Isotope Shift of $^{182}$Hg and an Update of Nuclear Moments and Charge Radii in the Isotope Range $^{181}$Hg – $^{206}$Hg

Institut für Physik, Universität Mainz, Federal Republic of Germany

S.A. Ahmad, W. Klempt, R. Neugart, and the ISOLDE Collaboration
CERN, Geneva, Switzerland

Received July 15, 1986

The technique of collinear fast-beam laser spectroscopy has been used to measure the isotope shifts of the even-even isotopes of Hg ($Z=80$) in the mass range $182 \leq A \leq 198$ at the on-line mass separator ISOLDE at CERN. The atomic transition studied ($6s\,6p\,3P_2 - 6s\,7s\,3S_1$, $\lambda=546.1$ nm) starts from a metastable state, which is populated in a quasi resonant charge transfer process. The resulting changes in nuclear mean square charge radii show clearly that $^{182}$Hg follows the trend of the heavier, even, weakly oblate isotopes. Correspondingly the huge odd-even shape staggering in the light Hg isotopes continues and the nuclear shape staggering and shape coexistence persists down to the last isotope investigated, $^{181}$Hg. An update of isotope shift and hyperfine structure data for $^{181-206}$Hg is given, with a revised evaluation of the differences in nuclear mean square charge radii and of spectroscopic quadrupole moments.

PACS: 21.10.Ft; 21.10.ky; 35.10.Fk

1. Introduction

Systematic studies by optical spectroscopy on long isotopic chains are a main source of information on nuclear ground state properties [1]. The hyperfine structure (hfs) and isotope shift (IS) of optical spectra allow the determination of the nuclear spins $I$, magnetic dipole moments $\mu$, spectroscopic quadrupole moments $Q_s$, and the changes of the nuclear mean square charge radii $\delta<r^2>$. The first element for which many isotopes were studied by optical methods is Hg ($Z=80$). This element is also exemplary for the interdependence of the development of experimental techniques concerning sensitivity and resolution on the one hand and accessibility of the isotopes on the other. Conventional optical spectroscopy has yielded data in the isotope range 192 ≤ $A$ ≤ 204 [2], [3]. The method of $\gamma$-radiation detected optical pumping ($\gamma$-RADOP) was first developed to investigate the isotopes $^{203}$Hg [4] and $^{199m}$Hg [5]. Measurements by the $\beta$-radiation detected optical pumping method ($\beta$-RADOP) extended our knowledge of nuclear ground state properties for the odd Hg isotopes into the mass range 181 ≤ $A$ ≤ 191 and to $^{203}$Hg [6], [7], [8]. One of the striking features resulting from this experiment was the large change in the $\delta<r^2>$ value between the isotopes $^{187}$Hg and $^{185}$Hg, which was attributed to a sudden oblate-prolate shape transition [6]. Since the RADOP method is not applicable to $I=0$ nuclei, a pulsed laser system was later used to measure the IS of the even...
Hg isotopes in the mass region $184 \leq A \leq 190$ and of $^{206}\text{Hg}$. In addition the hfs and IS of the $I=13/2$ isomeric states of the odd isotopes, $185 \leq A \leq 191$, could be studied. Preliminary results of these experiments using pulsed lasers have been published earlier [9], [10], [11], [12]. This work reports IS measurements on even-mass Hg isotopes in the range $182 \leq A \leq 198$ by collinear laser spectroscopy, which includes for the first time $^{182}\text{Hg}$ (preliminarily reported at the Alushta Heavy Ion Meeting 1983 [13]). All the measurements on short-lived Hg isotopes were performed at the on-line mass separator ISOLDE at CERN, Geneva [14].

After a brief description of the experiment in Sect. 2, a compilation of IS data of Hg isotopes is given in Sect. 3, including the values resulting from the final evaluation of the data from the earlier pulsed-laser experiments. The interpretation and discussion in Sect. 4 concentrates on the nuclear charge radii and shapes of the Hg isotopes, throwing new light on that interesting region. The re-evaluation of $\delta \langle r^2 \rangle$ and $Q_s$ is based on new values for the electronic field shift factor and the electric field gradient treated in two Appendices.

2. Experiment

As in previous experiments the neutron deficient Hg isotopes were produced at the ISOLDE facility at CERN [14] in a spallation reaction of 600 MeV protons on a molten-lead target. The volatile Hg fraction of the reaction products was ionized in a plasma ion source with a production yield as given in [14]. Special care was taken in the setting of the ion source in order to form an ion beam with constant energy and small emittance. The extracted 60 keV beam was mass separated and directed to the apparatus for collinear fast-beam laser spectroscopy.

Most of the known optical data on radioactive isotopes of Hg have been obtained in the ultraviolet intercombination line $6s^2 \, ^1S_0 - 6s \, 6p \, ^3P_1$ ($\lambda = 253.7$ nm). In spite of the deeply bound atomic ground states of Hg$^+$ and Hg the versatility of collinear laser spectroscopy, however, allowed the use of cw dye lasers in the visible range. The Hg$^+$ ions passed through a sodium-vapour cell. Since the charge exchange process favours a resonant electron transfer, the metastable $6s \, 6p \, ^3P_2$ state is strongly populated (see Fig. 1). This efficient mechanism for producing beams of metastable atoms was first exploited in collinear laser spectroscopy on hydrogen [15] and ytterbium [16].

The metastable Hg atoms were excited to the

![Fig. 1: Part of the energy level scheme of Hg I, including the ground state of the charge exchange partner Na relative to the ionization limit of Hg. The almost resonant exchange condition to the $^3P_2$ state is evident. The $\lambda = 546.1$ nm transition was studied by collinear laser spectroscopy.](image1)

![Fig. 2: Fluorescence signals as a function of the acceleration voltage for the case of $^{182}\text{Hg}$, $^{184}\text{Hg}$, and $^{198}\text{Hg}$. The integration time per channel was 1 s, 0.4 s, and 0.1 s, respectively.](image2)