1.2. SPECTROSCOPY WITH (α,n) AND (p,n) REACTIONS

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The investigation of (α,n) and (p,n) reactions is attractive because these reactions may lead to nuclei which are difficult to obtain otherwise. Excited states are formed with their spins well aligned, provided that the outgoing neutrons are detected at 0^o or 180^o to the beam direction.

In our experiments neutrons are detected at 0^o, in coincidence with γ-rays, in a 5.1 cm long by 17.8 cm diam. cylindrical cell filled with NE 213 scintillator liquid. The neutron detector is placed at a distance of 1.50 m from the target to enable neutron time-of-flight detection. Gamma-rays from the first few, well separated, excited states are detected in an array of five 12.7 cm long by 12.7 cm diam. NaI(Tl) detectors and, for higher excited states, in two or three large volume (125 cm^3) Ge(Li) detectors at variable angles. The detector set-up with associated electronics is schematically shown in fig. 1.

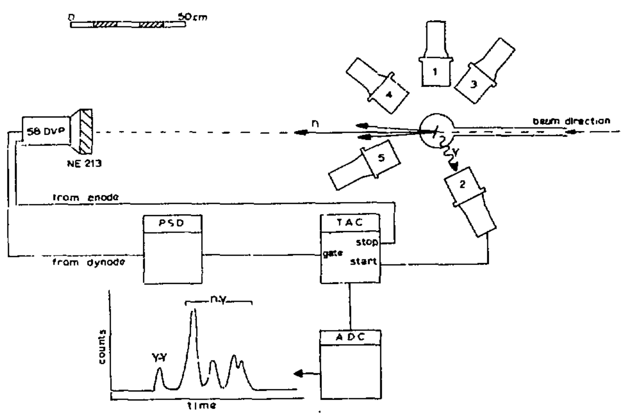

Fig. 1. The detector set-up and associated electronics, the latter shown for one γ-ray detector only, for nγ coincidence and angular-correlation experiments with the array of five NaI(Tl) detectors.

The neutron time-of-flight resolution is typically 3.5 ns (FWHM) with the scintillation detector array and 5.0 ns (FWHM) with the Ge(Li) detectors. Gamma-gamma coincidences between the neutron detector and the γ-ray detectors are suppressed by means of pulse-shape discrimination in the neutron detection channel. A typical neutron

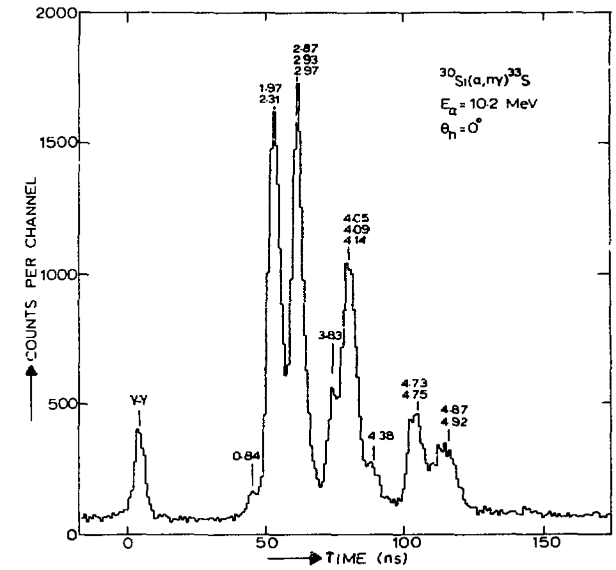

Fig. 2. Coincident neutron time-of-flight spectrum for the $^{30}Si(\alpha,n\gamma)^{33}S$ reaction at E_α = 10.2 MeV. The γ-radiation is detected with a Ge(Li) detector.

time-of-flight spectrum with γ-ray detection in a Ge(Li) counter obtained with the $^{30}Si(\alpha,n\gamma)^{33}S$ reaction at E_α = 10.2 MeV is shown in fig. 2.

The multi-parameter data are stored event by event on magnetic tape through a CDC 1700 computer interfaced with the experiment.

Neutron-gamma angular correlations measured with the $^{30}Si(\alpha,n\gamma)^{33}S$ reaction lead to three unambiguous spin and parity assignments and a number of quadrupole-dipole mixing ratios [1]. It is noteworthy that the values of a couple of mixing ratios obtained from the present *coincidence* work differ significantly from those quoted in the literature for γ-ray angular distribution measurements with the same reaction but without a neutron-gamma coincidence requirement. This implies that the usual procedure for the analysis of angular distributions, where population parameters for the magnetic substates are obtained from the statistical model, may lead to erroneous results.

Excited states of ^{27}Si and their γ-ray decay were investigated with the $^{24}Mg(\alpha,n\gamma)^{27}Si$ reaction at bombarding energies of E_α = 10.6, 10.9, 15.5 and 16.4 MeV. A preliminary analysis yields unambiguous spin and parity assignments together with excitation energies, lifetimes and E2/M1 mixing ratios for some of the observed γ-ray transitions; see table 1.

Table 1

Experimental results for ^{27}Si

E_x(keV)	J^{π}	δ a)
780.4 ± 0.2		
957.3 ± 0.2	$3/2^+$	-0.53 ± 0.07
2 163.7 ± 0.2	$7/2^+$	+0.48 ± 0.03
2 647.9 ± 0.8		
2 866.0 ± 0.5		
2 909.4 ± 0.3	$9/2^+$	
3 805.2 ± 0.9		
4 282.0 ± 1.2		τ_m(fs)
4 448.1 ± 0.3	$11/2^+$	500 ± 100
4 474.3 ± 0.9		
5 282.7 ± 0.3	$(7/2, 11/2)^+$	<30
5 316.4 ± 1.2		

a) For ground-state transitions.

The energy of the first $J^{\pi} = 0^+$, T = 2 state in ^{40}K at 4378 ± 16 keV [ref.[2]] was determined precisely with the $^{40}Ar(p,n\gamma)^{40}K$ reaction at E_p = 8.25 MeV. From nγ as well as γγ coincidence measurements with large-volume Ge(Li) counters it was found that the main γ-ray decay of this state goes via the 2.290 MeV level. In fig. 3 the γ-ray spectrum coincident with γ-rays from the 4.38 → 2.290 MeV transition is shown. The insert gives a neutron time-of-flight spectrum coincident with γ-rays detected in a large NaI(Tl) detector. The peak indicated with an arrow corresponds to neutrons feeding the T = 2 state.

The excitation energy of this state was found to be 4383.2 ± 0.6 keV. From the well known mass excess of ^{40}Ar and the poorly known (± 25 keV) excitation energy of the first $J^{\pi} = 0^+$, T = 2 state in ^{40}Ca one finds a mass excess for ^{40}Ti of -9120 ± 150 keV from the quadratic mass equation. The large error is entirely due to the uncertainty in the excitation energy in ^{40}Ca.

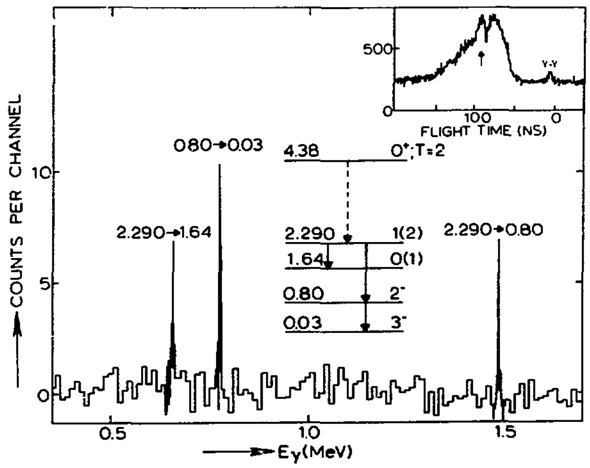

Fig. 3. Gamma-ray spectrum coincident with the 4.38 → 2.290 MeV transition in ^{40}K obtained with the $^{40}Ar(p,n\gamma)^{40}K$ reaction at E_p = 8.25 MeV. Between the γ-ray peaks the average contents over every ten channels is given. The insert shows a neutron time-of-flight spectrum in coincidence with γ-radiation with E_γ > 0.5 MeV.

1) W.A. Sterrenburg, G. van Middelkoop and F.E.H. van Eijkern, Nucl. Phys. A275 (1977) 48

2) P.M. Endt and C. van der Leun, Nucl. Phys. A214 (1973) 1