International Atomic Energy Agency

INDC(SAF)-011/G
INDC/P(90)-6

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

PROGRESS REPORT FOR SOUTH AFRICA FOR THE PERIOD 1989/90

D.W. Mingay
Atomic Energy Corporation of South Africa Limited
Pretoria 0001, South Africa

August 1990

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

INDC(SAF)-011/G

INDC/P(90)-6

Republic of South Africa

Progress Report to INDC
1990, compiled by D.W. Mingay

The work reported below was performed at the National Accelerator Centre, FAURE, and relates to work done in the year up to June 1990.

The major facilities at the National Accelerator Centre are a 6 MV Van de Graaff accelerator with terminal and post-acceleration bunching, and, a 200 MeV (protons) cyclotron facility consisting of a solid pole cyclotron as injector to a separated sector cyclotron.

1. VAN DE GRAAFF ACCELERATOR PROJECTS

1.1 Neutron Physics

1.1.1 Neutron inelastic cross-sections

R Carolissen*, W R McMurray, I J van Heerden*

* University of Western Cape, Bellville

The (n,n') and (n,n'γ) reactions provide useful information on the low-lying level structures of heavier nuclei. Our measurements on ^{159}Tb have been used to extract detailed information on the ^{159}Tb level scheme. The inelastic cross-sections however, are subject to normalisation uncertainties. An additional set of measurements has been undertaken specifically to check the normalisation factors obtained from available comparison-sample cross-sections.

1.1.2 Nuclear structure studies with (n,d) reactions at E_n = 22 MeV

D Aschman*, K Bharuth-Ram§, W R McMurray, L Qangule*

* University of Cape Town
§ University of Durban-Westville

We have previously reported on the ^{90}Zr(n,d)^{89}Y reaction {1}, the ^{27}Al(n,d)^{26}Mg reaction {2} the ^{56}Fe(n,d)^{55}Mn reaction {3} and have most recently completed measurements of the ^{51}V(n,d)^{50}Ti reaction all at E_n = 22 MeV.

A study of the ^{51}V(n,d) reaction has proved to be more difficult because, although the lower-lying states are well separated in energy and can be clearly resolved by the particle spectrometer {4}, the major part of the total transition strength is seen in the excitation of higher-lying states. Analysis of the data is continuing.

References

1. K Bharuth-Ram et al., Phys. Rev. C36 (1987) 1749

2. R Y Naidoo et al., Z. Phys. (in press)

3. National Accelerator Centre Annual Report NAC/AR/89-01 (1989) p 59

4. W R McMurray et al., Nucl. Instrum. and Meth. A288 (1990) 421

1.1.3 Response of NE213 scintillators to 14 MeV neutrons

C G L Henderson*, A Buffler*, M S Allie*, M J Oliver*, F D Brooks*, W A Cilliers*

* University of Cape Town

The response functions (pulse height spectra) of NE213 liquid scintillators for 14 MeV neutrons have been simulated by Monto Carlo calculation and measured experimentally, using tagged neutrons from the $^3H(d,n)^4He$ reaction. Two detectors have been studied: detector A, a cylinder of diameter and height 50 mm, viewed by a single 50 mm diameter photomultiplier; and detector B, a rectangular slab, 130 × 130 × 70 mm, viewed through opposing 130 × 70 mm sides by four 50 mm diameter photomultipliers. Detector B is one of the neutron detectors used for experiments on muon-catalysed fusion at the Rutherford-Appleton Laboratory (RAL) in England.

The Monte Carlo simulations included neutron interactions with both the carbon and the hydrogen components of the scintillators. Neutron histories were tracked, including multiple scatterings, until the neutron either escaped from the system or dropped to an energy less than 0.1 MeV.

The response functions were measured using an associated particle system. The NAC Van de Graaff delivered a DC deuteron beam of energy 1.5 MeV through a pair of air-cooled havar windows (each 2.5 μm) into the target cell filled with tritium gas at a pressure of 400 torr. An aperture on the side of the cell (diameter 2 mm and covered by a 1.6 μm havar window) permitted alphas emitted at 90° to the deuteron beam to escape through an evacuated tube to a NE102 plastic scintillator, 0.65 mm thick. Coincident neutrons emitted from the $^3H(d,n)^4He$ reaction at the associated angle of 83° were detected in a NE213 scintillator. A LINK 5010 pulse shape discriminator was used to reject gamma background events.

The incident deuteron energy was adjusted so that deuterons entering the T_2 gas were degraded to the energy 108 keV at the point exactly opposite the alpha exit-window. This is the deuteron energy corresponding to the peak of the well-known resonance for this reaction and was easily found by tuning the beam-energy to maximise the coincidence rate observed in a small neutron detector placed at the associated neutron angle. The neutron energy selected in this way was 14.18 MeV. The time delay spectrum of coincidences between the plastic and NE213 detectors showed a strong true coincidence peak, with negligible accidental coincidence background. A clear peak was also observed in the associated alpha pulse height spectrum.

The pulse height spectrum (response function) measured using the NE213 detector is in good agreement with the summed components of the Monte Carlo simulation for this detector. The simulated spectra have been convoluted with a gaussian distribution to allow for the pulse height resolution of the system. The width of this gaussian was adjusted for best fit at the 14.2 MeV recoil proton edge and constrained to vary as $L^{\frac{1}{2}}$ for other pulse heights L.

Several features of the response function are clarified by the decomposition of the Monte Carlo simulation into components. The principal component due to n-p elastic scattering in the scintillator, shows a rise at high pulse heights. This is attributed to neutrons undergoing multiple n-p scattering and producing two or more recoil protons which sum outputs in a single scintillation. The steep rise at low pulse heights is attributed to neutron reactions on the carbon component of the scintillator, particularly the reactions $^{12}C(n,\alpha)^{9}Be$ and $^{12}C(n,n')3\alpha$. It is evident that neutron interactions with carbon make significant contributions to the response function at 14 MeV and should be taken into account when considering neutron detection efficiencies at this or higher energies.

1.1.4 Tests on plastic scintillators in a tritium atmosphere

W A Cilliers*. F D Brooks*, R Pretorius, J E McLeod, H Schmitt

* University of Cape Town

The direct measurement of the sticking coefficient in the muon catalysed dt fusion experiment at the Rutherford-Appleton Laboratory (RAL) in the UK requires the determination of the α-n and αμ-n coincidence rates. Since the energy of the alpha is at most 3.4 MeV when entering the detector, any material placed in front of the detector must be very thin. This conflicts with the requirement that the detector be shielded against tritium decay electrons and bremsstrahlung as well as from tritium which might diffuse through the window material.

Up to now semiconductor alpha detectors have been used but they are not capable of the better than 1 ns coincidence time resolution required in the experiment. Because of their superior timing properties, the possible use of thin (<100 μm) plastic scintillators as alpha detectors has been investigated.

Some metal oxides form layers that are more or less impervious to hydrogen. Two barrier materials to shield the detector from the mentioned radiation and from the tritium were investigated. These materials were Havar (1.6 μm) and Al_2O_3 (0.3 μm), respectively. We have also tried to form Cr_3O_4 on the Havar by heating it for two hours in oxygen at 500°C. Immediately after the barrier has been exposed to tritium, the background (betas plus bremsstrahlung) count rate depends only on the range of these radiations in the barrier material. The increase in the background count rate as a function of time is a measure of the diffusion rate of tritium through the barrier. Such an increase in the background count rate may adversely affect the α-n coincidence time resolution through pile-up.

A simulation experiment was set up to check on the time resolution and to find a measure of the rate of tritium diffusion through the barrier. The variation of count rate with time was measured for Havar and Al_2O_3 barrier materials. What we have learned from the experiment so far is that either barrier material may be used in conjunction with plastic scintillators for alpha energies 0.7 MeV (at the scintillator) or higher. As far as coincidence timing is concerned it was found that pile up presented no problem even at the lowest threshold investigated. The very thin layer of Al_2O_3 used seems to be a remarkably good barrier and this material will probably be preferred to Havar which is more expensive, causes higher degradation of alpha energy and is prone to pin holes.

1.2 Charged-Particle Induced Reactions

1.2.1 Level structure, gamma ray branching, mean lifetimes, mixing ratios, spin and g-factors

L D Olivier§, M P Janse van Rensburg+, R E Julies&, D M van Rooyen, W J Naudé*, W A Richter*, J A Stander*, J W Koen*, W de K Loubser*, S W Steyn§

* University of Stellenbosch
§ ESKOM
\+ Department of Health
& University of the Western Cape

Levels in ^{55}Mn, ^{22}Ne, ^{29}Al, ^{51}V and ^{54}Cr were excited with (α,pγ) reactions on ^{52}Cr, ^{19}F, ^{26}Mg, ^{48}Ti and ^{51}V at E_α = 10 to 12 MeV. Proton-gamma coincidence measurements were performed using a multiparameter data acquisition system.

In the ^{51}V studies shell-model calculations have been carried out to compare experimental results with theoretical predictions. Experimental work on ^{51}V is continuing with emphasis on the excitation region of 3 to 4.5 MeV. A number of new levels, not reported previously, have been observed.

In the study of ^{22}Ne, work on the level energies and branching ratios for the first 46 levels up to 9.3 MeV excitation has been completed. Several new branchings were observed. An analysis for mean lifetimes is in progress.

In addition to (α,pγ) studies, γ-γ coincidence studies of some nuclei have been performed at incident alpha energies of about 6 to 12 MeV.

The ^{19}F(α,pγ)^{22}Ne reaction has been used at E_α = 12 MeV to determine mixing ratios of gamma ray transition in ^{22}Ne using Method II of Litherland and Ferguson. The values of a number of mixing ratios, not previously reported, were obtained from the analysis.

Data analysis is in progress on ^{58}Ni which was studied using the (p,p'γ) reaction at E_p = 5.6 MeV.

Spins of excited states in ^{22}Ne, ^{29}Al and ^{54}Cr are being studied using (α,pγ) reactions at E_α = 12 MeV. Comparing measured cross-sections with Hauser-Feshbach predictions is generally applicable for determining the spins of levels. The spin results on ^{55}Mn have been published {1}.

A report on the determination of g-factors of levels in ^{51}V and ^{55}Mn using 3 MeV protons has been accepted for publication {2}.

References

1. M P Janse van Rensburg et al., S. Afr. J. Phys. 12 (1989) 66

2. J C van der Merwe et al., S. Afr. J. Phys. (in press)

2. CYCLOTRON FACILITY PROJECTS

2.1 Integral excitation functions of proton-induced reactions on ^{nat}Cd and ^{nat}In

F M Nortier, S J Mills, G F Steyn

Integral excitation functions for the production of a variety of radioisotopes in the bombardment of ^{nat}Cd and ^{nat}In with protons were measured up to 100 and 200 MeV, respectively, by means of the stacked-foil technique. Cross-sections were obtained for ${}^{103\ 104\ 105\ 106m\ 110m}$Ag, ${}^{107\ 109\ 111m}$Cd, ${}^{108m\ 109\ 110m\ 111\ 112m\ 114m}$In and ${}^{109\ 110\ 111\ 113}$Sn in the case of ^{nat}In, and ${}^{103\ 105\ 106m\ 110m}$Ag, ${}^{104\ 107\ 109\ 115}$Cd and ${}^{107\ 108m\ 108\ 109\ 110m\ 111\ 112m\ 113m\ 114m}$In in the case of ^{nat}Cd. The primary aim of the experiment, namely to investigate suitable proton-induced production routes for ^{111}In up to 100 MeV, has been addressed in a forthcoming publication {1}.

Reference

1. F M Nortier, S J Mills, G F Steyn, Appl. Radiat. Isot. (in press)

2.2 Integral excitation functions of proton-induced reactions on ^{nat}Ge and ^{nat}Zn

F M Nortier, S J Mills, G F Steyn

The stacked-foil technique was employed to measure integral excitation functions of proton-induced reactions on ^{nat}Ge and ^{nat}Zn up to 100 MeV. Cross-sections were obtained for the production of ^{61}Cu, ${}^{63\ 65\ 69m}$Zn, ${}^{65\ 66\ 67\ 68\ 72\ 73}$Ga, ${}^{66\ 67\ 68\ 75}$Ge and ${}^{69\ 70\ 71\ 72\ 73\ 74\ 76}$As from ^{nat}Ge, and ^{52}Mn, ${}^{55\ 56\ 57\ 58}$Co, ${}^{56\ 57}$Ni, ${}^{60\ 61}$Cu, ${}^{62\ 65}$Zn and ${}^{63\ 65\ 66\ 67\ 68}$Ga from ^{nat}Zn. Thick-target production-rate curves of relevance to the production of ^{67}Ga and its main radioisotopic impurities were derived, and yield curves of ^{67}Ga suitable for medical use (99% as well as 99.9% radionuclidically pure), obtained by allowing an appropriate decay period for its contaminants after bombardment, were calculated. A paper on these results is in preparation.

2.3 Integral excitation functions of proton-induced reactions on ^{nat}Kr

G F Steyn, S J Mills, F M Nortier, F J Haasbroek

Integral excitation functions for the production of ${}^{79\ 81\ 81m\ 82m\ 83\ 84\ 84m\ 86}$Rb, ${}^{77\ 79\ 85m}$Kr and ${}^{77\ 82}$Br in the bombardment of ^{nat}Kr with protons were measured from threshold up to 116 MeV. Thick-target production-rate curves, based on the measured integral excitation functions, were derived for ^{81}Rb as well as ${}^{82m\ 83\ 84\ 86}$Rb, and the optimum incident energy for the production of ^{81}Rb/^{81m}Kr, as a function of the target thickness in MeV (or width of the production energy window), was derived. A paper on the results is in preparation.

2.4 Integral excitation functions of proton-induced reactions on ^{nat}Cu

G F Steyn, S J Mills, F M Nortier, F J Haasbroek

Integral excitation functions were measured for proton-induced reactions on ^{nat}Cu by means of the stacked-foil technique. The aim was to identify suitable monitor reactions on ^{nat}Cu that can be used for the determination of the total proton flux of irradiations in which beam-current integration cannot be performed with the desired accuracy. The need for using monitor foils for this purpose has arisen in radioisotope production development projects in which the beam is completely stopped in a target assembly which is irradiated outside the beam-line vacuum and/or from which secondary electrons can escape. Proton beam energies of 40, 66, 100, 120 and 200 MeV were used, and cross-section values were obtained from about 20 MeV up to 200 MeV for $^{62\ 63\ 65}Zn$, $^{60\ 61\ 64}Cu$, $^{56\ 57}Ni$, $^{55\ 56\ 57\ 58\ 60}Co$, $^{52\ 59}Fe$, $^{52\ 54\ 56}Mn$, $^{48\ 49\ 51}Cr$, ^{48}V and ^{46}Sc.

For beam-flux measurement purposes it is advantageous to make use of reactions yielding products with rather long half-lives. The monitor foils can then be counted to a sufficiently high degree of accuracy at a convenient time after completion of all other measurements. The measured excitation functions of the radioisotopes $^{56\ 57\ 58}Co$ and ^{65}Zn have been found most valuable in this regard.