in the amplitude of a resonance (associated with a change in material density) is overestimated in multigroup perturbation theory calculations by up to a factor of 2 [1]. Similarly, the reactivity worth associated with a change in the temperature of the resonance can be either overestimated or underestimated by as much as a factor of 2 even for an infinitesimal temperature change[2,3]. A clear correlation was found between the spectral fine-structure effects and the discrepancy between the calculated and experimentally determined material and Doppler worth observed for over a decade in fast assemblies.

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1. Greenspan, E., in: Proc. Meeting on Advanced Reactors; Physics, Design and Economics (J.M. Kallfeltz and R.A. Karam, eds.) Pergamon Press, 1975, p. 196.
2. Karni, Y. and Greenspan, E., Trans. Amer. Nucl. Soc. 21, 494 (1975)
3. Greenspan, E. and Karni, Y., Trans. Israel Nucl. Soc. 3, I-8, (1975)

DEVELOPMENTS IN GENERALIZED PERTURBATION THEORY

E. Greenspan

The generalized perturbation theory (GPT) formulations were extended to multiple ratios of linear functionals[1] as well as to composite functionals[2].

A composite functional has the general form

$$C_{IJK} = \prod_{i=1}^{I} \langle S_i^+,\phi\rangle^{P_i} \prod_{j=1}^{J} \langle\phi^+,S_j\rangle^{P_j} \prod_{k=1}^{K} \langle\phi^+,M_k\phi\rangle^{P_k}$$

where P_i, P_j and P_k can take the value of either +1 or -1. In another extension, GPT formulations were derived for functionals of eigensolutions of the time-absorption (α) eigenvalue equations(3).

A unified formulation and terminology for GPT was proposed(4). It was shown that Stacey's(5) and Usachev-Gandini's versions of GPT(6,7) can be derived using conventional perturbation techniques. It was also shown that their formulations of GPT are but two of many possible versions; these versions are distinguished by the criticality reset mechanism to which they correspond. Each version has its own range of applicability. Finally it was shown that the perturbations in the distribution functions can be taken into account in two different forms, in terms of generalized functions (the conventional form) or in terms of perturbations in distribution functions. The more efficient form for a given application is problem-dependent.

Other developments in GPT include the derivation of GPT for (a) reactivity in the integral transport theory formulation(8), and (b) calculating the effect of changes in input parameters on a given integral property in an altered system(9). All the developments mentioned above are summarized in Ref. (10).

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7. Gandini, A., J. Nucl. Energy 21, 755 (1967)
8. Greenspan, E., Trans. Israel Nucl. Soc. 2, 53 (1974)
9. ibid, p. 62.
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PERTURBATION THEORY AND IMPORTANCE FUNCTIONS IN INTEGRAL TRANSPORT FORMULATIONS[1]

E. Greenspan

Perturbation theory expressions for the static reactivity derived from the flux, collision density, birth-rate density and fission-neutron density formulations of integral transport theory, and from the integro-differential formulation, were intercompared. The physical meaning and the relation of the adjoint functions corresponding to each of the five formulations were established. It was found that the first-order approximation of the perturbation expressions depends on the transport theory formulation and on the adjoint function used. The approximations of the integro-differential formulation corresponding to different first-order approximations of the integral transport theory formulations were identified. It was found that the accuracy of all first-order approximations of the integral transport formulations examined is superior to the accuracy of first-order integro-differential perturbation theory.

REFERENCE:

1. Greenspan, E., Nucl. Sci. Eng., in press.

EXACT SOLUTION OF P_n SPACE-TIME DEPENDENT EQUATIONS WITH TIME-DEPENDENT CROSS SECTIONS FOR SLAB GEOMETRY[1]

M. Lemanska

Monoenergetic, space-time dependent P_n equations with time-dependent cross sections were solved using generalized Lie series. The variables were separated and the solution obtained. This solution was given in a closed form for the case of time-independent cross sections. Numerical results calculated for the P_3 approximation case were in good agreement with those obtained by the time-dependent S_4 code.

REFERENCE:

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NUMERICAL SOLUTION OF THE TRANSPORT EQUATION BY COLLOCATION WITH BIVARIATE SPLINES[1]

L. Finkelstein and A. Krumbein

A class of partial differential equations, directly connected with the transport equation was considered. It was shown that if the initial-boundary conditions are specified on a given net as univariate quadratic splines, then there exists a bivariate quadratic spline unique on the net, which satisfies exactly the initial-boundary conditions and satisfies the differential equation at the nodes of the net. The spline is then constructed by an exact finite-difference scheme. As a first application we provided a new algorithm for a spherically symmetric problem in neutron transport theory. This was further illustrated by numerical examples. Preliminary results were reported in Refs. (2) and (3).

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LATTICE STUDIES FOR NATURAL URANIUM FUELLED HEAVY-WATER MODERATED FUSION-FISSION HYBRID REACTORS

E. Greenspan and A. Schneider

Preliminary assessment of the performance of natural uranium fuelled, heavy water or graphite moderated blankets for fusion - fission hybrid reactors indicated[1] that the performance of such blanket concepts might be significantly superior to that of the corresponding fission reactor cores. To check the validity of our assessment[1] and to quantify it, we have initiated an investigation of the physical characteristics attainable from the lattices under consideration. The first series of calculations were performed with the lattice code HAMMER[2] and version II of the ENDF/B cross section files. The uranium oxide fuel (10.45 g cm^{-3}) is clad with aluminum (substituting Zircaloy owing to availability of cross sections) 0.04 cm thick. The heavy water contains 0.3% H_2O.

Figure 1 summarizes the relationship between the initial conversion ratio (CR) and the effective multiplication constant (k_{eff}) calculated for clean and cold (20^{o}C) lattices. This k_{eff} is calculated for a buckling of 0.00007 m^{-2}. Also shown in Fig. 1 is the volumetric power density attainable with the lattices considered (as a function of their k_{eff}) relative to that of Pickering[3]. It is taken to be the smaller of the relative changes in either the total length or the surface area of the fuel rods per unit blanket volume.

The results of these calculations confirm our preliminary assessment that natural uranium heavy water blankets can be designed to be good breeders, and at the same time, have high power densities.

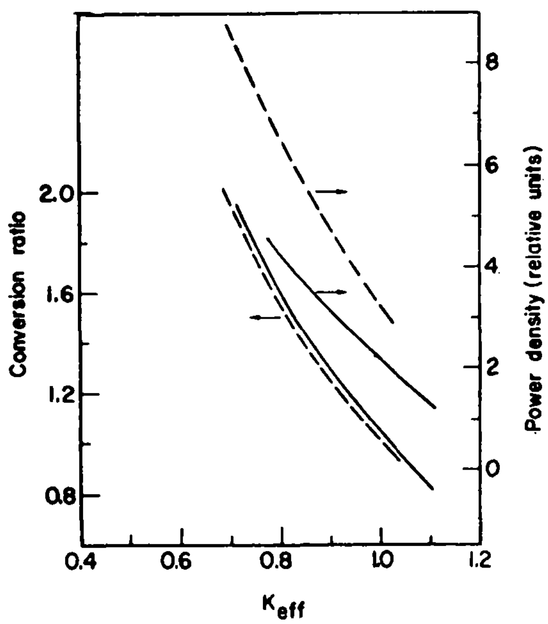

Fig. 1

Initial conversion ratio and volumetric power density for single rod natural uranium heavy water lattices
_ _ _ _ 0.40 cm radius; _____ 0.72 cm radius

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FISSION-FUSION SYMBIOSIS IN HIGHLY COMPRESSED MICROSPHERES[1]

A.D. Krumbein

In previous work[2], the feasibility of producing a power source or a copious source of neutrons by the compression of microspheres of fissionable material was investigated by means of numerical calculations. The results for pure fission sources with and without a moderating blanket led to the conclusion that only a coupling between fission and fusion, producing a species of chain reaction, could make the concept feasible.

As a first approximation to such a system, an external source of neutrons from either the D-D or D-T reactions was introduced into the calculations. This fusion neutron source was computed as a function of temperature using the expressions in Lovberg[3] above 1 keV and power series in temperature below

1 keV to match the values of $\langle \sigma v \rangle$ quoted by Thompson[4]. The temperature change with time was made to depend on the energy released in the fission process. The initial ion temperature distribution used in the calculations was taken from recent computational results reported by Brueckner[5] as occurring in an imploded sphere just before the fusion process begins.

The calculations were performed with five different mixtures of ^{239}Pu and deuterium, with volume fractions of plutonium ranging between 0.25 and 0.95. Spheres ranging in size from 0.005 to 0.40 cm in radius were included in the calculations. The three-region configuration of varying density[2], deduced from the calculations of Brueckner and Nuckolls, was used exclusively in these calculations. The neutron multiplication was computed as a function of time using the SNT[6] time-dependent neutron transport code to determine if a "runaway" neutron multiplication could be achieved. In none of the calculations, however, was an exponential increase in neutron multiplication, characteristic of such a runaway process, observed.

The above model, however, takes no account of thermal conduction in the plasma and is, therefore, in a sense conservative. A more detailed approach is now being implemented in which consideration is given to thermal conduction by electrons and ions in the plasma as well as the transfer of energy from electrons to ions. In this way, the energy produced by fission in compressed fissionable material can be transferred, for example, to the D-T portion of a layered configuration.

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STUDY OF U-238 BLANKETS FOR LASER FUSION REACTORS*[1]

A.D. Krumbein, M. Lemanska, Y. Gur and S. Yiftah

The economic feasibility of any laser-fusion process may depend critically on the inclusion of a blanket which breeds fissile fuel[2,3]. Such a blanket would contain ^{238}U or ^{232}Th and capture fusion neutrons to produce ^{239}Pu or ^{233}U.

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We have computed some of the properties of such a blanket using, as a model, a 14 MeV neutron source in vacuum surrounded by a spherical blanket containing ^{238}U. The SNG[4] spherical transport code was suitably modified for use in the calculations.

The results obtained to date for the number of fission, absorption and neutron multiplication events per 14 MeV source neutron give good agreement with Weale's[5] experimental results. The calculations are now being extended to study the effects of anisotropic scattering as well as that of the energy distribution of the neutrons produced in the (n,2n) and (n,3n) reactions. In addition, the sensitivity of the results to changes in neutron cross sections is under investigation. Work has likewise been undertaken to calculate blankets containing various coolants and structural materials.

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A MULTIGROUP MODEL FOR THE SLOWING-DOWN OF ENERGETIC IONS IN PLASMAS[1]

E. Greenspan and D. Shvarts

The energy dependent equation for the slowing-down of energetic ions in fully ionized plasma was cast into a multigroup form. The resulting multigroup equation is a linear equation for the flux of the energetic ions and is easy to solve. It can take into account large energy transfer reactions preserving their discrete nature. The sensitivity of the multigroup approximation to the group width and weighting function used for generating group constants was investigated. It was found that few groups with simple, problem independent weighting functions can yield results of reasonable accuracy. The relation between the multigroup and other methods for the solution of the slowing-down equation was considered.

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EFFECTS OF LARGE ENERGY TRANSFER REACTIONS ON SLOWING-DOWN PROPERTIES[1,2]

D. Shvarts and E. Greenspan

Large energy transfer (LET) reactions affect the slowing-down process via two mechanisms: a) discrete energy losses of the energetic ions leading to a faster slowing down process, and b) the production of energetic recoil ions from the bulk plasma that might also interact with the bulk plasma during slowing down.

The effects of LET reactions on the following plasma properties were investigated: a) the probability that high energy ions will cause fusion while slowing-down, b) the transfer of energy from the energetic ion to the bulk plasma ions and electrons, and c) the slowing-down time. Plasma parameters calculated with the MUGLET code, which takes into account LET interactions were compared with a continuous slowing down model (CSD). It was concluded that:

a) LET reactions have a non-negligible effect on the slowing down process for plasma electron temperatures above 10 keV and initial ion energies in the MeV range.
b) For high electron temperatures ($T_e \gtrsim 50$ keV) and high initial energies the fusion probability of a deuteron in a DT plasma is about two times greater when accounting for LET reactions, compared with the CSD model. This enhancement is mainly due to the contribution of the recoils.
c) With LET reactions taken into account, the bulk plasma ions get a larger fraction of the beam ion energy than predicted by the CSD model. The difference may reach a factor of two.
d) The slowing down time with LET reactions is shorter as compared with the CSD results. The inclusion of the recoils in the calculation may reduce the slowing down time even further.

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SPECTRUM HARDENING IN TWO-COMPONENT-TOKAMAKS

E. Greenspan and D. Shvarts

In the calculation of the slowing-down process in two-component-tokamaks (TCT) it is customary to assume that the beam ions slow down against bulk plasma ions and electrons having a maxwellian distribution. When the number of the slowing-down (or suprathermal) ions is not negligible compared with the number of thermal ions, however, the contribution of interactions between the suprathermal ions (i.e. beam-beam interaction) to the plasma properties may not be negligible. This contribution can be taken into account by describing the distribution of plasma ions, for the calculation of the slowing-down of the beam ions, as a superposition of a maxwellian and a slowing-down distribution (i.e., by considering a hardened spectrum).

Self-consistent calculations of the slowing-down process for plasma conditions typical to TCT devices were performed. The solution of the slowing-down equation was reached iteratively, using a modified version of MUGLET(1). Starting with a maxwellian distribution for the bulk plasma ions, the distribution of the suprathermal ions was calculated. By superposing the maxwellian and the slowing-down spectrum thus obtained, the solution of the slowing-down equation was repeated (now against a hardened maxwellian) and the bulk plasma ion distribution accordingly adjusted.

For example, in the case of a 440 keV deuteron beam injected into a D-T plasma of $T_i = T_e = 20$ keV and $n = 10^{14}$ cm^{-3}, it was found that whereas the probability that a beam ion will undergo fusion while slowing down in a maxwellian plasma is about 0.004, the hardening of the spectrum, obtained when the beam ions constitute 25% of the total plasma ions, enhances the fusion probability by up to 0.006.

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NUCLEAR SCATTERING CROSS SECTION FOR FUSION CHAIN REACTION CALCULATION - THE (D, ^{3}He) CYCLE

Y. Karni, E. Greenspan and D. Shvarts

It has been shown that nuclear scattering may lead to a fusion chain reaction(1). This is due to the fact that there are large energy transfer collisions which may generate a shower of fast recoils that undergo fusion reactions while slowing down. Such a chain has been shown to be self-sustaining under some conditions for the DT cycle(1). To study the feasibility of a chain reaction for the D^3He cycle, we first set out to find the differential cross sections for nuclear scattering among the various species (D, ^{3}He, P, α) of this cycle.

To obtain an evaluated set of nuclear scattering cross sections a least-squares calculation was performed on a large number of published experimental data in the energy range up to 15 MeV with scattering angles of 20°-160°.

A similar approach for the DT cycle used phase shift analysis[2] or some arbitrary polynomial function[3]. We found the latter method to be easier to apply and reasonably accurate. For example, for p-D scattering we used the function:

$$\sigma(E,\theta) = \frac{n}{E^2 \cdot (1-\cos\theta)^2} + \sum_{j=0}^{4} \sum_{m=0}^{3} a_{j,m} E^m (\cos\theta)^j$$

Taking 1300 data points from 19 references, a fit with an average relative deviation of 16% was obtained. Similar functions were used for the other scattering reactions.

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TDMG - A TIME-DEPENDENT, MULTIGROUP, ZERO-DIMENSIONAL CODE FOR PELLET FUSION STUDIES IN THE PRESENCE OF CHAIN REACTIONS

D. Shvarts

Recent stationary calculations[1] have shown that under suitable conditions fusion burn can proceed via fusion chain reactions. This is due to nuclear scatterings of the fusion burn particles that produce a shower of fast ions some of which undergo further fusion reactions during their slowing down. The purpose of the code developed is to study the dynamics of fusion burn via usual thermal reactions and chain reactions. Since fusion chain reaction proceeds via suprathermal ions, it is desirable, for a first study of the effects, to represent the energy dependence accurately, whereas the space dependence may be represented in an approximate manner.

The main physical assumptions and models of the present code are:

1. Point reactor model. We assume an homogeneous medium having the same temperature and density everywhere. Leakage phenomena due to the finite dimensions are considered by using approximate diffusion coefficients.

2. A multi-group, multi-species description of the suprathermal ion population. This is based on the multigroup formalism recently developed[2], accounting for coulomb friction processes as well as for large energy transfer reactions (due to nuclear scatterings) and nonthermal fusion reactions.
3. Two-temperature description for electrons and ions. The energy balance equations account for the following processes: energy transfer from fast ions to the bulk plasma ions and electrons; Bremsstrahlung radiation losses of the electrons; energy exchange between the bulk ions and electrons; expansion cooling.
4. Because hydrodynamic expansion is a dominant mechanism in the burn process, we have included its effect in an approximate manner, using the similarity assumption.

The code was checked against some published results of calculations of thermal burning of bare DT spheres with sophisticated codes[3], and the time dependent energy yield was found to be reasonably accurate.

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COMPUTATIONAL EXPERIMENTS WITH A ^{252}Cf SOURCE FOR POSSIBLE USE IN NEUTRON RADIOGRAPHY[1]

D. Kedem and M. Lemanska

The influence of the moderators Fe, Al, C, D_2O, Be and CH_2, and the reflectors, H_2O and C, on the thermal neutron flux was examined. Spherical assemblies with a ^{252}Cf source located at the center and at various distances from the center were considered. A configuration having a small thermalization factor and a flat thermal neutron flux, adaptable to neutron radiography, was obtained.

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NUCLEAR PHOTOEXCITATION[1]

R. Moreh

The various methods of nuclear photoexcitation using neutron capture γ-rays were considered. In particular, the photoexcitation of isolated nuclear levels by the method of random overlap between one of the incident lines of neutron-capture γ-rays and a nuclear level of the scatterer were illustrated. The extraction of nuclear spectroscopic data such as spin, parity and the width of the resonance levels were explained. The variation of the energy of the photons using both nuclear resonance scattering and Compton scattering were explained and the use of both methods for measuring the ground-state radiative widths of nuclear levels were illustrated. In addition, the photoexcitation of the continuum region using higher energy photons in the 9 MeV - 11.4 MeV region was considered. It was thus possible to study the low-energy branch of the giant dipole resonance and the nuclear Raman scattering and to test the theoretical predictions in this field. The effect of Delruch scattering of these photons was mentioned.

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THE 6.324 MeV HOLE STATE IN ^{15}N[1]

R. Moreh and O. Shahal

The 6.324 MeV level of ^{15}N was photoexcited by a chance energy overlap with a γ line obtained from the Cr(n,γ) reaction using thermal neutrons. By measuring the angular distribution of the scattered radiation and its polarization, the spin and parity of the level was determined to be $J^{\pi}=3/2^-$. The E2/M1 mixing ratio of the $3/2^- \rightarrow 1/2^-$ ground state transition was unambiguously determined to be X(E2/M1) = +0.137±0.005. An upper limit to the branching ratio of the decay of the level to lower lying levels in ^{15}N was obtained. The radiative width of the level was also measured and found to be Γ = 3.1±0.3 eV. The result was compared with theoretical predictions.

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ATTENUATION COEFFICIENTS OF γ-RAYS AT 9.00 AND 11.39 MeV

T. Bar-Noy and R. Moreh

Precise measurements of attenuation coefficients at 9.00 and 11.39 MeV in 10 elements between Be and U were carried out. The γ beam was obtained from the (n,γ) reaction on disks of metallic nickel. The results are given in Table 1, and are found to be much higher than the calculated values of Refs. 1 and 2. The systematic differences are very probably due to the fact that the calculated cross section for pair-production is underestimated.

TABLE 1

Measured total attenuation coefficients (mb/atom) compared with calculated values for photon energies 9.00 and 11.39 MeV

	E_γ=9.00 MeV			E_γ=11.39 MeV		
Element	Ref. 1	Ref. 2	Present work	Ref. 1	Ref. 2	Present work
Be	256.0	254.6	257.3±2.2	228.1	226.8	238.5±7.6
C	406.9	405.1	413.5±19.2	369.9	367.7	395.0±0.7
V	2310	2280	2322±4	2300	2277	2368±26
Fe	2751	2719	2729±13	2768	2743	2787±22
Ni	3067	3030	3068±18	3101	3074	3175±10
Zn	3402	3354	3434±19	3459	3420	3537±9
Ag	6724	6694	6865±16	7050	7007	7334±28
W	13793	13716	14170±13	14697	14631	14950±60
Pb	16265	16109	16520±33	17307	17255	18000±64
U	19513	19489	20040±109	20808	20801	22200±31

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ABSORPTION OF 6.42 MeV PHOTONS[1]

R. Moreh and Y. Wand

Precise measurements of the total attenuation coefficients of 6.418 MeV photons in 23 elements between Be and U were carried out with uncertainties which were generally less than 0.3%. The method utilizes resonance scattering of monochromatic photons obtained from thermal neutron capture in titanium. The resonant scatterer is ^{139}La; it serves as an analyzer of the γ beam energies passing through the absorber. The effective energy definition in this method is of the order of 20 eV. The measured coefficients were generally in close agreement (∿ 0.6%) with calculated values. A significant deviation was observed only in the case of Ta.

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A NEW HIGH RESOLUTION GAMMA RAY MONOCHROMATOR[1]

R. Moreh, I. Jacob and R. Mourad

A high-resolution gamma monochromator having a resolution of $\sim 10^{-6}$ was developed. The variable energy γ source is obtained by nuclear resonance scattering of neutron capture γ-rays through various scattering angles. Several possible examples of combinations of γ sources and resonance scatterers were considered. In particular, a lead target was employed to scatter the 7.28 MeV γ line of neutron capture γ-rays of iron. Variation of the angle of the resonantly scattered 7.28 MeV photons between 60°-150° permits an energy scan of 400 eV in any absorber. Thus, nuclear energy levels in some absorbers were photoexcited and the corresponding ground-state widths were extracted from the measured absorption spectrum. The results for the case of a Ce absorber were considered in detail.

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A NEW INTEGRATED TARGET-ION SOURCE FOR ISOTOPE SEPARATION WITH THE SOLIS

S. Amiel, G. Engler, E. Ne'eman, Y. Nir-El and M. Shmid

As part of the research program on mass and charge distribution in fission, the SOLIS on-line isotope separator is used to separate isotopes for measurements of half-lives, fission yields, nuclear decay properties and delayed neutron emission probabilities of short-lived isotopes. A new surface ionization integrated target-ion source was developed. The present version is an improvement over a previously described system[1]. The modifications were aimed at achieving higher temperatures and greater operational reliability. The target, which contains 1 g of uranium coated on specially arranged graphite foils, presents a large area for efficient and rapid release of products and a large cross section to match a broad neutron beam. The target is situated in an oven, heated by electron bombardment. The species released from the target are conducted through a heated tube and filament where surface ionization takes place.

The ion source operates in the temperature range of $\sim$1800°C which results in very short diffusion half-times i.e. about 1 sec for Rb isotopes and about 5 sec for Cs isotopes. This permits measurements of half-lives of isotopes down to about 0.1 sec.

Using this new source isotopes of Rb, Sr, Cs and Ba were separated by positive surface ionization and their half-lives measured using beta activity detected by a silicon surface barrier detector. The results are given in Table 2. Two isotopes ^{147}Ba and ^{148}Ba were identified for the first time and their half-lives measured. Other results verify in some cases previous determinations or improve values which were obtained with less reliable statistics.

TABLE 2

Half-lives of isotopes studied, sec

Mass	Element	Half-life	Mass	Element	Half-life
94	Rb	2.81 ±0.01	143	Cs	1.78±0.01
	Sr	76.6 ±1.0		Ba	15.17±0.38
95	Rb	0.402±0.008	144	Cs	1.02±0.03
96	Rb	0.225±0.012		Ba	11.85±0.57
	Sr	1.103±0.022	145	Cs	0.65±0.04
	Y	6.32 ±0.18		Ba	3.79±0.19
97	Rb	0.181±0.010	146	Ba	2.14±0.37
	Sr,Y	0.865±0.028		La	8.5 ±1.9
98	Rb	0.098±0.018	147	Ba	0.72±0.07
	Sr	1.04 ±0.11		La	4.43±0.54
			148	Ba	0.47±0.20
				La	2.62±0.61

It is planned to extend the research to study nuclear level schemes and to measure fission yields. The target-ion source is to be adapted for negative surface ionization which will make it possible to extend the research to isotopes of Br and I.

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DISTRIBUTION OF NUCLIDES IN FAST FISSION OF ^{232}Th

T. Izak-Biran and S. Amiel

An analysis of the independent fission yields of thermal fission of ^{235}U (1) revealed an enhancement of products with an even number of protons and a decrease in the number of products with an odd number of protons. This odd-even effect is now one of the important contributions to the understanding of the fission process, especially from saddle to scission. The odd-even effect was not analyzed in other fission nuclides because there are no measurements of independent fission yields available in the literature.

It was decided to measure independent yields in fast fission of ^{232}Th, as Th , like U , has an even number of protons and it is divided into 2 even fragments or 2 odd fragments. Only the ^{134}I and ^{135}I (2) fission yields of ^{232}Th have been reported. In this work the independent yields of ^{90}Kr, ^{91}Kr, ^{139}Xe, ^{140}Xe, ^{131}Sn, ^{132}Sn and ^{132}Sb were measured directly and the yields of ^{91}Rb, ^{140}Cs, ^{131}Sb, ^{132}Sb, ^{134}Te and ^{135}Te were determined indirectly. The yields were obtained from the gamma spectra of the isotopes that were measured at different times, from 20 sec after the end of irradiation up to a few hours.

Kr and Xe were extracted by a stream of He and their gamma spectra were measured. From these gamma activities and from the known gamma intensities and efficiency of the detector, the independent yields of these isotopes were calculated. The yields of Rb and Cs were obtained by subtracting the measured yields of Kr and Xe from the chain yields which are known from the literature. The method was checked for accuracy and reliability by taking similar measurements in thermal fission of ^{235}U. Excellent agreement between the measured yields and the yields cited in the literature was obtained.

Tin was separated chemically as a hydride and its gamma rays were measured. By comparing the activities measured in ^{232}Th with those that were measured under the same conditions in thermal fission of ^{235}U, and by knowing the tin yields in ^{235}U from the literature, tin yields in ^{232}Th were obtained. Antimony yields were obtained in the same way as those for Rb and Cs. In addition, ^{132}Sb separated as a hydride was measured directly from the growth and decay of its gamma spectra.

The odd-even effects of these isotopes were obtained by comparing the measured yields with the calculated "normal" yields. The average odd-even effect in ^{232}Th was 31%±13%. For the elements Kr, Xe, Sb and Te an effect of 31%±5% was revealed and an excellent fit was obtained for the complementary elements Kr and Xe. For ^{132}Sn, the effect is much higher than the mean value of ^{232}Th because ^{132}Sn has a closed shell of neutrons, N=82. The high odd-even effect that was obtained in ^{232}Th is in accordance with the mass distribution of this nuclide that reveals a fine structure and is in accordance with theoretical works of calculated fission barriers that also reveal a fine structure in ^{232}Th.

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RATIOS OF INDEPENDENT YIELDS OF KRYPTON AND XENON ISOTOPES TO THE CUMULATIVE YIELDS OF THEIR PRECURSORS IN THE THERMAL NEUTRON FISSION OF ^{235}U

H. Feldstein and S. Amiel

Krypton and xenon isotopes formed in the thermal neutron fission of U-235 were released from an uranium oxide - barium stearate target and mass separated by SOLIS (Soreq on-line isotope separator). The contamination of the separated isotopes by their precursors (iodine and bromine) was about 2%, and cross contamination by adjacent mass was less than 5%. The separated isotopes were beta counted during their accumulation in the collector and the yield ratio of the separated isotope to the cumulative yield of its precursor was calculated from the beta activity curve measured as a function of irradiation time (growth curve). The analysis of the growth curve was performed with the aid of the least squares computer program ON LINE assuming known half-lives of the separated isotope and its precursor, with correction for transfer time using an experimental transfer time function. Alternatively, an analysis of the exponential components of the growth curve was performed for the cases in which the transfer time could be neglected (CLSQ program). In the above calculations, a steady ion current is assumed, but otherwise the method does not impose any restrictions and is independent of counter efficiencies since only one isotope is counted. The basic equation for the calculation is (disregarding the transfer time function):

$$A = K[1-\exp(-\lambda t)] + K_p[1 - \frac{\lambda}{\lambda-\lambda_p} \exp(-\lambda_p t) + \frac{\lambda_p}{\lambda-\lambda_p} \exp(-\lambda t)]$$

where A is the measured activity, K is the constant rate of formation of the separated isotope, K_p is the rate of formation of the precursor, λ is the decay constant of the separated isotope, λ_p is the decay constant of the precursor. The results of the calculations are summarized in Table 3 and are in good agreement with other experimental results.

TABLE 3

Krypton and xenon yields in thermal neutron fission of ^{235}U

Isotope	Chain yield[1] %	Yield ratio*	Independent yield of noble gas, %	Cumulative yield of halogen, %	Other experimental values Noble gas	Halogen
Kr-87	2.55 ± 0.07	$3.87^{+0.1}_{-0.5}$	$0.507^{+0.06}_{-0.01}$	$1.96^{+0.01}_{-0.06}$	0.36 ± 0.03[2] 0.51 ± 0.06[3]	2.0 ± 0.22[3]
Kr-88	3.62 ± 0.07	2.07 ± 0.5	$1.16^{+0.22}_{-0.16}$	$2.405^{+0.16}_{-0.23}$	1.32 ± 0.1[2] 1.66 ± 0.11[3]	1.86 ± 0.44[3]
Kr-89	4.80 ± 0.10	-	3.40 ± 0.5	1.17 ± 0.5	3.26 ± 0.19[2] 3.41 ± 0.15[3]	2.32 ± 0.4[1] 1.07 ± 0.11[3]
Xe-137	6.26 ± 0.16	$2.7^{+0.2}_{-0.5}$	$1.726^{+0.245}_{-0.10}$	$4.66^{+0.10}_{-0.245}$	$2.97^{+0.4}_{-0.32}$[2]	1.81 ± 0.4[4]
Xe-138	6.80 ± 0.17	0.196 ± 0.05	$5.39^{+0.28}_{-0.16}$	$1.06^{+0.16}_{-0.28}$	$5.03^{+0.62}_{-0.50}$[2]	0.84 ± 0.17[4]
Xe-139	6.5 ± 0.12	0.094 ± 0.02	$4.67^{+0.08}_{-0.08}$	$0.44^{+0.08}_{-0.08}$	$5.16^{+0.5}_{-0.4}$[2]	0.47 ± 0.25[4]

*Ratio of the cumulative yield of the precursor to independent yield of the separated isotope

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SYSTEMATICS OF DELAYED NEUTRON EMISSION PROBABILITIES IN MEDIUM MASS NUCLIDES (FISSION PRODUCTS)

Y. Nir-El and S. Amiel

According to the delayed neutron emission probability formula the various types of delayed neutron precursors exhibit a systematic behavior governed by the level density, the excitation energy and the pairing of the precursor nucleus.

The updated population of precursors has recently been increased and now includes 45 precursors with relatively well-determined emission probability values. This permits revealing of group features with good precision. The systematic behavior was found to be determined by the nuclear pairing and the mass region of the precursor. The derivation of the systematics is based on a simplification of the general formula of the emission probability. The comparison made with the available experimental data leads to a semi-empirical formula for delayed neutron probabilities. This formula was used for the prediction of unknown values of emission probabilities for unidentified precursors.

EXCITATION ENERGIES AND PROMPT NEUTRON YIELDS IN LOW-ENERGY FISSION

Y. Nir-El and S. Amiel

Excitation energies and prompt neutron yields of primary fragments were calculated for the fission of ^{236}U induced by thermal neutrons. Excitation energies were calculated using the relation between excitation energy and nuclear temperature, assuming a thermal equilibrium at the moment of scission. A semi-empirical calculation of prompt neutron yields was based on prompt neutron and gamma ray emission data. The Jackson evaporation model was used to calculate theoretical neutron yields and the results were compared with experimental data. Further improvements of these calculations are in progress.

PROMPT NEUTRONS IN FISSION

Y. Nir-El and S. Amiel

A linear relation between the prompt neutron yields from fission and fragment masses was obtained using gaussian mass distributions of the primary (pre-) and secondary (post-neutron emission) fission fragments. This relation discloses a link between the trend of variation of prompt neutron output as a function of fragment mass and the widths of the primary and secondary gaussians. If the secondary gaussian is wider (narrower) than the primary one, then the number of prompt neutrons decreases (increases) with the mass of the emitting fragment. The comparison was made between the primary gaussian and the secondary "clean" one by excluding the dispersion of prompt neutrons which broadens the final distribution of the secondary fragments.

By using experimental values for the standard deviations of the two gaussians in the case of cesium fission fragments produced in $^{235}U(n_{th},f)$, it was found that the secondary gaussian is narrower by 8% than the primary one.

IMPLANTATION OF RADIOACTIVE ATOMS BY α-RECOIL

S. Abrashkin and N.H. Shafrir*

The aim of this work was to explore the possibility of implanting radioactive atoms in metals, to depths of up to 500 Å, in order to study processes characterized by a low rate of material removal (wear in hydrodynamic lubrication, corrosion, etc.). High-activity beams of radioactive atoms having well-defined energies and geometry can be implanted with special accelerators, but few such accelerators are available. Alternatively, alpha-radioactive sources can be used as sources of radioactive atoms having kinetic energies of about 100 keV and atomic masses in the vicinity of 220. Offsetting this narrow range in mass and energy are the availability and low cost of suitable radioactive sources and the flexibility in implantation conditions made possible by their use. The implantation takes place in the low energy region (L.S.S.'s ε = 0.03 to 0.08)(1).

Practically all previous work on alpha recoil stopping made use of gaseous, mostly light targets. When targets are of higher Z crystalline materials, the penetration profile is broadened by channeling effects(2), a large range straggling and higher ratios of projected-to-true ranges. While less amenable to theoretical interpretation, these broadened profiles are more suitable for measurement of surface wear.

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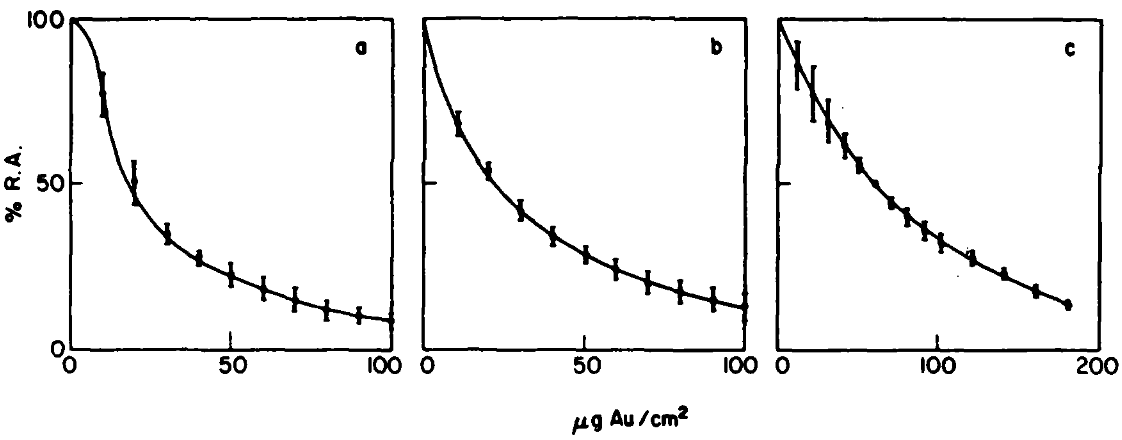

Fig. 1

Percent remaining activity (% R.A.) as a function of total thickness removed (μg Au/cm^2). Mean and standard error of 7,5, and 4 experiments for (a), (b) and (c) respectively

(a) % R.A. of ^{224}Ra, parallel beam implantation

(b) % R.A. of ^{224}Ra, isotropic implantation

(c) % R.A. of ^{212}Pb, implanted through 3 successive recoils from a planar ^{224}Ra source

A high atomic weight, microcrystalline material (metallic Au) was chosen as a target. Profiles of ^{224}Ra (recoil from alpha decay of ^{228}Th) were studied for two different implantation geometries (parallel and isotropic beam).The profile of ^{212}Pb, implanted from a ^{224}Ra source through three successive recoils, was also studied.

Very thin uniform sources of ^{228}Th, prepared by the ion-optical method of Leon and Shafrir[3], were used as energy standards, but were too weak to be used as implantation sources. These were prepared by evaporation of a $^{228}Th(NO_3)_4$ solution on polished Au foils. The targets were 99.99% pure gold foils, mechanically polished through 0.05 μ Al_2O_3 to a mirror finish. The implantation profile was determined by peeling successive layers of target and measuring the residual activity by alpha spectrometry. The corrosion-film peeling technique of Andersen and Sorensen[4,5] was tried without success. An electrochemical procedure based on Whitton and Davies[6] was used. Since the

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S U M M A R I E S

I. Experimental Nuclear Structure Physics

MEASUREMENT OF THE QUADRUPOLE MOMENT OF THE FIRST EXCITED 2^+ STATE OF ^{18}O

A.M. Kleinfeld*, K.P. Lieb*, D. Werdecker* and U. Smilansky

We measured the static electric quadrupole moment (Q_{2^+}) and $B(E2, 0_1^+ \rightarrow 2_1^+)$ of the first excited state of ^{18}O at 1.98 MeV. The values obtained were $(-0.19\pm0.02b)e$ (for the positive sign of the interference term involving the 2_2^+ state) and $(0.0048\pm0.0002b^2)e^2$ for Q_{2^+} and $B(E2,0_1^+ \rightarrow 2_1^+)$, respectively. For these values the ratio $|Q_{2^+}|/[B(E2,0_1^+ \rightarrow 2_1^+)]^{1/2}$ is about 3, whereas for no other nucleus does it exceed unity by more than 30%.

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NUCLEAR REACTIONS BETWEEN OXYGEN ISOTOPES

D. Kalinsky, D. Melnik, U. Smilansky, N. Trautner, B.A. Watson*, Y. Horowitz**, S. Mordechai**, G. Baur*** and D. Pelte***

Elastic and inelastic cross sections have been measured for the system $^{16}O+^{17}O$ at c.m. energies from 12.5 to 15.5 MeV, and for $^{16}O+^{18}O$ at c.m. energies from 12 to 20 MeV, at angles between 60° and 125°. Position-sensitive detectors were employed, using the kinematic coincidence technique. The data have been analyzed with particular attention to the contributions of multiple-exchange processes.

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DECOUPLING MEASUREMENTS WITH LOW-CHARGE OXYGEN IONS RECOILING INTO GAS

M.B. Goldberg, M. Hass and Z. Shkedi

A decoupling measurement with low-charge oxygen ions recoiling into gas was interpreted using a phenomenological approach. Values thus deduced for the g-factor of the 3^- level of ^{16}O and for the ion-atom collision cross-section were found to be in good agreement with results of other experiments.

THE MEAN-LIFE AND MAGNETIC MOMENT OF THE FIRST EXCITED STATE OF ^{20}O

Z. Berant, C. Broude, G. Engler*, M. Hass, R. Levy and B. Richter

The 2^+ first excited state of ^{20}O was excited by the reaction $^3H(^{18}O,p)^{20}O$. Using the recoil distance method, a decay curve with hyperfine interaction effects has been observed. The energy of the state has been measured as 1675.0±1.0 keV, the mean-life is 14.2±0.8 ps, and the value of $|g|$ is 0.39±0.04. Comparison is made with shell model calculations.

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A PARTICLE–GAMMA ANGULAR-CORRELATION MEASUREMENT SYSTEM FOR HIGH COUNTING RATES

E. Abramson, M. Birk and Z. Vager

A system employing four semiconductor detectors and four NaI(Tl) scintillation counters for particle–gamma angular-correlation measurements at high counting rates is described. Scintillation counter pulses are shaped into rectangular pulses of 200 ns duration in order to reduce pile-up effects, and a compensation circuit for gain variation with rate is used. A fast decision-making logic unit employing MECL 10000 I.C.'s controls data transfer into an on-line PDP-9 computer. Dead-time losses are measured using a pulse-pair generator simulating particle–gamma coincident pulses.
In an experiment with 5–8 MeV protons and 0.5–2.5 MeV gamma rays at a counting rate of approximately 100 000 cps at each of the scintillation counters, the gamma-energy resolution (fwhm) was 6–9%, depending on gamma energy, and the time resolution (fwhm) was 1.8 ns. Plots of typical results are shown.

OFFSET ELECTROSTATIC QUADRUPOLE TRIPLET CHARGE SELECTOR

G. Goldring, Z. Segalov and E. Skurnik

An electrostatic displaced triplet for charge selection in the terminal of a 14 UD Pelletron accelerator is described. The device was checked experimentally with purely geometric displacements and with combined geometric and electric offsets. The rejection rate of charges adjacent to a selected charge is better than 1/20 for a divergent beam of 7 mrad half angle and charges as high as 14+. For a collimated beam of 1 mrad half angle complete separation is achieved.

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Ranges of ^{252}Cf Fission Fragments by Gamma Spectrometry

Y. Laichter and N.H. Shafrir

Experimental data concerning fission fragment ranges in matter are of interest in determining the mechanism of the interaction of energetic heavy ions with matter. Such data concerning the spontaneous fission of ^{252}Cf are rare[1,2]. This study is aimed to measure ranges of individual fission fragments in various solid and gasseous media. Fission fragment ranges are measured using high resolution, high efficiency Ge(Li) gamma sprectrometry. The fragments are identified by their gamma radiation energy and their half life.

Using a thin ^{252}Cf source having an activity of approximately 10^8 fissions/min, ranges of more than twenty fission fragments in various solid and gasseous matter are under investigation.

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Fission Yields of ^{252}Cf as Measured by Gamma Spectrometry

N. Golczar, Y. Laichter and N.H. Shafrir

Cumulative yields of 18 products in the spontaneous fission of ^{252}Cf have been determined. Measurements were carried out by gamma spectrometry using a high resolution Ge(Li) detector. Yields calculations were made by an absolute method based upon the exact calibration of the measuring system.

The following parameters were determined:

- The photopeak area was determined by the gamma spectrum of the fission products.
- Source activity was determined by gamma spectrometry and found to be 8.2×10^4 fissions/min.
- Collection efficiency of products was determined as the geometrical factor and was equal to 0.44 (from 4π).
- The absolute full energy peak efficiency was calibrated by point source; fission products which are planar sources were adapted to the calibration geometry.
- Functional primary yields were determined by solving the Gaussian equation for the nuclear charge distribution.

Till now calculations of fission yields of ^{252}Cf were made by comparison methods based on the normalization as compared with one yield which was chosen as the reference.

The absolute method enables the independent determination of fission yields and eliminates systematic error introduced by the normalization process.

^{252}Cf Fission Fragment Mass and Energy Spectra

Y. Laichter and N.H. Shafrir

In connection with a study of the energy deposition efficiency of energetic heavy ions in matter, a computer code is developed to synthesize ^{252}Cf fission fragment mass and energy spectra in any media.

The spectra obtained are compared with experimental results measured with a Si-solid state detector. This comparison serves to test the validity of various theoretical and semi-empirical approaches for the energy deposition of heavy ions in matter,[1-4] as well as the accuracy of the fundamental data.

Spectra measured with no moderation are used to check the accuracy of the kinetic energy and r.m.s. width data for the various ^{252}Cf fission fragments. Spectra obtained after moderation in solid and gaseous media are used to check the validity of the stopping formulae and the most probable charge of the fission fragment isobaric chains moving in matter.

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Determination of Energy Spectra of Fission Fragments by Means of Dielectric Nuclear Track Detectors

H. Hershfeld and N.H. Shafrir

The spectrometric response of a number of solid state nuclear track detector (SSNTD) materials, have been previously studied.[1,2] Glasses with high phosphate content which were shown to have the most desirable properties for fission fragment energy spectrometry, were chosen for spectra determinations of ^{252}Cf fission fragments.

All the experiments were carried out using perpendicular irradiation, i.e. the fission fragments entered the detector at right angles. The energy of the fission fragments was controlled by the nitrogen pressure in the irradiation setup. Series of experiments at various energies and different etching times were carried out. The measured parameter of the track was the diameter and for each experiment a distribution of track diameters was obtained, showing similarity to Si-detector spectra.

Using a dynamic model of the track evolution during the etching, an attempt is made to determine the range of ^{252}Cf fission fragments in phosphate glass.

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Identification and Quantitative Assay by X-Ray Fluorescence Technique

D. Segal, Y. Segal and A.Notea

The intensity of a specific x-ray energy emitted from a sample following its excitation by external beam is not a linear function of the element content in it. The deviations from linearity result partially from the response function of the specific spectrometer and majorly due to the transport of the photons in the sample (e.g. the matrix effect, particles effect). Due to the complexity of the processes involved, most of the techniques employed at present are based on empirical (or semi-empirical) relations which are suitable for a very limited range.

In the present project the transport of the impinging (primary interrogation beam) and fluorescence photons is analyzed by numerical approaches developed for reactor physics calculations. The suitability of the Monte Carlo method for the analysis of the problem is tested. The obtained results provide a deep insight to the emission procedure and a better understanding of the significance of the parameters involved in the design of an assay system.

Evaluation of Radiation Transmission Techniques for Detection of Inhomogeneity in Medium

A. Ginsburg, A. Gutman, A. Fishman, A. Notea, Y. Segal and B. Shapiro

Defectoscopy depends on the characteristics of the radiation employed, the beam-sample-detector geometry, the examined medium and the detection system (e.g. the camera). The analysis of the result depends on the interpretational model derived. The project is aimed at the study of the relative importance of the various parameters and the definition of a reduced set of major characteristics. The approach is based on defining probability functions to the parameters and analyzing the distribution obtained for the measured parameter. Emphasis is given to the prediction of the measurement's quality that is expected under given working conditions. This will enable the optimization of the design-parameters of the systems.

The work is carried out for photons and neutron beams. The aspects under consideration involves transmission gamma gauges, gamma radiography and neutron radiography.

Benchmark Analysis of Plutonium Fueled Reactor Lattices

W. Rothenstein and E. Taviv

Analysis of Uranium fueled reactor lattice benchmarks, which have recently led to a renewed study of the adequacy of the ^{238}U basic nuclear data,(1) are being extended to Pu fueled thermal reactor cores in the data testing program.

The benchmark specifications of the Cross Section Evaluation Working Group include a number of unreflected critical spheres containing plutonium nitrate solutions.(2) These are used mainly to test the data in the thermal energy region although in some of the spheres containing ^{240}Pu the 1.0 eV resonance must also be taken into account.

In addition reactor lattices containing Plutonium, or mixed oxides as fuel must clearly also be studied with the latest ENDF/B data and analysis procedures which can handle these data exactly in accordance with the specifications, and perform the lattice analysis with sufficient precision.

In the current project a modified version of the HAMMER code(3) is used. It represents the resonances by detailed tabulations of their profiles. A modified group structure will probably have to be used than the one customarily employed for Uranium lattices so that the low ^{240}Pu resonance will be taken into account in the thermal energy region.

The modified code has proved to be effective in accounting in the case of Uranium fuel for a number of effects which are normally ignored, specially in resonance reaction rate calculations. It will now be used for the study of the Plutonium fueled systems and in particular for the lattices described in [4,5,6]. If necessary comparisons with Monte Carlo calculations in the resonance region will be made.

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Improvement of Thermal Benchmark Analysis Procedures

W. Rothenstein and J. Barhen

The adequacy of a nuclear data base for reactor applications is determined on the basis of the analysis of "benchmark" experiments. Methods used in the analysis of such experiments must be accurate enough to insure that uncertainties due to approximations in the analytic model are negligible with respect to nuclear data uncertainties.

A commonly used analytical procedure is based on the lattice analysis code HAMMER.[1] Calculations done with this code must however be corrected with the use of more accurate representations in some areas and in particular in the resonance region.

In the current project basic changes of the resonance reaction rate calculations are being made. These make full use of the latest ENDF/B data, and instead of evaluating resonance absorptions from the resonance parameters as was customary in lattice analysis codes in the past, the cross sections in the resonance region are represented by detailed tabulations[2] which can be accurately Doppler broadened.[3]

The algorithms for treating resonance shielding are based on the Nordheim Integral Treatment[4] and a modification of the RABBLE method[5] which can be applied to a numerical integration procedure on a fine energy mesh and utilises the detailed resonance cross section tabulations by linear interpolation. Resonance scattering is also taken into account in the modified calculations. In the unresolved resonance region the shielding of the p-wave as well as that of the s-wave resonances is allowed for.

The resonance treatment is performed for the heterogeneous unit cell of the reactor core, as though it were located in an infinite lattice of similar cells. Subsequent leakage calculations are performed on the basis of asymptotic reactor theory for a homogenised core. The interface between these two basic modules requires great care in the handling of the neutron balance so that heterogeneity and leakage are properly handled in the final evaluation of the resonance absorption rates.

The results based on the new code will be compared with previous analyses which relied on Monte Carlo estimates of the resonance absorption rates.

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Evaluation of Gamma Transmission Gauge for Assay of Water Content in Soil

A. Fishman and A. Notea

The attenuation of gamma radiation in soil is employed for the measurement of the water content in a layer of a given thickness. The characteristics of the gauge are analyzed as function of the soil type, thickness of the layer, field water capacity, gamma energy, detector geometry, efficiency, etc. An interpretational model is derived and is used for the resolving power estimation. The model is based on analytical approach and experimental data.

Parameter Analysis of an Electrostatic Particle Guide Using Radioactive Recoil Ions

A. Kenigsberg, J. Leon and N.H. Shafrir

A thorough parameter analysis of an electrostatic particle guide (EPG), constructed in the frame of a wider program for the study of nuclear stopping cross sections for slow heavy ions, has been performed. To obtain optimal performance for time-of-flight spectroscopy, the operational conditions of the system were studied in detail, using $\sim$100 keV alpha disintegration recoils. The parameters investigated were collector radial position, collector axial position, source radial position and wire voltage. Clear and sharp spectra with an energy resolving power of 1.5-3% FWHM, and transmission enhancement factors up to 300-400, were obtained.

Preparation and Testing of Multigroup Data for In-Core Power Reactor Physics Calculations

W. Rothenstein and L. Reznikov

Core physics calculations for power reactors require an accurate determination of the neutron spectrum over the entire energy range from the lowest energies of the thermal region to the high end of the fission spectrum. The neutron spectrum depends on the composition of the reactor core, which throughout its life changes with burnup. It must therefore be evaluated separately for each fuel element at numerous stages during its residence in the reactor. In addition, the spatial dependence of the neutron spectrum must be taken into consideration at energies where shielding is significant. This is the case in particular in the resonances of isotopes, like the fertile materials, which have pronounced resonance peaks and are present in the fuel rods at high atom densities. Shielding is also very important at thermal energies where cross sections of fissile isotopes become large, specially at the low end of the spectrum, and when the 1/v absorption of poison or control elements may also necessitate a space-energy spectrum calculation.

An efficient study of the spectral characteristics of the neutron population in a fuel element throughout its life in the reactor core must be based on rapid calculations which can be repeated as frequently as is deemed necessary. Yet accuracy must not be sacrificed for the sake of speed, nor should the calculations be purely mechanical. A detailed understanding of the procedures on which the calculations are based and the nuclear data which are employed is essential whenever special problems arise.

The LEOPARD program[1] may be regarded as one of the basic tools for accurate core physics calculations. This program has the advantage that it contains its own built-in neutron data libraries, but these libraries are relatively old and do not take most recent neutron microscopic cross section evaluations into account. In addition the number of isotopes in the library is not as complete as is desirable or necessary.

An updated ENDF/B-IV LEOPARD library is currently being prepared for all materials available at present in the code and other nuclides which may be considered to be desirable additions. Comparative studies of PWR fuel assemblies will be made throughout their life in the reactor for both the old and the new LEOPARD libraries. Special attention will be given to the resonance region where LEOPARD relies on correlations of resonance integrals with integral measurements[2]. It is of interest to determine to what extent these correlations are consistent with the latest ENDF/B-IV data evaluations, and this matter will be pursued to the extent to which this is feasible within the framework of the present proposal.

The comparative studies for fuel assembly calculations with the old and new libraries will lead to information of the relative changes which the recent data produce in the broad group fuel parameters and in particular k_∞ as a function of burnup.

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Shielding Effects in Fuel, Burnable Poison and Control Cells of Power Reactor Lattices

W. Rothenstein and I. Szabo

In core fuel management codes such as Penn State Fuel Management Package, frequently rely on data provided by the reactor manufacturer to calculate effective cross sections for burnable poison rods and control rods. On the other hand it is desirable to replace such empirical information by analytical procedures even in codes which perform the reactor lattice analysis rapidly and are designed to follow the fuel burnup.

Heterogeneity effects have considerable influence on the thermal neutron spectrum in power reactor fuel assemblies. The neutron flux in the rod of the reactor lattice unit cell is increasingly shielded when the absorption cross section Σ_a becomes large. This is the case for the fissionable isotopes which have high Σ_s's because of the close energy spacing of their resonances, and for control and burnable poison isotopes which are chosen for their large thermal absorption. In addition the 1/v dependence of Σ_a makes the shielding effect even more pronounced at the low energy end of the neutron spectrum.

Computer codes such as LEOPARD[(1)] which analyse the thermal, as well as the epithermal spectrum in fuel assemblies contain rapid techniques to determine the shielding factor and the neutron energy spectrum since the analysis must be made at frequent intervals during the life of the assembly in the reactor. LEOPARD relies for the heterogeneity calculation on the method of Amouyal, Benoist, and Horowitz[(2)] which it performs in each of the 172 thermal groups without allowing for the interaction with other groups. After homogenisation of the cell in the fine groups the Wigner Wilkins energy spectrum[3] is calculated in order to obtain the final one broad thermal group parameters for the fuel assembly by cross section averaging with flux weighting.

For burnable poison rods, the self-shielding effect must be calculated by a transport code which is not part of the LEOPARD code. Once the self-shielding is known, the rod can be replaced by an equivalent amount of soluble poison in the moderator to yield the same absorption rate. The control rod treatment is similarly approximate.

In the light of these considerations alternative methods are being studied to calculate the space dependent thermal spectrum in the fuel assemblies for the poison rods. These methods will also be applicable for fuel rod cells and will be compared with the current LEOPARD procedure. They will be based on the latest ENDF/B data including the scattering law for water and the THERMOS code.

On the basis of these investigations improved procedures for handling the shielding in cells containing burnable poison, and for handling control rod calculations, will be formulated and included in the LEOPARD code which is a basic program for in-core fuel management calculations.

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Modelling of Nuclear Fuel Waste Drum Assay by Passive Gamma Technique

A. Bar-Ilan, A. Knoll, A. Notea and Y. Segal

The spatial distribution of fuel contaminated solid wastes in drums is inhomogeneous and is unknown. The assay is based on the detection of the radiation leakage from the waste container. The count rate is not a single value function of the fuel content in the container. This study is based on estimating the possible deviation from an homogeneous distribution of the source, as well as of the waste materials. This deviation is treated as an additional source of error. The errors involved in the measurement and in the interpretation are analyzed and their relative contribution to the total error point at the pros and cons of the technique under given conditions.

Implantation of Radioactive Atoms by Alpha Recoil

S. Abrashkin and N.H. Shafrir

The penetration depths of ^{224}Ra recoils (from a ^{228}Th source)[1,2] in a polycrystalline target (Au) were measured, for parallel and isotropic implantation beams. Also measured were the penetration depths of ^{212}Pb (by ^{212}Bi - ^{212}Po measurements) from a ^{224}Ra source (i.e., atoms implanted by 3 successive alpha recoils). The peeling technique of Whitton and Davies was modified for the purpose of the work[3].

The results were examined from the viewpoint of a possible application in sensitive wear and corrosion measurements, as well as that of their agreement with L.S.S. theory. The results of the work do not agree with an often found explanation of the peculiar penetration profiles in polycristalline materials by means of a channeling contribution. An approximate calculation based on different assumptions (empirically derived from the results of this work for parallel beam implantation), gives reasonable agreement with the results for other implantation conditions.

Based on this approach, penetration parameters and profiles were calculated for alpha recoils in a range of metallic, polycrystalline targets.

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Effects of Physical and Operational Conditions on the Temperature Fields in Reactor Fuel Elements

E. Wacholder, E. Elias*, D. Hasan** and S. Kaizerman

Prediction of fuel element behaviour in a nuclear reactor following a postulated accident requires as its first step a knowledge of the temperature field during stead-state conditions which reflect the initial stored energy in the fuel. To accomplish this the dependence of the thermal properties (such as thermal conductivity of the fuel and cladding, and the thermal conductance of the gap between the fuel and cladding) on temperature and burnup must be taken into consideration.

The steady state problem, as stated above, has been solved by two methods:

(a) The numerical Successive Over Relaxation (S.O.R.) method (known also as the Extrapolated Liebman Method).[(1)]

(b) A computer oriented analytical method, based on Fourier Series and Kirchoff Transformation.[(2)]

These solutions have been employed for extensive parametric studies of the fuel elements' behaviour in the hot channels in a variety of modern reactors of practical interest.

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Light Water Reactor Accident Analysis

E. Wacholder, D. Hasan*, S. Kaizerman and S. Pryluk

The analysis of hypothetical accidents serves as an important tool in the determination of design-bases and in the evaluation and licensing activities related to nuclear reactors. Various computer codes are used by research institutions, official licensing agencies and various companies in order to predict the fluid - and thermodynamic behaviour in the light-water reactor systems during accidents.

The work currently carried out is divided into three topics:

(1) The transient solution of the thermal-hydraulic conditions in the reactor-core hot channel.

(2) The prediction of the fluid - and thermodynamic behaviour in the primary coolant system of a P.W.R. during accidents.

(3) The prediction of containment response to accidents and the estimation of the radiological consequences.

In the first topic, a computer program (TRANS2[1,2]) for the solution of the thermal response of the fuel-rod and the coolant in a hot channel, to transients, has been developed. The program utilizes the A.D.I. (Alternating Direction Implicit) method for the solution of the general-heat-conduction-equation in the fuel rod, coupled with the solution of the one-dimensional-energy-equation in the coolant, using an implicit method. In addition to it, the THETA1-B and RELAP4 computer codes are operated. Comparative analyses of various accidents are performed using the three above mentioned computer programs.[2,3]

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In the second topic, the details of modelling a specified reactor system and its components using the RELAP4 computer code are studied. The results of the calculations also serve as boundary conditions to the core heat-up calculations (first topic, above) and to the containment calculations (third topic, henceforward).

In the third topic, the containment response to accidents is calculated to serve as a tool which will enable the derivation of bases for the containment design. The PREST computer program has been operated, and is currently improved to suit the above target. A P.W.R. dry-containment is modelled also, using the CONTEMPT computer code.

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Safeguarding Nuclear Fuel During Burnup

A. Notea and S.H. Levine*

A research program has been started to develop inspection techniques to safeguard used fuel from being diverted for unauthorized reprocessing. The research involves a coordinated analytical-experimental program wherein sophisticated reactor physics techniques are used to define limits of detection when used fuel has been replaced with equivalent new fuel.

The analytical program uses accurate in-core fuel management computer programs, and the experimental program involves fuel characterization studies. The program should result in methods to provide improved safeguards for reactor fuels.

Minimization of Nuclear Fuel Costs

W. Rothenstein, M. Keren and S.H. Levine*

Optimization methods are to be studied for reloading nuclear reactors. The ultimate goal is to prepare procedures for automatically determining the reload configuration that minimizes fuel costs for the power plant. Computer programs are to be effected which enable the utility to make quick decisions on the fuel reload composition and configuration. Such computer programs are necessary when a power plant has been forced to make an unscheduled shutdown for an extended time period near the end-of-life of the core. The optimization programs will provide flexibility to vary the length of future reactor cycles so as to provide a global optimum operating condition in terms of minimum costs of the nuclear fuel.

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PROGRESS REPORT TO INDC
ON
NUCLEAR DATA ACTIVITIES IN PAKISTAN

PAKISTAN INSTITUTE OF NUCLEAR SCIENCE & TECHNOLOGY
P.O. NILORE, RAWALPINDI

March 1977

1. Inelastic Scattering of Neutrons from ^{128}Te and ^{130}Te

Inelastic scattering of 14.7 MeV neutrons from enriched isotopes of ^{128}Te and ^{130}Te has been studied using the time-of-flight technique. The spectra were taken at scattering angles of 29, 37 and 40 degrees. The analysis of these data leads to the existence of previously unreported levels at 6.40 ± 0.25, 7.48 ± 0.21, 8.12 ± 0.18 and 8.81 ± 0.15 MeV in ^{128}Te and at 4.65 ± 0.34, 6.51 ± 0.25, 7.37 ± 0.21 and 8.19 ± 0.25 MeV in ^{130}Te.

2. Computer Codes for Nuclear Data Evaluation

Two computer codes have been developed at PINSTECH for the evaluation of Nuclear data. These are as briefly described below:

i) An Optical model code: It is intended for calculating observable cross-sections such as differential and total elastic scattering cross-sections, penetrabilities and reaction cross-sections based on nuclear optical model of elastic scattering. The code has an in built provision for the use of Bechetti and Greenlees potentials. The differential scattering cross-sections and reaction cross-section for 17 MeV protons for gold obtained with the present code are compared in Tables 1 and 2 with the values obtained using two previously reported codes[1,2] with the same optical model parameters viz. U = -48 MeV, W = -8 MeV, a = 0.5 fm, rc = ra = 1.3 fm. No spin-orbit potential was used in either calculation.

ii) A computer code for calculation of nuclear cross-sections by Hauser-Feshback Theory: This computer code is meant for elastic and inelastic scattering cross-section calculations. The code includes an optical model sub-routine for calculation of penetrabilities which are required for Hauser-Feshbach calculations. The inelastic scattering cross-sections of 0.075 MeV neutrons from 2^+ excited state at 0.046 MeV in ^{238}U computed with the present

Cont'd..../2

code are compared in Tables 3 and 4 with the results obtained using a previously reported code[3]. The optical model parameters used for calculations of penetrabilities in both the codes are: U = -46.5 MeV, ru = 1.2598 fm, W = -15.8399 MeV, rw = 1.2373 fm, au = 0.66fm, aw = 0.48 fm. The variation of 4% in values of cross-sections between the two codes is mainly due to the variation in penetrabilities obtained using the corresponding optical model sub-routines.

Table 1

Scattering Angle in CM System	Calculated Differential Scattering Cross-sections (mb/str)		
	Buck et al[1]	Melkanoff[2]	Present work
20°	3.203×10^4	3.202×10^4	3.204×10^4
40°	1.549×10^3	1.549×10^3	1.552×10^3
60°	2.951×10^2	2.951×10^2	2.968×16^2
120°	14.58	14.60	14.76
160°	7.807	7.825	7.805

Table 2

Code	Calculated Reaction Cross Section (mb)
Buck et al[1]	985.2
Melkanoff[2]	984.7
Present work	982.8

Cont'd...../3

Table 3

Scattering Angle in CM System	Differential Inelastic Scattering Cross Sections (mb/str)	
	Wilmore[3)]	Present work
10°	70.90	68.33
20°	74.26	71.56
60°	92.47	89.01
90°	99.65	95.9

Table 4

Code	Total Inelastic Scattering Cross Section (mb)
Wilmore[3)]	1132.85
Present work	1090

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Cont'd..../4

3. Radiative Neutron Capture Studies

The study of the $^{142}Nd\ (n,\gamma)\ ^{143}Nd$ reaction with thermal neutrons was completed and the results have been reported in Nucl. Phys. A272 (1976) 133. The work on the analysis and interpretation of the data on the $^{144}Nd\ (n,\gamma)^{145}Nd$ and $^{146}Nd\ (n,\gamma)^{147}Nd$ reactions is being continued.

Work is also in progress on the measurement/analysis of γ-rays following thermal neutron capture in ^{170}Er and ^{176}Yb.

4. $^{14}N(n,\gamma)^{15}N$ Reaction as a Measure of Protein Content of Cereals

Effort is being made to develop a fast and accurate method for the determination of protein content of cereals by measuring the intensity of the 10.82 MeV γ-ray resulting from the $^{14}N(n,\gamma)^{15}N$ reaction. In order to achieve good statistical precision in a Ge(Li) detector measurement, the continuum events extending from just below the double escape peak upto the full energy peak are also taken into account. The back ground counts in the region produced by the random summing of signals are minimised by using the pile up rejection technique.

5. Neutron diffraction studies of the unit cell of Cellulose-II.

The neutron diffraction work on cellulose-I was extended to cellulose-II using the neutron spectrometer at PINSTECH. The double axis diffraction pattern was taken covering the region $\sin\theta/\lambda$ = 0.045-0.151A^{-1} at a neutron wavelength of 1.07A. A further detailed pattern in the selective range $\sin\theta/\lambda$ = 0.88-0.96A^{-1} was taken using a Ge(111) monochromator in order to check the second order contamination in this region..The results give cell parameters as 'a' = 15.7A 'b' = 10.3A 'c' = 18.4A and $\beta = 63^{\circ}$. The 'a' and 'c' values found are about twice the values obtained by x-ray diffraction[1]. The present results agree with the electron diffraction data[2].

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6. Temperature factors of UO_2 and UO_{2+x} by Neutron Diffraction

The Debye-Waller 'B' factors of $UO_{2.00}$ and the non-stoichemetric uranium oxide $UO_{2.11}$ have been studied by neutron diffraction. The values obtained are listed in Table 5.

Table 5.

Sample	'B' for Oxygen atoms	'B' for Uranium atoms
$UO_{2.00}$	$0.43 \pm 0.07A^2$	$0.23 \pm 0.07A^2$
$UO_{2.11}$	$0.81 \pm 0.08A^2$	$0.19 \pm 0.03A^2$

The 'B' for oxygen atoms in $UO_{2.11}$ is a good average of the corresponding values for $UO_{2.00}$ and for U_4O_9 (ref.1).

1) B.T.M. Willis, Le Journal de Physique 25 (1964) 431.

7. Nuclear Measurements Using Solid State Nuclear Track Detectors

Extensive use of solid state nuclear track detectors (SSNTDs) has been made at PINSTECH for nuclear measurements. In particular the plastic and glass track detectors have been used for in-core gamma dosimetry. Experiments are also in progress for fission rate and neutron temperature measurements in the core of the research reactor PARR at PINSTECH.

U-2 and U-3 uranium reference glasses (fabricated by Corning Museum of Glass, New York) have been employed for the measurement of $U(^3He, f)$ cross-section for incident ^3He particles of energy upto 30 MeV. (The irradiation was carried out at the University of Birmingham, U.K.). These glasses contain 43 ppm of uranium. The results show that the fission cross-section is ~ 0.192 barn for 30 MeV ^3He ions and it decreases rapidly with decreasing energy. Preliminary analysis indicates that Coulomb barrier is responsible for the low fission cross-sections below 28 MeV.

Cont'd..../6

8) Uranium ore analysis by Gamma ray spectroscopy

A method has been developed for the absolute measurement of Uranium concentration in rocks by gamma ray spectroscopy. Previously known techniques utilized the gamma rays emitted by long lived daughters in the decay chain of Uranium. However, accurate information on the parent nucleus will presume a geological equilibrium between the parent and the long lived daughters. This equilibrium does not always hold and therefore an inaccuracy is introduced in the measurement. The 93 keV gamma ray from ^{234}Th, which is the short lived daughter of ^{238}U and is in equilbrium with it, has been used to determine the uranium content in rocks. Although there are other gamma rays quite close to the 93 keV line, yet a Ge(Li) detector can resolve the 93 keV peak to a reasonable extent. The calibration of the system is done by counting 93 keV activity of several NBS standards in a fixed geometry. The unknown samples are then studied in the same geometry. All samples are first crushed to 250 mesh powder and thoroughly homogenized before counting.

This work was carried out at Nuclear Research Laboratory, Govt. College, Lahore.

9) Amplitude Analysis in Nuclear and Particle Reactions

As polarization transfer and spin correlation experiments in nuclear and particle physics have become increasingly versatile, associated theoretical problems have been brought into sharper focus. Pioneers in the development of the relevant theory have been Professor Michael Moravcsik and his group. Interest at PINSTECH has also been developed in this field over the past year or so. Work so far done by members of the Theoretical Physics Group, PINSTECH covers the areas of dtermination of amplitudes from observables and the propagation of errors in the process..

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PROGRESS REPORT

ON NUCLEAR DATA RESEARCH IN

POLAND

May 1975 - April 1976

compiled by

A. Marcinkowski

Editor's Note

This progress report on nuclear data research in Poland contains only information on research, which is closely related to the activities of the International Nuclear Data Committee of the International Atomic Energy Agency in the field of charged particles and neutron physics. It does not include any information about other nuclear research as for example the use of neutrons for solid state physics studies.

The individual reports are not intended to be complete or formal, and must not be quoted in publications without permission of the authors.

DIFFERENTIAL CROSS SECTIONS FOR THE $^{147}Sm(n,\alpha)^{144}Nd$ REACTION INDUCED BY 12.4 MeV AND 18.2 MeV NEUTRONS

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The absolute differential cross sections for the energy spectrum of α-particles emitted in the $^{147}Sm(n,\alpha)^{144}Nd$ at En = 12.4 MeV and for the angular distribution of α particles emitted in the $^{147}Sm(n,\alpha)^{144}Nd$ at En = 18.2 MeV have been measured by direct registration of α particles. The experimental arrangement used in the measurements is described in our earlier work [1]. The neutrons were obtained from the $^{3}H(d,n)^{4}He$ reaction with deuterons accelerated in the 3 MeV Van de Graaff accelerator. The neutron flux was measured by counting the recoil protons from a thin polyethylene foil. Recoil protons were registered by a CsI(Tl) scintillator followed by photomultiplier and standard electronics. The absolute calibration of the monitor was performed by measuring of the 847 keV γ-transition in ^{56}Fe produced in the $^{56}Fe(n,p)^{56}Mn$ reaction with succesive β-decay of ^{56}Mn. The cross section for the $^{56}Fe(n,p)^{56}Mn$ reaction was taken as 110 mb and 57 mb for neutron energies equal to 12.4 and 18.2 MeV respectively [2]. Uncertainty of the monitor calibration amounts to about 20%.

The targets were made of samarium enriched with ^{147}Sm to about 96.4%. The Sm_2O_3 layers /thicknesses of about 2.3 and 3.0 mg/cm^2/ were deposited onto thick carbon backings by sedimentation from suspensions in ispropyl alcohol.

The energy scale calibration of the alpha spectrometer was performed with employment of alphas from ThC and ThC and from the reaction $^{28}Si(n,\alpha)^{25}Mg$ produced in the silicon detector by the incident neutrons.

The results of the absolute differential cross sections for the energy spectrum of α -particles are shown in table 1. In the bottom of the table the energy of neutrons, the angular spread and the energy spread of measurements are shown.

The angular distribution α -particles emitted in the $^{147}Sm(n,\alpha)^{144}Nd$ reaction at 18.2 MeV neutrons are presented in table 2. This distribution contains all α -particles with energies corresponding to excitations of the final nucleus up to 7 MeV. In the bottom of the table 2 the angular spreads of the measurements are also shown. These spreads were calculated by Monte Carlo method [3]. The errors indicated in the tables are only statistical.

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3. L.Zemło, INR Report 1464/I/PL/B (1973)

Table 1

Differential cross sections for $^{147}Sm(n,\alpha)^{144}Nd$ reaction at En = 12.4 MeV

E_α^{lab} [MeV]	$d^2\sigma/d\Omega dE$ [μb/sr MeV]	E_α^{lab} [MeV]	$d^2\sigma/d\Omega dE$ [μb/sr MeV]	E_α^{lab} [MeV]	$d^2\sigma/d\Omega dE$ [μb/sr MeV]
14.79	44.7± 98.0	17.58	184.6± 44.7	20.37	173.8± 29.7
14.89	116.8±101.3	17.68	250.6± 45.7	20.47	91.4± 24.0
14.99	161.6± 87.6	17.78	260.9± 45.2	20.56	136.6± 25.9
15.09	10.8± 81.5	17.88	253.9± 46.2	20.66	86.7± 21.7
15.19	31.6± 75.8	17.98	243.0± 45.7	20.76	81.5± 21.2
15.29	129.1± 71.1	18.07	244.0± 41.9	20.86	99.9± 21.7
15.39	125.3± 69.7	18.17	327.8± 44.7	20.96	105.5± 23.1
15.49	-20.3± 68.3	18.27	281.2± 42.9	21.06	92.8± 22.1
15.58	138.9± 70.7	18.37	326.4± 45.2	21.16	59.3± 16.5
15.68	89.0± 66.4	18.47	330.6± 43.8	21.26	40.5± 14.1
15.78	54.2± 65.5	18.57	293.4± 42.4	21.36	44.3± 15.5
15.88	114.9± 65.0	18.67	306.2± 41.0	21.46	67.8± 17.9
15.98	24.5± 63.1	18.77	292.0± 41.9	21.56	57.0± 16.5
16.08	72.1± 57.0	18.87	287.3± 40.5	21.66	38.6± 15.1
16.18	183.2± 56.5	18.97	210.1± 35.3	21.76	51.8± 16.5
16.28	106.0± 56.0	19.07	176.6± 34.9	21.86	61.7± 17.4
16.38	110.2± 55.1	19.17	187.5± 36.7	21.96	69.7± 19.3
16.48	121.5± 53.2	19.27	137.5± 32.5	22.06	86.7± 21.2
16.58	153.5± 50.9	19.37	116.8± 29.7	22.16	69.7± 18.8
16.68	163.4± 55.1	19.47	148.4± 31.1	22.26	73.5± 18.4
16.78	189.8± 52.8	19.57	137.5± 27.3	22.36	62.6± 17.0
16.88	245.9± 51.3	19.67	113.0± 25.9	22.46	61.7± 17.0
16.98	187.0± 51.3	19.77	136.1± 27.3	22.56	27.8± 11.3
17.08	208.2± 49.0	19.87	86.7± 20.7	22.66	22.6± 11.3
17.18	268.9± 48.0	19.97	55.6± 18.8	22.76	33.9± 13.7
17.28	146.5± 46.6	20.07	118.7± 24.0	22.86	30.1± 11.8
17.38	195.9± 48.5	20.17	119.2± 24.5	22.96	18.8± 9.4
17.48	246.8± 50.9	20.27	130.5± 25.4		

Cross section integrated in the 14.75-22.96 MeV range is equal to 1.12 ± 0.04 mb/sr

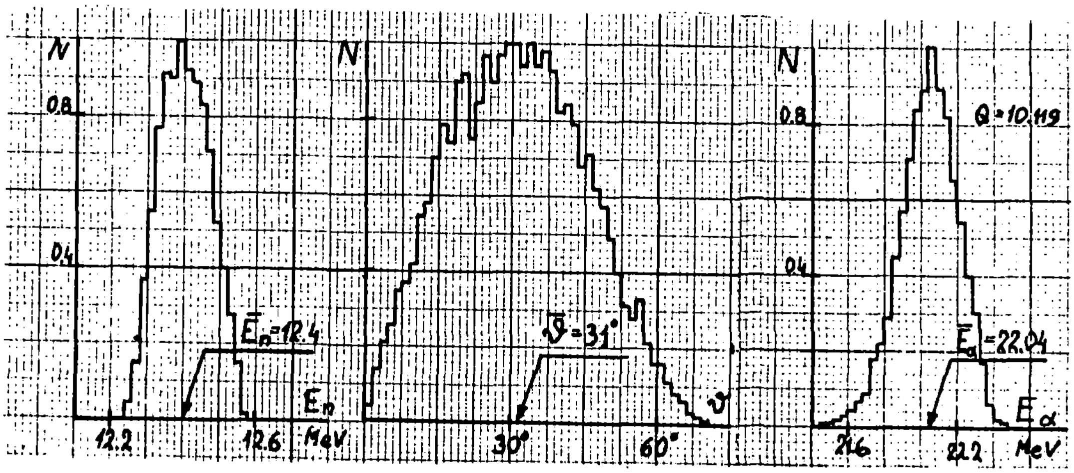
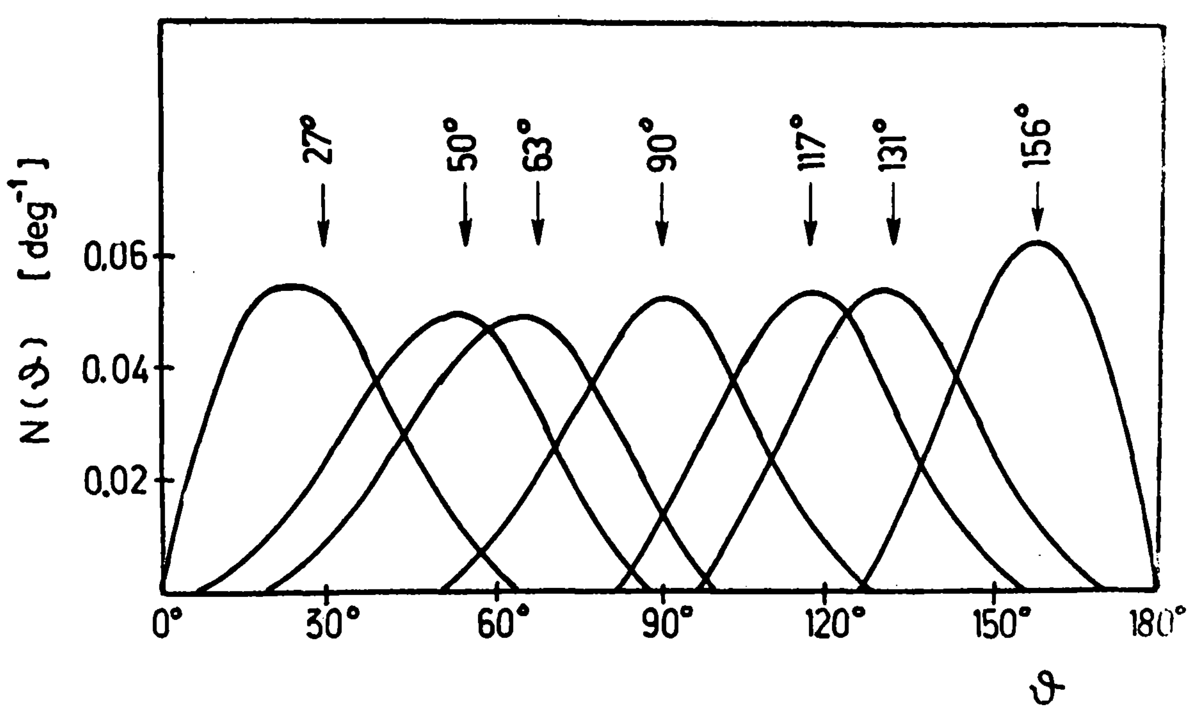


Table 2
Angular distribution of α-particles for $^{147}Sm(n,\alpha)\,^{144}Nd$ reaction at En = 18.2 MeV.

$\bar{\vartheta}$ [deg]	$d\sigma/d\Omega$ [mb/sr]
27	1.13 ± 0.05
50	0.50 ± 0.05
63	0.25 ± 0.07
90	0.14 ± 0.05
117	0.01 ± 0.05
131	-0.05 ± 0.06
156	0.09 ± 0.06



ANGULAR DISTRIBUTION OF α PARTICLES FROM (the) $^{14}N(n,\alpha)^{11}B$ REACTION AT 14.1 MeV

S.Burzyński, K.Rusek, W.Smolec, I.M.Turkiewicz, J.Turkiewicz and P.Żuprański

The absolute diferential cross sections for the $^{14}N(n,\alpha)^{11}B$ reaction have been studied by direct registration of α particles with a telescopic system. The experimental set up was described in our earlier work [1].

The nitrogen target was prepared by evaporation of melamine $C_3H_6N_6$ onto tantalum foil.

The thickness of the nitrogen target amounted to 1.5 mg/cm^2. The results are presented in Tables 1-2 (and in Figs.1,2). Data are given in c.m. system. The angular spreads were calculated with a Monte Carlo method [2]. The cross section errors are only statistical.

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Table I

Differential cross sections for the $^{14}N(n,\alpha_0)^{11}B$ reaction at neutron energy 14.1 MeV

ϑ [deg]	$\Delta\vartheta$ [deg]	$d\sigma/d\Omega$ [mb/sr]	$\Delta d\sigma/d\Omega$ [mb/sr]
11.0	5.7	3.54	0.12
17.4	5.5	2.58	0.10
25.1	5.5	2.25	0.11
46.8	5.5	0.58	0.06
57.6	4.5	0.64	0.07
68.4	3.5	0.75	0.07
79.0	3.3	0.73	0.07
89.5	3.0	0.43	0.06
99.5	2.5	0.86	0.08
109.4	2.3	0.35	0.06
128.2	2.3	0.42	0.13

Table II

Differential cross sections for the $^{14}N(n,\alpha_1)^{11}B$ reaction at neutron energy 14.1 MeV

ϑ [deg]	$\Delta\vartheta$ [deg]	$d\sigma/d\Omega$ [mb/sr]	$\Delta d\sigma/d\Omega$ [mb/sr]
11.1	5.7	1.17	0.09
17.6	5.5	1.03	0.08
25.4	5.5	1.20	0.08
47.3	5.5	0.48	0.06
58.3	4.3	0.45	0.06
69.1	3.5	0.16	0.04
80.0	3.3	0.16	0.05
90.3	3.0	0.23	0.05
100.4	2.5	0.46	0.11
110.2	2.3	0.02	0.10
128.9	2.3	0.04	0.33

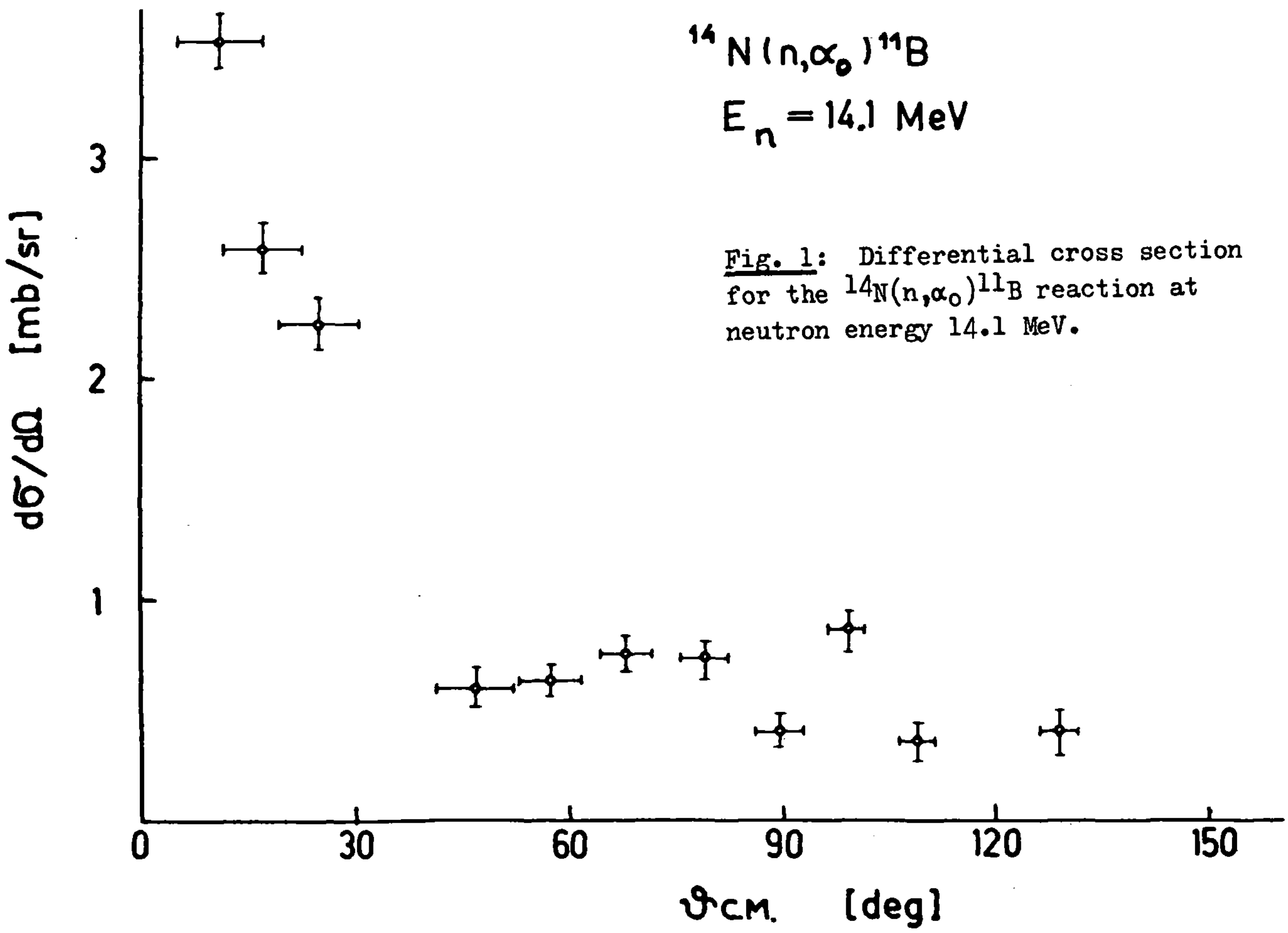

Fig. 1: Differential cross section for the $^{14}N(n,\alpha_0)^{11}B$ reaction at neutron energy 14.1 MeV.

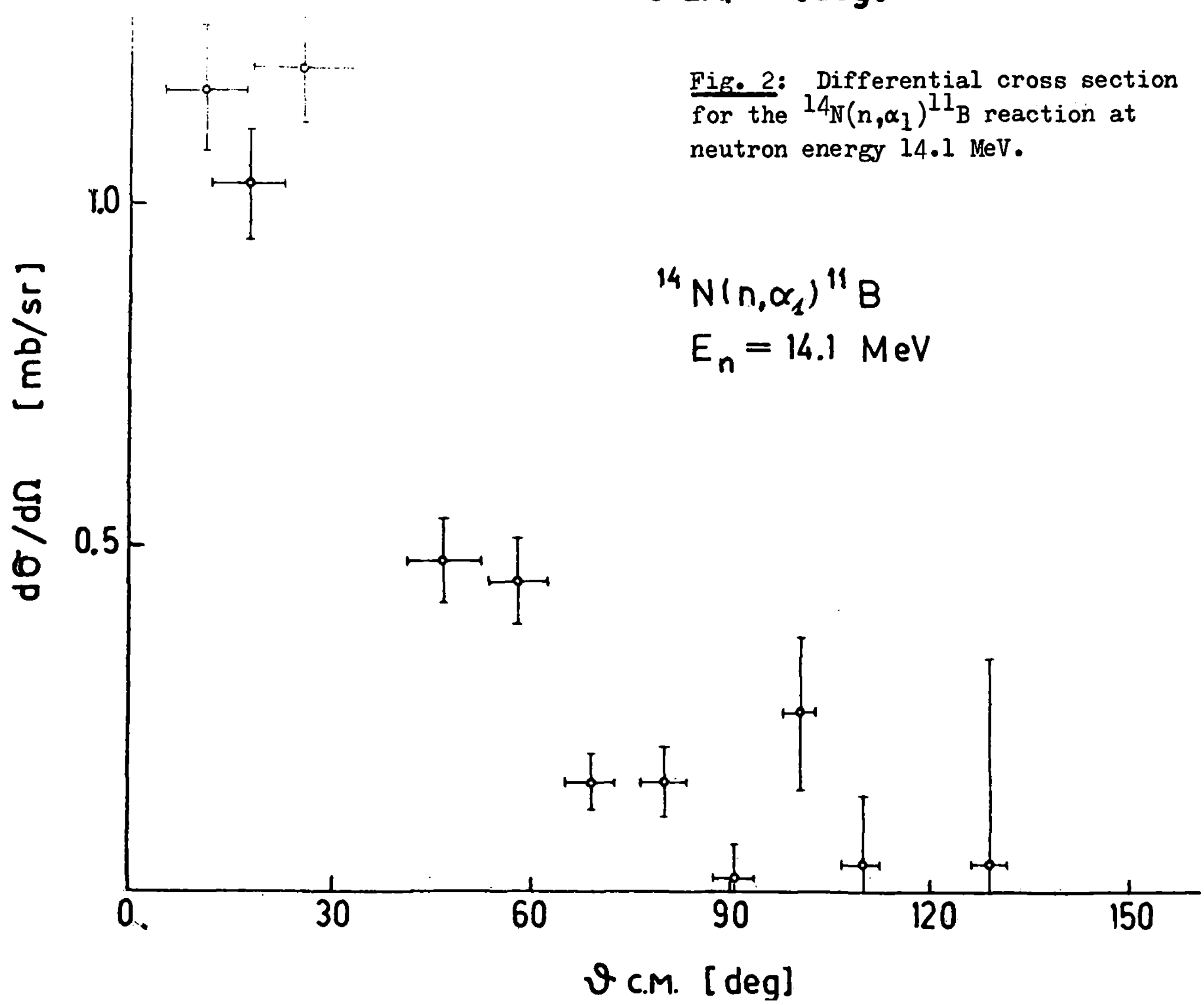

Fig. 2: Differential cross section for the $^{14}N(n,\alpha_1)^{11}B$ reaction at neutron energy 14.1 MeV.

Cross Sections for /n,alpha/ Reactions on the ^{31}P, ^{51}V, ^{55}Mn, ^{59}Co, ^{75}As and ^{93}Nb Nuclei in the Neutron Energy Range 13- 18 MeV.

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The activation method was used to measure the cross sections of the $^{31}P/n,\alpha/\ ^{28}Al$, $^{51}V/n,\alpha/\ ^{48}Sc$, $^{55}Mn/n,\alpha/\ ^{52}V$, $^{59}Co/n,\alpha/\ ^{56}Mn$, $^{75}As/n,\alpha/\ ^{72}Ga$ and $^{93}Nb\ /n,\alpha/\ ^{90m}Y$ reactions in the neutron energy range from 13.0 MeV to 17.8 MeV.
The $^{3}H/d,n/^{4}He$ reaction induced by deuterons of energies from 0.4 MeV to 1.8 MeV was used as a source of monoenergetic neutrons. Neutron energies were varied by the change of the irradiation angle of the samples and by using different deuteron energies.
The γ- activities of the irradiated samples were measured with a 30 cm^3 Ge/Li/ spectrometer.The corresponding level schemes and transition probabilities were taken from the tables of Lederer et al [1] .Relative detector efficiencies for the γ ray energies involved were determined with ^{226}Ra, ^{169}Yb and ^{133}Ba sources[2-4] .The cross sections of the investigated reactions were measured in reference to the $^{56}Fe/n,p/\ ^{56}Mn$ reaction cross section,using the cross section values given by Liskien and Paulsen [5] .
The details of the samples used are given in table 1 together with

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the characteristics of the γ transitions employed. The experimental results are presented in table 2. The mean neutron energies and energy spreads were calculated with a Monte Carlo method [6] taking into account the kinematics of the $^{3}H/d,n/^{4}He$ reaction and the deuteron energy loss in the target. The errors quoted for the cross sections consist of the statistical error, the uncertainty of the neutron flux, the error of the detector efficiency, the error of the sample weight and the reference cross section error.

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Table 1

The details of the samples and the characteristics of the γ transitions

Reaction	Sample	γ-transition energy MeV	Half-life
$^{31}P/n,\alpha/^{28}Al$	red phosphorus, analytical reagent	1.780	2.30 min
$^{51}V/n,\alpha/^{48}Sc$	spectroscopically pure vanadium	0.983	1.83 day
$^{55}Mn/n,\alpha/^{52}V$	spectroscopically pure manganese	1.434	3.76 min
$^{59}Co/n,\alpha/^{56}Mn$	spectroscopically pure cobalt	0.847	2.58 h
$^{75}As/n,\alpha/^{72}Ga$	arsenic, analytical reagent	0.835	14.10 h
$^{93}Nb/n,\alpha/^{90m}Y$	niobium oxide $/Nb_2O_5/$, analytical reagent	0.202	3.10 h

Table 2

	Measured Cross Sections (mb)									
Neutron energy /MeV/	13.0±0.1	13.3±0.1	13.9±0.2	14.5±0.2	15.1±0.1	15.5±0.2	15.9±0.1	16.6±0.2	17.4±0.1	17.8±0.2
Reaction										
$^{31}P/n,\alpha/^{28}Al$	126.9±10.5	131.5±7.0	126.0±6.6	123.3±5.9	109.7±5.6	93.5±4.7	90.8±8.0	82.3±6.7	68.7±4.7	55.7±4.5
$^{51}V/n,\alpha/^{48}Sc$	13.5±1.0	13.2±0.8	15.1±0.9	14.7±0.9	15.6±1.0	16.9±1.2	16.4±1.2	16.4±1.4	18.3±1.7	17.0±1.5
$^{55}Mn/n,\alpha/^{52}V$	21.9±2.1	21.8±1.3	24.1±1.5	27.7±1.6	29.2±1.9	24.9±1.8	23.7±2.2	23.9±2.6	21.3±2.6	18.1±2.4
$^{59}Co/n,\alpha/^{56}Mn$	25.8±1.2	29.0±1.4	29.5±1.3	27.4±1.3	25.9±1.3	25.9±1.4	25.1±1.6	23.7±1.5	22.4±1.6	19.0±1.5
$^{75}As/n,\alpha/^{72}Ga$	9.2±0.5	10.0±0.5	10.1±0.6	11.0±0.6	9.9±0.6	9.8±0.6	9.9±0.7	9.8±0.7	9.1±0.7	8.4±0.6
$^{93}Nb/n,\alpha/^{90m}Y$	4.5±0.5	3.6±0.3	3.7±0.3	4.9±0.3	5.7±0.3	6.1±0.5	5.2±0.4	5.1±0.5	4.9±0.4	4.4±0.4

Cross Sections for Fast Neutron Induced Reactions on Palladium and Osmium Isotopes

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Excitation curves of the (n,p) and (n,2n) reactions were measured using the activation method. Samples of high purity Pd and Os were irradiated with neutrons from the $^{3}H(d,n)^{4}He$ reaction. Tritium absorbed targets were bombarded with deuterons accelerated in a Van de Graaff accelerator ~~up to~~ to the energies 0.44 MeV, 0.99 MeV and 1.80 MeV. The neutron energy in the range 12.9 - 17.8 MeV was selected by a suitable choice of the emission angle. The reaction products were identified by their characteristic γ-decay. The neutron induced γ-activity of the samples was measured with the use of a 30 cm^3 Ge(Li) detector. Relative efficiency of the detector has been determined with help of ^{226}Ra, ^{163}Yb and ^{133}Ba sources of known γ-ray branching ratios [1 - 3].

In table I we specify the details of the decay characteristics of the investigated residual nuclei, adopted in the present data analysis. The measured cross sections were refered to the cross sections of the neutron monitoring reaction $^{56}Fe(n,p)^{56}Mn$ [4]. The results of cross section measurements are presented in tables II and III . These cross sections were corrected for the attenuation of γ-rays in the samples. The attenuation factor was calculated by the Monte Carlo method with use of a FORTRAN code SELFA [5]. Its values for the different γ-ray energies are attached in table I (last column) . Special attention was paid to correcting of the cross sections of the (n,2n) reaction for the contribution from (n,γ) reaction on target isotope with mass number lower by two units, when present in the sample, which leads to the same residual nucleus as the (n,2n) reaction. The (n,γ) reaction is induced with considerable cross sections by the low energy neutrons arrising from the $^{2}H(d,n)^{3}He$ reaction due to deuterons accumulated in the tritium target during deuteron bombardment. It was found that the $^{108}Pd(n,\gamma)^{109}Pd$ reaction has influenced considerably the measured cross sections of the $^{110}Pd(n,2n)^{109}Pd$ reaction at deuteron energies higher than 0.5 MeV and at small emission angles.

The erroes attached in table II and III contain the statistical errore as well as the systematic errors. The latter ones consist of uncertainties: (a) caused by fluctuations of the beam current during irradiation 0.8%, (b) sample weight < 1%, (c) of counter efficiency 5 - 8%, (d) of the γ-ray attenuation in the sample < 2%, (e) in the integration of the pulse height spectrum 2 - 9%, (f) of the cross sections of the monitoring reaction 3 - 5%. The neutron energy spread was determined from the energy distribution of neutrons incident on the samples, calculated with the use of the Monte Carlo code LOS [6].

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Table I

Decay and sample characteristics

Reaction	E_γ keV	$T_{1/2}$	branching ratio	conversion coeff.	target isotope abundance	γ-ray attenuation in the sample
$^{102}Pd(n,2n)^{101}Pd$	296	8.4 h	0.1836	0.019	0.0088	0.9538
$^{105}Pd(n,p)^{105}Pd$	319	35,9 h	0.1998	-	0.224	0.9563
$^{110}Pd(n,2n)^{109g}Pd$	87.7	13.47h	0.9999	22.4	0.1265	0.6033
$^{110}Pd(n,2n)^{109m}Pd$	188	4.7 min	1.0000	0.52	0.1265	0.9074
$^{192}Os(n,2n)^{191g}Os$	129	15.0 d	0.986	1.9	0.41	0.6060
$^{192}Os(n,2n)^{191m}Os$	129	13.0 h	0.986	1.9	0.41	0.6060

Table II

Neutron energy MeV	Reaction cross sections in mb										
	12.9±0.2	13.0±0.1	13.3±0.1	13.9±0.3	14.5±0.2	15.1±0.1	15.5±0.1	15.9±0.1	16.6±0.2	17.4±0.1	17.8±0.2
Reaction											
$^{102}Pd(n,2n)^{101}Pd$	470±110	718±86	904±64	984±70	1227±87	1180±94	1025±79	1011±99	1102±110	1051±155	1085±148
$^{105}Pd(n,p)^{105}Rh$*		32.4±4.5	31.2±2.0	33.7±2.0	39.7±2.2	40.3±2.7	42.0±2.4	42.8±4.1	44.8±4.4	68.9±9.0	75.9±9.3
$^{110}Pd(n,2n)^{109}Pd$	1810±250	1814±169	1727±124	1855±134	1884±136	1786±138	1731±125	1507±143	1524±149	1558±254	1433±246
$^{192}Os(n,2n)^{191}Os$		2552±138	2246±85	2156±89	2370±103	2091±80	1890±77	1894±98	1625±103		
$^{192}Os(n,2n)^{191m}Os$		1130±226	854±205	720±173	1067±318	711±73	719±112	828±84	795±99		

* measured $^{105}Pd(n,p)^{105}Rh + ^{106}Pd(n,np)^{105}Rh + ^{106}Pd(n,pn)^{105}Rh + ^{106}Pd(n,d)^{105}Rh$

Table III

Neutron energy MeV	Reaction cross sections in mb							
	13.0±0.1	13.6±0.3	13.9±0.3	14.5±0.2	14.8±0.3	15.4±0.1	15.9±0.1	16.6±0.2
Reaction								
$^{110}Pd(n,2n)^{109m}Pd$	516±49	411±25	508±31	462±29	452±33	482±30	596±56	537±50

The decay of ^{128}Cs to levels in ^{128}Xe

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The level structure of ^{128}Xe has been studied from the β^+ decay of ^{128}Cs by observing gamma rays and gamma-gamma coincidences. The ^{128}Cs sources were produced in the ^{128}Xe $(pn)^{128}Cs$ reaction at a proton energy of $E \approx 9.5$ MeV. The measurements were performed using two Ge(Li) detectors, the standard ORTEC coincidence circuitry and the Nuclear Data 4420 multiparametric system.

The coincidence data and the energy sums allow us to construct the decay scheme of ^{128}Cs shown in Fig. 1. The energies and intensities of gamma transitions belonging to ^{128}Cs decay are listed in Table 1. The half - life of ^{128}Cs as measured by us is equal to (3.62 ± 0.02) min what is in agreement with the result of Ref. [1]. For the log ft calculation we used $Q_{EC} = (3928 \pm 6)$ keV taken from Ref. [2] and we assumed that $I_{\beta^+}(442)/I_{\beta^+}$ (ground state) = 0.35 [2,3]. The analysis of log ft values and branching ratios of the gamma transitions allow us to conclude the spin values which are shown in Fig. 1. In addition to that, the 1032.8 keV level can probably be identified with the (1033 ± 1) keV state observed by Bergström et al. [4]. The spin value 4^+ assigned in [4] is consistent with the log ft value found by us. Taking into account systematic trends in the level schemes of $^{124, 126, 130, 132, 134}Xe$ nuclei one can suggest a spin 3^+ for the 1429.4 keV level.

The structure of ^{128}Xe nuclei cannot be described in terms of the harmonic vibrator or rigid rotator models because of the energy ratios of levels and the branching ratios of gamma transitions which are far from the vibrational and rotational limits. It was the reason that the model described by Rohoziński et al. [5] which takes into account the softness of nuclei for the gamma deformation was used. Using formulae and parameters given in [5] one can obtain for ^{128}Xe the results presented in Table 2. It seems that the theoretical values given in Table 2 are in satisfactory agreement with the experimental ones for energy levels below 1.8 MeV (for the high spin levels see Ref. [4]). For energy levels higher than 2 MeV the situation becomes more complicated because of the occurence of the two-quasiparticle states.

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Table 1

Energies and intensities of the gamma transitions observed in $^{128}Cs \rightarrow {}^{128}Xe$ decay

E_γ (keV)		I_γ		E_γ (keV)		I_γ	
442.76	(11)	100.0		1663.65	(21)	0.083	(5)
460.07	(37)	0.12	(2)	1684.14	(9)	0.40	(2)
526.47	(10)	9.1	(5)	1918.81	(12)	0.136	(7)
570.23	(13)	0.08	(1)	1977.94	(10)	0.173	(7)
590.04	(11)	0.24	(1)	1987.83	(12)	0.094	(5)
613.41	(9)	1.23	(6)	2039.38	(13)	0.108	(5)
969.41	(8)	2.18	(9)	2077.89	(37)	0.035	(4)
986.60	(14)	0.103	(7)	2148.65	(14)	0.148	(8)
1030.21	(8)	0.70	(4)	2155.67	(11)	0.54	(2)
1081.16	(17)	0.056	(5)	2190.34	(12)	0.19	(1)
1140.04	(8)	3.9	(2)	2275.62	(18)	0.057	(4)
1161.19	(50)	0.03	(1)	2361.99	(12)	0.194	(8)
1239.68	(27)	0.059	(6)	2394.38	(14)	0.074	(5)
1303.40	(9)	0.40	(2)	2416.43	(13)	0.119	(5)
1340.33	(14)	0.037	(6)	2430.39	(21)	0.026	(3)
1392.91	(16)	0.046	(6)	2592.08	(26)	0.025	(2)
1513.12	(10)	0.195	(9)	2633.65	(35)	0.022	(2)
1541.11	(16)	0.064	(4)	2859.69	(29)	0.020	(2)
1629.10	(9)	0.47	(2)	2937.49	(35)	0.009	(2)
1644.93	(41)	0.033	(5)				

The errors of the experimental data are given in parenthesis in units of the last digit.

Table 2

Spins and energies of levels in ^{128}Xe in terms of the Wilets-Jean model; the parameters $C = 160$ MeV, $B = 50$ MeV^{-1}, $\beta_0 = 0.28$ taken from Rohoziński et al. [5].

$E_{n_\beta,\lambda} - E_{0,0}$ (MeV)	Quantum numbers n_β, λ	Spin and parity
0.440	0,1	2^+
1.020	0,2	$2^+, 4^+$
1.692	0,3	$0^+, 3^+, 4^+, 6^+$
1.789	1,0	0^+
2.229	1,1	2^+
2.423	0,4	$2^+, 4^+, 5^+, 6^+, 8^+$
2.809	1,2	$2^+, 4^+$
3.193	0,5	$2^+, 4^+, 5^+, 6^+, 7^+, 8^+, 10^+$
3.481	1,3	$0^+, 3^+, 4^+, 6^+$

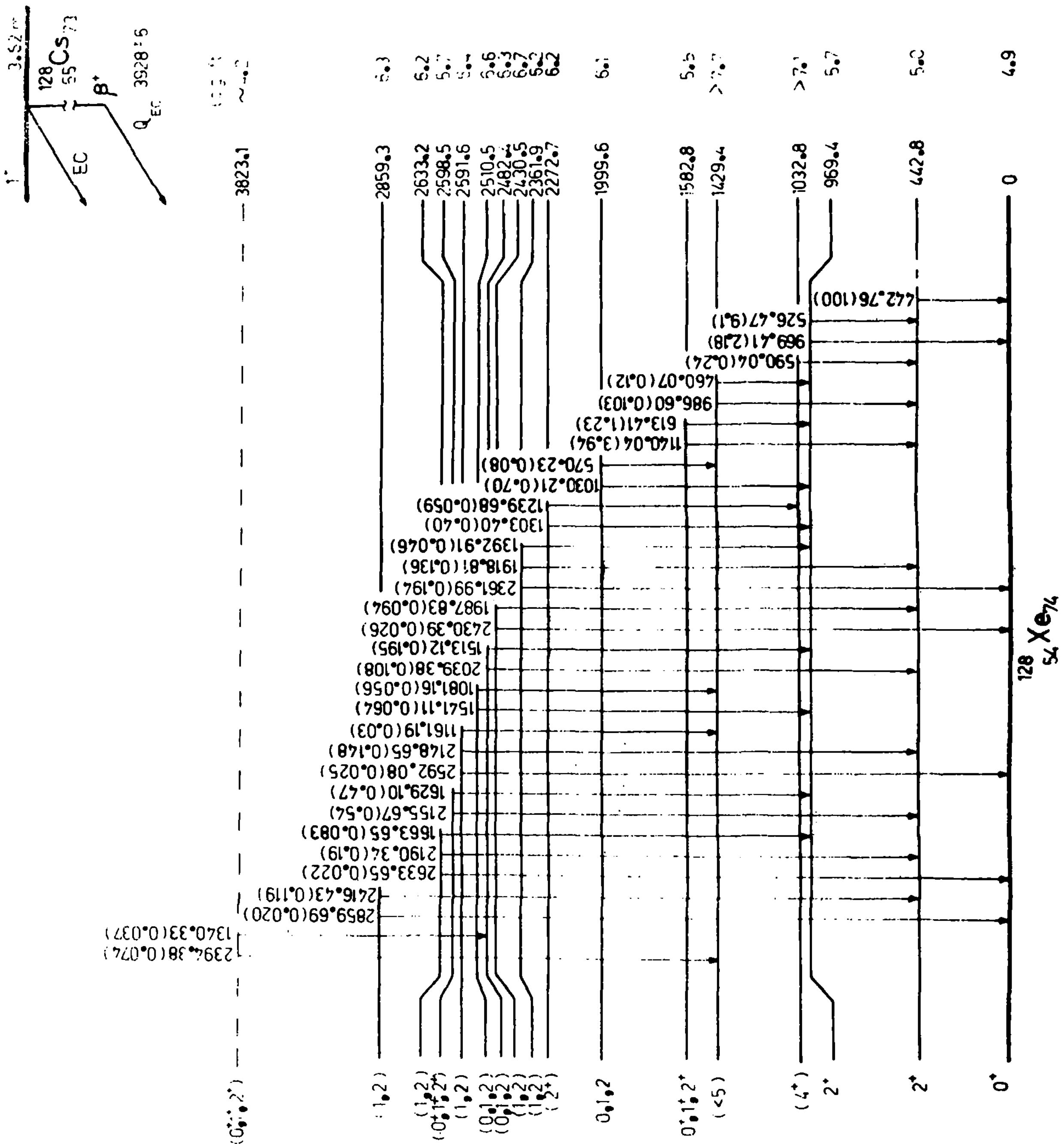

Fig. 1. Decay scheme of ^{128}Cs. The energy available for the electron - capture decay Q_{EC} was taken from [2].

ANGULAR DISTRIBUTION OF 14 MeV NEUTRONS SCATTERED ON SILICON TO ISOLATED STATES IN A VERY WIDE ANGULAR RANGE

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The problem of obtaining reliable experimental data for the analysis of nuclear scattering is of great importance. Usually the data are restricted to an easily accessible angular range. Few attempts have been made to extend the known range to the small angle scattering and to the backward scattering region [1, 2, 3].

Differential cross sections for 14 MeV neutrons scattered on silicon have been measured by several authors. However, their measurements were restricted to certain parts of the angular range see, e.g. [4, 5, 6]. The experiment of Bonazzola et al. [3] extended those data to the extreme backward angles. In our laboratory differential cross sections for transitions to the ground and to the first excited states have been neasured using the same nethod, in an angular range from 6.2^{o} to 176.6^{o}. Plate geometry was used throughout the experiment and two small /1.5" x 1.5"/ liquid scintillators detected the scattered neutrons at the same angle at a distance of 135 cm or 160 cm from the scatterer. The scatterer /40 cm x 20 cm x 2 cm/ was high purity natural silicon.

The time-of-flight spectrometer worked with associated particle method. The time spectra of neutrons and gamma rays were detected for both detectors. In order to diminish the background very efficient neutron gamma discrimination was used and the experimental conditions have been carefully chosen. A single run took approximately 72 hours. The stability of the resolution obtained was high. This allowed a complete separation of the measured transitions. The resolution was checked during the experiment by an auxiliary electronic pulse and by the shape of the fast gamma peak. For any long time run the gamma peak half width was better than 1 nsec. The intensity of those peaks was a check for the quality of monitoring, and of the stability of the detector efficiency. Fig. 1 schematically shows the experimental arrangement and Fig. 2 gives two examples of the neutron and gamma ray time spectra for two angles. The neutron differential cross sections measurements were corrected for the shape of the incident neutron flux distribution, for finite angular resolution of the system as well as for attenuation and multiple scattering of neutrons in the sample. There is a good agreement with most of the known data except the extreme backward angles. Our analysis led us to the conclusion that this discrepancy is due to unsatisfactory resolution of the quoted data [3].

The very large angular range allows an interesting analysis, because the backward scattered neutrons come much closer to the scattering centre. Thus some valuable results on the LS coupling potential have been obtained. The obtained deformation parameter β_2 is in good agreement with the other known data. The results of the analysis by the DWBA and coupled-channels theories will be published elsewhere [8]. Additional informations on experimental details are given in [7, 8, 9].

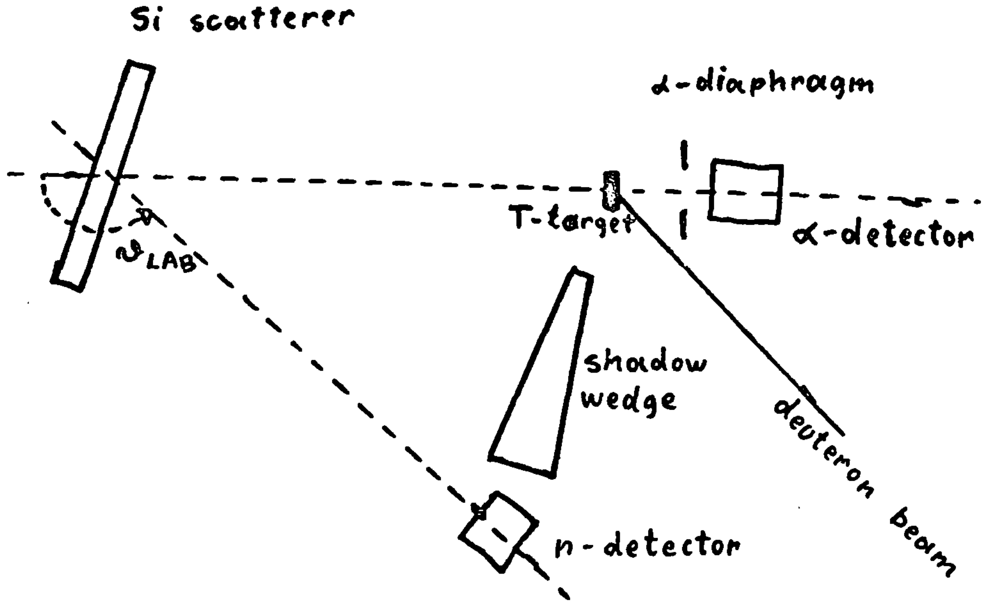

Fig. 1. Experimental arrangement - top view

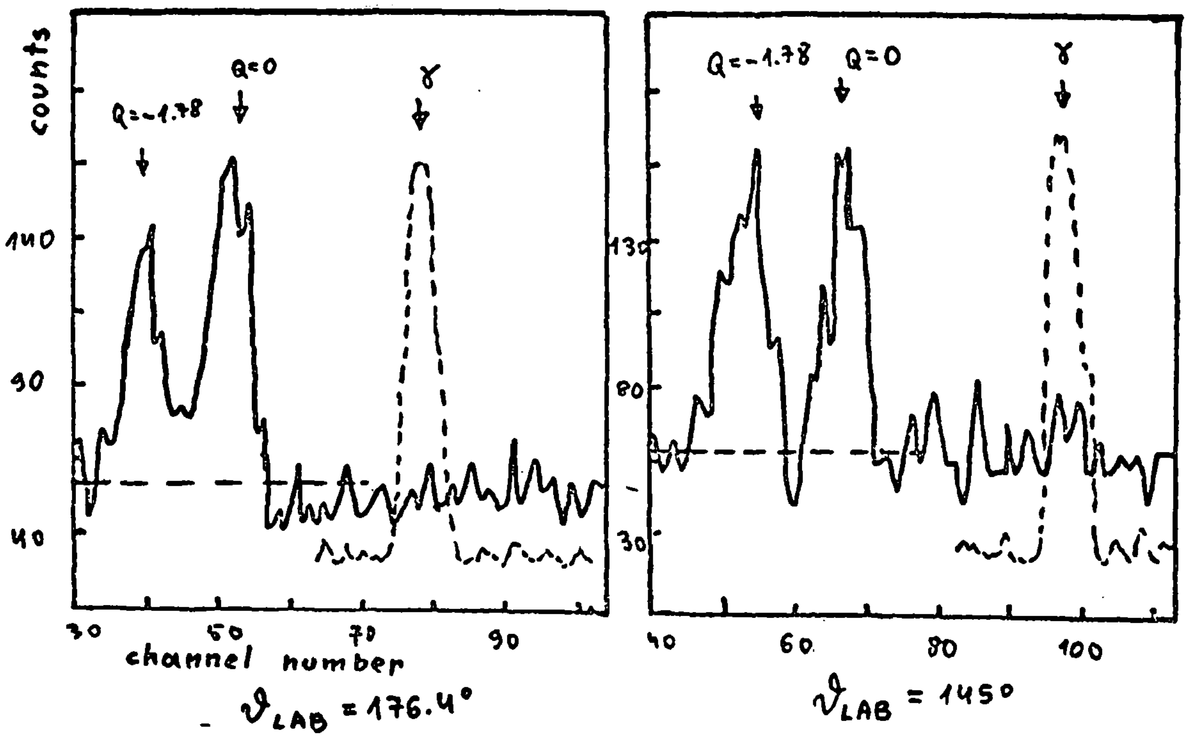

Fig. 2. Examples of the neutron and gamma ray time spectra

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ANGULAR DISTRIBUTION OF ALPHA PARTICLES FROM $^{14}N(n,\alpha)^{11}B$ REACTION AT 18.0 MeV

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The telescopic system described in our earlier work [1] has been used for the study of the $^{14}N(n,\alpha)^{11}B$ reaction induced by 18.0 ± 0.26 MeV neutrons. Neutrons were obtained from the $^{3}He(d,n)^{4}He$ reaction using the 2 MeV deuteron beam from the Van de Graaff accelerator. The flux of neutrons was measured by proton - recoil counter. The nitrogen target was prepared by evaporation of melamine $(C_3H_6N_6)$ onto a tantalum foil. The thickness of the target amounted to 1.5 mg/cm^2. The three - - dimentional analyses of each event enregistered in the telescope was performed with Nuclear Data 4420 multiparameter system. All events were stored on a CDC compatible magnetic tape and then fed for further processing off line to obtain alpha - particle energy spectra. Fig. 1 presents an alpha - particle spectrum taken with the telescope set at zero degree. Two groups of alphas coresponding to the transitions to the ground (α_0) and the first excited (α_1) states of the ^{11}B nucleus can be distinguished. The angular distributions of alpha particles are presented in Tables I and II, and also in Fig. 2. The data are given in c.m. system. The angular spreads were calculated with a Monte Carlo method [2]. The indicated errors are statictical only.

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TABLE I

$E_n = 18$ MeV $\quad$ $^{14}N(n, \alpha_0)^{11}B$

Θ [deg]	$\Delta\Theta$ [deg]	$d\sigma/d\Omega$ [mb/sr]	$\Delta\, d\sigma/d\Omega$ [mb/sr]
11.0	6.0	0.62	0.07
15.0	6.0	0.72	0.11
25.0	5.0	0.60	0.11
36.0	5.0	0.66	0.11
47.0	5.0	0.61	0.08
58.0	5.0	0.33	0.19
68.5	4.5	0.43	0.09
79.0	4.0	0.31	0.07
94.5	4.0	0.21	0.09
109.4	3.0	0.37	0.10
125.0	2.8	0.03	0.16
146.0	2.5	0.63	0.12

TABLE II

$E_n = 18$ MeV $\quad$ $^{14}N(n, \alpha_1)^{11}B$

Θ [deg]	$\Delta\Theta$ [deg]	$d\sigma/d\Omega$ [mb/sr]	$\Delta\, d\sigma/d\Omega$ [mb/sr]
11.0	6.0	0.84	0.08
15.3	5.5	0.45	0.11
25.3	6.0	0.53	0.11
36.3	5.5	0.65	0.09
47.3	5.5	0.90	0.09
58.3	5.0	1.01	0.19
69.0	4.5	0.51	0.09
79.7	4.5	0.25	0.08
95.0	4.0	0.38	0.10
110.0	3.5	0.36	0.10
125.0	2.8	0.0	0.05
146.4	2.7	0.48	0.20

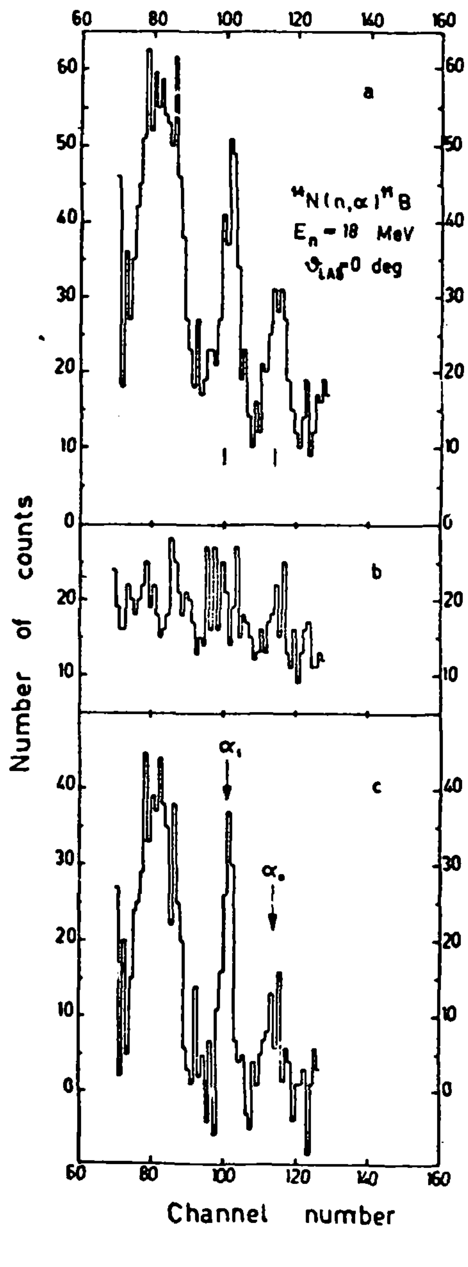

Fig. 1. The alpha-particle spectra at zero degree.

a/ The alpha spectrum measured with melamine target.

b/ The background spectrum.

c/ The background - corrected spectrum of alpha particles from the $^{14}N(n,\alpha)^{11}B$ reaction.

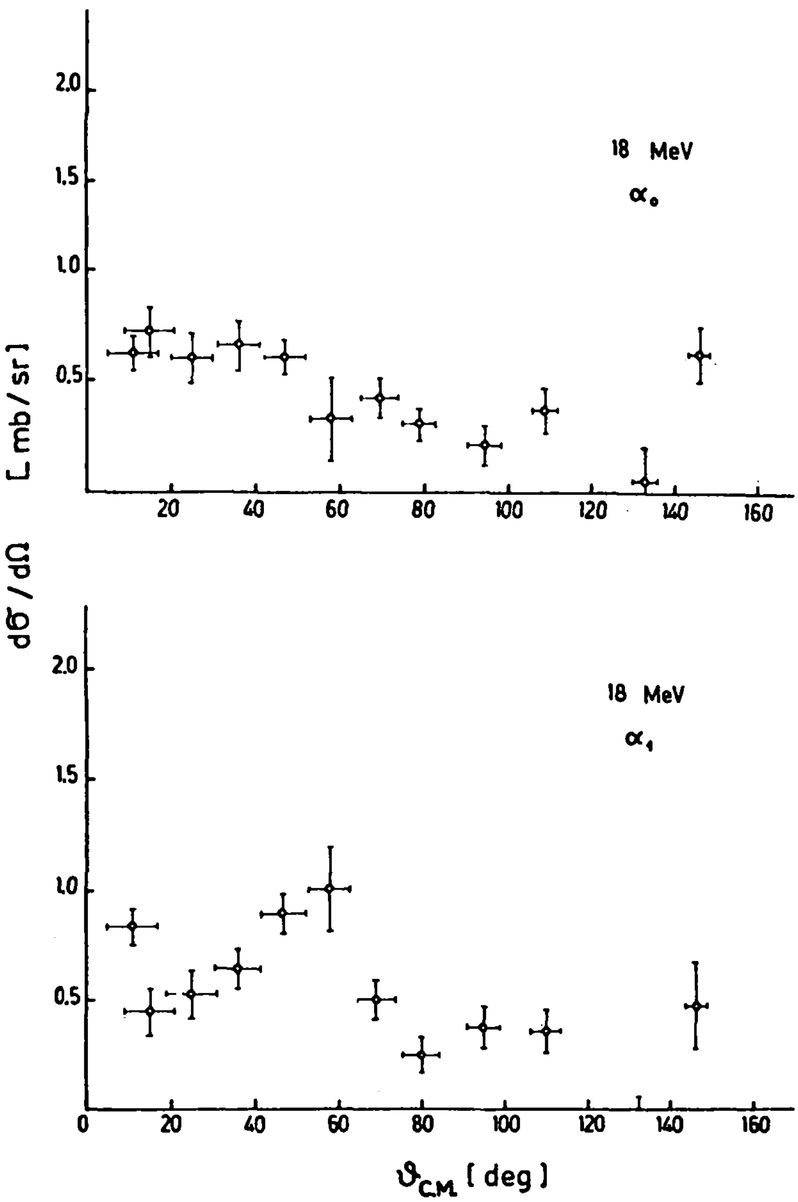

Fig. 2. The angular distributions of alpha particles leading to the ground (α_0) and the first (α_1) excited states of ^{11}B.

DIFFERENTIAL CROSS SECTIONS FOR THE $^{143}Nd(n,\alpha)^{140}Ce$ REACTION INDUCED BY 18.2 MeV NEUTRONS

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Using semiconductor α -particle spectrometer [1] the energy distribution of α -particles from $^{143}Nd(n,\alpha)^{140}Ce$ reaction at $E_n = 18.20 \pm 0.16$ MeV have been measured. The neutrons were obtained in the Van de Graaff accelerator LECH from the $^{3}H(d,n)^{4}He$ reaction. The neutron flux was monitored by counting the recoil protons from thin polyethylene foil. The absolute calibration of neutron monitor was performed by using the activation method. The measurements were refered to $^{56}Fe(n,p)^{56}Mn$ reaction, the cross section for which was accepted as 57 mb for neutron energy 18.2 MeV [2]. Uncertainty of the monitor calibration amounts to about 15%. The samples of neodymium were made of oxide Nd_2O_3 isotopically enriched in ^{143}Nd (88.4%). The target thickness was equal to 3 mg/cm^2.

The results of the absolute differential cross sections are listed in Table 1 and also presented in Fig. 1. Only statistical errors are included. As can be seen from the Fig. 1 the characteristic feature of the α -particle spectrum is the presence of two peaks corresponding to the ground state and excited states of the residual nucleus ^{140}Ce.

In Fig. 2 the energy distribution of neutrons the angular spread and the energy spread of measurements are shown. These spreads were calculated by Monte Carlo method [3].

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TABLE 1

Differential cross sections for $^{143}Nd(n, \alpha)^{140}Ce$ reaction

at E_n = 18.2 MeV

E_α^{lab} [MeV]	$d^2\sigma/d\Omega dE$ [μb/sr·MeV]	E_α^{lab} [MeV]	$d^2\sigma/d\Omega dE$ [μb/sr·MeV]	E_α^{lab} [MeV]	$d^2\sigma/d\Omega dE$ [μb/sr·MeV]
20.00	218.7± 66.2	22.90	373.9± 46.0	25.80	57.0± 19.0
20.10	225.1± 62.0	23.00	323.8± 45.5	25.90	38.1± 14.7
20.20	353.9± 60.6	23.10	341.1± 43.0	26.00	29.5± 11.8
20.30	259.6± 59.3	23.20	302.8± 39.7	26.10	35.2± 13.0
20.40	181.5± 58.0	23.30	318.0± 39.2	26.20	53.9± 13.8
20.50	242.7± 57.8	23.40	391.7± 39.8	26.30	14.1± 13.2
20.60	153.0± 56.0	23.50	395.8± 40.8	26.40	11.6± 12.3
20.70	219.7± 55.1	23.60	377.4± 41.2	26.50	-10.2± 10.2
20.80	268.2± 55.1	23.70	537.7± 45.1	26.60	14.4± 10.4
20.90	135.9± 53.9	23.80	452.2± 41.9	26.70	19.0± 10.2
21.00	178.5± 54.7	23.90	423.4± 40.9	26.80	16.9± 9.6
21.10	219.7± 53.7	24.00	380.9± 41.5	26.90	13.5± 11.0
21.20	247.1± 50.8	24.10	314.7± 40.3	27.00	.8± 10.5
21.30	192.4± 48.2	24.20	225.5± 35.0	27.10	29.9± 9.3
21.40	194.1± 49.9	24.30	270.9± 32.5	27.20	53.5± 14.9
21.50	252.3± 48.7	24.40	211.4± 32.3	27.30	36.2± 12.7
21.60	200.5± 49.7	24.50	140.0± 26.4	27.40	82.0± 17.5
21.70	209.8± 45.7	24.60	86.0± 24.4	27.50	130.4± 18.7
21.80	141.9± 44.0	24.70	51.2± 18.7	27.60	118.8± 20.3
21.90	209.5± 46.9	24.80	27.9± 19.9	27.70	77.2± 16.8
22.00	285.3± 47.7	24.90	21.9± 19.9	27.80	48.8± 15.2
22.10	195.9± 44.0	25.00	33.9± 19.7	27.90	27.1± 11.8
22.20	248.0± 46.2	25.10	26.7± 19.1	28.00	27.3± 10.8
22.30	308.9± 46.2	25.20	68.3± 19.3	28.10	-2.2± 5.3
22.40	293.1± 45.3	25.30	89.6± 18.2	28.20	-6.1± 4.2
22.50	315.7± 45.4	25.40	89.7± 19.3	28.30	-5.6± 5.2
22.60	324.5± 44.0	25.50	62.3± 15.5	28.40	10.2± 8.8
22.70	393.6± 44.5	25.60	82.6± 18.4		
22.80	349.6± 45.4	25.70	87.7± 19.7		

Cross section integrated in the 20.00 - 28.40 MeV range is equal 1.45 ± 0.03 mb/sr.

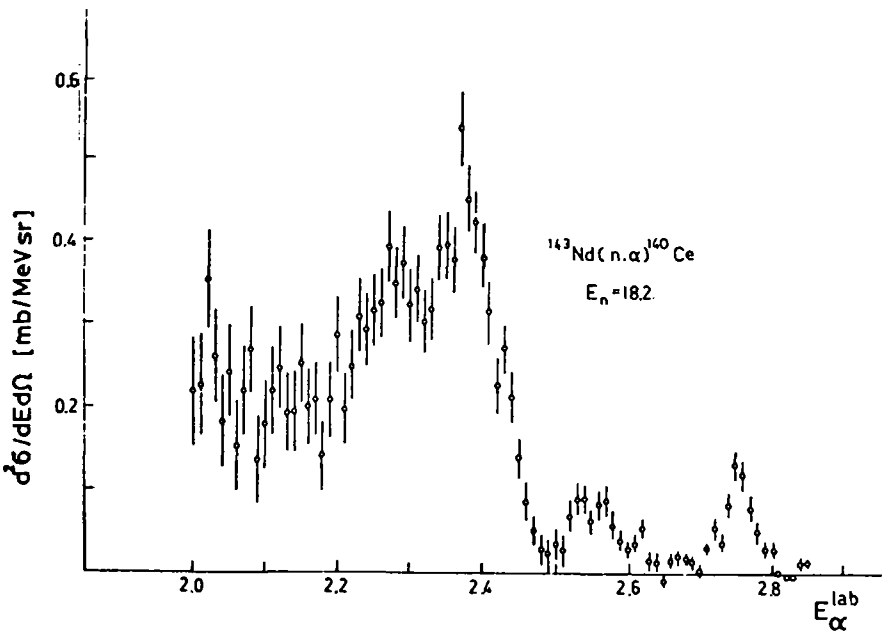

Fig. 1. Energy spectrum of α -particles from the $^{143}Nd(n, \alpha)^{140}Ce$ reaction at 18.2 MeV.

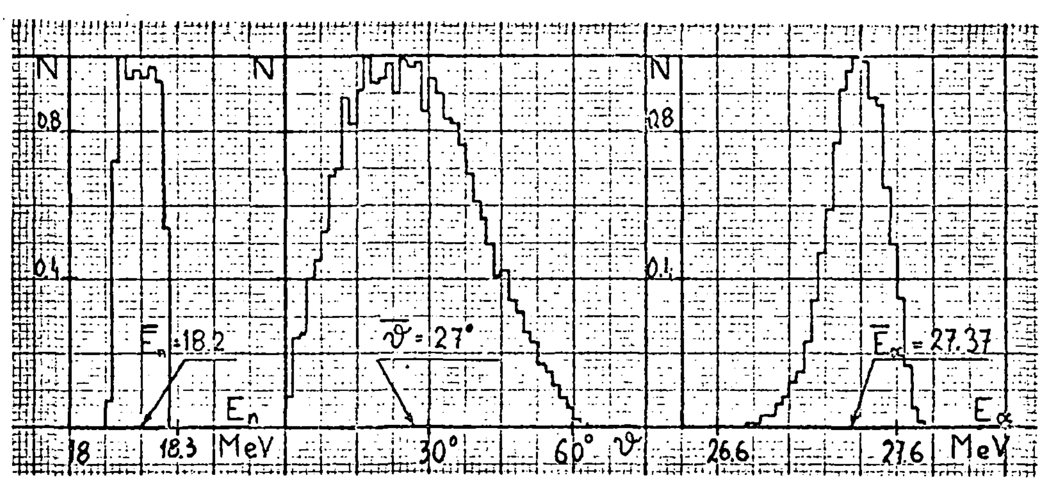

Fig. 2. The experimental energy distribution of neutrons as well as energy and angular spreads of α -particles.

ANGULAR DISTRIBUTIONS OF ALPHA PARTICLES FROM THE $^{147}Sm(n,\alpha)^{144}Nd$ REACTION INDUCES BY 12.1 AND 14.1 MeV NEUTRONS

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Angular distributions of α -particles emitted in the $^{147}Sm(n,\alpha)^{144}Nd$ reaction at En = 12.1 and 14.1 MeV were measured by direct registration of α -particles. The experimental arrangement used in the measurements was described in our earlier work [1]. The neutrons were obtained from the $^{3}H(d,n)^{4}He$ reaction with deuterons accelerated up to 2 MeV in the Van de Graaff accelerator "LECH". The neutron energy was selected by a suitable choice of the emission angle. The neutron energy spreads due to the deuteron energy loss in the ^{3}H-Ti target and geometrical conditions were 200 and 300 keV for 12.1 and 14.1 MeV neutrons respectively. The neutron flux was measured by counting the recoil protons from a thin polyethylene foil. The recoil protons were registered by a thin CsI(Tl) scintillator followed by photomultiplier and standard electronics. The absolute calibrations of the neutron monitor was performed by measuring of the 847 keV γ - transition in ^{56}Fe produced in $^{56}Fe(n,p)^{56}Mn$ reaction with successive β -decay of ^{56}Mn. The cross sections for the $^{56}Fe(n,p)^{56}Mn$ reaction were taken as 110 mb for both neutron energies [2]. Uncertainty of the monitor calibration amounts to about 15%.

The investigated targets were made of samarium oxide enriched with ^{147}Sm to about 96.4%. The Sm_2O_3 layers thicknesses of about

2.3 and 3.0 mg/cm^2 were deposited onto thick carbon backings by means of sedimentation from suspensions in isopropyl alcohol.

The energy calibration of the alpha spectrometer was performed with employment of alphas from ThC and ThC′ and from the reaction $^{28}Si(n,\alpha)^{25}Mg$ produced in the silicon detector by the incident neutrons.

The angular distributions of α -particles emitted in the $^{147}Sm(n,\alpha)^{144}Nd$ reaction at 12.1 and 14.1 MeV neutrons are presented in Tables 1 and 2. These distributions contain all α -particles with energies corresponding to excitations of the final nucleus up to 5.5 MeV. In the bottom of the tables the angular spreads of the measurements are also shown. These spreads were calculated by Monte-Carlo method [3]. The errors indicated in the tables are only statistical.

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TABLE II

Angular distribution of α -particles for $^{147}Sm[n,\alpha]^{144}Nd$ reaction at E_n = 14.1 MeV

$\bar{\vartheta}$ [deg]	$d\sigma/d\Omega$ [mb/sr]
27	0.83 ± 0.06
46	0.43 ± 0.05
63	0.28 ± 0.04
90	0.14 ± 0.04
117	0.02 ± 0.03
134	0.01 ± 0.03
155	-0.01 ± 0.04

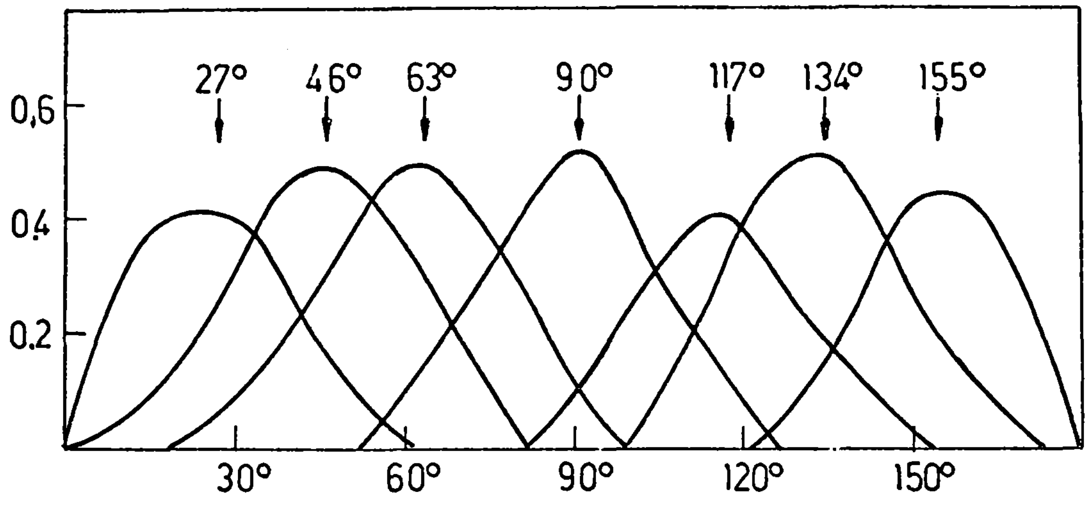
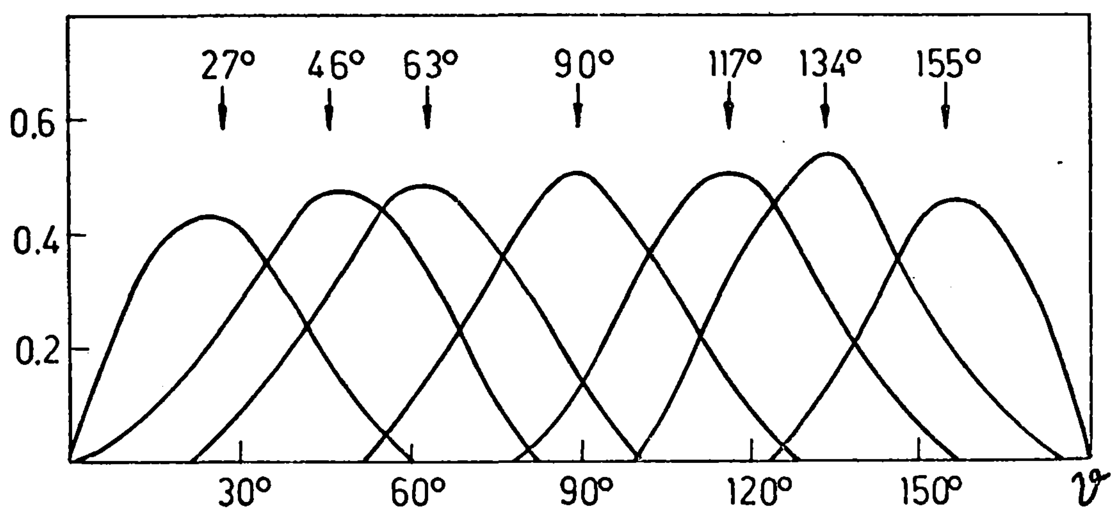


TABLE 1

Angular distribution of α -particles for $^{147}Sm(n,\alpha)^{144}Nd$ reaction at E_n = 12.1 MeV

ϑ [deg]	$d\sigma/d\Omega$ [mb/sr]
27	0.72 ± 0.06
46	0.42 ± 0.05
63	0.21 ± 0.04
90	0.12 ± 0.04
117	0.06 ± 0.04
134	0.01 ± 0.04
155	0.02 ± 0.04



CROSS SECTIONS FOR THE $^{139}La(n,alpha)^{136}Cs$ REACTION INDUCED BY FAST NEUTRONS

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Excitation function of the $^{139}La(n,alpha)^{136}Cs$ reaction was measured in the neutron energy range 13-17 MeV by the activation method. Neutrons were produced in a titanium-tritium target with 440 keV and 990 keV deuterons from the Van de Graaff accelerator. The angular dependence of the neutron energy from the $T(d,n)^{4}He$ reaction was used to obtain monoenergetic neutrons of a desired energy. Samples of pure (99.56% purity) metallic lantanium were used. The activities induced in the lantanium samples were determined by means of a 30 cm^3 Ge(Li) detector. The photopeak of the 1050 keV gamma line od the ^{136}Cs decay was used for the activity determination.

The cross sections of the investigated reaction were measured in reference to the $^{56}Fe(n,p)^{56}Mn$ reaction cross section. For the $^{56}Fe(n,p)^{56}Mn$ cross sections the values reported by Liskien and Paulsen were used [1]. The level schemes and transition probabilities were taken from the tables of Lederer et al. [2].

The experimental results are given in Table I.

The cross section error consists of the statistical error, the uncertainity of the neutron flux, the error of the Ge(Li) detector efficiency,

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the error of the sample weight and the reference cross sections error. The neutron energy spreads were calculated with a Monte Carlo method using the computer code LOS [3]. The gamma ray attenuation was calculated using the computer programme Selfa [4] with the gamma-ray attenuation coefficients taken from Lejpunski et al. [5].

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TABLE I

Cross sections for the $^{139}La(n,\alpha)^{136}Cs$ reaction

Neutron Energy MeV	Measured cross sections mb
13.0 ± 0.1	1.4 ± 0.2
13.3 ± 0.1	1.4 ± 0.1
13.9 ± 0.2	1.6 ± 0.1
14.5 ± 0.2	1.6 ± 0.1
15.1 ± 0.1	1.7 ± 0.1
15.5 ± 0.2	2.0 ± 0.2
15.9 ± 0.1	2.2 ± 0.4
16.6 ± 0.2	2.4 ± 0.5

CROSS SECTIONS FOR THE $^{191}Ir(n,2n)^{190}Ir$ AND $^{193}Ir(n,2n)^{192}Ir$ REACTIONS

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The $(n,2n)$ reaction on Ir isotopes is of importance in reactor dosimetry applications using the activation technique. The present work fulfils the request listed in the WRENDA 76/77 edited by the NDS of IAEA [1]. The excitation curves for the $^{191}Ir(n,2n)^{190g+m1}Ir$, $^{191}Ir(n,2n)^{190m2}Ir$ and the $^{193}Ir(n,2n)^{192g+m1}Ir$ reactions were measured in the neutron energy range from 13.04 MeV to 17.86 MeV.

The samples of natural high purity irydium were irradiated with neutrons from the $^{3}H(d,n)^{4}He$ reaction at deuteron energies 0.4 MeV, 0.9 MeV and 1.8 MeV. The activated samples were counted for their γ -activities by a 30 ccm Ge(Li) spectrometer. In case of $^{190g+m1}Ir$ the decay with a half-life 12 d of the 361 keV, 371 keV, 407 keV and 518 keV γ- rays was followed. The $^{190m2}Ir$, 3.2 h, activity was identified by measuring the 361 keV and the 502 keV γ -rays, and for $^{192g+m1}Ir$ decaying with the half-life 74.2 d the sum of the 308 keV and 316 keV as well as the 468 keV γ -rays were measured. The observed γ -activities were refered to the activities induced in the monitoring reaction $^{56}Fe(n,p)^{56}Mn$ with known cross section [2].

The results of measurements together with the reference reaction cross sections are presented in Table 1. The errors attached contain the statistical uncertainties as well as the systematic errors with inclusion of the errors of the monitoring reaction. The decay data adapted in the calculations of the cross sections are gathered in Table 2.

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TABLE II

Decay data adopted for cross section determination [3]

Residual nucleus	E_γ	Intensity	Conversion coeficient
^{190}Ir	371	0.217	0.05
	361	0.123	0.0518
	518	0.315	0.0728
	407	0.27	0.0364
$^{190m2}Ir \rightarrow {}^{190g}Ir$	-	0.05	-
$^{190m2}Ir \rightarrow {}^{190m}Os$	-	0.95	-
^{190m}Os	502	1.0	0.024
^{192g}Ir	308	0.342	0.092
	316	0.945	0.078
	468	0.514	0.027

TABLE 1. Cross sections for (n,2n) reaction on Ir isotopes and the reference reaction cross sections

E_n MeV	$^{191}Ir(n,2n)^{190g+m1}Ir$ mb	$^{191}Ir(n,2n)^{190m2}Ir$ mb	$^{193}Ir(n,2n)^{192g+m1}Ir$ mb	$^{56}Fe(n,p)^{56}Mn$ mb
13.04 ± 0.38	1763 ± 121	87.0 ± 6.1	1824 ± 131	113.0
13.35 ± 0.24	1790 ± 99	85.7 ± 5.4	-	114.0
13.87 ± 0.34	1752 ± 97	92.8 ± 5.4	1750 ± 130	112.0
14.49 ± 0.34	1875 ± 97	105.6 ± 6.5	-	107.0
15.04 ± 0.28	1882 ± 105	109.4 ± 6.1	1775 ± 132	99.2
15.40 ± 0.24	1711 ± 127	104.0 ± 6.7	1513 ± 111	92.5
15.94 ± 0.46	1781 ± 113	142.0 ± 9.9	1721 ± 127	86.5
16.59 ± 0.11	1512 ± 93	138.2 ± 10.1	1459 ± 111	74.5
17.42 ± 0.44	1192 ± 78	141.1 ± 10.4	1193 ± 91	64.5
17.86 ± 0.08	1005 ± 64	128.5 ± 9.3	1008 ± 76	60.0

EVALUATION OF THE EXCITATION CURVE FOR THE $^{58}Ni(n,2n)^{57}Ni$ REACTION

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The aim of this work was to evaluate the excitation curve for the $^{58}Ni(n,2n)^{57}Ni$ reaction in the neutron energy range from the threshold energy up to 28 MeV. The cross sections for this reaction have been requested in WRENDA 76/:: by A.Michaudon /ref. no 250/ for fission reactor development and by D.Breton /ref. no 1409/, Y.Seki /ref. no 1410/ and G.D.McCracken /ref. no 1411/ for fusion reactor purposes.

The evaluation was based on 15 accepted experimental data sets or single-energy cross sections. The recommended cross sections have been tabelarized in 0.1 MeV energy steps. The estimated accuracy is 11.4% for energies lower than 14 MeV, 8.7% between 14 MeV and 16 MeV, and worse at higher energies. The detailed description of the evaluation procedure will be published in our forthcoming paper. Some of the results are presented in Figs 1 and 2.

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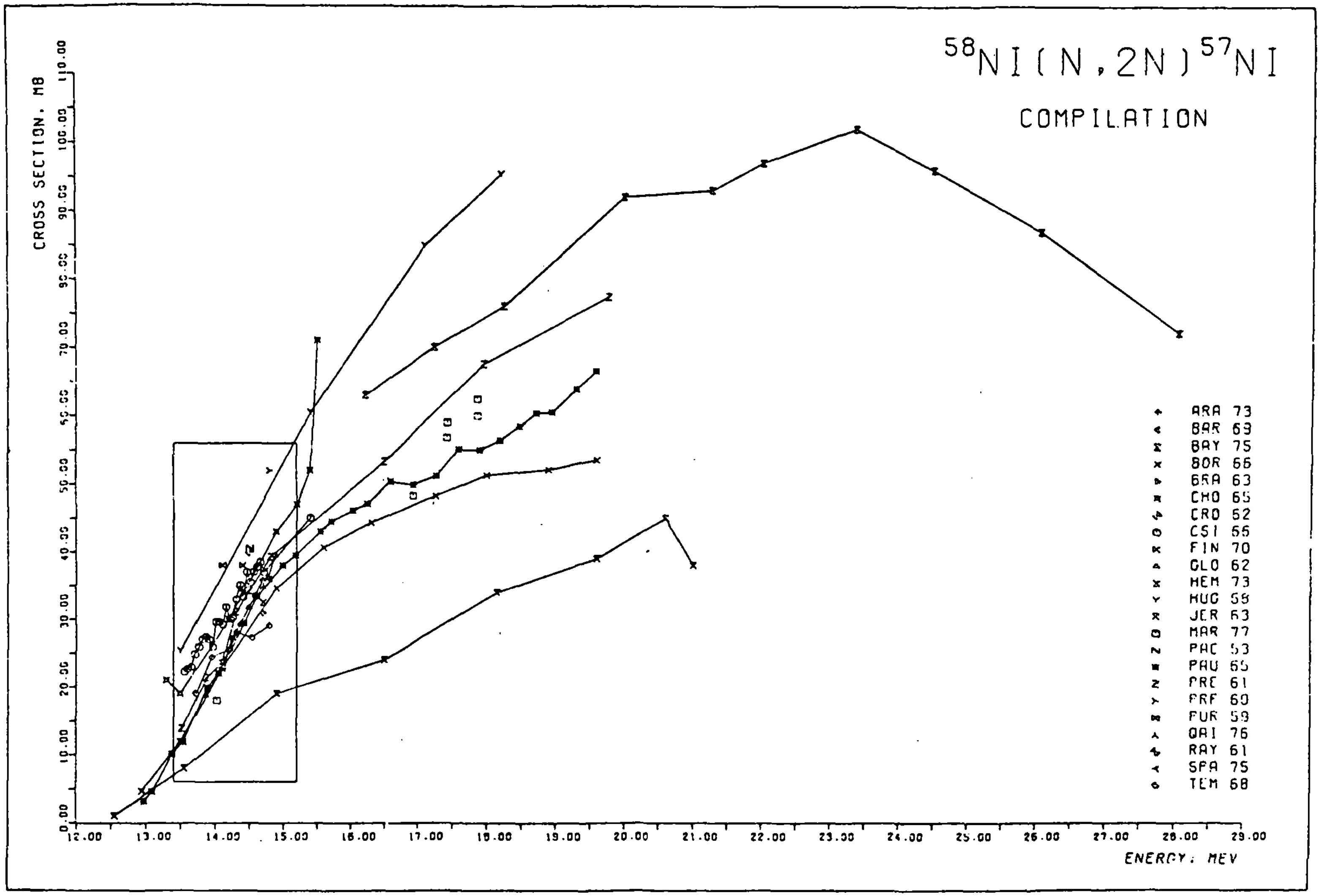

^{58}NI(N,2N)^{57}NI
COMPILATION
CROSS SECTION, MB
ENERGY, MEV
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
29.00
ARA 73
BAR 63
BAY 75
BOR 66
BRA 63
CHO 65
CRO 62
CSI 66
FIN 70
GLO 62
HEM 73
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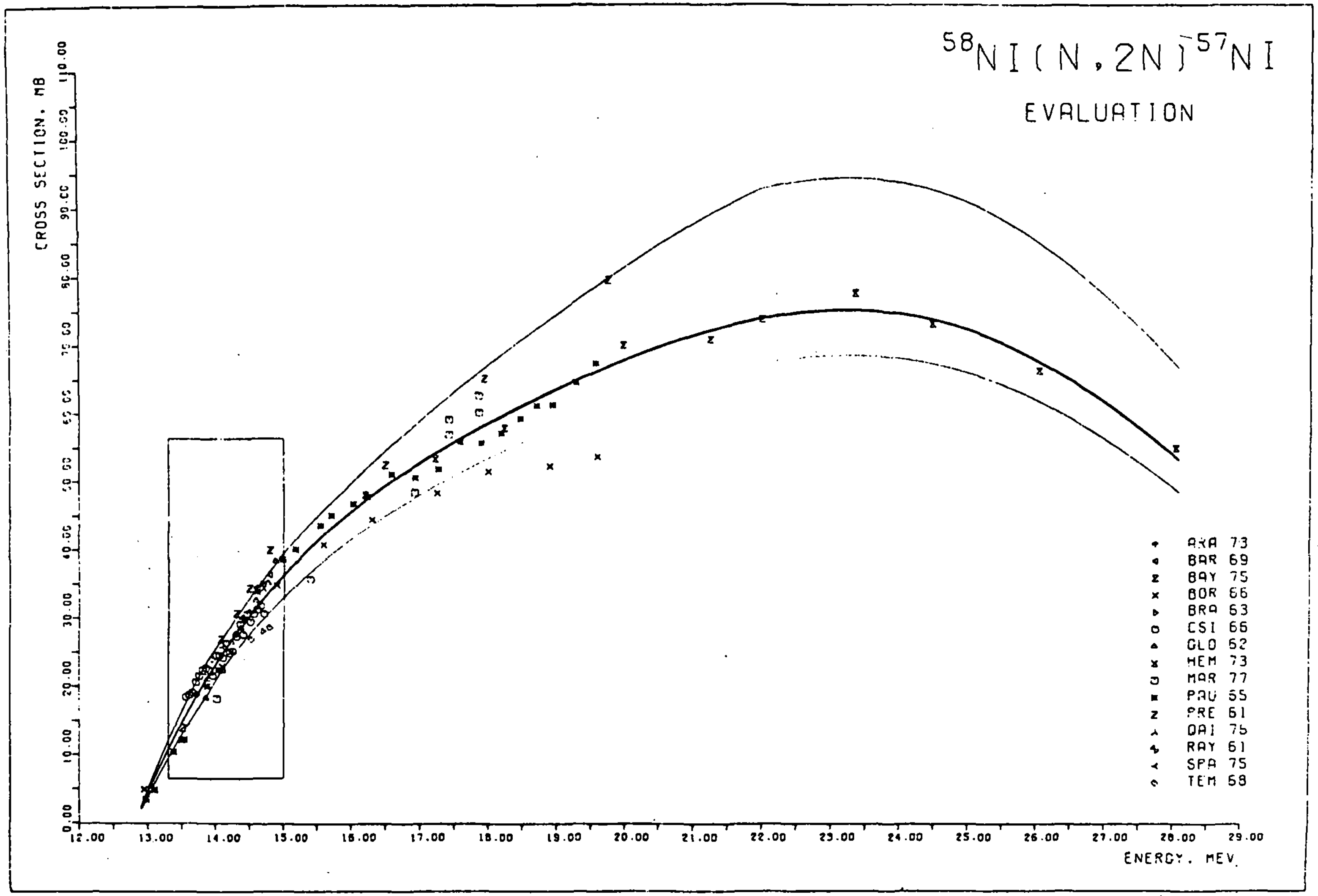
RAY 61
SPA 75
TEM 68



^{58}NI(N,2N)^{57}NI
EVALUATION
CROSS SECTION, MB
ENERGY, MEV
ARA 73
BAR 69
BAY 75
BOR 66
BRA 63
CSI 66
GLO 62
HEM 73
MAR 77
PAU 55
PRE 61
QAI 75
RAY 61
SPA 75
TEM 68

A "FORTRAN" PROGRAM FOR CALCULATION OF THE SUPER-CONDUCTIVITY FUNCTIONS AND THE NUCLEAR LEVEL DENSITY

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The theory of sperconductivity has been applied to the description of the pairing effects in the nuclear level density [1 - 4] . The calculation scheme of the nuclear level density proposed in the present work was used repeatedly in calculations of the excitation curves for nuclear reactions in the frame of the statistical model. The aim of this work lies in describing the physical concept underlying the method prior to describing the FORTRAN code itself.

An approximate general expression for the density of nuclear states can be obtained on the basis of thermodynamics

$$\omega = \frac{\exp S}{(2\pi)^{1/2 n} \sqrt{\det\left(\frac{\partial^2 S}{\partial\mu_i \partial\mu_j}\right)_{\mu_0}}} \quad (1)$$

where S is the entropy of the nucleus, μ_i are the Lagrange multipliers corresponding to the integrals of motion considered, n of this integrals is taken into account. Here μ_0 defines the point in space, where the Lagrange multipliers are taking physical meaning. The entropy of a nucleus is the sum of the neutron and proton entropies, the same beeing true for the energy of the system.

The pairing Hamiltonian [1] provides the following expressions for the entropy

$$S = 2\sum_k \ln\left[1+\exp(-\beta E_k)\right] + 2\beta \sum_k \frac{E_k}{1+\exp(\beta E_k)}, \qquad (2)$$

and energy

$$E = \sum_k \varepsilon_k \left[1 - \frac{\varepsilon_k - \lambda}{E_k} \operatorname{tgh}\left(\tfrac{1}{2}\beta E_k\right)\right] - \frac{\Delta^2}{G}, \qquad (3)$$

where $E_k = \sqrt{(\varepsilon_k - \lambda)^2 + \Delta^2}$, k is the index of the singleparticle levels with energies ε_k taken from the Nillson model, λ is the Fermi level, β the inverse of the thermo-dynamic temperature t, Δ the energy gap in the level spectrum and G is a constant defining the strenght of the pairing interaction taken from ref. [5].

For practical calculations it is necessary to know the values of λ and Δ for both neutrons and protons, as functions of the temperature t. These can be obtained from the state equation

$$\frac{2}{G} = \sum_k \frac{\operatorname{tgh}\left(\tfrac{1}{2}\beta E_k\right)}{E_k} \qquad (4)$$

and the equation defining the number of nucleons N of a given kind

$$N = \sum_k \left[1 - \frac{\varepsilon_k - \lambda}{E_k} \operatorname{tgh}\left(\tfrac{1}{2}\beta E_k\right)\right] \qquad (5)$$

Nuclear state density for a given excitation energy U and angular momentum projection M is calculated from the following expressions

$$\omega(U,M) = A(U)\,\omega\left(U - \frac{M^2 t}{2\sigma^2}\right),$$

$$A(U) = \frac{\omega(U)}{\sum_M \omega\left(U - \frac{M^2 t}{2\sigma^2}\right)} ,$$

$$U = \frac{M^2 t}{2\sigma^2} + U_t \qquad , \qquad (6)$$

where σ^2 is the spin cut-off function as given in ref. [3] and $\frac{M^2 t}{2\sigma^2}$ stands instead of the rotational energy. The quantities S_n, S_p, $\det\left(\frac{\partial^2 S}{\partial\mu_i \partial\mu_j}\right)_{\mu_0}$, $A_n, \Delta_p, \lambda_n, \lambda_p, E_n, E_p$ / n - neutrons, p - protons/, which define $\omega(U)$ as well as the $\sigma^2 = \sigma_n^2 + \sigma_p^2$ are calcultaed as functions of t and ascribed to the excitation energy

$$U_t = \left[E_n(t) - E_n(0)\right] + \left[E_p(t) - E_p(0)\right] . \qquad (7)$$

The gap $\Delta = 0$ defines the critical temperature t_c above which the superconductivity disappears.

Introducing of the σ^2 functions to the description of the spin dependence of the level density encompasses the approximations described in detail in ref. [6]. The σ^2 taken from ref. [3] fails in describing the moment of inertia of the nucleus at low energies. In order to improve the behaviour of $\frac{M^2 t}{2\sigma^2}$ at low energies the true rotational yrast energies have been calculated within the approach proposed originally by Kammuri [2], who considered the additional integrall of motion namely the projection of the angular momentum M, and the corresponding Lagrange multiplier ω.

In this formalism we obtaine in the zero-temperature limit the following modified expressions insted of eqs. (4) and (5)

$$\frac{2}{G}=\sum_{E_k>\omega m_k}\frac{1}{E_k}, \tag{8}$$

$$N=\sum_{E_k<\omega m_k}1+\sum_{E_k>\omega m_k}\left[1+\frac{\varepsilon_k-\lambda}{E_k}\right]. \tag{9}$$

In these equations m_k are the projections of the singleparticle level angular momenta. From eqs. (8) and (9) with $\Delta=0$ the critical values ω_{cr} and λ_{cr} may be evaluated. For $\omega>\omega_{cr}$ the following equation is valid

$$N=\sum_{|\varepsilon_k-\lambda|<\omega m_k}1+\sum_{|\varepsilon_k-\lambda|>\omega m_k}\left[1-\frac{\varepsilon_k-\lambda}{|\varepsilon_k-\lambda|}\right]. \tag{9a}$$

When solving eqs. (8) and (9) the effective rotational energy E_{rot} can be calculated from equations similar to (3) and (7) taken in the zero-temperature limit [2] . The corresponding yrast spin projection /beeing a sum of the projections for protons and neutrons [4] / is given by the formula

$$M_y=\sum_{|\varepsilon_k-\lambda|<\omega m_k}m_k\ . \tag{10}$$

Such calculations, when omitting some spurious solutions, provide yrast lines, which were approximated by the following expression

$$E_{rot} = a M_y^2 + b M_y \quad , \tag{11}$$

where a = 0.072 exp [- 0.02039A], b = 0.26 amd A is the mass number of the nucleus. It has been found that the approximation $\frac{M^2 t}{2\sigma^2} = E_{rot}$ for $\frac{M^2 t}{2\sigma^2} > E_{rot}$ describes fairly well the exact dependence of the effective rotational energy on t predicated by the Kammuri model.

The superconductivity model describes the even-even nuclei. The level density for an odd-mass nuclei can be obtained by appropriate energy shifts, ΔU, consisting of two components, one ΔU_1, taking account of the energy difference between the ground states of the odd-mass or odd nucleus and the neighbouring even nuclei, the second one, ΔU_2, accounting for the fact that in the vicinity of closed shells addition of an odd nucleon affects also the properties of the highly excited nucleus. These shifts are calculated according to the method described in refs. [7].

The computer code WAXWA founds the superconductivity parameters with use of the minimizing procedure MINCON [8]. The program provides 3 x 60 values of $\omega(U)$, $\frac{t}{2\sigma^2}$ and M_y with energy step ΔU = 0.5 MeV from 0.5 MeV to 30 MeV. Additionally the output contains the angular momentum distribution of the level density, calculated from the formula

$$\rho(U,J) = \omega(U,M=J) - \omega(U,M=J+1) . \tag{12}$$

These are tablerized with an energy step ΔU = 3 MeV from 0.5 MeV to 30 MeV for 30 spin values starting with 0 or 1/2.

The only input data required are the mass-number A and the atomic number Z of the nucleus in question.

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ANALYSIS OF THE TOTAL RADIATION WITH FOR NEUTRON RESONANCES

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In this work we have analysed the dependence of the total readiation width Γ_γ on the resonance energy E_{res}. The measured radiative widths of 1500 resonances for 102 isotopes from ^{45}Sc to ^{238}Cm have been considered. The dependence of the total radiative width on the resonance energy was described by means of Czebyszew's polynomials [2]. The fit to the experimental data has been performed [1] using the least squares method. It was found that the majority of the experimental widths are fitted best by the zero-order polynominal. In cases where the total radiation width is determined with accuracy better than 5% a weak dependence of Γ_γ on E_{res} can be noticed. Basing on these results we have assumed that the radiation width does not depend on the resonance energy. Taking this into account the average radiation width were calculated and their dependence on the effective excitation energy U as well as on the level density parameter a /determining the density of single-particle states close to the Fermi energy/ and the mass number A has been investigated. The following expression for the total radiation width was obtained

$$\Gamma_\gamma = 11.7\, A^{-1.6}\, U^{0.8}\, a^{-0.2}.$$

Here Γ_γ is expressed in eV, U in MeV and a in MeV^{-1}. The parameters U and a describing best the experimental radiative width as well as Γ_γ obtained from formula (1) are presented in Table 1. It is worthwhile to note that the average radiation width obtained in the present work differ from those reproted in refs [3, 4].

TABLE 1

Izotope	A	U MeV	a MeV^{-1}	Γ_{γ} meV
1	2	3	4	5
Sc	46	8.77	7.4	
Cr	54	6.52	8.4	
Fe	57	6.39	7.9	
Co	60	7.49	8.4	
Ni	59	7.60	9.3	
Ni	61	6.44	10.5	
Ni	62	7.35	9.7	
Cu	64	7.92	9.4	496
Cu	66	7.07	9.8	367
Ga	70	7.65	11.1	360
Ga	72	6.52	12.3	388
Ge	71	6.41	12.3	177
Ge	73	5.76	13.3	187
Ge	74	6.88	13.5	239
Ge	75	5.57	12.2	217
As	76	7.33	13.3	325
Se	75	6.74	13.8	247
Se	77	6.28	13.7	230
Se	78	7.09	14.0	332
Se	79	5.64	14.5	203
Se	81	5.46	14.6	190
Rb	86	8.65	10.9	198

1	2	3	4	5
Rb	88	6.03	10.9	132
Sr	89	5.08	11.1	197
Zr	91	5.88	12.3	320
Zr	92	6.50	12.6	152
Zr	93	5.72	13.9	342
Zr	95	5.34	14.5	260
Rh	104	7.00	18.5	136
In	116	6.78	17.1	111
Sb	122	6.81	17.7	117
Sb	124	6.47	17.0	84
Te	123	5.74	18.9	173
Te	124	6.74	18.0	158
Te	125	5.44	19.6	115
Te	126	6.30	18.5	150
Te	127	5.19	19.7	145
Te	129	4.98	20.0	172
Xe	130	6.70	17.8	110
Xe	132	6.29	16.7	126
Ba	131	6.32	19.1	124
Ba	135	5.80	17.6	94
Ba	136	7.04	15.5	127
La	140	5.16	15.9	64
Pr	142	5.84	16.7	94
Nd	144	5.54	18.9	86
Nd	145	4.57	19.5	90
Nd	146	5.24	21.0	48

1	2	3	4	5
Nd	147	4.26	23.9	50
Nd	149	4.09	27.8	72
Pm	148	5.90	20.9	85
Sm	148	5.91	20.7	55
Sm	150	5.37	25.3	51
Sm	151	4.37	26.4	85
Sm	152	5.55	25.9	73
Sm	153	4.79	25.0	74
Sm	155	4.84	22.9	112
Eu	152	6.31	24.8	128
Eu	154	6.44	23.1	106
Gd	153	5.27	25.9	68
Gd	155	5.57	24.6	83
Gd	156	6.44	23.2	101
Gd	157	5.40	22.8	111
Gd	158	5.98	22.4	97
Gd	159	6.90	17.2	122
Tb	160	6.38	21.7	117
Dy	162	5.95	23.2	140
Dy	163	5.75	20.7	159
Dy	165	4.60	22.7	69
Ho	166	6.24	21.9	78
Er	167	5.52	22.9	112
Er	168	6.27	21.1	102
Tm	170	6.59	21.1	94
Yb	172	6.30	22.8	111

1	2	3	4	5
Yb	173	5.52	21.6	104
Yb	174	6.12	20.7	99
Yb	175	4.96	21.9	86
Hf	178	5.93	23.4	57
Ta	182	6.06	21.7	52
W	183	5.53	21.9	94
W	184	5.87	22.9	95
W	185	5.15	22.5	60
W	187	4.89	22.9	74
Re	186	6.18	22.4	55
Re	188	5.87	23.2	72
Ir	192	6.20	23.2	73
Ir	194	6.07	21.8	79
Pt	196	6.19	21.1	86
Au	198	6.51	19.1	141
Pa	232	5.56	25.3	49
Pa	235	4.68	34.9	58
U	234	5.32	30.1	52
U	235	4.54	31.4	19
U	236	4.87	32.2	41
Np	238	5.49	29.2	58
Pu	239	4.97	29.7	46
Pu	240	5.22	30.3	51
Pu	241	4.57	31.0	30
Pu	242	4.91	31.5	48

1	2	3	4	5
Am	242	5.53	28.9	41
Am	244	5.36	30.1	50
Cm	245	4.81	29.6	42

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NEUTRON ORBIT RADII IN THE INVESTIGATIONS OF SUB-COULOMB (d,p) STRIPPING

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Quite the contrary to the information about proton distribution in atomic nuclei, experimental data on neutron distribution are scarce and not reliable e.g. [1] . A promissing way of obtaining the information about rms radii of neutron orbits $\langle r^2_{nlj} \rangle^{1/2}$, is based on comparison of the measured differential cross sections of sub-Coulomb single-neutron transfer with the cross sections calculated by means of DWBA method [2, 3] . Due to the low energy in both reaction channels the results of calculations slightly depend on the choice of optical model parameters for protons and deuterons, but they are sensitive to the choice of parameters of the bound state potential of transfered neutron, particularly to r_o and a . However, all pairs of values of these parameters (r_o, a) which correspond to the theoretical cross section equal to the experimental one /using spectroscopic factor from another independent experiment/, lead to almost identical values of $\langle r^2_{nlj} \rangle^{1/2}$.

Excitation functions and absolute differential cross sections of the reactions $^{62}Ni(d,p)^{63}Ni$, $^{64}Ni(d,p)^{65}Ni$ and $^{74}Ge(d,p)^{75}Ge$, leading to different states of final nucleus up to excitation energy 4 MeV, discussed in this paper, were measured by means of scattering chamber with cooled surface barrier silicon detectors. Experiments were carried out in energy range 2,7 - 3,3 MeV and angular range 70^{o} - 160^{o}. Deutron beam was delivered by Warsaw van de Graaff accelerator "LECH". Experimental energy resolution was 24 - 35 keV. The targets used were made of enriched isotopes and were 100 - 200 $\mu g/cm^2$ thick.

The results for $^{62}Ni(d,p)^{63}Ni$ were analysed on the basis of DWBA calculations using DWUCK 2 code. Up to now with help of spectroscopic factors from paper [4], we have obtained values of rms radii of neutron orbits for three selected levels of ^{63}Ni. These preliminary results with error cautiously estimated for about $\pm$0,30 fm are presented in Table 1.

TABLE 1

Excitation energy MeV	Separation energy MeV	nlj	S	$\langle r^2_{nlj} \rangle^{1/2}$ fm
0	6,841	$2p_{1/2}$	0,37	4,38
1,002	5,839	$2p_{1/2}$	0,33	4,63
2,953	3,880	$3s_{1/2}$	0,19	5,52

Our result for $2p_{1/2}$ orbit in ^{63}Ni is in agreement with $4{,}38 \pm 0{,}15$ fm value obtained by Chapman et al [5] for $2p_{1/2}$ orbit in ^{61}Ni. Further experimental and theoretical work is in progress.

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THE LEVEL STRUCTURE OF THE ^{127}Cs NUCLEUS

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The structure of low lying levels in the ^{127}Cs nucleus is known from ref. 1 where the isomeric state with $I^{\pi} = 11/2^-$ was populated in the $^{127}I(\alpha,4n)^{127}Cs$ reaction and its γ-decay was studied. Some information is also available from the β^+-decay of the ^{127}Ba nucleus /see refs. 2, 3/. In the present work the band structure in ^{127}Cs above the $11/2^-$ isomeric state was studied. The existence of a decoupled band based on the $11/2^-$ state /proton in the $h_{11/2}$ subshell/ was expected. Such decoupled bands were observed in the neighbouring nuclei with Z = 57 /refs. 4, 5/ and Z = 59 /ref. 6/ giving information on the shape of nuclei /sign of the deformation, departure from the axial symetry - ref. 7/.

In the present experiment the excited states of the ^{127}Cs nucleus were populated in the $^{127}I(\alpha,4n)^{127}Cs$ reaction at an alpha particle energy of 51 MeV. The measurements of the single gamma spectra /prompt and delayed/, the gamma - gamma two dimensional coincidences and the γ-ray angular distributions were performed using Ge(Li) detectors. Besides, the excitation function was measured at four alpha energies ranging from 43 MeV up to 51 MeV. The preliminary analysis of results gives evidence on the existence of a band structure. The main two bands are built on the isomeric $11/2^-$ and the $7/2^+$ states at the excitation energy of 453 keV and 273 keV, respectively. The tentative level scheme of ^{127}Cs is given in figure 1.

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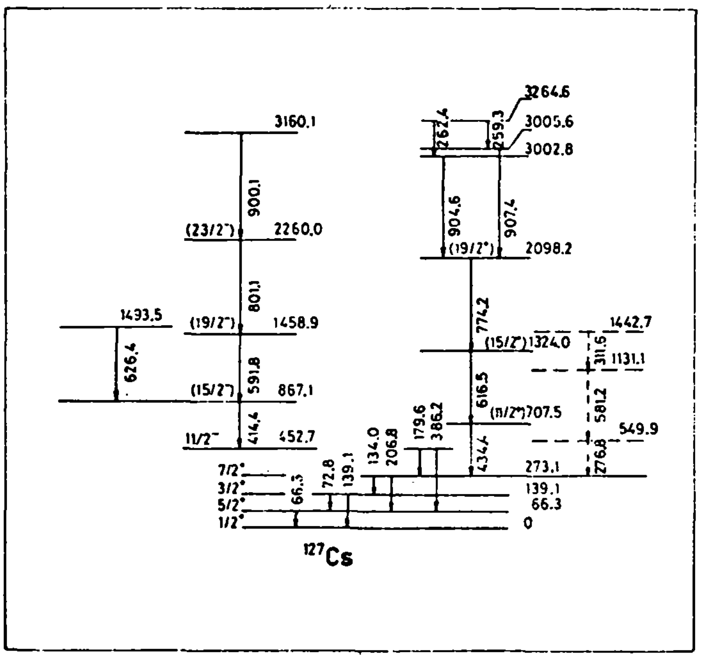

Fig. 1. Tentative level scheme for ^{127}Cs. The isomeric state (11/2) and the states below it are known from refs. 1, 3.

STUDY OF ^{124}Xe AND ^{126}Xe STRUCTURE

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The β^+ decay of ^{124}Cs and ^{126}Cs was investigated. These nuclei were obtained in (p,n) reactions with 10 MeV protons from Proton Linear Accelerator at Swierk. The gaseous Xe targets, enriched with 124 and 126 isotopes, were used. Single γ- ray and γ-γ coincidence spectra were measured. Proposed level schemes of ^{124}Xe and ^{126}Xe are shown on the figure.

Even - even Xe isotopes are typical examples of transitional nuclei. Potential energy surface calculated by macroscopic - - microscopic method exhibits very weak dependence on γ - deformation. It indicates a tendency to the strong coupling between γ - vibrations and rotation and very important role of the γ - dependence of the kinetic energy part of the collective Hamiltonian. Therefore, the collective model taking into account the γ - dependence of the inertial functions [1] was used to interpret the energies of levels and transition probabilities B (E2) for $^{124,\,126}Xe$. It was shown that the model can quantitatively reproduce the experimental data, but the renomalization of the microscopic inertial functions was needed.

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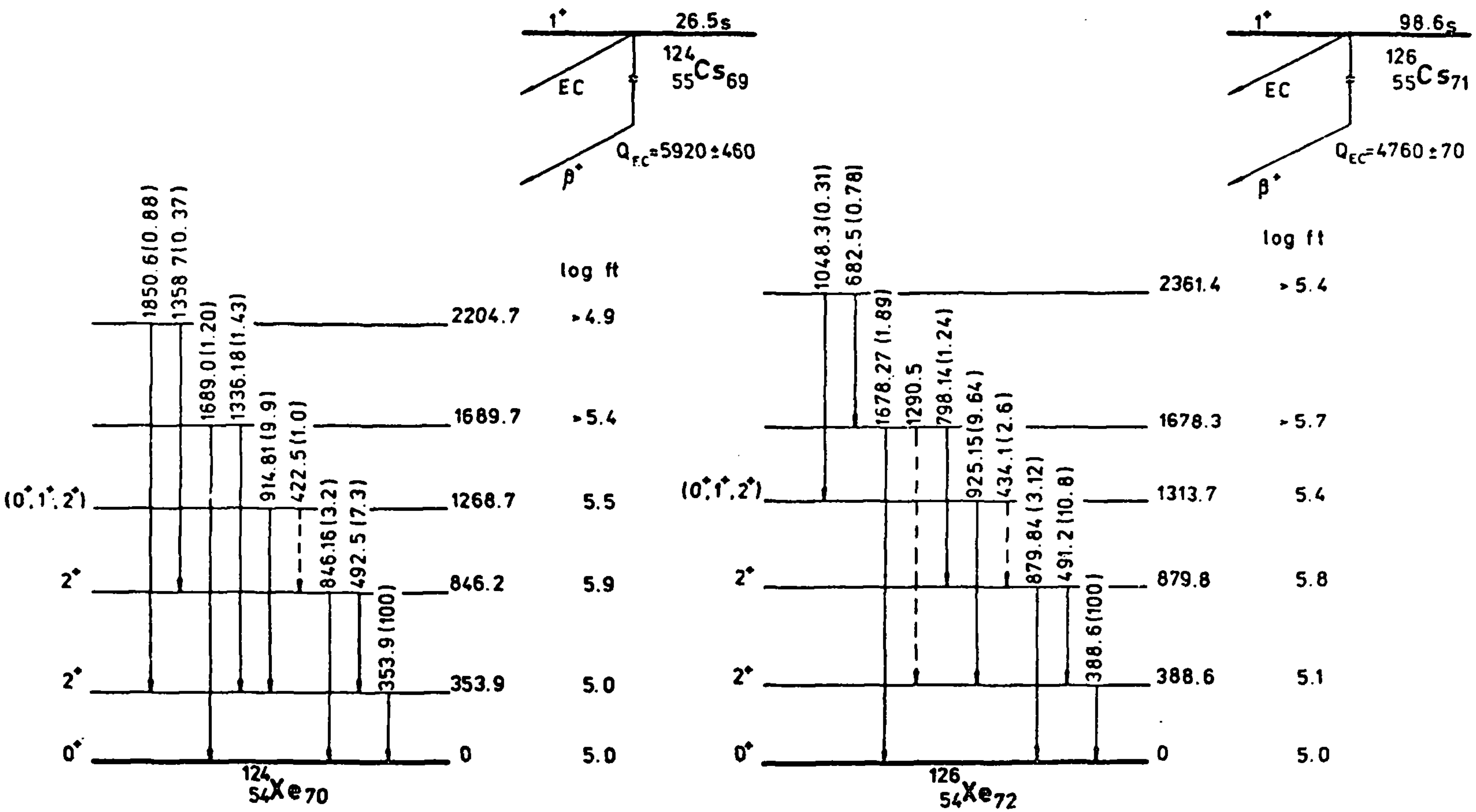
1+ 26.5s
124 55 Cs 69
EC
β+
Q EC=5920±460
log ft
1850.6(0.88)
1358.7(0.37)
1689.0(1.20)
1336.18(1.43)
914.81(9.9)
422.5(1.0)
846.16(3.2)
492.5(7.3)
353.9(100)
2204.7 >4.9
1689.7 >5.4
(0+,1+,2+) 1268.7 5.5
2+ 846.2 5.9
2+ 353.9 5.0
0+ 0 5.0
124 54 Xe 70
1+ 98.6s
126 55 Cs 71
EC
β+
Q EC=4760±70
log ft
1048.3(0.31)
682.5(0.78)
1678.27(1.89)
1290.5
798.14(1.24)
925.15(9.64)
434.1(2.6)
879.84(3.12)
491.2(10.8)
388.6(100)
2361.4 >5.4
1678.3 >5.7
(0+,1+,2+) 1313.7 5.4
2+ 879.8 5.8
2+ 388.6 5.1
0+ 0 5.0
126 54 Xe 72

State Committee for Nuclear Energy

ANNUAL REPORT

on Nuclear Data in Romania

1976

Compiled by

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Bucharest 1977

NOTE

This annual report contains the main nuclear data works performed during the year 1976 in the Institute for Atomic Physics and the Institute for Nuclear Technology.

The individual reports are not intended to be complete or formal. Consequently, they must not be quoted, abstracted or reproduced without the permission of the authors.

INTRODUCTION

The report on the nuclear data activities in Romania presents the work carried out during 1976 as follows:

A. A brief review of the activities concerinig experimental measurements of neutron and non-neutron data.

B. A brief rewiew of activities related with the compilation and evaluation of neutron nuclear data and the calculation of multigrup constants for reactors.

A. Within the nuclear physics sections of the Institute for Nuclear Tehnology and the Institute of Atomic Physics the activity of obtaining nuclear experimental data was continued and developped.

In order to perform absolute cross section measurements on various nuclear materials, a system ΣΣ located at the thermal column of the VVR-S reactor has been used. The thermal flux available in the empty cavity is 1,98 x 10^9 (± 3%) neutron/cm^2.s at the reactor power of 1 Mw.

The following measurements have been carried out:

- absolute fission cross-sections, mediated in the ΣΣ spectrum for ^{235}U, ^{233}U, ^{238}U, ^{232}Th.

- absolute cross-sections for non-fissionable isotopes, mediated on the ΣΣ spectrum for ^{197}Au, ^{27}Al, ^{115}In, ^{47}Ti, ^{58}Ni, ^{46}Ti, ^{48}Ti.

- using derivate configurations of the system,ΣΣ materials such as Fe, Ni, steel and concrete have been studied by spherical transmission measurements.

Codes PERCENT, FLUXPERT, AMARA coupled with code ANISN to determine cross-sections in the range of 10 KeV - 3 MeV were used.

At the cyclotron U-120 were performed the following measurements:

- obtaining and study of new fissionable isomers of the *Am, Pu, U*;

- measurements of the statistical parameters of some heavy nuclei as ^{134}La, ^{136}La, ^{158}Tb;

- measurements of the angular distribution of the recoil nuclei from reaction ^{239}Pu (α, xn);

Another group of measurements aimed at accumulating new information on the atom nucleus and the mechanisms of producing nuclear reactions was much developped especially at the I.A.P. tandem, namely:

- measurements on the lifetime of excited nuclear states in the range 10^{-10} - 10^{-15} sec by the method of attenuating the Doppler (DSMA) and Planger shift;

- obtaining of new isomers and determination of g factors for medium nuclei;

- spectroscopy in heavy ion reactions;

- study of analog isobar resonances and of some anomalies in the excitation functions (d,p) and (p,p) on opening other channels;

- measurement of angular distributions for the particles resulted from reactions with transfer of one or more nucleons;

- measurements of internal conversion X rays and of gamma rays.

Using the betatron accelerators, a number of measurements were performed on dipole photoabsorbtion cross-section for ^{51}V, ^{52}Cr, ^{55}Mn, ^{59}Co, ^{58}Ni, ^{60}Ni and yield ratios for some isomeric states populated reactions.

At the I.A.P. reactor the research carried out to supply new neutron data:

- thermal neutron cross-sections of *Al*, *Si*, *Cu*, *Zn*, *Ge*, *Sn*, *Pb* and *Bi*;

- absolute determination of ^{235}U fission cross section for 2.200 m/s neutrons.

- statical structure factor and pair interaction potential in liquid *Sn*.

B. During 1976 the nuclear data activity has been developped significantly within I.A.P. (Nuclear Data Laboratory) and I.N.T. Thus, much effort was directed to the preparation of the computing programmes for nuclear data processing. On this line several research groups specialized on this subject. These programmes and groups could be summarized as follows:

A library of computing programmes for nuclear data was prepared. Particularly, nuclear data for isotopes as D_2O, D, ^{16}O were evaluated.

A program for group constant calculations has been carried out. By means of this program were performed calculations of group constants for D, ^{16}O and ^{239}Pu in epithermal and fast neutron energy range. Both experimental and theoretical works on nuclear data were carried out in accordance with the known requirements and at the same time with the WRENDA requirements for data.

So as in previous years, during 1976 we have benefited of the permanent support of I.A.E.A. and especially of the Nuclear Data Section, which for we express our grateful thanks.

LEGINT - a code for smoothing evaluated data, interpolation law establishment and automatic generation of smooth files in DANEM format

G. Vasiliu, S. Mateescu

The evaluated data obtained from experimental data, generally represent a quite large set of points, even for threshold reactions.

Even if the general shape of the curves is simple, some fluctuations can appear.

Any attempt for interpolation law establishment set out to linear law for small energy ranges, maintening too many points in file.

It is necessary in this case to "smooth" preliminary evaluated data.

The method of vertical parable in 5 equal spaced points has used for such "smoothing".

Starting with one preliminary evaluated data set and with corresponding interpolation laws (linear laws usually), the program generates equal spaced energies grid and computes the corresponding cross sections by interpolation. These points are smoothed using the following relation:

$$\tilde{y}_i = y_i - \frac{3}{35}\Delta^{IV} y_{i-2} \qquad (1)$$

where y_i is the cross section at energy E_i, $\tilde{y}_i$ is the corrected (smooth) cross section at the same energy, and $\Delta^{IV} y_{i-2}$ is taken as:

$$\Delta^{IV} y_{i-2} = y_{i-2} - 4y_{i-1} + 6y_i - 4y_{i+1} + y_{i+2} \qquad (2)$$

The relation (1) is used successively over all points of the set, and standard deviation is computed also. According to this, the smoothing process is started again or not.

Finally, the recommended data set with suitable interpolation laws is generated.

On this way, usually we obtain a more compact final data set, containing only 10-20% from initial points number.

VERIF and COMBRES - programs for checking and processing of evaluated data files from DANEM library

G. Vasiliu, S. Mateescu

The checking of the structure, formats, and consistency of the evaluated data stored in the DANEM-library, is done by the program VERIF - an IBM-370/135-IFA version of the program CHECKER.

The program does also some other simple physical tests, such as checks for negative angular distributions, negative probabilities, or unreasonable values of average number of neutrons per fission.

The program has been tested for evaluated data files of Th^{232}.

For the evaluation in the resonance energy range, or for some group constants generation, and for averaged cross sections calculations, sometimes is necessary to have pointwise files for total, elastic, radiative capture and fission data. The program COMBRES, an IBM-370/135-IFA modified version of the program RESEND has been adopted. The code, using the resonance parameters stored in the file 2 of the DANEM library, and the background cross sections stored in the file 3, generates unbroadened point cross sections for infinite dilution in the DANEM format.

For the resolved resonances range the Breit-Wigner single and multi-level, Reich Moore and Adler-Adler formalismes are used. In the unresolved range the cross sections have been obtained by averaging over a Porter-Thomas distribution.

The code generates finally a new file 2 (without resonance parameters) and, a new file 3 into a pointwise representation, and original files 1, 4, 5 and so on.

The program has been tested on O^{16}, Th^{232} and Pu^{239}.

MEDMAX, MEDFIS and MEDGRUP - programs for averaged cross sections on different spectra and resonance integrals calculations

G. Vasiliu, S. Mateescu

For comparison of some preliminary evaluated data in DANEM format, with integral measurements (such as thermal cross sections, averaged cross sections on fission or Maxwell spectrum, resonance integrals) IBM 370/135 modified versions of the programs INTER (as MEDMAX), INTERX (as MEDFIS) and INTEND (as MEDGRUP) have been generated.

The programs process the files 3 of DANEM library into a pointwise representation (eventually supplied by COMBRES code).

The program MEDMAX computes the Maxwellian averaged cross section $\bar{\sigma}_M$, the g-factor, $g = \frac{2}{\sqrt{\pi}} \frac{\bar{\sigma}_M}{\sigma_0}$, where σ_0 is $\sigma(E_0)$ at E_0 = 0.0253 eV, and the resonance integrals for infinite dilution.

The program has been tested on Pu^{239} for fission and $(n \cdot \gamma)$ cross sections, obtained results being in good agreement with data from literature.

The program MEDFIS calculates averaged cross sections on the U^{235} thermal fission neutron spectrum. Original version has been completed to allow more than one nuclear "temperature" (given in the input data) in the same run.

The program has been tested for $Al^{27}(n \cdot \alpha)$ cross sections, Fe^{56} and Ni^{59} for $(n \cdot 2n)$ and $(n \cdot p)$ reactions at different nuclear temperatures.

The program MEDGRUP is performing group constants calculations on an energy group structure of 26, 99, 620 groups using optionally a VE weighting function or VE joined to a fission spectrum.

The output is supplied in the DANEM format.

The program has been tested for O^{16} on 26 and 99 groups structure.

Evaluation of neutron nuclear data for deuterium

E. Bădescu, M. Ciodaru, O. Bujoreanu, L. Pintiliescu

In order to evaluate the neutron nuclear data for deuterium, a compilation of the experimental works has been performed, by using CINDA-Index as references.

Some of the experimental data have been obtained from "Nuclear Data Section - AIEA-Viena", the remainder of them being compiled by us and introduced in the experimental data library "DANEX".

The experimental data concerning neutron-deuterium interaction between 10^{-6}-15 MeV, have been analysed and evaluated, taking into account those reactions with the cross sections greater than 0.5 mb.

The following quantities have been evaluated:

- the total cross section (σ_t)
- the elastic scattering cross section (σ_{el}) and elastic angular distributions
- the cross section for $(n,2n)$ reaction ($\sigma_{n,2n}$).

Thus, a consistent evaluated nuclear data set was obtained between the energy limits mentioned above. The (n,γ) process has been neglected.

Evaluation of nuclear data for heavy water in thermal region

C. Munteanu, N. Mateescu

The code DEINT for the slow neutrons scattering by heavy water was performed.

The model for the scattering law for heavy water used in these calculations was given by D. Butler [1], [2]. Interference scattering between any two atoms of the same molecule is included. A simple model is presented for intermolecular interference scattering of neutrons. Intermolecular and intramolecular interference scattering are significant for the differential cross section, which depends sensitively on both types of interference scattering.

The physical quantities which can be obtained by code DEINT are:

- the scattering law: $S(\alpha,\beta)$;
- scattering kernel and its Legendre moments:

$$\sigma_{\ell}(E_0 \rightarrow E) = \int \frac{d^2\sigma}{d\Omega dE} P_{\ell}(\cos\theta) d\Omega \quad (\text{for } \ell = 0,1,2,3)$$

- total scattering cross section:

$$\sigma_T(E_0) = \int \sigma_0 (E_0 \rightarrow E) dE$$

- the mean cosine of scattering angle:

$$\bar{\mu}(E_0) = \int \sigma_1 (E_0 \rightarrow E) / \sigma_T(E_0)$$

- transport cross section:

$$\sigma_{tr}(E_0) = \sigma_T(E_0)(1-\bar{\mu}(E_0))$$

- THERMOS kernels defined by:

$$P_{ij,\ell} = 0.0506\ v_i v_j \Delta v_j \sigma_\ell(E_j \to E_i) \qquad (i \neq j)$$

$$P_{ii,\ell} = v_i \sigma_T^\ell(v_i) - \sum_{\substack{j=1 \\ j \neq i}}^{N} P_{ji,\ell} \Delta v_j / \Delta v_i$$

The results for $S(\alpha,\beta)$ were compared with the experimental values, which were compiled and introduced in the library of experimental data DANEX.

For small values of α there are some discrepancies with the experimental values. But it is well known that this domain is affected of multiple scattering. It is supposed that for these values of α,a more complex intermolecular model is necessary.

MINP2 - a program for evaluation of elastic differential cross sections

S. Mateescu, G. Vasiliu

The purpose of the program MINP2 is to generate the Legendre expansion coefficients given in the file 4 of the DANEM library, to describe elastic scattering angular distributions (g_i).

The program starts with an attempt to fit the experimental points by Hermite polynomials of different degrees and gives the best order of them.

In the second run, grid of equal-spaced points with a sufficiently large number is generated, in the range -1, +1 for $\mu_i = \cos\theta_i$, and the corresponding angular distributions are calculated by Hermite polynomials. These are easily fitted by a Legendre polynomial series of the same order. The Legendre expansion coefficients $f_\ell(E)$ are obtained as:

$$f_\ell(E) = \frac{\sum_{i=1}^{n} y_i w_i P_\ell(\mu_i)}{\sum_{i=1}^{n} w_i P_\ell^2(\mu_i)} \times \frac{4\pi}{\sigma(E)(2\ell+1)} \qquad (1)$$

with $f_0(E) = 1$,

where "n" is the number of points, "w_i" are the relative weights, P_ℓ μ_i are the Legendre polynomials of "ℓ" degree, $\sigma(E)$ is the integral elastic cross section at energy E.

We used the program INTERP to calculate the cross sections $\sigma(E_i)$ at the energies having angular distributions.

The program INTERP is compatible with a DANEM file format ($MF=3$, $MT=2$) and uses the interpolation laws existing into the file.

The program MINP2 allows also optionally to plot on printer with different signes, the experimental points, and the calculated data by Legendre and Hermite polynomials.

Finally, the program computes the integrated cross sections for comparison with these from file 3.

On this formalism, the Legendre expansion coefficients describing elastic scattering angular distributions for O^{16} at 84 neutron incident energies, from 0.344 eV until 14.14 MeV have been calculated.

The results are in good agreement with data from other libraries.

The evaluation of total and $(n \cdot \alpha)$ cross sections for O^{16}

S. Mateescu, G. Vasiliu

Using the computerised evaluation methods developed in the frame of the Nuclear Data Laboratory - IAP (the programs INEX, REDEX, SINTEX, PREG-1, PREG-2, LISTPLOT, SPN--SIGMA-FIT, LEGINT) the total and $(n \cdot \alpha)$ cross sections for O^{16} have been evaluated.

The experimental data used have been supplied by kindness of NDS - IAEA and from our own compilations.

In the resonance range of the total cross section, the Breit-Wigner multi-level formalism (the program SIGMA-2) was used.

The evaluated data have been expressed in the DANEM format library.

The obtained data set was compared with the evaluated data from LLLNDL and KEDAK libraries. There are some differences between LLLNDL and KEDAK libraries, our data being in better agreement with the LLLNDL data.

For $(n \cdot \alpha)$ reaction we have a good agreement with the LLLNDL library until 12 MeV.

Calculation of unconventional multigroup constants

V. Cuculeanu, D. Gheorghe

For calculating the following unconventional multigroup constants, $I_g = \int_{\Delta E_g} \frac{1}{\sigma_t(E)+\sigma_0} \frac{dE}{E}$, ETOX-DANEM program was adapted.

In the above definition $\sigma_t(E)$ is microscopic total cross section and σ_0 is the dilution.

As fundamental microscopic nuclear data, the DANEM evaluated nuclear data file was used.

These quantities are especially devoted to the preparation of group constants for fast reactor calculations.

Moreover the ETOX-DANEM code actually allows calculations of the high order momenta of transfer matrix because a MIGROS-type subroutine was included in.

Group constants calculations for D, O^{16}, and Pu^{239} is epithermic and fast energy range

S. Mateescu, G. Vasiliu

The group constants from the evaluated nuclear data files (DANEM library) have been generated, supplying the output for GAM-II code.

According with the isotope, the calculated group constants have been all or a part from the following: elastic and inelastic scattering, (n,γ), (n,p), (n,d), $(n{\cdot}2n)$, (n,f), (n,α), $(n,2\alpha)$, capture and absorbtion reactions, averaged number of neutrons per fission, and resonance integrals.

Weighting function used has been *VE* joined at 67,379 KeV to a fission spectrum.

Resonance contributions for Pu^{239} have been computed using a Breit-Wigner formalism. In the case of O^{16}, the input file used has been generated in a pointwise representation by COMBRES code.

Statical structure and pair interaction potential in liquid *Sn*

I. Pădureanu, S. Râpeanu, N. Deciu

In a recent experiment [1] we have measured the statical structure factor $S(\theta)$ in liquid *Sn* at various temperatures extending from the melting point up to 870°C using neutron diffraction technique. Experimental structure factors were compared with theoretical ones derived by using the hard sphere pair interaction potential. The difference between the two structure factors shows that long range effects in the pair interaction potential play an important role in the structure of liquid *Sn*. By Fourier inversion we have calculated the radial distribution function $g(r)$, the density distribution function $4\pi r^2 ng(r)$, the direct correlation function $C(r)$ and the coordination number at different temperatures [2]. To obtain $g(r)$ from $S(\theta)$ an iterative procedure suggested in [3] was applied. This is based on the idea that $g(r)$ does not show oscillations at distances smaller than atomic diameter. From the obtained results, the positions and the intensities of the maxima in $g(r)$ have been analysed at each temperature. Making use of the atomic density distribution function calculated from $g(r)$ we have evaluated the packing effect of the atoms as a function of temperature which is given by the coordination number. For the range of temperatures investigated a slow change of the coordination number has been noted.

The density distribution function indicated that in liquid *Sn* there are at least two interatomic separations. This could be connected with the two crystalline forms of *Sn*, the grey form stable below 13°C and the white one above 13°C. The method for determining the coordination number it was based on the assumption that the first coordination shell is symmetrical. At higher temperatures the assymmetry of this shell become noticeable. This behaviour is associated with the nature of the interaction forces in liquid *Sn*.

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ABSOLUTE DETERMINATION OF ^{235}U FISSION CROSS SECTION FOR 2200 m/sec. NEUTRONS

I.Berceanu, C.Borcea, I.Brâncuş-Mihăilescu, A.Buţă, F.Cîrstoiu, C.Constantinescu, A.Galeriu, A.Isbăşescu, I.Lazăr, I.Mihai, T.Năşcuţiu, P.Osiceanu, M.Petraşcu, M.Petrovici, V.Savu, V.Simion, G.Voiculescu

The absolute U^{235} fission cross-section measurements are performed applying a method elaborated in our laboratory which avoids the knowledge of an intermediate cross-section for neutron detection |1|.

The fission fragments detection efficiency is obtained by means of two pulse ionization chambers, one containing a thin ^{235}U target, the other a thick one. Using a 5000 rot/min chopper rotation speed and a 16 μs time channel width, the time distribution of neutrons and of fission fragments are measured simultaneously. To obtain an accuracy of about 0.5% in the ^{235}U absolute fission cross-section, several time-of-flight runs are performed, implying 700 hours of continuous measurements and leading to a statistics of about 100,000 fission events.

The neutron flux is determined through the reaction $^{10}B(n, \alpha)^{7}Li$, by using a ^{10}B target thick enough to absorb practically, all the 2200 m/sec. neutrons and counting the 477.4 keV gamma rays of ^{7}Li with a Ge(Li) spectrometer. The gamma ray detection efficiency, ε_γ, can be determined in two ways:

1. Irradiating with neutrons gold foils, identically to the boron targets, and recording the gold 411.8 keV line in the same geometry as the 477.4 keV line |2,3|, ε_γ is determined as the ratio between the photopeak counting rate and the absolute activity of the gold foil, which is measured absolutely with a 4π β-γ counter |4|. Using standard gamma sources, a correction, k_γ , to get the detection efficiency for the 477.4 keV gamma rays, is applied. By this method we succeeded to determine thermal neutron fluxes with an accuracy of the order 0.5% |5|.

2. Based on 4π α-γ coincidences, we have also tested a new method to determine absolutely ε_γ as the ratio between the number of (α - γ) coincidences and the number of detected alpha particles |6|. Thus, a simplification over our previous method is performed, since the correction k_γ drops out and the advantages of the 4π - geometry and those of coincidence method is preserved, permitting in a careful arrangement to obtain an accuracy of the order 0.2% |7|. By using a number of 10 boron targets, one expects a contribution of nonuniformity to the standard error of the average ε_γ of the order of 0.2%. By applying this method of 4π α - γ coincidences, one can expect an accuracy in determining thermal neutron fluxes better than 0.5%. In the next 1977 year, it is emphasized to investigate thoroughly the possibilities of this method in performing cross-section measurements.

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Thermal neutron cross sections of Al, Si, Cu, Zn, Ge, Pb and Bi in the single crystal state

B. Grabcev, V. Cioca and S. Todireanu

The single crystals are largely used in thermal neutron spectroscopy as beam filters, monochromators and samples as well. In all cases, if we wish to calculate effects or to perform corrections for the experimental conditions it is necessary to know the total cross section of the material in the single crystal state. The need of these data has been appeared in our laboratory in connection with the study of the reflecting properties of crystal monochromators. The measurements have been performed with monochromatic beams in the energy range from 0.003 to 0.2 eV. In order to remove eventually elastic-coherent contributions the measurements have been repeated slightly reorienting the crystal, several times for each energy. The cross section of Bismuth single crystal has been measured at room temperature as well at 77°K. The experimental results are in a good agreement with the theoretical predictions.

U^{235} fission thermal effective cross section

I. Cristian* and I.M. Mihăilescu - Brâncuş**

* Institute for Nuclear Technology

** Institute for Atomic Physics

Using the ^{235}U fission cross section measured by M. Petrascu et al., this paper presents the effective cross section factor, g and the fission thermal effective cross section values for U^{235} at different temperatures.

In order to generate these values a weighting spectrum, characteristic to a heavy water reflector, calculated by means of SATAN code was used.

To obtain useful data for SATAN code, which uses 9 and 15 groups till the cut-off energy of $E^* = 0.23$ ev and $E^* = 0.625$ ev, respectively, the multigroup cross-section values were prepared by taking into consideration the value at the middle point of each energy group.

The use of a heavy-water reflector cell allows to obtain the values for the neutron temperature equal to the physical temperature $T_n = T_o$.

The value of $g(t)$ obtained for $T_0 = 293^{\circ}$K is equal to 0.978, in good agreement with the AIEA recommended value of G.C. Manna.

The authors point out that there is no dependence of the thermal cut-off energy for small temperatures. For temperatures greater than 555°K there is an influence of the thermal cut-off energy.

Yield ratios for some isomeric states populated through photonuclear reactions

G. Baciu, D. Catană, V. Gălăţanu , M. Grecescu

The analytic determination of several elements through photonuclear activation is based on the production of isomeric states. The evaluation and optimization of the threshold sensitivity and precision requires an accurate knowledge of the photonuclear yields.

The dependence of these values on the maximum bremsstrahlung energy is usually not available.

For practical purposes, the most useful quantity is the yield ratio:

$$R = \frac{Y_i}{Y_i + Y_g}$$

where Y_i and Y_g are the yields for the population of the isomeric state and of the ground state respectively.

For the photoactivation analysis of Sc, Rb and Zn the yield ratios can be readily determined by gamma ray spectroscopy, since the ground states are radioactive.

The activation was performed with the bremsstrahlung beam of a 25 MeV betatron provided with an accurate energy stabilization system (±10 keV). The activity was measured by a conventional $Ge(Li)$ gamma-ray spectrometer.

The results are summarized in table . For comparison, the values obtained at 20 MeV by Y. Oka e.a., Bull. Chem. Soc. Japan 41 (1968) 1606 are also given.

Reaction	15 MeV	$R_{exp.}$ 20 MeV	25 MeV	Y. Oka e.a. 20 MeV
$^{45}Sc(\gamma,n)^{44}$ ^{44i}Sc	0.073±0.025	0.13±0.02	0.19±0.02	0.084
$^{85}Rb(\gamma,n)^{84}$ ^{84i}Rb	0.13±0.02	0.25±0.03	0.28±0.03	0.24
$^{90}Zr(\gamma,n)^{89}$ ^{89i}Zr	0.60±0.03	0.47±0.025	0.426±0.025	0.33

A calculation based on the statistical model is in progress for comparison with the experimental data.

Statistical parameter determinations of some heavy nuclei

Elena Nicuţi-Truţia

Studying energy and angular distributions of the evaporation neutrons from (p,n) reactions at various bombarding energies we found the best conditions for determining statistical parameter values. The interpretation, in the last time, of the particle spectra in terms of preequilibrium decay models led us to an attentive analysis of the spectra to choose the statistical emission region necessary for determining statistical parameters. At each bombarding energy and emission angle we performed a separation of the emission cross section of the neutrons with energy ε in equilibrium and preequilibrium contributions of form

$$\sigma(\varepsilon,\theta) \propto \varepsilon\sigma_{inv}[\alpha(\theta)\omega(U) + \beta(\theta)\omega_{n-1}(U)] \qquad (1)$$

where $\omega(U)$ and $\omega_{n-1}(U)$ are nuclear densities of the residual nucleus in the framework of the statistical and preequilibrium model, respectively. $\alpha(\theta)$ and $\beta(\theta)$ quantities justify the participation of the statistical or preequilibrium emission.

We performed such analysis in the case of $^{134}Ba(p,n)$ ^{134}La and $^{136}Ba(p,n)^{136}La$ reactions at 7.4, 9.1 and 10.5 MeV bombarding energies and we found that only at bombarding energy equal to 7.4 MeV the emission of neutrons is purely statistical. The results are presented in the following table.

Parameter	T(MeV)	a(MeV)$^{-1}$
^{134}La	0.46 ± 0.02	17.27 ± 0.20
^{136}La	0.52 ± 0.01	16.54 ± 0.37

At the other bombarding energies the statistical emission decreases quickly in favouring the preequilibrium one and from the separation of the spectral shapes (1) we established that the statistical parameter describing the two nuclei ^{134}La and ^{136}La is nuclear temperature.

The study of the statistical emission of neutrons from $^{158}Gd(p,n)^{158}Tb$ reaction at 7.4 MeV bombarding energy showed the presence of the preequilibrium neutrons even at this low bombarding energy, so that the statistical parameter values, obtained from the emission spectra at $\theta > 100°$ are as follows

$$T = (0.54 \pm 0.01)\ MeV$$

$$a = (20.63 \pm 0.92)(MeV)^{-1}$$

The fitting of the spectral shapes at $\theta < 100^{o}$ has also shown that the parameter T characterizes the nucleus ^{158}Tb.

Our study on (p,n) reactions in heavy nucleus has shown that the statistical emission of neutrons occurs at low bombarding energy and constant temperature of the residual nucleus.

Angular distribution of recoil nuclei

E. Bodo, D. Galeriu, M. Marinescu, D.N. Poenaru,
I. Vîlcov, N. Vîlcov

In this experiment we have studied the angular dispersion in helium of Curium nuclei recoiled out of the target following the reaction $^{239}Pu(\alpha,xn)$ at 26 MeV incident energy [1]. The recoil nuclei are collected on a 20 μm thick aluminum catcher foil placed at 21 mm downstream to the target.

We determine the recoil nuclei distribution along catcher foil radius by measuring the α-activity of these nuclei in various points of the catcher foil.

The angular distribution of the Curium nuclei was measured at pressure values within 0-60 torr.

Finally we compared the experimental data with those generated by a Monte Carlo technique [2]. We considered 20.000 points on the target surface the "events" were generated along (φ,θ) directions, with φ uniformly distributed and θ normally distributed with the σ dispersion.

The best values of the dispersion found with this method are given in the last column of Table 1.

Table 1

Experimental conditions	Dispersion (Gaussian law)	Dispersion (integrated Gaussian law)	Dispersion (Monte Carlo method)
ϕ = 4 mm p = 0 torr	16.4	14 (6,7,8,9,10) 15 (5,6) 13 (11,12,13)	24
ϕ = 4 mm p = 20 torr	11.5	9 (5,6) 8 (7,8,5) 7 (9,10)	17
ϕ = 4 mm p = 60 torr	13.5	11 (5,6) 10 (8,9,10)	18
ϕ = 8 mm p = 0 torr	12.5	11 (8,9) 10 (10,11) 9 (12,13)	20
ϕ = 8 mm p = 35 torr	14.5	10 (8,9,10) 9 (10,11)	19

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Dipole photoabsorbtion cross-section for nuclei in the $1f$-$2p$ shell

D. Catană, G. Baciu, V.J.R. Niculescu, V. Gălățanu

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A systematic investigation of (γ,p) cross-sections for medium-A nuclei was undertaken with the bremsstrahlung beam of a 25 MeV betatron.

The energy stabilization system of the betatron provided an overall stability of ± 10 keV at energies up to 25 MeV.

The particle detectors were mounted in an evacuated target chamber. Four *Si(Li)* detectors 1 mm thick were used for the measurement of the reaction yield and other surface-barrier *Si* detectors were used for photoproton spectra measurements. The yield curves were recorded with a 200 keV energy beam.

Special precautions were taken in order to prevent high-energy electrons to interact with the detectors.

A cleaning magnet was placed in front of the target chamber and the target itself was placed in a magnetic field.

The (γ,p) cross-sections were measured for the following nuclei: ^{51}V, ^{52}Cr, ^{55}Mn, ^{59}Co, ^{58}Ni, ^{60}Ni. The results support the existence of two components (Tand T + 1) of the giant resonance in the particle-hole formalism.

REPUBLIC OF SOUTH AFRICA

PROGRESS REPORT TO THE INDC

1976

Compiled by D. Reitmann

1. SOUTHERN UNIVERSITIES NUCLEAR INSTITUTE, FAURE, CAPE PROVINCE

The major research facility at SUNI is a 5.5 MV pulsed Van de Graaff accelerator which is also used by staff members and students from the universities of Cape Town and Stellenbosch. The research program covered a wide variety of topics, the most relevant of which are listed below:

1.1 Neutron reaction studies

1.1.1 Level structure of ^{232}Th using neutron scattering

W.R. McMurray, E. Barnard*, I.J. van Heerden, D.T.L. Jones**

Elastic (n,n) and inelastic (n,n') scattering of neutrons from ^{232}Th have been measured using the fast neutron time-of-flight facility at the Atomic Energy Board and the (n,n'γ) reaction has been studied using the SUNI facilities [1]. A comparison of the inelastic scattering cross sections deduced from the two methods of measurement is given in figure 1. Also shown are Hauser Feshbach calculations of the inelastic scattering cross sections using the programme PELINSCA [2] with the standard Engelbrecht potential and a variable enhancement correction [3].

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* S.A. Atomic Energy Board, Pretoria

** While working at the S.A. Atomic Energy Board

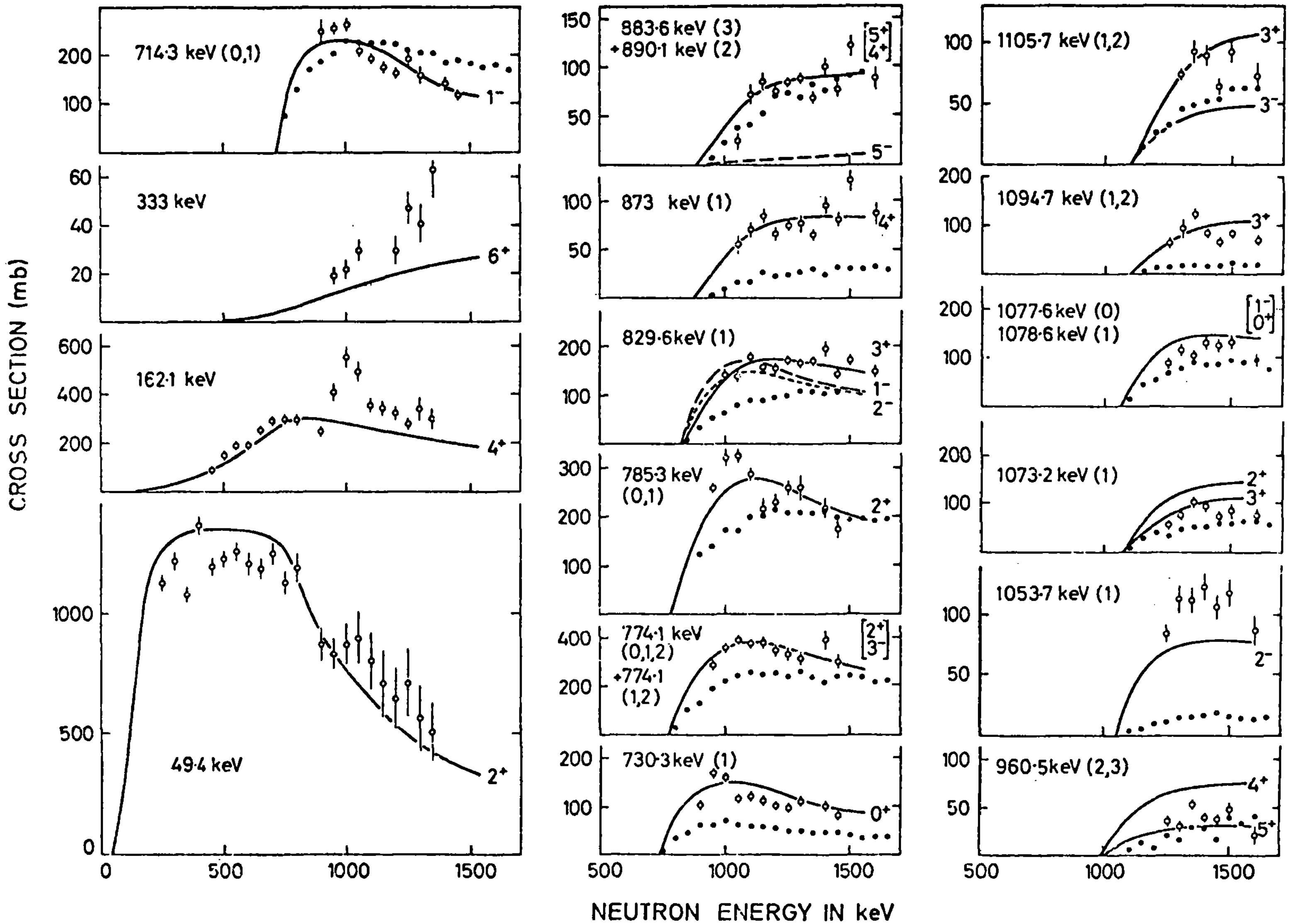

Fig. 1. Comparison of the measured (n,n') cross sections with those deduced from (n,n'γ) data (•) for ^{232}Th.

TABLE 1 LEVEL STRUCTURE OF THORIUM 232

PRESENT WORK (n,n') (n,n'γ)			COULOMB EXCITATION[5,7] AND RADIOACTIVE DECAY[8]			(d,d') Ref.[9]		REALISTIC LEVEL SCHEME.
Level	Decay	Jπ	Level	Decay	KJπ	Level	KJπ	KJπ
0			0		0,0+	0	0+	0,0+
(49.37)			49.37		0,2+	48	2+	0,2+
(162.12)			162.12		0,4+	161	4+	0,4+
(333.2)			333.2		0,6+	334	6+	0,6+
			556.96		0,8+			0,8+
714.31	0,1	1-	714.0	0,1	0,1-	713	1-	0,1
730.27	1	0+	730.4	1	0,0+	731	0,0+	0,0+
774.12	0,1,2	2+	774.1	0,1,2	0,2+			0,2+
774.12	1,2	3-	774.1	1,2	0,3-	776	3-	0,3-
785.25	0,1	2+	785.3	0,1,2	2,2+	786	2,2+	2,2+
829.57	1	3+						2,3+
872.97	1	4+	873.0	2	0,4+			0,4+
883.60	3	5-	884.1	3	0,5-	885	5-	0,5-
890.10	(1),2	(3-)4+						2,4+
960.46	2,3	(4-)5+						2,5+
			(1023)	(E0)	(0,6+)			0,6+
			(1045)	(0,1)	(0,1-)			---
1053.74	1	2-(3)	1053.5	1	2-	1054		2,2-
1073.17	1	2(+)	1072.2	0,1	2+			2+
1077.60	0	1-	1077.3	0	1-	1078		1,1-
1078.60	1	0+						0,0+
1094.72	1,2	2-,3+	(1095)	(1)	(0,3-)			1.2-
1105.65	1,2	3-	1105.7	1,2,h	3-	1107	3-	2,3-
1121.83	0,1,2,h	2+						0,2+
1143.37	2	4±						2,4-
1148.35	2,3	4,5				1149		(4)
1182.69	1	3-	1182.4	1,2,h	3-	1181		1,3-
1207.82	2	5-	1209.0	2,3	5-	1208	(5-)	2,5-
1218.30	(2),3	4-(5)						1,4-
			1294.0	3	5-	1294		---
			1322.2	0	2+			---
1329.27	2	5-				1329		1,5-
1352.92	(1)	(2)						(2)
1387.40	0,1,2	2+	1386.9	0,1,2	0,2+	1419		0,2+
1450.12	(1)							(1)
1480.04	1		1477	0,1,h	2+			2+
1484.94	(2)					1485		
1489.26	0,1							
1519.37	1							
1554.35	1,2							
1561.45	0					1562		
1572.90	0,1							
1609.12	2							
1619.12	(1)					1618		
1647.75	1,2							
1691.17	(1)					1692		
1716.5	(0)							
1721.8	(0)							
						1738		
						1791		

Decays to 0, 49.37, 162.12, 333.2 keV and higher levels are denoted as 0, 1, 2, 3 and h respectively.

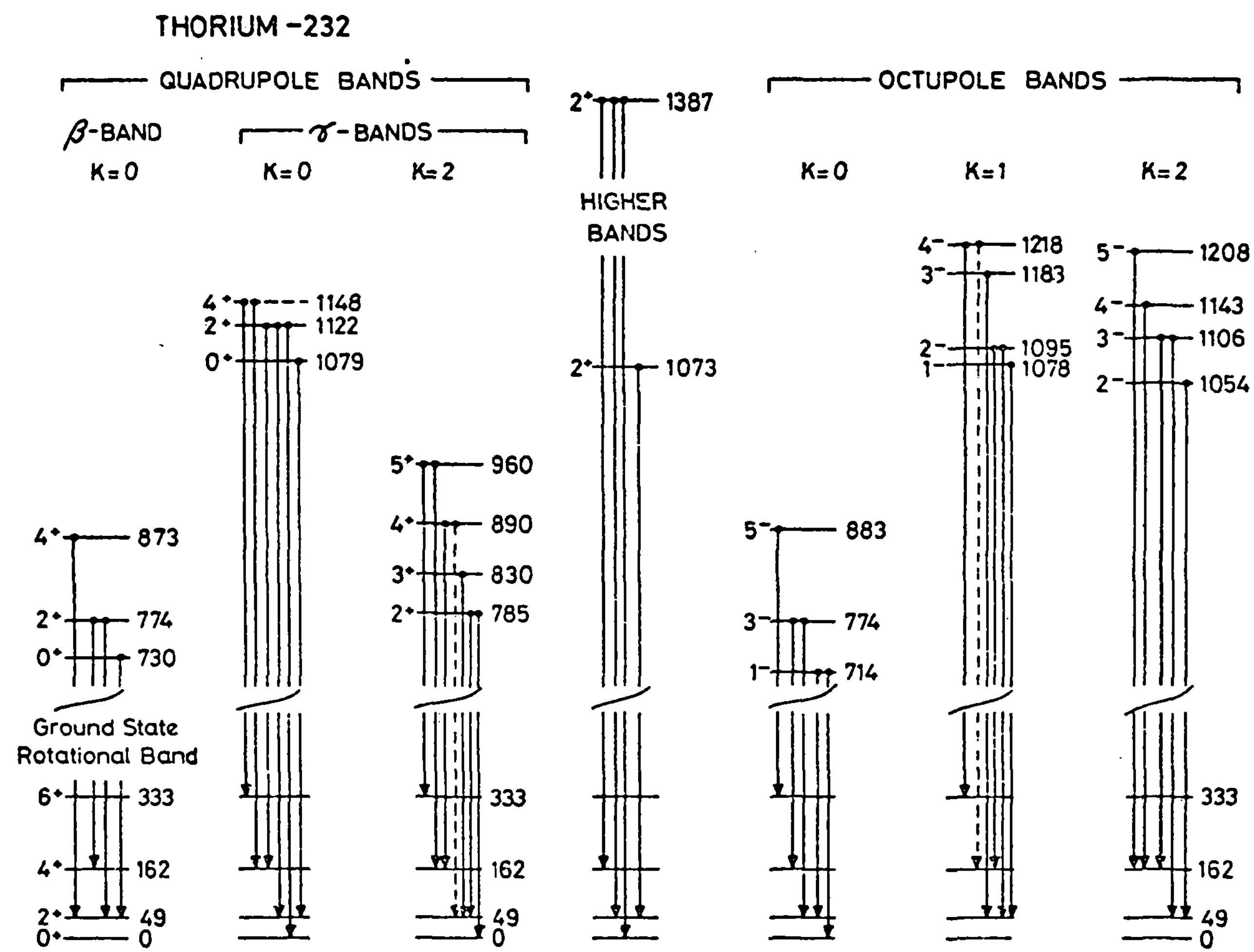

Fig. 2. The deduced collective band structure of ^{232}Th. The separation of levels into octupole K = 1 and 2 bands is tentative.

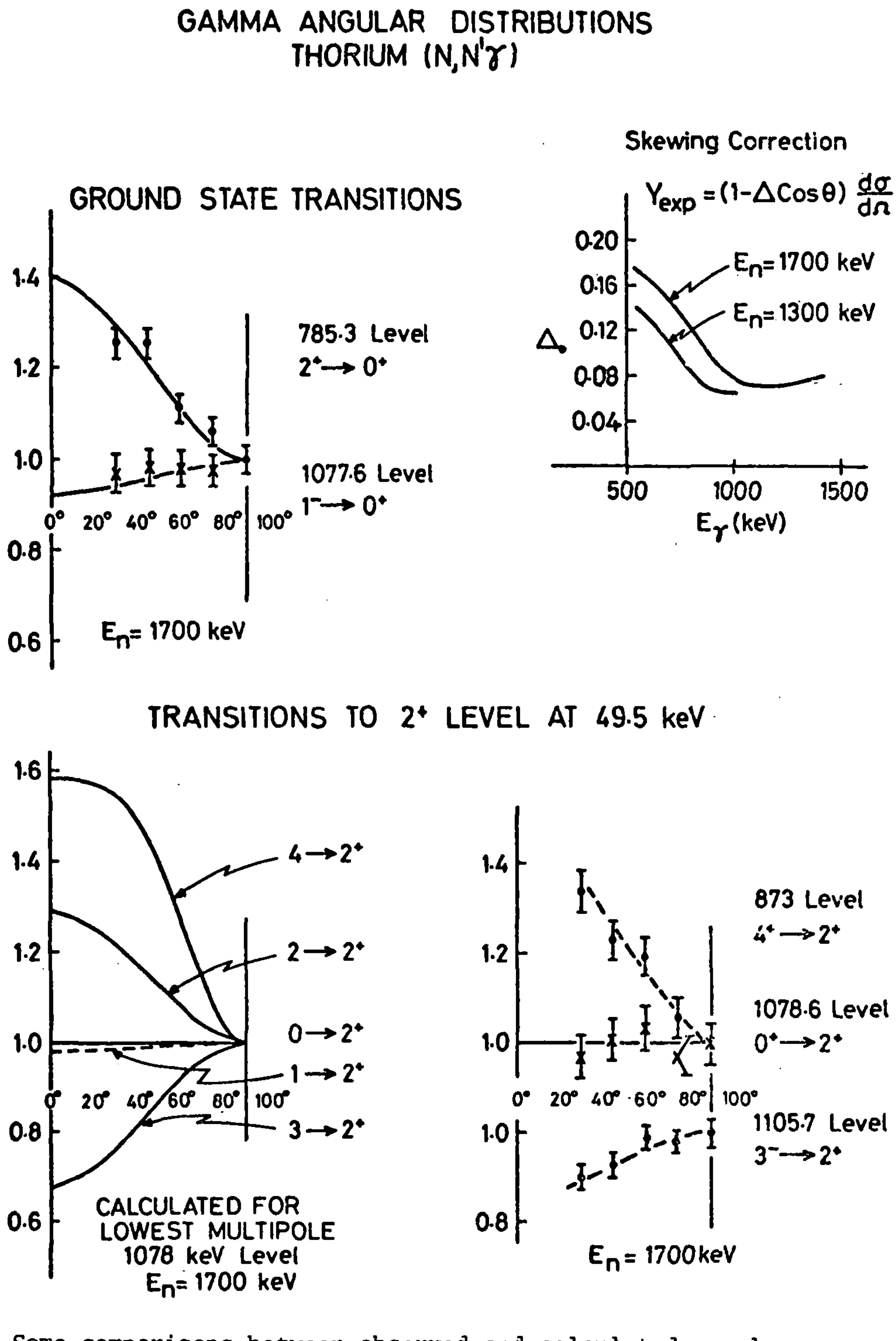

Fig. 3. Some comparisons between observed and calculated angular distributions for γ-decays from levels in ^{232}Th.

The theoretical predictions give a good fit to the measured (n,n') cross sections for those levels for which spin and parity are known and they therefore provide a guide to the Jπ values of previously unassigned levels. Further indications are provided by the decay parameters obtained from the (n,n'γ) measurements. A comparison of the level scheme of ^{232}Th derived from studies using different methods of excitation is given in table 1. A tentative assignment of these levels to collective bands (as presented in figure 2) is based on all the available data as well as the theoretical predictions of Vogel [4] for the octupole band structure. Figure 1 shows that the (n,n'γ) measurements do not provide reliable inelastic scattering cross sections for thorium. A similar result was also found in our study of the ^{238}U(n,n'γ) reaction. The discrepancies between (n,n') and (n,n'γ) cross sections can be ascribed to

(a) the existence of strong E0 transitions [5,6];
(b) the non observation of lower energy branch gamma rays due to internal conversion and gamma-attenuation; and,
(c) the consequent inability to make adequate corrections for the feeding of levels by gammas decaying from higher levels. No such corrections have been made to the data presented in figure 1.

Angular distributions of the observed decay gammas have been measured. The data are still being analysed. Some preliminary results are compared with corresponding theoretical predictions (Using PELINSCA) in figure 3.

1) Item 2.1.1, SUNI Annual Research Report (1975)
2) C.A. Engelbrecht et al., AEB Report PEL-202 (1974)
3) J.W. Tepel et al., Phys. Lett. 49B (1974) 1
4) K. Neegard and P. Vogel, Nucl. Phys. A149 (1970) 217
5) F.S. Stephens et al., Proc. Conf. on reactions between complex nuclei, Asilomar (1963) 303
6) F.K. McGowan et al., Phys. Rev. C10 (1974) 1146
7) F.K. McGowan, Oak Ridge report CONF-720669 (1972) 38
8) M. Schmorak et al., Nucl. Phys. A178 (1972) 410
9) T.W. Elze and J.R. Huizinga, Nucl. Phys. A187 (1972) 545

1.1.2 Level structure of ^{238}U using neutron scattering

W.R. McMurray, I.J. van Heerden

Recent high resolution measurements of the gammas from the $^{238}U(n,n'\gamma)$ reaction have been made to supplement previous data taken with lower resolution and efficiency [1]. Gamma spectra have been obtained at incident neutron energies up to 1750 keV. An analysis of all the available data has provided excitation cross sections for about 45 gammas decaying from about 35 levels (see figure 4). The deduced level scheme below 1200 keV excitation differs only in detail from that based on earlier work [1]. The deduced collective band structure [2] also remains essentially unchanged.

Table 2 presents a comparison of the results of the present work on the level structure of ^{238}U with other published results. The level scheme deduced by us from a neutron inelastic scattering study at Harwell [4] is also included because it directly observes the low-spin level structure. The excitation energies derived from that work are, however, clearly too large (due to an error in the accelerator energy calibration). The $KJ\pi$ values given in the last column of table 2 are based on all the available data.

1) W.R. McMurray and I.J. van Heerden, Z. Physik 253 (1972) 289
2) Item 2.1.2, SUNI Annual Research Report (1973)
3) M. Schmorak et al., Nucl. Phys. A178 (1972) 410
4) E. Barnard et al., Nucl. Phys. 80 (1966) 46
5) W.P. Poenitz, Argonne App. Phys. Ann. Report (1969-70) 24
6) G. Herrman et al., Int. Conf. on properties of nuclei from the region of β-stability, vol. II, CERN (1970) 985
7) F.K. McGowan et al., B.A.P.S. 16 (1971) 493
8) T.W. Elze and J.R. Huizinga, Nucl. Phys. A187 (1972) 545

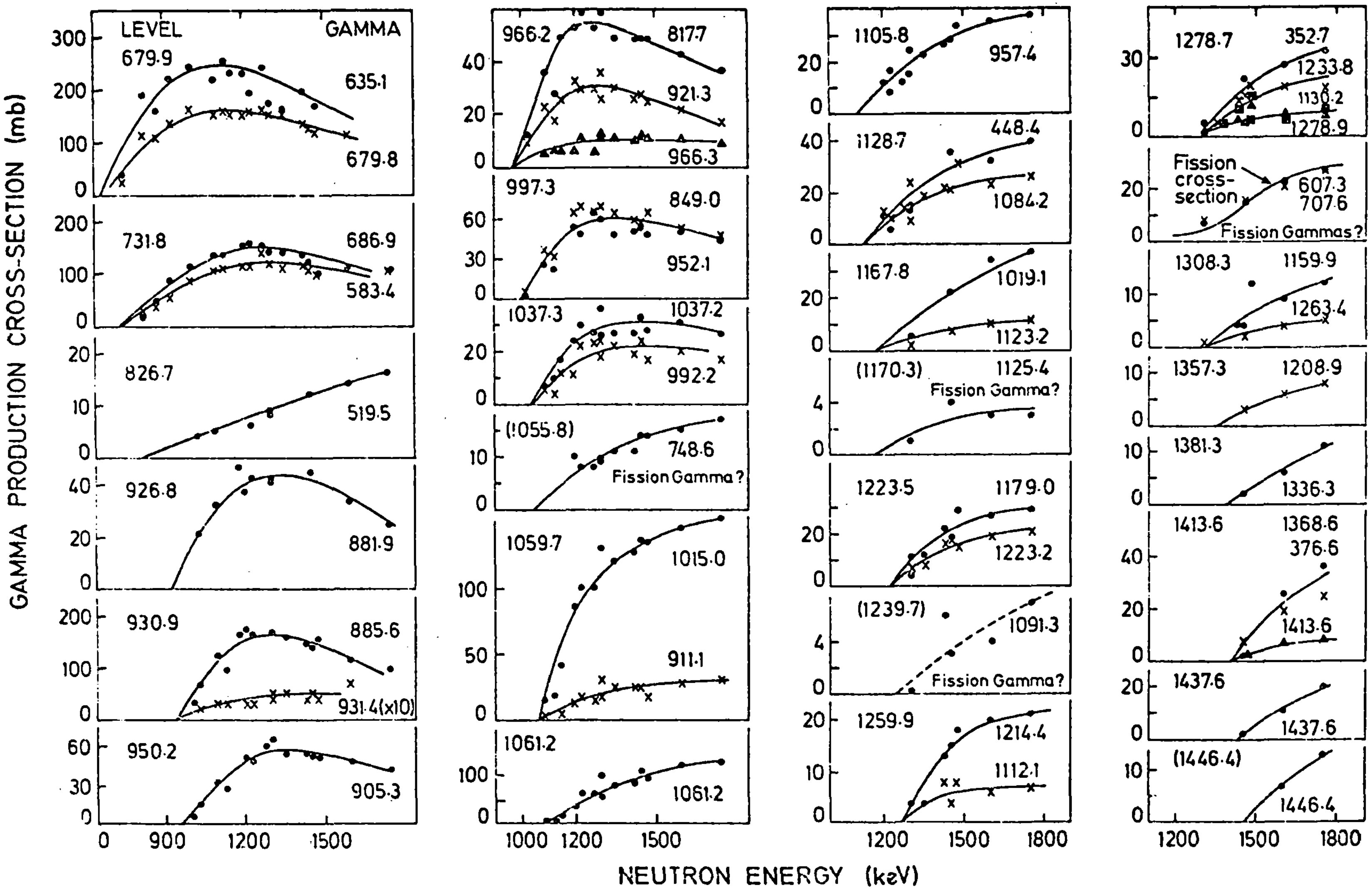

Fig. 4. Measured excitation curves for γ-rays from the $^{238}U(n,n'\gamma)$ reaction.

TABLE 2 LEVEL STRUCTURE OF URANIUM 238

PRESENT WORK		BARNARD et al.[4]	POENITZ[5]		HERRMANN et al.[6]		McGOWAN[7]		ELZE AND HUIZINGA[8]	REALISTIC LEVEL SCHEME.
(n,n'γ)		(n,n')	(n,n'γ)		(Radioactivity)		Coulomb Excitation		(d,d')	
Level	Decay	Level	Level	Decay	Level	Decay	Level	Decay	Level	K^{π}
0		0	0	0	0		0		0	0,0+
44.92		45					44.9		45	0,2+
148.41	See	149					148.4		149	0,4+
307.21	Ref.	300					307.3		308	0,6+
518.3	3)								520	0,8+
776.6										0,10+
1077.8										0,12+
1416.8										0,14+
679.9	0,1	681	679.3	0,1	680.0	0,1	680.0	0,1	679	0,1-
731.8	1,2	732	731.7	1,2	731.9	1,2	732.0	1,2,h	731	0,3-
826.7	3	838	(827)	3	826.4	2,3	827	2,3	825	0,5-
926.8	1									0,0+
930.9	0,1	939	930.6	0,1	930.5	0,1,h	930.5	0,1,h	930	1,1-
950.2	1		950.5	1	949.9	1,h	950.0	1,h		1,2-
996.8	0,1,2	968	966.5	1,2			966	0,1,2	967	0,2+
997.3	1,2	1006	997.3	1,2	997.5	1,2,h	937.5	1,2,h	998	0,0+
997.3							(998	0)		1,3-
1037.3	0,1,2	1047	1038.1	0			1037.3	0,1,2	1037	0,2+
1055.8	3									(1,4-)
1059.7	1,2	1076	1061.5	0,1	1059.5	0,1,(2)	1060.2		1061	2,2+
1061.2	0,(1),2				1060.2	1,2				0,4+
1105.8	01,2	1123	(1106)		1105.6	1,2			1103	2,3+
1128.7	1,h	1150	(1132)	(0),1	1128.3	1,h	1129	1,h	1126	2,2-
1167.8	1,2		(1169)		1167.5		1169	2,h	1169	2,3-
(1170.3)	1	1190	(1180)		1168.9	1,2,h				(2,4+)
		(1210)	(1202)							---
1223.5	0,1	1246	(1224)				1224	0,1	1231	2+
(1239.7)	2				1242.9	2				(2,4-)
1259.9	1,2	1272	(1261)	(1)						( )
1278.8	0,1,2,h		(1279)							2+
1308.3	1,2								1288	(2),5-
1357.3	2									
(1381.3)	(1)								1375	
1413.6	0,1,h									
1437.6	0									
(1446.4)	(0)									
1455.1	1,2									
(1502.9)	(1)									
(1515.4)	(1)								1512	

Decays to 0, 44.92, 148.41, 307.21 keV and higher levels are denoted as 0, 1, 2, 3 and h respectively.

1.1.3 Polarization in n-p and n-d scattering at $E_n < 23$ MeV

B.R. Simpson, F.D. Brooks, I.J. van Heerden

The need for further high precision measurements of the polarization in n-p elastic scattering at energies of 20-30 MeV has recently been emphasised [1]. The anthracene scintillation polarimeter [2] used at SUNI for such measurements is therefore being modified with a view to improving its precision and reducing systemic errors. The modifications include the introduction of digital stabilisation in the multiparameter data acquisition electronics, an improved system for rotating the crystal about the neutron beam and the use of auxilliary side detectors for measurements at scattering angles $\theta_{cm} \lesssim 90^{o}$. A pilot run has been made with the partially-completed new system and the results are now being analysed.

1) G.E. Bohannon, T. Bart and P. Signell, Phys. Rev. C13 (1976) 1816
2) D.T.L. Jones and F.D. Brooks, Nucl. Phys. A222 (1974) 79
3) F.D. Brooks and D.T.L. Jones, Nucl. Instrs. and Meth. 121 (1974) 69

1.1.4 Cross section for neutron-proton bremsstrahlung

J.J. Whittaker, F.D. Brooks, I.J. van Heerden

Work is continuing on the project [1] to measure the cross section for n-p bremsstrahlung at 22 MeV. A coincidence arrangement is used in which the target is an anthracene scintillation crystal, yielding information on the recoil proton energy and angle, and a second detector gives the outgoing neutron energy by time-of-flight. The bremsstrahlung event is identified by kinematic constraints on these parameters and the cross section is determined relative to the n-p elastic cross section.

The low ration of the bremsstrahlung to the elastic cross section, which is typically predicted as $\sim 10^{-4}$, makes it difficult to identify brems events unambiguously. The background against which these events must be identified includes accidental coincidences and other processes, such as double scatters involving the $^{12}C(n,n'\gamma)$ reaction on the carbon in the target, which mimic the brems event and are more prolific. Stricter selection criteria have therefore been introduced to overcome this problem. In particular a third detector (sodium iodide) has been added for the emitted photon so that all three products of the brems process are detected.

1) Item 2.1.4, SUNI Annual Research Report (1975)

1.1.5 Neutron cross sections for alpha production in ^{12}C

A.P. Stevens*, F.D. Brooks, I.J. van Heerden

The cross sections for the $^{12}C(n,\alpha)^9Be$ and $^{12}C(n,n')3\alpha$ reactions have been measured for incident neutrons in the energy range 18-22 MeV. The target and detector for the reaction was a deuterated anthracene scintillation crystal and pulse shape discrimination was used to identify the alpha reaction products [1]. Cross sections were measured relative to the D(n,n') elastic cross section by simultaneously observing the spectrum of recoil deuterons released within the crystal. The cross section values obtained are shown in figure 5 where they are compared with other measurements [2,3] and with a recent evaluation by Lachkar et al [4].

1) Item 2.1.5, SUNI Annual Research Report (1975)
2) G.M. Frye, L. Rosen and L. Stewart, Phys. Rev. 99 (1955) 1375
3) S.S. Vasil'ev, V.V. Komarov and A.M. Popova, Sov. Phys. JETP 6 (1958) 1016
4) J. Lachkar et al., unpublished report NEANDC(E)168"L" (1975)

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* S.A. Atomic Energy Board, Pretoria

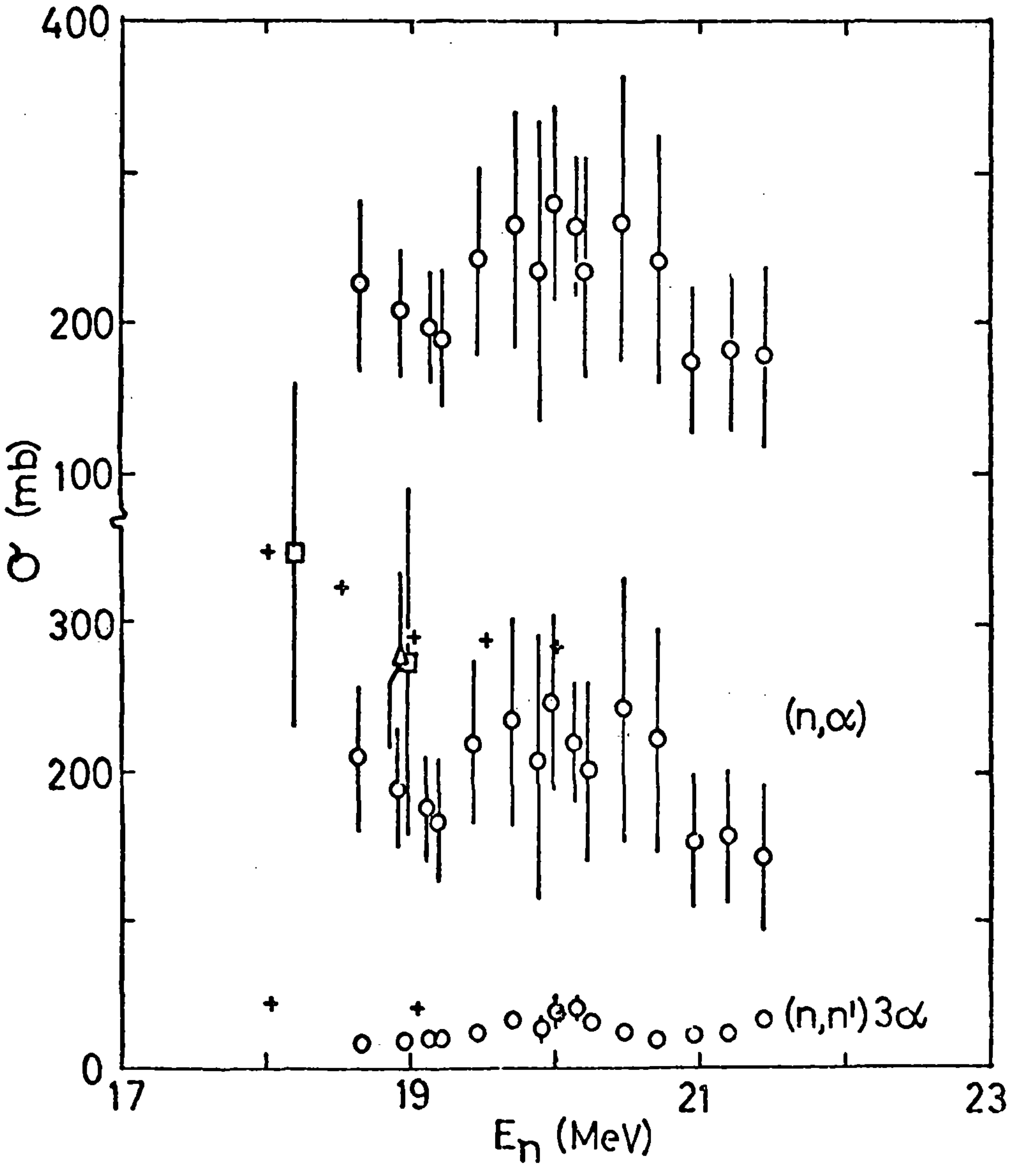

Fig. 5. Cross sections for production of alpha particles in neutron-induced reactions on carbon, showing total alpha production cross sections (above) and components due to the reactions $^{12}C(n,\alpha)^{9}Be$ and $^{12}C(n,n')3\alpha$ (below). The data are: present work (circles); Frye et al[2] (triangle); and Vasil'ev et al.[3] (squares). The crosses show the results of an evaluation by Lachkar et al.[4], based on the earlier measurements[2,3].

1.1.6 Prompt neutrons from fission of ^{252}Cf and $^{236}U^*$

J.S. Pringle, F.D. Brooks, D.W. Mingay*, C. Hofmeyr*, C. Franklyn*, A.P. Stevens*

Measurements at SUNI on the n-n angular correlation for neutrons emitted in spontaneous fission of ^{252}Cf have been reported [1,2]. As an extension of this work, measurements were made at the Atomic Energy Board of the angular correlation of neutrons emitted in thermal neutron induced fission of ^{235}U.

Experimental techniques used for the $^{236}U^*$ measurements were similar to those used for ^{252}Cf at SUNI. A sub-thermal neutron beam from the SAFARI I reactor was used to induce fissions in a uranium sample enriched to 30 % ^{235}U. Two neutron detectors mounted in a plane perpendicular to the thermal neutron beam were used to measure the coincidence rate of pairs of fission neutrons emitted at relative angles ranging from 9^o to 189^o. Foreground and background two-parameter spectra were acquired simultaneously. The parameters recorded were the energies of the recoil protons in the neutron detectors for each n-n coincidence event.

The angular correlation for $^{236}U^*$ fission neutrons with energies $\geqslant$ 1.0 MeV is shown in figure 6, together with a Monte Carlo simulation of this measurement. The results indicate that the fission neutron angular correlation for $^{236}U^*$ is similar to that observed for ^{252}Cf. In both nucleides the observed n-n correlation is more strongly peaked at small angles than is predicted by the evaporation model. This enhancement may result from a process analogous to that which gives rise to enhanced polar emission of charged particles in ternary fission.

The results of an anlysis of the two parameter spectra to investigate the energy dependence of the n-n angular correlation for $^{236}U^*$ are shown in figure 7. As a consequence of the Maxwellian form of the fission neutron spectrum the n-n coincidence

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* S.A. Atomic Energy Board, Pretoria

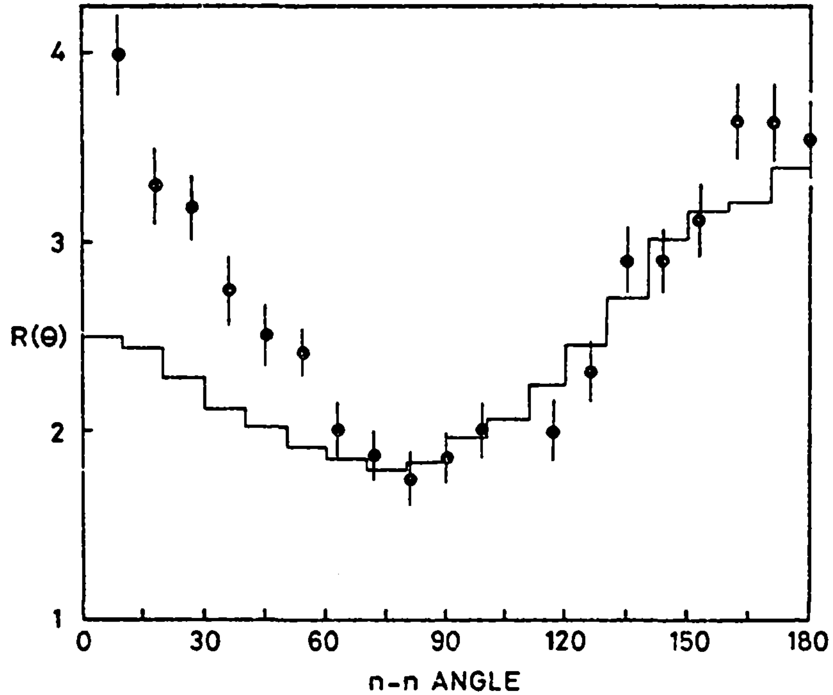

Fig. 6. The n-n angular correlation R(θ) for $^{236}U^*$ fission, showing experimental measurements (points) and Monte Carlo simulation (histogram).

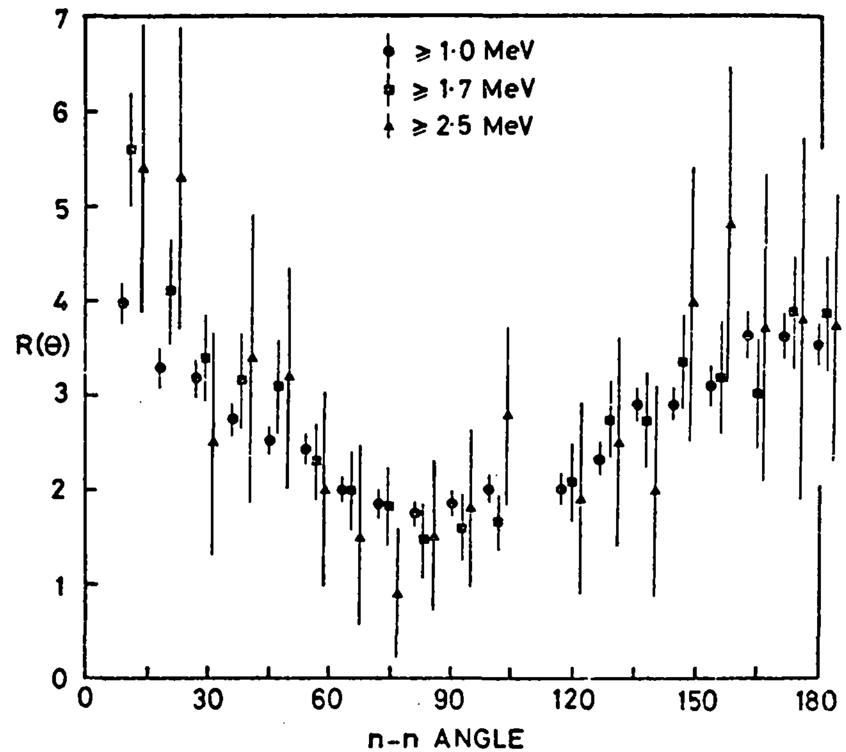

Fig. 7. The n-n angular correlation R(θ) for $^{236}U^*$ fission neutrons above different energy thresholds. The circles are plotted at the correct angles. The squares and triangles are displaced 2° and 4° respectively for clarity.

rate decreases sharply at higher neutron energies, and thus the standard deviations of the experimental points for high energy neutrons are large.

The trends displayed by the ^{236}U* data at different neutron energy thresholds are similar to those observed for ^{252}Cf. In both nucleides the angular correlation function at higher energies becomes more strongly peaked at small angles ($\lesssim 60^{\circ}$) and large angles ($\gtrsim 150^{\circ}$) relative to the value of 90°. The energy-dependent trends of the angular correlation are in qualitative agreement with those predicted by the Monte Carlo model.

1) Item 2.1.6, SUNI Annual Research Report (1975)
2) J.S. Pringle and F.D. Brooks, Phys. Rev. Letts. 35 (1975) 1563

1.1.7 Excitation of analogue dipole states via (n,p) reactions

K. Bharuth-Ram*, F.D. Brooks, W.R. McMurray, S.M. Perez, S. Wynchank

The study of the ^{28}Si(n,p)^{28}Al reaction has been described in previous reports [1] and in a recent publication [2]. Spectra of protons from the ^{28}Si(n,p) reaction showed enhancements which corresponded in position with the analogue of the giant dipole resonance (GDR) in ^{28}Si. The method used to derive absolute differential cross sections from the proton spectra were checked by carrying out a similar analysis for the deuteron spectra corresponding to the ^{28}Si(n,d) reaction. The results were comparable with the published work of Bohne et al. [3]. The ^{28}Si(n,p) measurements were corrected for an underlying component resulting from compound nucleus reactions. The remainder was analysed in terms of collective model theory using a Lane isospin coupling potential [2]. In ^{28}Si(N=Z) only one isospin component is present in the GDR. In neutron-rich nuclei (N > Z) the (n,p) reaction is

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* University of Durban-Westville, Durban

potentially able to provide the isospin structure of the GDR since it excites only the $T_>$ component of the corresponding analogue states. Work on the $^{90}Zr(n,p)^{90}Y$ reaction has been initiated.

1) Item 2.1.7, SUNI Annual Research Report (1975)
2) K. Bharuth-Ram et al., Nucl. Phys. (in press)
3) W. Bohne et al., Nucl. Phys. A111 (1968) 417

1.2 Charged Particle Reaction Studies

1.2.1 Angular correlation measurements

J.W. Koen, W.J. Naudé, N.J.A. Rust

Angular correlation measurements between gamma rays and protons (Litherland and Ferguson Method II) have been carried out for the reaction $^{48}Ti(\alpha,p\gamma)^{51}V$. The results are being analysed. First indications are that the statistics might be too poor on the higher levels due to the small beam of doubly ionised 12 MeV ^{4}He-particles available at the time of measurement. The experiment will be repeated using the Penning heavy ion ion-source.

1.2.2 Lifetime measurements

J.A. Stander, N.J.A. Rust, W.J. Naudé, J.W. Koen

Doppler broadening of gamma-ray line shapes

Doppler broadened gamma peaks from the reaction $^{19}F(\alpha,n\gamma)^{22}Na$, have been analysed to determine lifetimes of excited states in ^{22}Na. The reaction was studied at α-energies just above threshold (E_α = 5 to 6 MeV) which gave rise to the emission of ^{22}Na-nuclei in a small cone along the Z-axis. This ensured that angular distribution effects were absent from the intensity distribution.

The theoretical function compared to experimental distributions contained a part pertaining to nuclei decaying in flight while being decelerated by the stopping material and a delta function describing the contribution from nuclei at rest. The response function of Ge(Li)-detector was folded into the theoretical equation to take account of the finite resolution of the detector. The response function was assumed to be Gaussian.

Examples are shown in figure 8. The lifetimes deduced from the line shapes for the 1528 and 1983 keV states were 2.3 $\pm$ 0.3 ps and 0.9 $\pm$ 0.2 ps respectively. The result for the 1983 keV state is in agreement with the lifetime obtained using the usual DSAM.

Delayed Coincidences

The time distributions of proton-gamma coincidences have been measured for the reactions $^{41}K(p,p'\gamma)^{41}K$ and $^{44}Ca(p,p'\gamma)^{44}Ca$ at Ep = 6.0 MeV with the ND/PDP-15 multi-parameter data requisition system. Coincidences pertaining to the 980 keV (prompt) and 1294 keV (delayed) levels in the ^{41}K are shown as examples in figure 9. The slope of the decay curve for the 1294 keV state sorresponds to a lifetime $\tau = 11.6$ns. Results for the $^{44}Ca(p,p\gamma)^{44}Ca$ reaction were less satisfactory due to yield problems.

1.2.3 Level structure and branching ratios

J.A. Stander, W.J. Naudé, J.W. Koen, N.J.A. Rust

The level structure and decay properties of low-lying states in ^{39}K and ^{41}K have been measured with $(p,p'\gamma)$ reactions at Ep = 6.2 MeV. Protons and gamma rays were registered in coincidence using the ND/PDP-15 multiparameter data acquisition system. Results are being analysed.

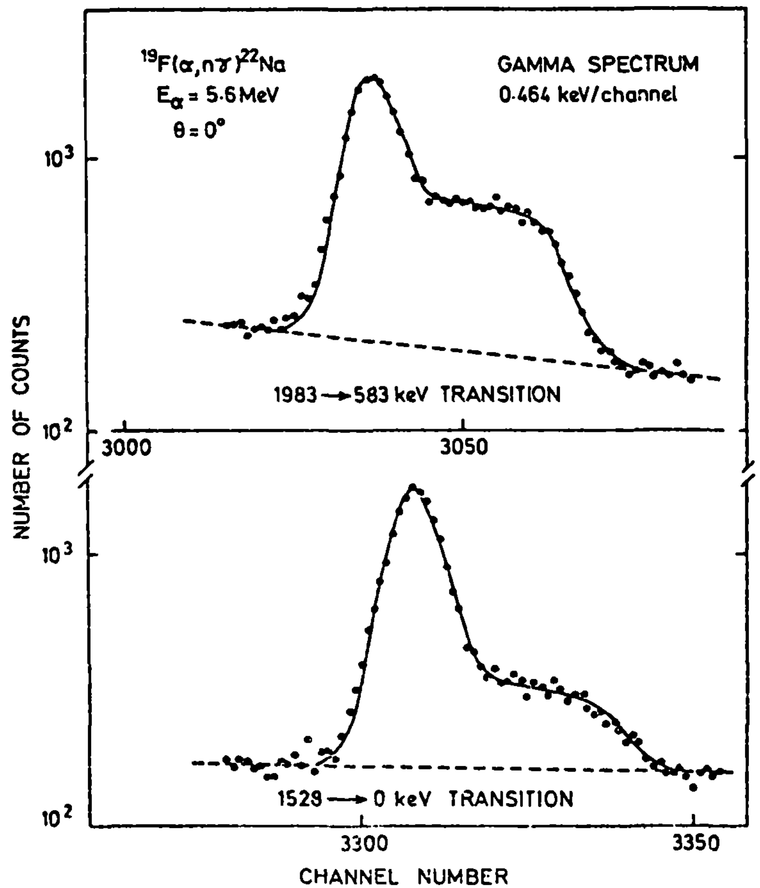

Fig. 8. Theoretical fits to observed Doppler broadened line-shapes. The target was 717 μg/cm^2 of CaF_2 on Ta.

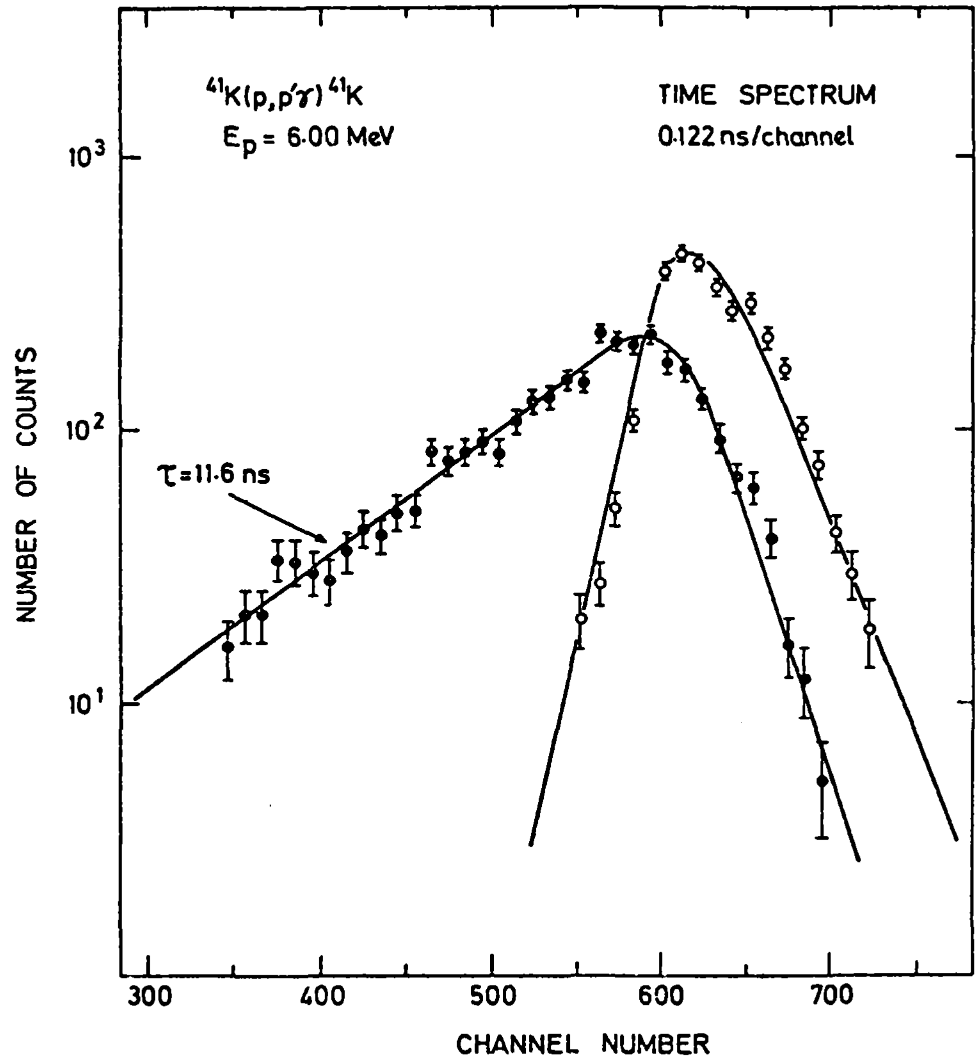

Fig. 9. The time distributions of gammas decaying from the 980 (o) and 1294 keV (•) states in ^{41}K.

2. PHYSICS DIVISION, ATOMIC ENERGY BOARD, PELINDABA, TRANSVAAL

The major facilities used for neutron physics research are the 20 MW research reactor, Safari I, and a 3.75 MV pulsed Van de Graaff accelerator with terminal bunching and an on-line computer.

2.1 Neutron capture reactions

C. Hofmeyr

Measurements were done on the in-flight annihilation of positrons and its possible effect on the two-gamma decay in the H(n,γ)D-reaction. The feasibility of observing the two-gamma decay was further investigated. The use of the thermal neutron beam from Safari I to investigate n-n angular correlation for prompt fission neutrons from ^{235}U was described under item 1.1.6 of this report. A facility for providing an external beam of high energy characteristic photons from neutron capture was added to Safari I.

2.2 Fast neutron scattering

2.2.1 ^{103}Rh

E. Barnard and D. Reitmann

The investigation of elastic and inelastic scattering of fast neutrons from ^{103}Rh by time-of-flight measurements, with special reference to the excitation of the 40 keV isometric state, as reported at the Washington conference [1] in 1975, has been extended to (n,n'γ) measurements up to 1950 keV incident neutron energy. Many unknown gamma transitions have been observed and several additional energy levels in ^{103}Rh have been postulated. Cross sections for excitation of the isomeric state were deduced from these data and extend the energy range up to 1950 keV. Data anlysis and comparison with Optical Model and Hauser-Feshbach calculations are still in progress.

1) D. Reitmann et al., Proc. Conf. on Nuclear Cross Sections and Technology, Washington (1975) 879

2.2.2 The (n,n'γ)-reaction on Ag

E. Barnard, D.W. Mingay, D. Reitmann and J. White

The gamma rays from inelastic neutron scattering from silver were observed at incident neutron energies between 800 and 1950 keV. Excitation functions were obtained for about 100 gamma transitions. Many new energy levels in the two silver nuclei have to be postulated in order to explain the observed gamma rays.

3. NUCLEAR PHYSICS RESEARCH UNIT, UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

The major research facilities include an EN-tandem, a 1.5 MV Cockroft-Walton and a 14 MeV neutron generator.

3.1 Charged particle Nuclear Cross Sections

J.P.F. Sellschop, R.J. Keddy, J.M. Carter, R.G. Clarkson, V. Hnizdo, E. Friedland, U. von Wimmersperg, H.J. Annegarn, U. Karfunkel and M.C. Stemmet

Description:

1. (p,n) total cross sections 3-8 MeV on targets of ^{84}Kr, ^{86}Kr, ^{88}Sr, ^{92}Zr, ^{96}Zr using neutron anti-detection.
2. (d,p γ) on ^{9}Be target at 1 MeV.
3. (α, α) and (α, α') up to 18 MeV on ^{40}Ca target.
4. (^{6}Li,d), (^{6}Li,t), (^{7}Li,d), (^{7}Li,t) up to 24 MeV on ^{24}Mg target.
5. (^{9}Be,^{9}Be) and (^{9}Be,^{9}Be') up to 30 MeV on ^{9}Be target.
6. (^{14}N,^{14}N) and (^{14}N,^{13}Cp) up to 42 MeV on ^{14}N target.
7. (^{16}O,^{16}O) and (^{16}O,^{16}O') up to 42 MeV on targets ^{12}C, ^{16}O, ^{24}Mg, ^{28}Si.
8. (^{18}O,^{18}O) and (^{18}O,^{18}O') up to 42 MeV on ^{16}O target.

Selection of recent references/reports:

1. Elastic and Inelastic Scattering of ^{16}O and ^{12}C from ^{24}Mg near the Coulomb Barrier
J. Carter, R.G. Clarkson, V. Hnizdo, R.J. Keddy, D.W. Mingay, F. Osterfeld and J.P.F. Sellschop, Nuclear Physics A273 (1976) 523-532

2. Elastic and inelastic scattering of ^{16}O and ^{12}C from ^{24}Mg near the coulomb barrier
J. Carter, R.G. Clarkson, V. Hnizdo, R.J. Keddy, D.W. Mingay, F. Osterfeld and J.P.F. Sellschop, Proceedings Int Conf on Nuclear Physics with Heavy Ions, Caen, September 1976
3. The absolute determination of a particle-gamma angular correlation function, with application to stripping reactions
U. Karfunkel and M.C. Stemmet, Nucl. Inst. & Meths 130 (1975) 527-531

3.2 Neutron Cross Sections; 15-30 MeV

U. von Wimmersperg and J.P.F. Sellschop

Description:

1. (N,n) recoil induced collective X-ray emission in Ne, Ar, Kr, Xe.
2. (n,n) differential and (n,p), (n,α) total cross sections on targets of Ne, Ar, Kr, Xe, C, O.

3.3 Alpha Radio Activity

U. von Wimmersperg, J.P.F. Sellschop, A. Richter, R. van Grieken, H.J. Annegarn, R.J. Keddy, M.J. Renan and C.C.P. Madiba

Description:

1. Determination of proton radiation damage ghreshold in mica for investigation of giant halo formation via $^{1}H(\alpha,\alpha)p$.
2. 3 MeV proton induced X-ray analysis of monazite composition.

Selection of recent references/reports:

1. U. von Wimmersperg and J.P.F. Sellschop
Proton induced giant halos in mica from inclusions containing water: Submitted to Phys Rev Lett, February 1977

2. H.J. Annegarn, H. Genz, D.H.H. Hoffmann, W. Löw, C.C.P. Madiba, A. Richter, J.P.F. Sellschop and R. van Grieken, Analysis of X-ray spectra excited by X-rays, electrons and protons in monazite: Submitted to Phys. Rev, March 1977

3.4 Plasma Physics

U. von Wimmersperg

Description:

Merged electron-ion beam neutralization at velocities of a few MeV/amu.

3.5 Activation Analysis

3.5.1 Using charged particles

M.J. Renan, R.J. Keddy, H.J. Annegarn, C.C.P. Madiba, J.P.F. Sellschop, U. von Wimmersperg, J.I.W. Watterson, C.S. Erasmus and R. Rolle

Description:

1. $^{19}F(p,\alpha\gamma)$ prompt γ detection in dental enamel depth profiling of fluorine.
2. $^{1}H(^{19}F,\alpha\gamma)$ prompt γ detection in depth profiling of hydrogen in diamond.
3. $^{14}N(\alpha,n)^{17}F$ followed by β^+ annihilation γ detection for nitrogen in diamond and SiC.
4. (p,n) induced, weak interaction delayed γ spectrometry using coulomb barrier sensitivity enhancement for the analysis of B in steel and medium mass contaminants in platinum group metal standards.

5. 3 MeV proton induced X-ray analysis of elemental composition of the following materials: zircon, chromite, sphalerite, gold flakes, ground water, aerosols from remote areas of southern Africa, biological samples.

3.5.2 Using thermal neutrons

J.I.W. Watterson, C.S. Erasmus, H.W. Fesq, E.J.D. Kable, B. Eddy, D. Pearton, M. Tredoux

Description:

Materials of geological and industrial interest are being analyzed:

1. Kimberley Reef Conglomerate
2. Granite
3. Antimony in Bushveld igneous complex
4. Hydrothermal gold (Barberton area)
5. Platinum group metals
6. Trace elements in diamond
7. Diamond bearing material
8. Study of the origin of gold particles by trace element analysis
9. Ru, Rh, Ir concentrates
10. Au in coal
11. Sulphide ores
12. Trace elements in archaelogical samples
13. Samples taken at different stages of routine mineral processing
14. Reference sample development

3.5.3 Using Epithermal Neutrons

C.S. Erasmus and J.I.W. Watterson

Description:

1. Biomedical samples
2. Environmental samples of water, sludge, aerosol

3.5.4 Using 14 MeV Neutrons

B.T. Eddy and J.I.W. Watterson

Description:

1. Determination of oxygen and nitrogen in grain and other materials.
2. Ag and Cu in gold bullion.

3.5.5 Activation with neutrons from ^{252}Cf

C.S. Erasmus and J.I.W. Watterson

Description:

Bulk analysis of Au in-line and in-plant.

Selection of recent references/reports:

1. Hydrogen in diamond
J.P.F. Sellschop, H.J. Annegarn, R.J. Keddy, M.J. Renan and C.C.P. Madiba, Proceedings Diamond Conference (Bristol) July 1976
2. A Non-Destructive Nuclear Method for the Determination of Nitrogen in Solids
J.P.F. Sellschop, R.J. Keddy, D.W. Mingay, M.J. Renan and D.G. Schuster, Int J of App Rad & Isotopes (1975) 26 640-647
3. Coulomb Barrier Enhancement of Sensitivity in the Detection of Trace Elements, Using Charged Particles
U. von Wimmersperg, C.S. Erasmus, M.J. Renan, J.P.F. Sellschop and J.I.W. Watterson, Proceedings Int Symp on Analytical Chemistry in the Exploration, Mining and Processing of Materials, August 1976 (Johannesburg)
4. Charged Particle Analysis of ^{19}F in Tooth Enamel
K.W. Jones, H.J. Annegarn and J.P.F. Sellschop, Proceedings 1st Int Conf on 'Physics in Industry' Dublin, March 1976

5. Qualitative Analysis of a Powered Diamond Sample by Particle Induced X-ray Emission (PIXE)
C.C.P. Madiba, H.J. Annegarn, M.J. Renan and J.P.F. Sellschop, NPRU Report No 77/1
6. A Subdivision of the Upper Witwatersrand System based on the Statistical Analysis of Trace Element Data
S.E. Rasmussen, NPRU Report No 77/4
7. The Determination, by Instrumental Neutron Activation Analysis, of Some Trace Elements in Sulphide Ores and Concentrates
D.C.G. Pearton, B.T. Eddy and D.M. Bibby, NIM Report No 1792 15 March 1976
8. The Rapid Determination of Manganese, Vanadium and Aluminium by Instrumental Neutron Activation Analysis
J.I.W. Watterson, B.T. Eddy, D.C.G. Pearton, NIM Report No 1790 20 April 1976
9. The Geochemical Behaviour of Zr, Hf, Nb and Ta in Upper Mantle Derived Material
E.J.D. Kable and H.W. Fesq, Proceedings International Geological Congress, Australia 1976
10. Some Incompatible Elements in Oceanic Basalts
E.J.D. Kable and A.J. Erlank, Proceedings International Geological Congress, Australia 1976
11. Natural Diamonds - Major, Minor and Trace Impurities in Relation to Source and Physical Properties
C.S. Erasmus, J.P.F. Sellschop, D.M. Bibby, H.W. Fesq, E.J.D. Kable, D.M. Hawkins, D.W. Mingay, M.J. Renan, S.E. Rasmussen and J.I.W. Watterson, Proceedings 1976 Int Conf on 'Modern Trends in Activation Analysis', Munich (September 1976)
12. The NIMROC Samples as Reference Materials for Neutron Activation Analysis
C.S. Erasmus, E.J.D. Kable, S.E. Rasmussen, J.P.F. Sellschop and T.W. Steele, Proceedings 1976 Int Conf on 'Modern Trends in Activation Analysis', Munich (September 1976)
13. Instrumental Neutron Activation Analysis for Uranium in Barberton and Bushveld Granites
C.S. Erasmus and J.I.W. Watterson, NIM Report No 1749
7 November 1975

14. Geology and Geochemistry of Bouvet Island
W.J. Verwoerd, A.J. Erlank and E.J.D. Kable, International Association of Volcanology and Chemistry of the Earth's Interior. Reprint from Proceedings of the Symposium on 'Andean and Antarctic Volcanology Problems' (Santiago, Chile, September 1974) 1-35

15. Nuclear Probes in Physical and Geochemical Studies of Natural Diamonds
J.P.F. Sellschop, NPRU Report No 76/2

16. The Significance of Incompatible Elements in Mid-Atlantic Ridge Basalts from 45^{o}N with Particular Reference to Zr/Nb
A.J. Erlank and E.J.D. Kable, Contrib Mineral Petrol 54, (1976) 281-291

17. The Determination of Arsenic, Antimony, Cobalt, Cadmium, Iron and Nickel in Pure Zinc Sulphate Solutions by Instrumental Neutron Activation Analysis
B.T. Eddy, NIM Technical Memorandum No 10056 26 November 1976

18. Investigation of Radiochemical Methods for the Platinum Group Metals for Neutron Activation Analysis
M. Tredoux, Report NPRU No 76/1

19. Multielement Analysis for Air and Water Pollutants in Gold Mines by Thermal and Epithermal Neutron Activation
C.S. Erasmus, J.I.W. Watterson and J.P.F. Sellschop, Proceedings 8th Materials Research Symposium: Methods and Standards for Environmental Measurement (Washington, September 1976)

20. Epithermal Neutron Activation Analysis for Uranium in Barberton and Bushveld Granites
C.S. Erasmus and J.I.W. Watterson, NIM Report No 1749 7 November 1975

21. The Determination of Some Impurities in Zirconium Metal by Instrumental Neutron Activation Analysis
B.T. Eddy, D.C.G. Pearton and J.I.W. Watterson, NIM Report No 1861 20 September 1976

22. Multi-Element Neutron Activation Analysis and the Recognition of Geochemical Patterns for Mineral Exploration
J.I.W. Watterson, S.E. Rasmussen, J.P.F. Sellschop and D.M. Hawkins, Proceedings Int Symp on Analytical Chemistry in the Exploration, Mining and Processing of Materials, 23-27 August 1976 (Johannesburg)

23. Neutron Activation Analysis in the Mineral Processing Industry
J.I.W. Watterson, B.T. Eddy, D.C.G. Pearton, J.P.F. Sellschop and T.W. Steele, Proceedings Int Symp on Analytical Chemistry in the Exploration, Mining and Processing of Materials, 23-27 August 1976 (Johannesburg)

24. Determination of the noble Metals by Radiochemical Neutron Activation Analysis
C.S. Erasmus and M. Tredoux, Proceedings Int Symp on Analytical Chemistry in the Exploration, Mining and Processing of Materials, 23-27 August 1976 (Johannesburg)

25. Activation Analysis Techniques and the South African Mining Industry
R.J. Keddy and J.P.F. Sellschop, Proceedings 1st Int Conf on 'Physics in Industry' March 1976 (Dublin)

26. The Regional Geological Setting of Mineralization in the Murchison Range with Particular Reference to Antimony
M. Viljoen, C. van Vuuren, T. Pearton, R. Minnitt, R. Muff and P. Cilliers, Proceedings S.A. Geological Society Congress in Stellenbosch July, 1975

27. Aspects of the Geochemistry of Kimberlites from the Premier Mine, Transvaal
H.W. Fesq, E.J.D. Kable and J.J. Gurney, Phys & Chem of the Earth 9 (45) (1975) Eds. L.H. Ahrens, J.B. Dawson, A.R. Duncan & E.J. Erlank 687-707

28. A Comparative Trace Element Study of Diamonds from Premier, Finsch and Jagersfontein Mines
H.W. Fesq, D.M. Bibby, C.S. Erasmus and E.J.D. Kable and J.P.F. Sellschop, Phys & Chem of the Earth 9 (52) (1975) Eds. L.H. Ahrens, J.B. Dawson, A.R. Duncan & E.J. Erlank 817-836

29. The Significance of the Inter-Element Relationship of Some Refractory Elements in S African Kimberlites
E.J.D. Kable, H.W. Fesq and J.J. Gurney, Phys & Chem of the Earth 9 (46) (1975) Eds. L.H. Ahrens, J.B. Dawson, A.R. Duncan & E.J. Erlank 709-734

3.6 Biological and Medical Research

R.J. Keddy, M.J. Renan, T. Nam and B. Spoelstra

Description:

Trace element determination using charged particle induced nuclear reactions and X-ray emission as well as neutron activation on the following materials:

1. Tumour and blood samples from esophagus cancer patients and related soil, water, food and tobacco samples.
2. Samples from various sarcoma.
3. Articular cartilage samples.
4. Blood samples from Kwashiorkor patients.

3.7 Radiation Protection

T. Nam and R.J. Keddy

Description:

Investigation of X-ray doses received by patients undergoing Xeroradiography.

3.8 Radiation Damage

T.E. Derry, R.W. Fearick and J.P.F. Sellschop

Description:

Radiation damage and channeling of protons, alpha particles and C ions in diamond [1].

1) Ion Channeling and Damage Location Studies in Diamonds T.E. Derry, R.W. Fearick and J.P.F. Sellschop, NPRU Report No 75/13

3.9 Environmental Isotope Studies

B. Th Verhagen and P.E. Smith

Description:

Utilising isotopic species present in the environment, but not necessarily natural, in the study of natural processes. Radioactive isotopes employed:

^{3}H (tritium) $t_{\frac{1}{2}}$ = 12,26 yr

^{14}C (radiocarbon) $t_{\frac{1}{2}}$ = 5730 yr

Stable isotopes employed (in relation to most abundant species): $^{2}H/^{1}H$; $^{13}C/^{12}C$; $^{18}O/^{16}O$.

Facilities available:

1) Low-level gas proportional counters (6) with associated chemical conversion systems, electrolytic enrichment installation etc. for ^{3}H and ^{14}C measurement.

2) Double collecting mass spectrometer (Micromass 602C) with associated chemical conversion systems for ^{2}H; ^{13}C and ^{18}O measurements.

Fields of application of these isotope techniques include

1) Bomb ^{3}H fallout (IAEA network).

2) Groundwater turnover studies. ^{14}C and ^{3}H concentrations indicate balance between input/output.

3) Soil moisture infiltration rates with bomb ^{3}H.

4) Ground- and surface water typing and tracing with ^{2}H and ^{18}O.

5) Carbonate exchange processes using ^{13}C and ^{14}C.

6) Dating of secondary limestones with ^{14}C.

7) Paleotemperature studies of carbonate deposits with ^{2}H, ^{18}O and ^{13}C.

8) Archaeological dating with ^{14}C.

Selection of recent references/reports:

1. The Dating of Cave Development - an Example from Botswana
H.J. Cooke and B. Th Verhagen, Proceedings 7th International Speleological Congress, Sheffield, September 1977

2. Hot Springs of Rhodesia: Their Noble Gases, Isotopic and Chemical Composition
Emanuel Mazor and B. Th Verhagen, Journal of Hydrology, 28 (1976) 29-43

3. Some Environmental Isotope Studies in Southern Africa
B. Th Verhagen, J.P.F. Sellschop and R.J. Keddy, Proceedings First Int Conf on 'Physics in Industry' Dublin, March 1976

4. Northern Kalahari Ground Waters: Hydrologic, Isotopic and Chemical Studies at Orapa, Botswana
E. Mazor, B. Th Verhagen, J.P.F. Sellschop, M.T. Jones, N.E. Robins, L. Hutton, C.M.H. Jennings, Submitted to J of Hydrology (September 1976)

5. A Study of the Effectiveness and Application of Environmental Tritium as a Ground Water Tracer in a Semi-Arid Region of Botswana
B. Th Verhagen, J.P.F. Sellschop and C.M.H. Jennings, NPRU Report No 75/2