The Energy of Levels of $^{45}$Sc up to 3 MeV from the $^{44}$Ca ($p, \gamma$) $^{45}$Sc Reaction

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The gamma-ray decay of the 1658 keV resonance, which is a member of the isobaric analogues of the 1904 keV $3/2^-$ level in $^{44}$Ca, has been studied with a Ge(Li) detector. A number of gamma-ray transitions are described and associated with the decay of 15 levels between 1.50 and 3.05 MeV. These observations have made it possible to deduce spin and parity assignments to some of the levels. By comparing excited levels of $^{43}$Sc and $^{45}$Sc it has been possible to assign certain levels as members of one negative-parity band and two positive-parity bands with $K^\pi = 1/2^+$ and $3/2^+$.

Introduction

Since our latest report about the energies and branching ratios of the low-lying levels in $^{45}$Sc was published in 1967$^{1,2}$, several new investigations have been made.

Energies of excited levels have been determined in two experiments, where the energy of the outgoing particle in a particle in, particle out experiment has been measured. Ohnuma$^3$ has used the ($d$, $^3$He) reaction on $^{46}$Ti and has obtained spectroscopic factors and also spins and parities of all the excited levels up to 1800 keV. Inelastic proton scattering from $^{45}$Sc has been studied and the differential cross sections for several excited levels up to 4.51 MeV have been obtained by Mani$^4$.

The inelastic scattering process has been used in several experiments with various particles. In these experiments the reaction gamma rays have been measured mostly with Ge(Li) detectors to determine the energies of the excited levels. Goldberg and Hooton$^5$ used the $^{45}$Sc($^{16}$O, $^{16}$O') and $^{45}$Sc($^{35}$Cl, $^{35}$Cl') reactions and deduced particle strengths. Chasman et al.$^6$, Broman et al.$^7$ and Eastham and Phillips$^8$ have measured gamma-

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ray energies from the $^{45}\text{Sc}(p, p'\gamma)$ reaction. Eastham and Phillips have also used the $^{45}\text{Sc}(\alpha, \alpha'\gamma)$ reaction and measured the cross section for $E2$ excitation of the 377, 720 and 1236 keV levels. The gamma-ray spectra and production cross sections of the deexcitation gamma rays from neutron inelastic scattering were measured by Rogers et al.$^9$. The decay of $^{45}\text{Ti}$ by $\beta^+$ and EC to excited levels in $^{45}\text{Sc}$ have been investigated by Zuk et al.$^{10}$ and they found a new branch to the 974 keV level. Zuk et al.$^{11}$ have also used the $^{42}\text{Ca}(p, \gamma)^{45}\text{Sc}$ reaction and by measuring particle-gamma angular correlation have deduced spins and parities for most of the levels up to 1661 keV.

Dubois and Idetjärn$^{12}$ have investigated the gamma-ray decay of several resonances in the $^{44}\text{Ca}(p, \gamma)^{45}\text{Sc}$ reaction with a rather small Ge(Li) detector which gave limited information. The same reaction has been used by Demeter et al.$^{13}$ but their aim was to investigate the radiation width at $E_p=1640$ keV which is the isobaric analogue of the 1904 ($3/2^-$) level in $^{45}\text{Ca}$. The isobaric analogue of this level, which is actually split into six levels, has been investigated by Browne et al.$^{14}$ by means of elastically scattered protons observed at different angles.

In the present paper we report from a study of the gamma-ray decay of the 1658 keV member of the isobaric state mentioned above. The decay strengths to the low-lying levels with spin and parity $3/2^-$ have been compared with such decays in $^{43}\text{Sc}$ and $^{49}\text{Sc}$ and the decays of the negative parity band and the $K^*=1/2^+$ and $3/2^+$ bands in $^{43}\text{Sc}$ and $^{45}\text{Sc}$ have also been compared.

**Experimental Arrangements**

The $^{44}\text{Ca}$ target was supplied by AERE, Harwell, England, and consisted of a 20 $\mu$g/cm$^2$ thick layer of enriched $^{44}\text{Ca}$ (97.0%) on a tantalum backing, and as a shield against corrosion a thin layer of gold.

The target was bombarded by protons from the University of Lund 3 MeV Van de Graaff accelerator. The gamma-ray energies were measured with a 47 cm$^3$ Ge(Li) ORTEC detector, and the amplifier system consisted of an ORTEC 120B preamplifier and a Tennelec TC200 main amplifier.

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12 Dubois, J., Idetjärn, S. O.: Private communication.