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SPECTROSCOPY OF ^{57}Co BY γ–γ–RECOIL COINCIDENCES WITH THE ^{40}Ca(^{20}Ne, 3pγ)–REACTION AND THE ^{55}Mn(α, 2nγ)–REACTION*

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High spin states of ^{57}Co have been studied with the ^{40}Ca(^{20}Ne,3p) and ^{55}Mn(α,2n) reactions at 68 MeV and 25 MeV respectively. The first measurement used γ-γ-recoil coincidences with the OSIRIS γ-spectrometer and the Recoil Filter Detector (RFD). The RFD measured the velocity vector of the fusion evaporation residues; therefore an event by event Doppler correction could be applied with a significant improvement for the γ-energy resolution. The analysis of the γ-γ-recoil coincidence spectra resulted in 43 new γ-transitions of energies between 300 keV and 3300 keV that are assigned to ^{57}Co and established 25 new excited states. Also a DCO analysis has been performed on the present data, however it does not lead to an unambiguous spin assignment for most states as the measured DCO–ratio is often compatible with different spin combinations. The reaction ^{55}Mn(α, 2n) was studied with a compact setup of two Ge-detectors. Singles γ- and γ-γ-coincidence spectra were measured. Mainly low spin states were populated, and 26 previously known γ-transitions as well as 21 excited states of ^{57}Co have been confirmed. In this contribution results are presented on ^{57}Co, the nucleus with two neutrons and one proton hole.

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Introduction

Nuclei around doubly magic ^{56}Ni find renewed great interest. The structure of ^{56}Ni likely shows great similarities to ^{100}Sn, that is much more difficult to study experimentally. Both nuclei have $N = Z$ and consequently the neutron–proton interaction is strong; also the shell closure holds only for j-j but not for l–s coupling. The first excited state of ^{56}Ni is 2^+ at 2.701 MeV, which is 3.7 MeV below the lowest unperturbed particle–hole excitation. Its B(E2, $2^+ \rightarrow 0^+$) amounts to 9.4(20) W.u. [1], which is usually considered as characteristic for a vibrational nucleus. Spin might be gained by holes in the strongly bound $f_{7/2}$ orbital or by particles in the high lying $g_{9/2}$ orbital. Therefore about 1 MeV is needed to gain one unit of spin for shell model levels, and one might suspect that non-spherical shapes become yrast at moderate spins already.

Experiments

Nuclei around ^{56}Ni have been studied by the reactions of 68 MeV ^{20}Ne with a 1 mg/cm^2 ^{40}Ca target (99.7% enriched) using the OSIRIS γ-spectrometer in coincidence with the RFD [2] at the VICKSI accelerator of Hahn-Meitner-Institut. The experiment has been described in Ref. [3]. The main feature is, that the RFD measures the velocity vector of the γ-emitting nucleus and the measured γ-energies can then be corrected for Doppler shift event by event. This reduced the line width by a factor 3 ($E_\gamma > 2$ MeV) and facilitated the analysis of the coincidence spectra, that contain transitions from many nuclei produced in the reaction. 19 million γ-γ-RFD coincidences have been accumulated.

An additional experiment, aiming at the study of lower spin excitations in ^{57}Co, was performed at the IFJ Krakow cyclotron. In this measurement a 40 mg/cm^2 metallic ^{55}Mn target was hit with a 25 MeV α beam, populating ^{57}Co by the (α, 2n)–reaction. The experimental data include single spectra as well as 120 million γ-γ-coincidences measured with two Ge-detectors at 135° in a very compact geometry.

Results and Discussion

The level scheme of ^{57}Co as deduced from the present experiments is shown in Fig. 1. The strongest and therefore likely yrast cascade is extended beyond the highest previously known [4–6] (19/2) level at energy 5918.9 keV with three new states at 6976.4 keV, 7527.3 keV and 8874.1 keV. The measured DCO ratios confirm the spins for the first two excited yrast states, *i.e.* $9/2^-$ and $11/2^-$ at 1223.9 keV and 1690.0 keV [5, 7, 8]. However, for the

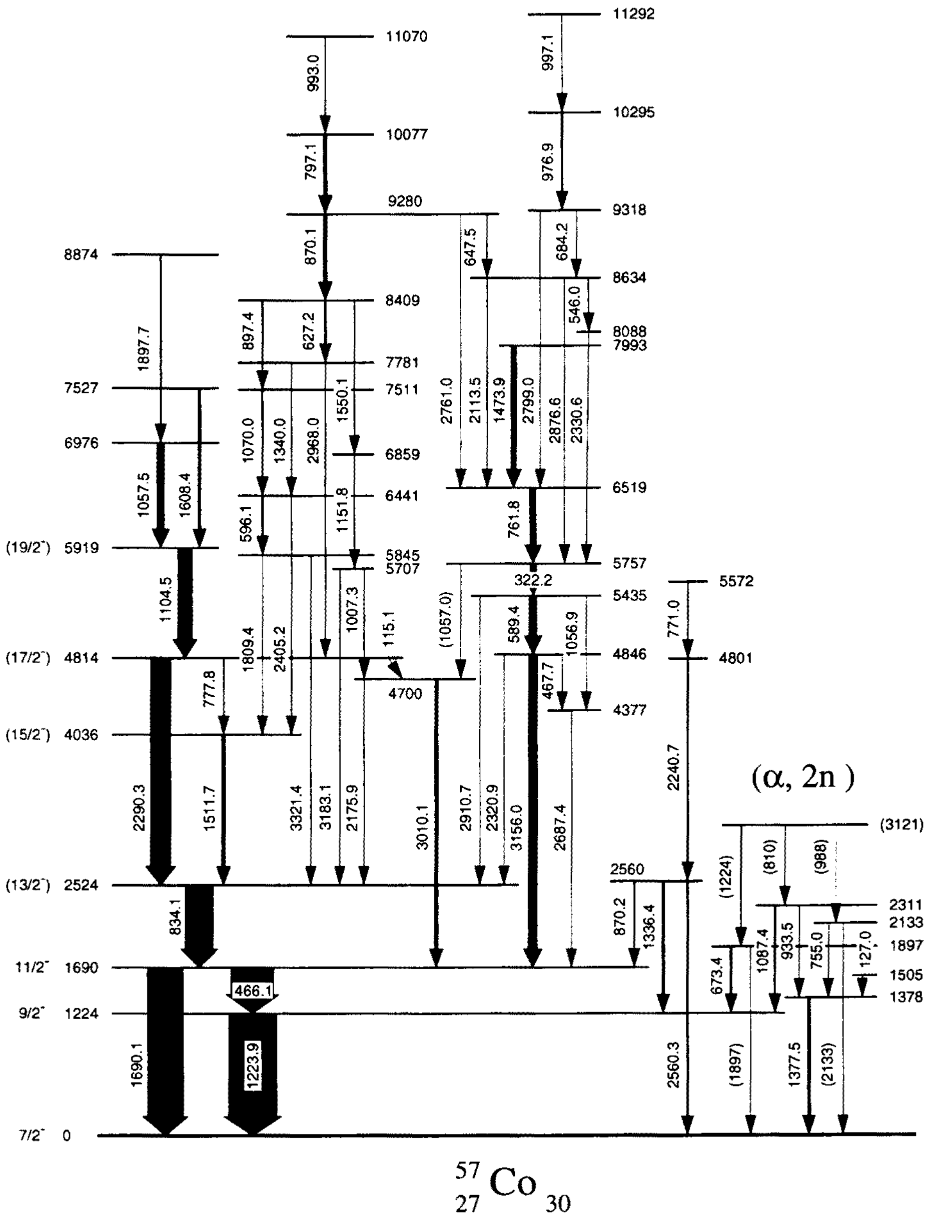

Fig. 1. The level scheme of ^{57}Co deduced from the ^{40}Ca(^{20}Ne,3p) and ^{55}Mn(α, 2n) reactions. The widths of the arrows give the intensities as observed in the ^{20}Ne experiment, except for the marked part to the right. This has only been observed in the α-reaction and some levels are of known low spin.

higher lying states, spins cannot be determined as often two different spins together with an appropriate M1/E2 mixing ratio can reproduce the measured DCO–ratios. Considering its life time [4–6], one can exclude $11/2^-$ for the level at 2524.1 keV of the possible ($9/2^-$,$11/2^-$,$13/2^-$) assignments; in fact the measured mixing ratio would give a B(E2) value larger than 100 W.u. for the 834.1 keV transition. Very likely one can also exclude $9/2^-$ for this state as the strongest cascade should not proceed from lower to higher spin. For the remaining yrast states the sequence ($15/2^-$), ($17/2^-$), ($19/2^-$) is likely, as it agrees with the DCO results and the enhancement of the population of such states in the ^{40}Ca(^{20}Ne,3p)^{57}Co reaction compared to the ^{55}Mn(α,2n)^{57}Co reaction indicates rising spin.

The strongest cascade terminates at 8.874 MeV. Many other new states have been found between 4.5 and 8.5 MeV excitation energy with a complex decay pattern. Above 9 MeV only two cascades remain, but there also the limit of the detection efficiency is approached.

The lack of spin assignments for most levels makes an interpretation of the scheme very difficult. As the DCO-ratios mostly allow for two different spin assignments, additional and different data, as linear polarization or life times, are needed. ^{57}Co and neighbouring nuclei also pose a challenge for theory. The residual interaction between the shell model orbitals is comparable to the spacing between them and consequently configuration mixing and excitations of the ^{56}Ni core are important already for the lowest states. So, the $9/2^-$ and $11/2^-$ states at 1224 keV and 1690 keV can be regarded as belonging to the neutron excitation to the 2^+ state in ^{58}Ni; but the splitting between the ($13/2^-$) and ($15/2^-$) levels, that should both belong to the 4^+ state in ^{58}Ni, is already 1.5 MeV.

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