The spectroscopy of neutron-rich ^{35}P and ^{37}P

A. Hodsdon[1], X. Liang[1], R. Chapman[1], F. Azaiez[3], S. Beghini[8], B. Behera[6], M. Burns[1], L. Corradi[6], D. Curien[2], A. Deacon[7], Zs. Dombrádi[9], E. Farnea[8], A. Gadea[6], F.Ibrahim[3], A. Jungclaus[4], K. L. Keyes[1], A. Latina[6], N. Margineau[6], G. Montagnoli[8], D. Napoli[6], J. Ollier[1], A. Papenberg[1], F. Scarlassara[8], J. Smith[7], K.-M. Spohr[1], M. Staniou[3], A. Stefani[6], M. Trotta[6], D. Verney[5]

1 Institue of Physical Research, University of Paisley, Paisley, PA1 2BE, UK, 2 IReS,23 rue du Loess, 67037 Stratsbourg, France, 3 IPN, IN2P3-CNRS and Universitè Paris-Sud, F-91406 Orsay Cedex, France, 4 Dep. De Fisica Theorica, Universidad Autonoma de Madrid, E-28049 Madrid, Spain, 5 Ganil, BP 5027, 14021 Caen Cedex, France, 6 INFN, Laboratori Nazionali di Legnaro, I-35020 Leganro, Padova, Italy, 7 Schuster Laboratory, University of Manchester, Manchester, M13 9PL, UK, 8 Dipartimento di Fisica and INFN-Sezione di Padova, Università di Padova, I-35131 Padova, Italy, 9 ATOMKI, H-4001 Debrecen, P.O. Box 51, Hungary

INTRODUCTION

In the last decade there has been an increasing interest in using deep-inelastic processes to populate and study neutron-rich nuclei. With thick target measurements, use of this reaction has led to the requirement of a high efficiency Ge gamma detector array in order to carry out high fold coincidence measurements to resolve the γ-ray cascades of the many final nuclei produced, particularly since many of them are produced with low cross-sections [1,2]. An alternative approach to studying such nuclei via this reaction has been to use a magnetic spectrometer in conjunction with a high efficiency Ge detector array enabling the projectile/target-like fragments to be detected in coincidence with their associated γ-rays, thus overcoming some of the problems in identifying the origin of the emitted γ-ray, particularly in cases where there have been no previously observed γ-ray transitions. In this report we present results obtained using such a method in the study of neutron-rich P isotopes.

EXPERIMENTTAL SET-UP

The combined XTU-Tandem and ALPI accelerators at the INFN Legnaro laboratory , Italy were used to deliver a beam of ^{36}S ions at 215 MeV (5.97 MeV/u) onto a thin ^{208}Pb target. The target, which had a thickness of 300μg·cm^{-2}, was isotopically enriched to 99.7 % and had a carbon backing of thickness 15 μg·cm^{-2}. The experiment was conducted over a period of 6 days with an average beam current of $^{36}S^{9+}$ ions of 60enA. Projectile-like species produced via quasi-elastic and deep-inelastic reactions were detected by the Prisma magnetic spectrometer, in coincidence with their associated γ-rays detected by the Clara Ge array of 24 escape suppressed Ge detectors. Time of flight information together with ion tracking through the magnetic spectrometer was used to determine the velocity of projectile-like fragments. This allowed Doppler corrections to be performed on an event by event basis.

RESULTS AND DISCUSSION

The mass spectrum in figure 1 shows that the phosphorus isotopes with mass numbers A=33, 34, 35, 36 and 37 were successfully populated in the experiment. Figures 2 and 3 show γ-ray spectra corresponding to gates placed on the ^{35}P and ^{37}P mass peaks respectively.

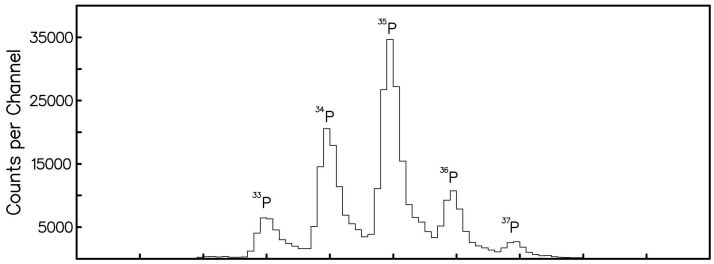

Figure 1: A mass spectrum showing the phosphorus isotopes with mass numbers A=33, 34, 35, 36 and 37 populated in this experiment.

In both the ^{35}P and ^{37}P γ-ray spectra the peaks labelled "x" are Pb x-rays. In the ^{35}P γ-ray spectrum, the 4 photopeaks at energies of 127, 273, 323 and 861keV correspond to previously unobserved transitions in this nucleus, whilst the transitions at energies of 469 and 665keV were previously tentatively assigned to the level scheme of ^{35}P by Ollier *et al.*[3]

The two peaks labelled "^{36}P" in the ^{37}P γ-ray spectrum of figure 3 are contaminants associated with the neighbouring ^{36}P isotope which, in the present experiment, has two very strong transitions at these energies. The peaks labelled at 439, 861, 869, 1046, 1181, 1300 and 1658keV are associated with the ^{37}P isotope. Prior to this experiment, only one γ-ray transition had been identified in ^{37}P. In the fragmentation experiment of Sorlin *et al.*[1], an 868keV transition was observed connecting the $(3/2^+)$ first excited

state to the ($1/2^+$) ground state. The uncertainty in the photopeak energies in the present work is approximately ± 1 keV.

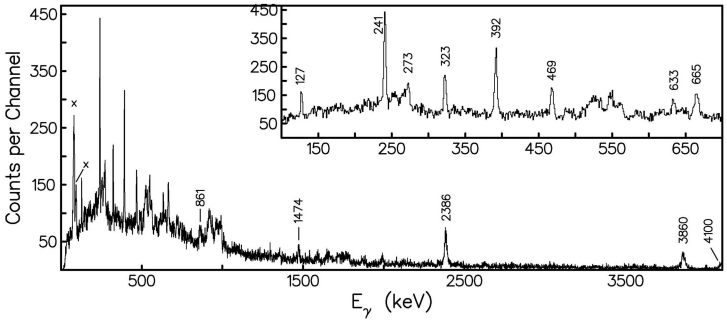

Figure 2: A γ-ray spectrum corresponding to the de-excitation of ^{35}P, produced from the placing of a gate on the mass spectrum shown in figure 1.

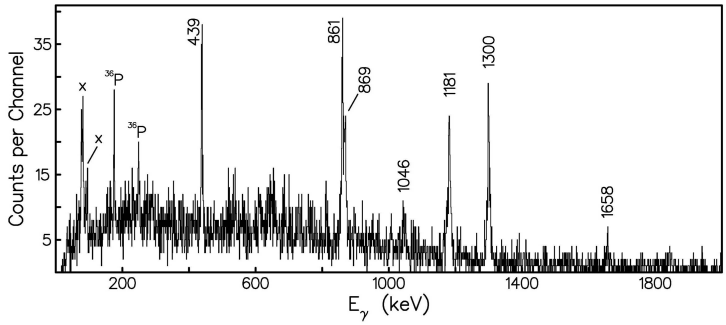

Figure 2: A γ-ray spectrum corresponding to the de-excitation of ^{37}P.

The relative intensities of the observed photopeaks provides an indication to the order of the transitions for each of the isotopes studied, consequently aiding the construction of a level scheme. Figure 4 shows the level schemes of ^{35}P and ^{37}P constructed from the present results. The validity of the ^{37}P level scheme shown in figure 4 has subsequently been tested and confirmed using a γγγ data cube obtained from a previous experiment conducted by Ollier *et al* [3,4]. Ollier studied the level schemes of projectile-like and target-like species resulting from the interaction of 230 MeV ^{36}S ions with a thick target of ^{176}Yb. Since no γ-ray transitions in ^{37}P were known at the time of the original data analysis, Ollier was unable to establish a level scheme for this isotope of phosphorus.

Data analysis continues.

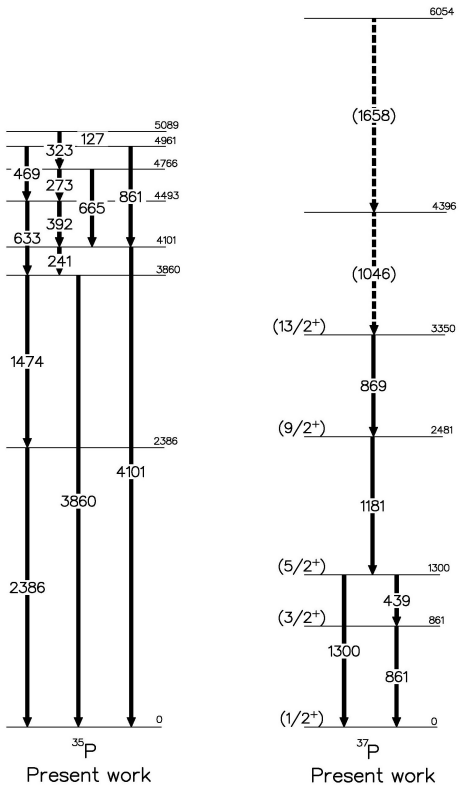

Figure 4: Level schemes of ^{35}P and ^{37}P produced from the results of this experiment.

ACKNOWLEDGEMENTS

The author would like to acknowledge that this work was partly funded by the EPSRC.

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