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THE ISOTOPE SHIFT OF THE RADIOACTIVE Cd-ISOTOPES
($102 \leq A \leq 120$) DETERMINED BY ON-LINE LASERSPECTROSCOPY

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By use of a pulsed tunable dye laser the isotope shift of the radioactive Cd-isotopes ($^{102}\text{Cd} \leq A \leq ^{120}\text{Cd}$) in the $5s^2\ ^1S_0 - 5s\ 5p\ ^3P_1$, $\lambda = 326\text{ nm}$ line has been measured at the on-line mass separator ISOLDE/CERN.

During the last years systematic measurements of the hyperfine structure (hfs) and isotope shift (IS) have been performed at the on-line mass separator ISOLDE/CERN [1] on a long chain of mercury isotopes ($181 \leq A \leq 206$) [2]. Here we report on an experiment where we applied essentially the same technique to investigate the Cd isotopes in a range $102 \leq A \leq 120$. For this element data on stable and long lived isotopes ($T_{1/2} > 1\text{ h}$) were already available [3].

Radioactive Cd-isotopes are produced at ISOLDE by proton-induced spallation. The 600 MeV proton beam of the synchro-cyclotron with an intensity of about $1\ \mu\text{A}$ is focused on a liquid Sn-target (115 g/cm^2). The volatile Cd-isotopes evaporate out of the target material through a heated transfer tube into the ion source of the on-line mass separator. A maximum yield of 10^9 ions per second and mass is obtained around mass number $A = 109$. The experimental set-up is shown in Figure 1.

The ion beam is focused onto a Mo foil, mounted inside a quartz resonance vessel. After collection times of up to 1 half life, the foil is heated to about 1200°C to release the radioactive atoms. The quartz cell is kept at a temperature of about 600°C shortening the adsorption time of the Cd atoms on the walls. Furthermore, He gas of a pressure of 200 Torr is filled in, in order to prolonge the diffusion time of the Cd atoms to the cold parts of the valve separating the resonance cell from the vacuum in the beam tube. By these means we could observe the free atoms for about one minute.

The intercombination line $5s^2\ ^1S_0 - 5s\ 5p\ ^3P_1$, ($\lambda = 326\text{ nm}$) is used for the measurement of the hfs and IS. Laser light of this wavelength is generated by doubling the output frequency (652 nm) of a tunable dye laser which is pumped by a pulsed N_2 laser. Typically 150 W peak power is obtained in a pulse of 3 ns width at a repetition rate of 40 Hz.

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Figure 1. Experimental set-up.

ADC = analog-digital-converter, DC = dye-cell, E = Fabry-Perot-etalon, F = UG11 filter, FD = frequency doubling crystal, G = gate, GG = gate generator, GR = grating, H_0 = magnetic field for the reference cell, L = lens, M = mirror, P = polarizer, PM = photo-multiplier, S = beam splitter, T = beam expanding telescope, O = oven.

Figure 2.

Hfs spectrum of the $5s^2 \ ^1S_0 - 5s \ 5p \ ^3P_1$ ($\lambda = 3261 \text{ \AA}$) line of the ^{103}Cd ($I = 5/2$). The points indicate the experimental values; the solid line is the best fit by a convolution of a Gaussian and a Lorentzian due to Doppler and pressure broadening.

The resonance fluorescence is observed by a photomultiplier. Normalization of the signal to constant laser intensity is achieved by monitoring the latter with a photo diode. The laser frequency is determined by recording simultaneously the resonance light of the stable ^{114}Cd isotope in a reference cell placed in the gap of a magnet. The Zeeman-split resonance signals of ^{114}Cd provide a convenient frequency scale by use of the known g_j factor. Because of the long life time of the $^3\text{P}_1$ state ($\tau = 2.2 \mu\text{s}$) the laser light directly scattered on the walls of the resonance vessel during the short laser pulse can be eliminated by delayed observation. The currents of the photomultipliers and of the photodiode are analyzed by ADC's and stored in the memory of an on-line computer. In cases of very low abundant radioactive isotopes photon-counting is applied instead.

Previous tests with stable isotopes showed a detection limit of 10^{10} ions collected on the Mo foil. With the yield available at ISOLDE we thus could observe signals for all unstable isotopes between ^{102}Cd ($T_{1/2} = 330 \text{ s}$) and ^{120}Cd ($T_{1/2} = 60 \text{ s}$). As an example Figure 2 shows the signal of ^{103}Cd ($I = 5/2$). The Doppler broadening (1.6 GHz), the pressure broadening (1.3 GHz) and the laser bandwidth (1.1 GHz) add up to a final linewidth of 3.3 GHz. As this linewidth is comparable to the hfs splitting, the hfs pattern is barely resolved and great care has to be taken to fit the data of the odd isotopes. The situation becomes even more complicated when an isomeric state is present. In addition, a contamination by stable or long lived isotopes has to be taken into account in some cases.

$^{\text{x}}\text{Cd}$	$\delta v^{114-\text{x}}$ (MHz)	A (MHz)	$\delta \langle r^2 \rangle^{114-\text{x}}$ (fm ²)
102	3400	1150	- 1.07
103	3080		- 0.98
104	2450		- 0.79
105	2170		- 0.70
107	1650		- 0.53
118	- 520		0.18
120	- 620		0.23

Table 1

Table 1 contains the preliminary results for the hfs and IS data of those isotopes being investigated for the first time in this experiment. For others, known data have been confirmed. The nuclear spin $I = 5/2$ was used to determine the A factor of ^{103}Cd [5]. The errors are estimated to be of the order of 150 MHz and include the following effects: statistical uncertainty of the fit, non-linearity of the laser scan, calibration error of the magnetic field over the resonance cell, and the uncertainty of the pressure shift [6]. The changes in the RMS radii are calculated with the help of $\delta\langle r^2 \rangle^{114-112} = 0.133 \text{ fm}^2$ [3].

Figure 3.
Plot of $\delta\langle r^2 \rangle$ in the series of Cd isotopes. The reduced standard line has been added for comparison.

Figure 3 shows a still incomplete plot of $\delta\langle r^2 \rangle$ values obtained from this and earlier experiments. The heavier isotopes comply with the reduced standard shift, which is usually observed near magic proton numbers ($Z = 50, 82$) and indicates more or less constant nuclear shape. At the light end, however, $\langle r^2 \rangle$ is contracting progressively when the magic neutron number is approached.

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