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INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

Progress Report

on

Nuclear Data Activities in South Africa

1983/1984

July 1984

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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Progress Report to the INDC

1984

Compiled by E Barnard

1. Physics Division, Nuclear Development Corporation of South Africa, Pelindaba, Transvaal

The major facilities used for physics research are a research reactor Safari I, a medium sized tokamak and the pulsed 3.75 MV Van de Graaff accelerator with terminal bunching and an on-line computer.

1.1 Scattering of fast neutrons

- E Barnard and D Mingay

The work associated with (n,n'γ) measurements on Ag, Au and Nb is being carried out at a low level at present.

Cross correlations between results obtained from (n,n'γ) measurements on Zr, ^{56}Fe and ^{7}Li which are used as standards in such measurements are being investigated.

1.2 Neutron Capture Reactions

- C Hofmeyr and C B Franklyn

The results of a collaborative measurement of ^{73}Ge(n,γ)^{74}Ge transitions at ILL Grenoble have largely been accounted for in a ^{74}Ge level and decay scheme which is being correlated with results from various other types of experiments (eg β-decay, charged particle reactions). Due to the number of observed transitions (~800) a large number, especially weak ones, remain unplaced or ambiguous.

Neutron capture gamma-ray studies by the same group on the level schemes of ^{40}K and ^{76}Se have been concluded and published [1,2].

1. "Levels and Gamma transitions of ^{40}K studied by Neutron Capture"
T von Eggidy, P Hungerford, H H Schmidt, K P Lieb, B Krusche, G Borreau, H G Borner, R Brissot, C Hofmeyr and R Rascher
J Phys G 10 (1984) 221

2. "The $^{75}Se(n,\gamma)$ ^{76}Se reaction and the Low-lying Structure of ^{76}Se"
Y Tokunaga, H Seyforth, O W Schult, H G Borner, C Hofmeyr, G Borreau, R Brissot, U Kamp and G Monkmeyer. Nucl Phys A 411 (1983) 209.

1.3 <u>Neutron Induced Fission</u>
- C B Franklyn and C Hofmeyr

The current research into the fission process relates to the measurement of fission fragments, neutrons and gamma-rays emitted when a ^{235}U foil (approximately 1 mgm/cm^2 thick) inside a reaction vacuum chamber is irradiated by a thermal neutron beam. Fission fragments are detected by either silicon surface barrier detectors or by thin plastic scintillators and the mass assymetry is identified using time-of-flight and pulse height information. Simultaneously, time-of-flight measurements with respect to the detection of a fission fragment and pulse height information are used to detect gamma rays and determine the energies of neutrons emitted in a fission event. Four neutron detectors (in which gammas are also recorded) are used, two being NE213 scintillators and two NE102A plastic scintillators. Three of the detectors are fixed at 0^o, 90^o and 180^o with respect to the fragment detector, the fourth being movable between 0^o and 180^o.

The multiparameter data taking is fully computerised and allows for the presentation as a function of various combinations of parameters. Clear separation of light and heavy fragment detection is achieved and present analysis is concerned with determining the ultimate mass resolution obtainable for the data. In spite of an extremely low count rate, adequate statistics for angular correlations of neutrons and gamma-rays with respect to light fission fragments are being obtained.

The previous neutron-neutron time-of-flight data, taken with a thick ^{235}U target is being re-analysed taking into account the complexities introduced as a result of the large variations in background contributions during data acquisition.

PROGRESS REPORT FOR THE PERIOD 1983/84

Laboratory

Van de Graaff Group
CSIR National Accelerator Centre
P.O. Box 72
Faure 7131
South Africa

Major research facility

6 MV Pulsed Van de Graaff

Full Research Programme

Nuclear and atomic physics
Nuclear Analysis : research and applications
Solid state and materials research
Radiobiology
Applications of nuclear techniques
Data processing

Relevant work reported here for INDC report

1. Status report on the 6 MV Van de Graaff accelerator
2. Nuclear reactions, nuclear structure and techniques
    - 2.1 Neutron physics
    - 2.2 Charged particle induced reactions
    - 2.3 Techniques

Submitted to

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IAEA
P.O. Box 100
A 1400 VIENNA
Austria

1983 - 1984

ANNUAL REPORT OF THE VAN DE GRAAFF GROUP

CSIR National Accelerator Centre, Faure

1. Status report on the 6 MV Van de Graaff accelerator

H. Schmitt, G. Ackermann, P. Groenewald, T. Swart, J.J. Kritzinger, W.R. McMurray

1.1 Operation

The accelerator passed a major milestone in December 1983 when it achieved 100 000 hours of running time after nearly 20 years of operation, an average of over 5000 hours per year. The accelerator utilisation remains at a high level. The total running time during the calender year 1983 was 5600 hours. About 50% of the available time was devoted to nuclear and atomic physics, more than 20% to nuclear analytical chemistry, and about 8% to ion-solid interaction studies.

Research groups from several universities and research institutions have used the accelerator facilities separately and in collaboration with Van de Graaff Group staff. The users and students who have undertaken work with the facilities are listed elsewhere. The demand for accelerator time remains in excess of available time. During the year under review, research groups have been provided with beams of H^+, D^+, He^{++}, Ar^{++}, Kr^+, N^+ and O^+. More than 1 μA of low energy oxygen beam was made available on target using the penning-type ion source. The gas stripper above the analyzing magnet made it possible to deliver higher energy beams to the target areas. The accelerator has also been run for long periods with 6 MV on the terminal, in particular, for studies making use of 12 MeV He^{++} beams. A duoplasmatron ion source is installed for pulsed beam operation. During the past year, pulsing requirements have been limited to the 1.5 ns pulses available from the top terminal bunching system. Post acceleration bunching to 0.2 ns is available but has not yet been required.

1.2 Maintenance and Development

Most of the time required for maintenance (about 15% of the total running time) was taken up by routine ion-source changes and the subsequent conditioning up to operating voltages. The pulsing and bunching system in the terminal were overhauled and some of the circuits were modified for greater reliability.

The duoplasmatron ion source requires cooling with circulating freon. Trouble has been experienced over a number of years with sparking down the insulating pipes carrying the cooling freon from the base to the top terminal of the accelerator. A new set of pipes has been made of polythene tubing formed into spirals about 150 mm in diameter. They have functioned satisfactorily for several months up to 5.5 MV on the terminal. The original 50 kV belt-charge supply failed and has been replaced by a modern supply which is functioning satisfactorily.

A liquid nitrogen storage tank (600ℓ capacity) was installed to provide for the needs of vacuum pumps and research equipment. This was at first found to be a costly exercise because a significant fraction of the liquid was wasted as boil-off. The solution to this problem was to pipe the boil-off nitrogen into the storage tank for the Van de Graaff accelerator-gas thus reducing the regular requirement for purchased nitrogen gas.

2. NUCLEAR PHYSICS AND NUCLEAR STRUCTURE AND TECHNIQUES

2.1 Neutron Physics

2.1.1 Neutron cross section of ^{89}Y analysed in terms of the level structure and reaction mechanisms

W.R. McMurray, M.J. Renan, I.J. van Heerden*, C. Budtz-Jorgensen**
P.T. Guenther***, A.B. Smith***, J.F. Whalen***.

Yttrium is mono isotopic and magic in neutron number (N=50). Despite extensive charged-particle studies its level structure above 3 MeV was essentially unknown and uncertainties remained at lower excitations. Low lying levels of ^{89}Y have been attributed to a proton coupled to excitations of the ^{88}Sr core[1] and there is some support for core excitations which are collective in nature. It has also been suggested that the absorption strength of the optical-model potential is small near shell closures[2]. There is thus basic interest in both the level structure and the neutron interactions in this energy region. There is additional applied interest in that yttrium is a fission-product in the neutron fission of ^{232}Th and ^{240}Pu.

The present study was a collaborative effort between NAC (which provided the (n,n'γ) data and level scheme information) and Argonne National Laboratory (which provided total, elastic scattering, and (n,n') data).

Total cross sections were deduced from the observed transmissions of approximately monoenergetic neutrons through the samples using the Argonne total cross-section apparatus. Total cross section measurements were made at incident neutron energies of 0.5 x 0.1 to 4.2 MeV.

Differential neutron scattering measurements were made using the Argonne time-of-flight facility which incorporates ten shielded detectors at different angles. Measurements were made at 50 keV intervals from 1.5 to 4.0 MeV. Differential inelastic scattering cross sections were determined concurrently with the elastic scattering cross sections. Seven inelastic neutron groups were observed corresponding to the more detailed level structure deduced from the (n,n'γ) measurements.

Inelastic gamma ray measurements were made on the NAC 6 MV Van de Graaff using a pulsed proton beam with pulse duration of 1.5 ns. The $T(p,n)^3He$ reaction was used as a neutron source with the tritium in a gas cell 3 cm long. The scattering sample was placed 9 cm from the tritium gas target and γ-rays were detected in a time-gated Ge(Li) detector about 60cm from the sample at an angle of 125° to the incident neutrons. Results were obtained at 100 keV intervals from 1.6 to 3.8 MeV neutron energies. A mixed sample of Al, Na and Ca was irradiated together with the yttrium sample at a few neutron energies to provide internal gamma-energy calibrations relevant to the well known levels of these stable isotopes[3]. Levels in yttrium were assigned from the threshold of observation of the γ-rays, together with the requirement that γ-rays from cascade transitions must show similar excitation shapes and that their energies must sum to the level energy within experimental errors. In this manner, 30 levels were identified extending up to an excitation energy of 3715-kev. Levels at 2893 and 3247 keV reported from (p,p') measurements were not observed. No comparable data is available for excitations above 3260 keV.

Considerable effort was devoted to the absolute normalisation of the photopeak γ-ray yields via the observed yield of a known γ-ray

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from a "reference" sample[5]. Several such reference samples were compared. ^{7}Li was eventually used because the inelastic excitation of the 478 keV level is slowly varying over the energy range from 1 to 4 MeV and free of the sharp fluctuations which complicate the similar use of ^{56}Fe as reference. Sample size effects were also investigated. The angle-integrated cross section data from (n,n'γ) measurement agreed within the experimental errors with the (n,n') cross-sections derived from neutron time-of-flight measurements at Argonne.

One objective of this work was the derivation of the parameters of a spherical optical-statistical model, illuminating underlying physical properties, and suitable for interpolation in this mass energy region. The parameters of such a model were deduced by concurrently chi-square fitting the measured differential cross sections. Compound nucleus processes contribute predominantly at the energies of the present work. They were calculated using the Hauser-Feshbach formalism as modified by Moldauer. The theoretical predictions give a reasonable fit to all the experimental data. The present work[6] has provided a comprehensive yttrium data base and a good basis for extrapolation to unmeasurable cross sections of applied interest.

1 : P. Hoffmann-Pinther and J. Adams, Nucl. Phys. A229 (1977) 365.

2 : A. Lane, J. Lynn, E. Melkanian and E. Rae, Phys. Rev. Lett. 2 (1959) 424.

3 : W.R. McMurray, M.J. Renan and I.J. van Heerden, SUNI Annual Research Report (1980) p 3.

4 : Table of Isotopes, 7th Edition, C.M. Lederer and V.S. Shirley, J. Wiley and Sons, New York (1978).

5 : W.R. McMurray, E. Barnard, I.J. van Heerden and M.J. Renan, SUNI Annual Research Report (1982) p 3.

6 : C. Budtz-Jorgensen, P. Guenther, A. Smith, J. Whalen, W.R. McMurray, M.J. Renan and I.J. van Heerden, Z. Phys. (submitted)

2.1.2 Fast neutron cross sections of elemental indium ; decay scheme of ^{115}In and optical model parameters

I.J. van Heerden*, W.R. McMurray, A.B. Smith**, P.T. Guenther**, J.F. Whalen**.

Elemental indium is 96% ^{115}In which is one $g_{9/2}$ proton short of the closed shell at N = 50. Previous studies of the properties of this nucleus have provided evidence for 25 levels in the excitation range 0.5 to 2.0 MeV. The average level spacing of about 60 keV makes it very difficult to experimentally observe inelastically scattered neutrons from this excitation of discrete levels. The present neutron measurments at the Argonne facilities were therefore confined to the total and elastic scattering cross sections. A separate study using the (n,n'γ) technique was made at the NAC Van de Graaff at Faure. It has been possible to identify at least 35 levels up to an excitation of 2442 keV.

Total cross sections were measured by the observed transmissions of essentially monoenergetic neutrons through the measurement sample. The neutron energy was varied from 0.8 to 4.5 MeV in steps of less than 50 keV.

The neutron elastic scattering cross sections were measured with the Argonne ten-angle time-of-flight system. The neutron detectors were placed 5.4 m from the scattering sample to separate the elastically scattered neutrons from inelastically scattered neutrons.

Neutron inelastic scattering cross sections for individual states in ^{115}In were obtained from (n,n'γ) measurements. Gamma spectra were obtained at intervals of about 100 keV for neutron energies between 0.86 and 2.4 MeV. Yields were obtained in the usual way for the excitation of gamma decays from levels of ^{115}In. Inelastic scattering cross sections from the measured yields of the gamma rays have to be unraveled from the unusually complicated excitation functions of the decay gammas. In this work the gamma-ray yields were normalised to the yield of the 846.8 keV gamma from a "reference" sample of ^{56}Fe. Effects due to the fluctuations in the known $^{56}Fe(n,n'\gamma)$ cross sections were minimised by the large energy spread in the incident neutron beam and by measuring the "reference" yield at 4 different energies between 1400 and 2400 keV.

The sum of the γ-deduced inelastic cross sections, is the total inelastic scattering cross section. That sum compares favourably with the nonelastic cross section obtained from the Argonne neutron measurements (total less elastic cross sections).

The optical model interpretation was based on the differential elastic scattering cross sections assuming a spherical optical statistical model. A real potential energy dependence was assumed in accord with global models. The imaginary potential strength was assumed to be energy independent. A spin-orbit potential of the Thomas form was included. Compound elastic and inelastic cross sections were calculated using the modified Hauser-Feshbach formula. The calculations explicitly treated the excitation of the first 19 deduced levels. Higher energy excitations were represented by the statistical formalism and parameters of Gilbert and Cameron[1]. The set of optical model parameters thus obtained gave

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a good account of all the observed neutron cross section data. The absorption strength of the present model is found to be relatively small, as is characteristic of nuclei near shell closures. In most cases the calculated inelastic scattering excitation cross sections give a reasonable fit to the observed cross section data.

There is however evidence that the measurements are incompletely explained by the deduced level and decay properties. In particular, the data points for the 597.1 keV level indicate the existence of additional feeding transitions. Another anomaly is the indication of a $^{9}/_{2}+$ level at 933.9 keV rather than the expected $J^{\pi} = {}^{7}/_{2}+$.

The present work has extended the present knowledge of the decay scheme and provided a basis for an optical model which quantitatively describes the observations[2].

1 : A. Gilbert and A. Cameron, Can. J. Phys. 43 (1965) 1446.
2 : A.B. Smith, P.T. Guenther, J.F. Whalen, I.J. van Heerden, W.R. McMurray, J. Phys. G. (Submitted).

2.1.3 Studies involving (n,p) and (n,d) reactions

W.R. McMurray, K. Bharuth-Ram*, F. Gafoor*

The study of the Zr(n,p)Y reaction in collaboration with S.M. Perez (University of Cape Town) has been completed[1]. Resonant structure observed in the energetic proton emission from this reaction has been shown to correspond in position, gross and fine structure, and in strength and angular dependence of the resonant cross sections, with expectations for the excitation of the $T_>$ giant dipole resonance of ^{90}Zr. DWBA cross sections were derived and fitted to the experimental data with a Lane potential of 150 MeV.

Recent work has been directed at the observation and analysis of several (n,d) reactions. Initial work on ^{90}Zr(n,d)^{89}Y obtained with an enriched ^{90}Zr target foil has previously been reported[2]. Additional results have been obtained for ^{56}Fe(n,d)^{55}Mn and ^{27}Al(n,d)^{26}Mg. Analysis of the experimental data and comparison with DWBA calculations has begun.

All the earlier work undertaken by ourselves, used a particle spectrometer[3] operated in air and consisting of 3 thin multi-wire proportional counters 200 mm in front of a curved scintillator 5 mm thick, 50 mm wide and 300 mm long. The necessary foil windows and air path lengths which had to be penetrated by particles before entering the scintillator energy-and-angle-detector increased the threshold energy of the system and worsened the particle identification. A simple vacuum chamber has been constructed to contain the curved scintillator and reduce on the energy attenuation of particles detected by the spectrometer. The system has been shown to operate satisfactorily and has been used for the most recent measurements on the ^{27}Al(n,d)^{26}Mg reaction.

1 : W.R. McMurray, K. Bharuth-Ram, S.M. Perez, Z. Phys. A315 (1984) 189.

2 : W.R. McMurray, K. Bharuth-Ram, F. Gafoor, SUNI Annual Research Report (1982) p17.

3 : W.R. McMurray, K. Bharuth-Ram, to be published.

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2.1.4 Photodisintegration of the deuteron near threshold

F.D. Smit*, F.D. Brooks*, D.W. Mingay**, E. Stadler**

The angular distribution of neutrons emitted in photodisintigration of the deuteron at energies close to threshold (2.226 MeV) provides a means for determining the dipole cross section ratio (i.e. ratio of M1 and E1 contributions) at these energies. Measurements of this ratio are of particular relevance in view of the present interest in the role of two-body interaction currents in the N-N system[1] and the current interest in deuteron photodisintegration[2].

Measurements of the neutron angular distribution for $E_\gamma < 3$ MeV were reported before 1951 by various authors[3]. They used gamma rays from radioactive sources and BF_3 counters or activation techniques for neutron detection. Despite the great advances that have been made in neutron detection methods in the meanwhile, it appears that no new precision measurements have been reported of the neutron angular distribution from this reaction. The present project was initiated with the aim of measuring the angular distribution for incident gamma-rays of 2.313 MeV from the $^{14}N(p,p'\gamma)$ reaction[4]. Interest has now shifted to measurements with the same sources as used in the earlier experiments[3] notably, ^{228}Th (2.61 MeV), ^{24}Na (2.75 MeV) and ^{72}Ga (2.51 MeV). The experimental method involves producing the photodisintegration in a deuterated anthracene crystal (~ 2 cm^3) which then also detects the photoproton. The photoneutron time-of-flight to a liquid scintillator at a distance of ~ 10 cm is also measured and pulse shape discrimination is employed in both detectors. A two-parameter analysis as a function of photoproton pulse height and photoneutron time-of-flight shows a very clear signature (peak) for the $^2H(\gamma,n)^1H$ reaction. A number of measurements have been made at the incident gamma energies of 2.61 and 2.75 MeV.

1 : J.F. Mathiot, Nucl. Phys. A412 (1984) 201.

2 : B.J. Hughes, A. Zieger, H. Wäffler and B. Ziegler, Nucl. Phys. A267 (1976) 329.

3 : G.R. Bishop, H. Halban, P.F.D. Shaw and R. Wilson, Phys. Rev. 81 (1951) 219, and references therein.

4 : F.D. Smit, F.D. Brooks, W.A. Cilliers, W.R. McMurray and D.T.L. Jones, SUNI Annual Research Reports, 1981 p 3, 1982 p 6.

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2.1.5 Polarization in n-p and n-d scattering at 16.9 and 21.6 MeV

B.R.S. Simpson*, R.D. Brooks*, D.T.L. Jones***

Accurate values of the analysing power in n-p scattering are needed[1-3] for N-N phase-shift analyses, where they are vital for fixing the T = 0 phase parameters, especially the S-D coupling parameter, ε_1. If sufficiently accurate measurements are made it may also be possible to detect the isospin splitting of the Δ^P_{LS} phase parameter, by comparing data obtained from p-p and n-p experiments at incident energies close to 25 MeV.

Our earlier data have been adjusted from those originally published[4,5] in order to incorporate more accurate values of the incident neutron beam polarization which have meanwhile become available[8]. These adjustments reduce the previously noted[1-3] discrepancies between different experimental data and between experiment and theory[6,7], but do not remove these discrepancies entirely.

A large amount of new experimental data has been gathered at 21.6 MeV and at 16.9 MeV, using an improved version[9] of the anthracene scintillation polarimeter developed at the University of Cape Town[4]. About one quarter of the new measurements made at 21.6 MeV have now been processed using new data reduction procedures designed to detect and remove systematic false asymmetries. These procedures have themselves been rigorously tested using computer-simulated data. The precision attained is comparable with that of the earlier data[4,5] and should be significantly improved when the reduction of all the data is completed. The data obtained at 16.9 MeV are also being analysed.

A programme of measurements of the analysing powers in neutron-deuteron elastic scattering at the same incident energies has also been undertaken using an analogous technique based on a deuterated anthracene crystal polarimeter. The data from these measurements will be analysed after the analysis of the n-p measurements is complete.

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2 : G.E. Bohannon, T. Burt, P. Signell, Phys. Rev. C13 (1976) 1816.

3 : D.V. Bugg, Progress in particle and nuclear physics (ed D. Wilkinson) 7 (1981) 47.

4 : D.T.L. Jones and F.D. Brooks, Nucl. Phys. A222 (1974) 79.

5 : C.L. Morris, T.K. O'Malley, J.W. May, Jr and S.T. Thornton, Phys. Rev. C9 (1974) 924.

6 : R.E. Seamon, K.A. Friedman, G. Breit, R.D. Haracz, J.M. Holt and A. Prakash, Phys. Rev. 165 (1968) 1579.

7 : M.H. MacGregor, R.A. Arndt and R.M. Wright, Phys. Rev. 182 (1969) 1714.

8 : J.R. Smith and S.T. Thornton, Nucl. Phys. A187 (1972) 433.

9 : B.R.S. Simpson, F.D. Brooks, C.M. Bartle, D.T.L. Jones, I.J. van Heerden, SUNI Annual Research Report 1980, p 11.

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2.1.6 Neutron spectrum from ^{252}Cf fission

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Previous investigations, e.g. by Bowman et al.[1], have attributed 90% of the prompt neutrons emitted in ^{252}Cf spontaneous fission to a neutron evaporation process from the fully accelerated and highly excited fragment nuclei and the balance to neutrons emitted at "scission". However, the observed neutron spectra, when transformed to the rest frames of the emitting fragments are found to deviate significantly from the simple form : $N(E) = (4E/\langle E\rangle^2) \exp(-2E/\langle E\rangle)$ expected from an evaporation mechanism for a spectrum of average energy $\langle E\rangle$.

Although experimental techniques have improved considerably in the past 20 years and several detailed studies have been made of the laboratory neutron spectrum from ^{252}Cf fission, little additional information has been reported about the form of the neutron spectrum in the fragment rest frame. In order to transform laboratory observations to this frame the fragment direction and velocity must be measured together with the neutron direction and velocity, in each event detected. The present work consists of such a measurement and uses a 12 μm thin film plastic scintillation (TFPS) detector to measure the fragment velocity and time-of-flight to measure the neutron velocity. The measurements were performed at a neutron-fragment angle, (in the laboratory frame) of 0°. Data were recorded in multiparameter on buffer tape and analysed off-line.

A preliminary analysis of the data was made by assuming that all neutrons for which $v_n > v_f$ originated from the fragment moving towards the neutron detector, where v_n = lab velocity of the detected neutron and v_f = lab velocity of the associated fragment moving parallel to the detected neutron. Note that this fragment was not directly detected and that v_f was calculated from the velocity v_f' of the detected complementary fragment, v_f' having been estimated from the pulse height response of the TFPS detector.

The assignment of the parent fragment made in this analysis will be incorrect for a small fraction (estimated < 15%) of the selected events. Some of these may be events in which scission neutrons were detected or events in which the detected neutron was emitted (with relatively high rest frame energy) from the receding fragment. The transformation to the fragment rest frame makes allowance for the effects of the fragment and the neutron motions on the acceptance solid angle of the neutron detector. The derived spectrum, agrees with an equivalent spectrum derived from the results of Bowman et al.[1] and deviated from the prediction of the simple evaporation form. Further data have been taken in this experiment and they are now being analysed.

1 : H.R. Bowman et al., Phys. Rev. 126 (1962) 2120 adn 129 (1963) 2133

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2.2 Charged particle induced reactions

2.2.1 The level structure, gamma-ray branching and mean lifetimes of states in ^{43}Sc, ^{43}K and ^{55}Mn

S. Froneman*, L.D. Olivier*, M.P. Janse van Rensburg*, W.J. Naudé*, J.W. Koen*

Levels in ^{43}Sc, ^{43}K and ^{55}Mn were excited with $(\alpha,p\gamma)$ reactions on ^{40}Ca, ^{40}Ar and ^{52}Cr at E_α = 12 MeV. Gamma-rays were observed in coincidence with associated protons using a multi-parameter online data acquisition system. Measurements on ^{43}K and preliminary results for ^{43}Sc have been reported previously[1]. The experimental study of ^{43}Sc has now been completed. Although no new levels are reported, more accurate energies were obtained for several of the higher lying states; new branchings were observed and the branching ratios determined. Mean lifetimes were measured with the DSAM and new information of the mean lifetimes of excited states above 2 MeV excitation in ^{43}Sc was obtained. Levels at 2.114, 2.875, 3.123 and 3.327 MeV as adopted by Endt and van der Leun[2], were not observed.

For the $^{40}Ar(\alpha,p\gamma)^{43}K$ reaction where the deceleration time of ^{43}K-nuclei is relatively long in the low density target-gas, DSAM-results support the long mean lifetime of 275 ns previously reported for the second excited state at 738 keV. The decay found for the ninth excited state at 1866 keV in ^{43}K is not in agreement with literature where present results yield branches of 22%, 54% and 24% to the ground, and the two excited states at 561 keV and 975 keV respectively.

1 : S. Froneman, L.D. Olivier, W.J. Naudé, J.W. Koen, SUNI Annual Research Report (1982) p 17.

2 : P.M. Endt, C. van der Leun, NUcl. Phys. A310 (1978) 646.

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2.2.2 Angular correlation measurements with (α,pγ) reactions

S. Froneman*, M.G. van der Merwe*, W.J. Naudé*, J.A. Stander*, W.A. Richter*

The experimental arrangement for proton-gamma angular correlation measurements with $^{40}Ca(\alpha,p\gamma)^{43}Sc$ and $^{48}Ti(\alpha,p\gamma)^{51}V$ reactions at E_α = 12 MeV using Method II of Litherland and Ferguson, has been described previously[1].

Some of the mixing ratios as obtained from these studies are listed in the table below.

Since the analysis of these results, the experiment on $^{48}Ti(\alpha,p\gamma)^{51}V$ was redone in order to improve on statistics. This was accomplished by absorbing the α-particles with aluminium foil in the detection of the protons instead of using a ΔE-E telescope, and at the same time increasing the effective solid angle subtended by the particle detector at the target.

1 : S. Froneman, J.A. Stander, W.J. Naudé, W.A. Richter. SUNI Annual Research Report (1982) p 19.

2.2.2 Table 1 Mixing ratios of gamma-ray transitions in ^{43}Sc and ^{51}V

Nucleus	$E_i \rightarrow E_f$ (keV)	Radiation Type	$J_i^\pi \rightarrow J_f^\pi$	δ
^{43}Sc	844 → 0	M1/E2	$5/2^- \rightarrow 7/2^-$	−0.12 ± 0.02
	880 → 152	M1/E2	$5/2^+ \rightarrow 3/2^+$	+1.06 ± 0.08
	1337 → 0	E1/M2	$7/2^+ \rightarrow 7/2^-$	−0.04 ± 0.11
	1337 → 152	E2/M3	$7/2^+ \rightarrow 3/2^+$	−0.07 ± 0.02
	1406 → 0	M1/E2	$7/2^- \rightarrow 7/2^-$	−0.19 ± 0.02
	1406 → 844	M1/E2	$7/2^- \rightarrow 5/2^-$	−0.29 ± 0.09
	1931 → 880	E2/M3	$9/2^+ \rightarrow 5/2^+$	−0.09 ± 0.04
	1931 → 1337	M1/E2	$9/2^+ \rightarrow 7/2^+$	+0.01 ± 0.11
	1963 → 472	M1/E2	$5/2^- \rightarrow 3/2^-$	−0.15 ± 0.07
	2289 → 0	M1/E2	$5/2^- \rightarrow 7/2^-$	−0.41 ± 0.17
^{51}V	321 → 0	M1/E2	$5/2^- \rightarrow 7/2^-$	−0.11 ± 0.04
	929 → 321	M1/E2	$3/2^- \rightarrow 5/2^-$	0.8 ± 0.3
	1608 → 0	E2/M3	$11/2^- \rightarrow 7/2^-$	−0.06 ± 0.04
	1814 → 0	M1/E2	$9/2^- \rightarrow 7/2^-$	−0.22 ± 0.08

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2.2.3 Spins of excited states in ^{43}Sc, ^{43}K and the mechanism of $^{48,50}Ti(p,p'\gamma)^{48,50}Ti$ and $^{48,50}Ti(\alpha,\alpha'\gamma)^{48,50}Ti$ reactions at E_p = 6 MeV and E_α = 12 MeV

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Spins of excited states in ^{43}Sc and ^{43}K were determined by comparing $^{40}Ca(\alpha,p)^{43}Sc$, $^{40}Ca(\alpha,p\gamma)^{43}Sc$ and $^{40}Ar(\alpha,p)^{43}K$ cross sections at E_α = 12 MeV with Hauser-Feshbach predictions.

Spins of states in ^{43}Sc up to the level at 3139.9 keV have been deduced. For ^{43}K new spin values were determined for excited states at 1205 keV and at 1866 keV. For the first level, possible values of $^1/_2$, $^3/_2$, $^5/_2$ + were deduced whilst for the second a limit of ≤ $^5/_2$ was established.

(p,p'γ) and (α,α'γ) reactions leading to final states of known spin in $^{48,50}Ti$ wwere studies at E_p = 6 MeV and E_α = 12 MeV to determine the contribution of Coulomb Excitation (CE) to Compound Nucleus (CN) formation in this mass and energy region. Results show that although CN-formation is dominant, CE-contributions cannot totally be excluded in (α,α') reactions at low nuclear excitation.

1 : P.M. Endt, C. van der Leun, Nucl. Phys. A310 (1978) 646.

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2.2.4 Shell-model calculations in the s-d and f-p shells

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M.G. van der Merwe*, S. Froneman*, W.J. Naude*

The work on the spin-tensor analysis of effective interactions in collaboration with Drs B.A. Brown and B.H. Wildenthal was carried a step further with a detailed analysis of recent effective interactions. A new empirically-derived effective interaction (BRW Brown-Richter-Wildenthal) was compared with recent effective interactions derived from the Paris and Reid nucleon-nucleon potentials using a microscopic folded diagram effective interactions theory. The BRW interaction is based on a fit of 440 binding and excitation energy data in which all 63 two-body matrix elements and three single-particle matrix elements were allowed to vary.

The comparisons between the various effective interactions are based on a technique employing a spin-tensor analysis of the L-S coupled two-body matrix elements. From these comparisons we hope to obtain an improved method of calculating reliable effective interactions to be used in nuclear structure calculations.

In particular, a reliable effective interaction for the 0f-1p shell of quality comparable to those available for lower shells is required. Work in this direction is being pursued by M.G. van der Merwe.

Calculations on a nucleus in this shell region, viz ^{43}Sc, are in progress. These calculations will complement experimental work done on this particular nucleus.

R.E. Julies, is presently completing a thesis on the mathematical basis of modern nuclear shell-model programmes employing the second quantisation formalism. He has also assisted in adapting programmes brought over from Oxford University to local Univac computers.

Several programmes relating to the abovementioned work have been brought over from the National Superconducting Cyclotron Laboratory, Michigan State University, and put into operation on the new VAX computer of the University of Stellenbosch. A new high-speed multiword version of the original Oxford shell-model code will soon be added.

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2.3 Techniques

2.3.1 Response of thin film plastic scintillators to fission fragments

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Thin film plastic scintillators (TFPS) are useful, as indicated in item 2.1.6 of this report, for determining the velocities of fragments from the spontaneous fission of ^{252}Cf. With this application in mind, a study has been made of the scintillation pulse height response of TFPS prepared from Ne102 plastic scintillator by the mthod described by Muga[1].

The response L was measured as a function of fragment velocity v and film thickness t for $1 < t < 70\,\mu m$. The fragment velocity was measured by time-of-flight using a gamma detector to detect the time of fission. The fragment time-of-flight T and the TFPS pulse height response L were recorded in dual-parameter on buffer tape and analysed off-line.

Prominent features of the results obtained are :

(a) the linear dependence of L on v;

(b) the abrupt increase (by a factor of ~ 3) of the gradient $\Delta L/\Delta v$ of this dependence in the range $6 < t < 15\mu m$; and

(c) the extrapolated detectable threshold velocity v_o = 7-9 mm ns^{-} for the detection of fission fragments.

The Voltz model[2,3] of the scintillation mechanism in organic scintillators appears to provide a basis for understanding these features and an exploratory study along these lines is now being undertaken.

1 : M.L. Muga, Nucl. Instr. and Meth. 105 (1972) 61.

2 : R. Voltz et al., J. Chem. Phys. 45 (1966) 3306 and J. Physique 29 (1968) 159.

3 : F.D. Brooks, Nucl. Instr. and Meth. 162 (1979) 477.

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