NEW SPECTROSCOPIC DATA ON ^{102}Cd*

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Gamma ray spectroscopy of neutron deficient nuclei close to the doubly magic nucleus ^{100}Sn has been performed using a heavy-ion reaction and the NORDBALL Ge-detector array. Evaporation residues were identified by means of charged particle and neutron detection. Transitions in 31 different evaporation residues were identified. New results on ^{102}Cd are presented.

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The main interest in nuclei close to ^{100}Sn is the expected doubly magic nature of ^{100}Sn. The experimental information has been scarce due to several difficulties involved in the study of these nuclei far from the beta stability line. This situation may now change with the development of new experimental techniques and large detector systems. Here is presented an experiment utilising a multidetector system where particle detectors were used to detect charged particles and neutrons emitted in coincidence with the γ rays. With this method one has a very selective device for the identification of new nuclei. The aim was to use this method to obtain more experimental information in the region around ^{100}Sn. As a result excited states of ^{99}Cd [1] and possibly also ^{101}In [2], were observed for the first time. The level schemes of several other nuclei have been considerably extended for example ^{101}Cd [3]. This paper reports on new results in ^{102}Cd.

The experiment was performed at the Tandem Accelerator Laboratory of the Niels Bohr Institute in Denmark. A pulsed beam of ^{58}Ni with an energy of 261 MeV and a frequency of 6.25 MHz was used to irradiate targets of ^{50}Cr, yielding the compound nucleus ^{108}Te. Two different target thicknesses; 3.1 and 4.8 mg/cm^2 were used with a backing of gold thick enough to stop evaporation residues from reactions on Cr. The target thickness provided an energy spread of the beam down to the Coulomb barrier. The enrichment of ^{50}Cr in the target was 96.8%.

Detection of γ rays was done with the detector array NORDBALL [4] consisting in this experiment of 15 BGO Compton suppressed HPGe detectors. NORDBALL was complemented with charged particles and neutron detectors for channel selection, and with 30 BaF_2 scintillators.

The charged particles were detected in 21 silicon detectors, which formed an inner ball [5] with an effective solid angle of about 90% of 4π. The silicon detectors, having a thickness of 170μm, are thin enough for α particles and protons to pass through, thus depositing only part of the kinetic energy in the detector. Conveniently, the protons in general deposit less energy than the α particles, allowing for a discrimination of protons and α particles [5]. Absorbers where put in front of each detector to protect the silicon detectors from direct hits of the beam. Partly because of this, the efficiency for detection and identification of protons and α particles was only about 60% and 40%, respectively. Events could therefore be misinterpreted due to missed detection of particles. Thus, when producing a γ-ray spectrum or matrix gated on a specific particle condition, peaks belonging to the wrong exit channel, leakages, were seen in the spectrum.

The neutrons were detected in 11 liquid scintillation detectors placed downstream from the target, covering a solid angle of about 1π. The total measured neutron detection efficiency was 24%. The scintillators are also sensitive to γ rays, which were discriminated against with the help of the different pulse shape for neutrons and γ rays. A pulse-shape-discrimination unit [6] that integrated and differentiated the pulse was utilised, which gave the so-called zero-crossover spectrum. Also the time-of-flight of the neutrons was measured using as a time reference the signal from the BaF_2 detectors (see below). Correlating the zero-crossover with the time-of-flight provided an excellent discrimination in two dimensions between γ rays and neutrons. Still, about 0.8% of the γ rays were interpreted as neutrons. Further, scattering of one neutron between detectors gave rise to false two-neutron events in about 5% of the two neutron events.

The 30 BaF_2 detectors were used as a time reference for each event. They were also used to measure the multiplicity and sum energy of the γ rays.

The target contained, in addition to the ^{50}Cr, 3.0% of ^{52}Cr. This gave rise to γ-ray peaks from residual nuclei with two extra neutrons leaking into the selected channel in about 3% of the total events. In addition, during the experiment, a buildup of ^{12}C took place on the target. As a result, in the weakest, *i.e.* most neutron deficient channels the events related to ^{12}C were dominating due to the more favored cross sections for neutron emission from the compound nucleus ^{70}Se, which complicated the analysis. A separate run on a thick target of ^{12}C was performed during three days to distinguish from ^{12}C related events.

An event was accepted for readout if it fulfilled either of two conditions; a) at least two γ rays were detected in the Ge detectors together with at least one γ ray in the BaF_2 detectors, b) at least one γ ray detected in the Ge detectors together with at least one γ ray in the BaF_2 detectors and at least one signal from the neutron detectors. The signal from the neutron detector could be either a γ ray or a neutron since only a rough pulse-shape-discrimination was done online. During 25 days of effective beamtime, a total of about 1.0×10^9 events of the first type where collected together with about 1.4×10^9 events of the second type.

A rather involved procedure was performed off-line to process the data. This will be described in more detail in Ref. [7]. A set of one and two dimensional Ge spectra and matrices were produced with different particle gating conditions. One problem in the analysis was the leakages of contaminating channels mentioned above. In the projection spectra this was partly taken care of by a spectrum subtraction technique described in Ref. [8].

A total of 31 residual nuclei were identified with a measured relative yield given in Fig. 1. The weakest exit channel identified was ^{95}Pd with a relative yield of 0.001%, which shows the very high sensitivity of the present experimental setup. The relative yield of ^{99}Cd was only 0.008%. Five excited states where found in ^{99}Cd for the first time in the present experiment through a cascade of five γ rays in mutual coincidence [1, 8].

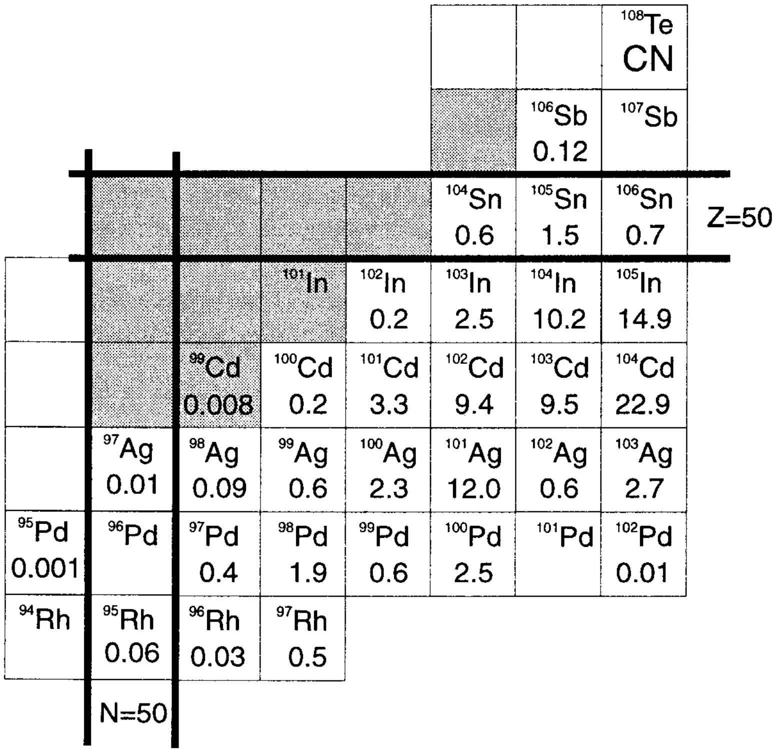

Fig. 1. Nuclear chart of the populated nuclei. The relative yield of the channels identified are given in %. In the nuclei in the shaded boxes no excited states were known prior to the present experiment.

The relative yield of ^{102}Cd is about 9.4%.

An example of a particle gated projection spectrum corresponding to the rather strong one alpha two proton (1α2p) channel of ^{102}Cd, can be seen in Fig. 2. It illustrates the problem of leakages. Peaks belonging to channels with higher proton multiplicities are dominating due to missed detection of one or two protons (^{101}Ag, ^{100}Pd). Also peaks belonging to missed detection of one alpha, ^{98}Pd, can be seen as well as transitions in ^{64}Zn from the ^{12}C reaction. In a strong channel such as ^{102}Cd, this problem partly disappears when gating on a γ-ray transition. This can be seen in Fig. 3 where the spectrum obtained by gating on the 241 keV transition in ^{102}Cd is shown. Mainly peaks belonging to ^{102}Cd are left but a few peaks from ^{101}Ag, labeled by dots, still remain due to a weak transition with the same energy in ^{101}Ag. The peaks with energies 263 keV, 361 keV and 398 keV are in ^{102}Cd but they are still to be placed in the level scheme.

The level scheme of the nucleus ^{102}Cd is presented in Fig. 4. It was

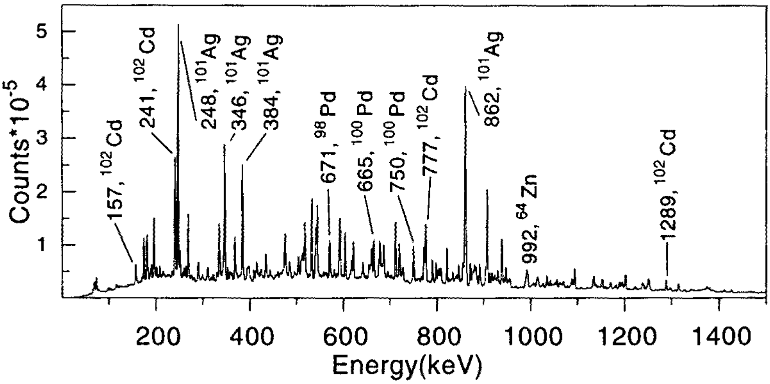

Fig. 2. The γ-ray projection obtained by selecting $1\alpha2p$ events. Some of the stronger peaks are labeled with their energy and respective nucleus.

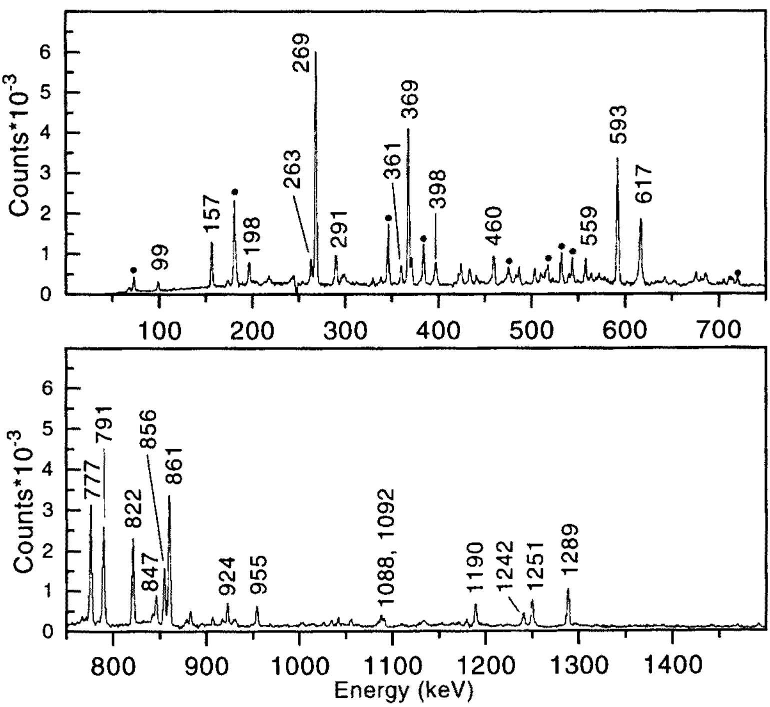

Fig. 3. Gamma-ray spectrum obtained by gating on $1\alpha2p$ and the transition energy 241 keV.

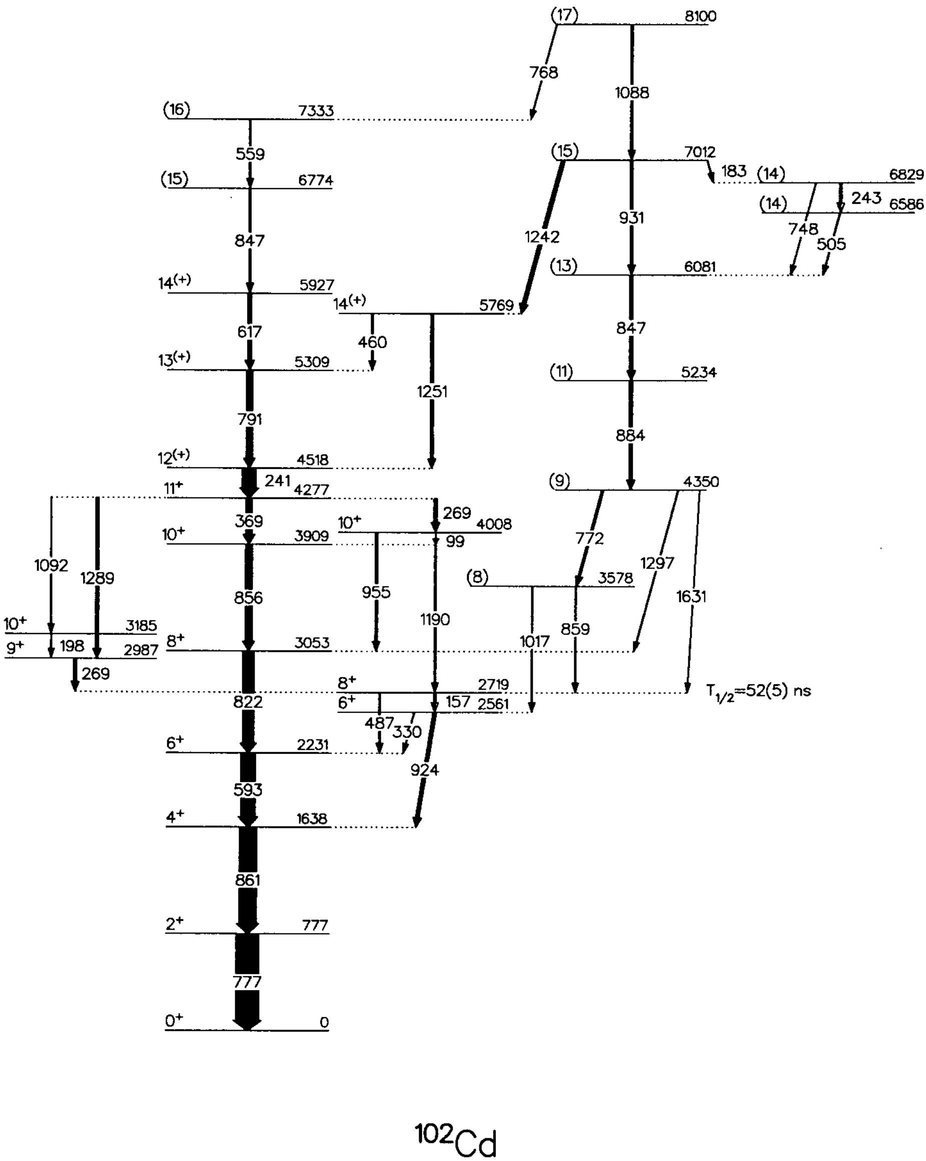

Fig. 4. Present level scheme of ^{102}Cd. Spins in parenthesis are tentative.

constructed from the particle gated matrix using traditional $\gamma\gamma$-coincidence techniques with the help of RADWARE [9]. The spin assignments were made from angular distribution ratios [7].

The level scheme of ^{102}Cd was previously known up to the 3053 keV level as well as the yrast 10^+, 11^+ and 12^+ states [10]. In the present experiment the yrast states have been extended up to 7333 keV as well as a side structure up to 8100 keV. The ordering of the 847 and 884 keV transitions, and the spin and parity assignments in the side structure are tentative. The lowest excited states of ^{102}Cd have been interpreted [10] as arising mainly from neutron excitations into the $d_{5/2}$ and $g_{7/2}$ orbitals above the $N = 50$ shell closure, while the isomeric 2719 keV level has been suggested [10] to be of almost pure two-proton character. In the heavier even-even Cd isotopes a regular collective structure is observed on top on an aligned $(\nu h_{11/2})^2$ 10^+ state [11–14]. The nucleus ^{102}Cd instead shows an irregular yrast cascade of dipole transitions above the 10^+ state at 3909 keV. The side structure have similarities with a recently observed structure in ^{104}Cd [14], where a negative parity band of E2 transitions was observed on top of a 9^- state. The side band in ^{102}Cd can therefore possibly be attributed to the two-quasiparticle $\nu(h_{11/2}, g_{7/2})$ or $\nu(h_{11/2}, d_{5/2})$ configurations as in ^{104}Cd [14]. The detailed theoretical interpretation of the new structures in the level scheme is still to be done.

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