RIMS Workshop



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Research on Sr-RIMS under the Triple Resonance Excitation $5s^2 {}^1S_0 \rightarrow 5s5p {}^1P_1^{\circ} \rightarrow 4d^2 {}^1D_2 \rightarrow 4dnf$ or 4dnp

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Resonance Ionization Mass Spectrometry (RIMS) leverages the energy differences in transition states between various elements and isotopes to achieve isobaric suppression and heightened isotopic selectivity. Furthermore, multi-step resonance ionization processes are capable of exciting atoms to specific Rydberg states, thus enhancing ionization efficiency. The focal point of this research is the three-step resonance ionization pathway involving the transition $5s^2 \ 1S_0 \rightarrow 5s5p \ 1P_1^{\circ} \rightarrow 4d^2 \ 1D_2 \rightarrow 4dnf$ or 4dnp. The measurement of the isotope shift (IS) among Sr natural isotopes, the evaluation of resonance ionization efficiency, and the observation and analysis for Stark shift in high Rydberg-state Sr atoms have been done in this study.

Keywords: Resonance Ionization Mass Spectrometry, Sr-90 analysis, ionization efficiency, isotope shift, isotopic selectivity.

1.Introduction

RIMS for the determination of Sr-90 holds great promise in achieving a lower detection limit and a significant advantage in terms of high isotopic selectivity, particularly when employed within a multi-step ionization scheme. However, there is a need for further research into more efficient ionization schemes and the clarification of isotope shifts of Sr-90 concerning other Sr isotopes. In our laboratory, we have conducted related research on Sr-90 RIMS, with a focus on investigating the three-step resonance ionization schemes $5s^2 {}^{1}S_0 \rightarrow 5s5p {}^{3}P_1 \rightarrow 5s5d {}^{3}D_2 \rightarrow 4dnf$ or 4dnp, as documented in previous studies[1],[2]. Additionally, we explored the scheme $5s^2 {}^{1}S_0 \rightarrow 5s5p {}^{1}P_1^{\circ} \rightarrow 4d^2 {}^{1}D_2 \rightarrow 4dnf$ or 4dnp, as detailed in reference [3].

In this study, the scheme of $5s^2$ ${}^{1}S_0 \rightarrow 5s5p$ ${}^{1}P_1 \rightarrow 4d^2$ ${}^{1}D_2 \rightarrow 4dnf$ or 4dnp (corresponding to the laser scheme of 460.9 nm $\tilde{}$ 655.2 nm $\tilde{}$ 426.3 nm, named with the "scheme II") was selected for in-depth research and analysis of its isotope selectivity, ionization efficiency, and the energy level characteristics of Rydberg-state Sr atoms in this transition channel.

The experiment setup is named with resonance ionization-quadrupole mass spectrometer (RI-QMS). The Sr atoms absorb three laser photons in the scheme II, transiting to the Rydberg state ($n^* = 39.4$), and subsequently autoionize under the influence of a weak electric field (few V/cm). The Sr ions produced are selected by the QMS (Extrel RP 2010_A) and detected by the microchannel plate (MCP) for spectrum analysis.

For assessing the ionization efficiency, the two-stage resonance ionization process (460.9 nm $^{\sim}$ 405 nm; 5s² $^{1}S_{0} \rightarrow 5s5p \ ^{1}P_{1}^{\circ} \rightarrow (4d^{2}+5p^{2})^{1}D_{2}$, named with the "scheme I"), was used for comparison.

2.Methodology and experimental contents

To measure the isotope shift (IS) of the 460.9 nm laser, the resonance ionization spectrum under scheme I was directly employed. For the 655.2 nm laser, it was introduced to disrupt the resonance ionization spectrum under the scheme I, and IS was measured through the valleys on the new spectra.

In the RI-QMS, a weak electric field was employed to induce the ionization of excited Sr Rydberg atoms and propel the generated Sr ions from the ionization region into the QMS. In this scenario, the Stark effect occurs, and the energy level of $n^* = 39.4$ is no longer singular and straight. Instead, the electric field strength and the energy level shifts adhere to a parabolic distribution, referred to as the quadratic Stark shift. This shift can be elucidated from a classical physics perspective, wherein the induced electric dipole moment by the external electric field interacts once again with the external electric field. To elucidate the characteristics of the Stark shifts for Sr atoms at this energy level, a method termed "dual electric field ion transport" was devised to convey Sr ions generated under the electric field near 0 V/cm into the QMS and MCP for a more comprehensive spectrum inspection.

3.Conclusion

In this study, the examined three-stage scheme (460.9 nm \degree 655.2 nm \degree 426.3 nm) showed notably higher ionization efficiency for Sr-88 compared to the two-stage scheme. The isotope shift for natural Sr isotopes with the 460.9 nm laser was measured and compared with peer-reviewed work. The isotope shift for the 655.2 nm laser was measured for the first time.

The Stark effect around the energy level of $n^* = 39$ was explored. Findings show the quadratic Stark shifts with two opposite trends. Remarkably, negative polarizability values, a first at this energy level, were observed and explained by MQDT.

Reference

- [1] Cheon D. et al. J. Spectrosc., 2018, 2018.
- [2] Iwata Y. et al. Hyperfine Interact., 2020, 241: 1-8.
- [3] Iwata Y. et al. J. Quant. Spectrosc. Radiat. Transf., 2021, 265: 107549.
- [4] Bushaw B. A. et al. Spectrochim. Acta B At. Spectrosc., 2000, 55(11): 1679-1692.
- [5] Anselment M. et al. Z. Phys. D At. Mol. Clust., 1986, 3(4): 421-422.

Workshop Themes

RIS, scheme development, atomic spectroscopy

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