Yield investigation of neutron-rich W isotopes produced by multi-nucleon transfer reactions of ^{136}Xe + ^{nat}Ir

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Nuclear charge radius is a quantity sensitive to changes in nuclear structure, such as shape transition, shell closure, and proton-neutron pairing. The nuclei around Z = 72–78 are known as transitional nuclei, which exhibit a multitude of nuclear shapes depending on the neutron and proton numbers.[1] In the W isotopic chain, nuclear shape evolution has been investigated up to ^{190}W in terms of the properties of the first 2^+, 4^+ excited states[2] and K-isomers[3] via γ-ray spectroscopy using relativistic ions produced in fragmentation reactions. However, laser spectroscopic data obtained using low-energy isotope separator on-line (ISOL) beams are lacking, especially in the neutron-rich side of this nuclear region,[4] due to the refractory nature of these elements. Thus, to investigate the ground state shape evolution with the help of theoretical calculations, we are planning to study the change in nuclear mean-square charge radii of neutron-rich ^{188,190}W via in-gas-cell laser ionization spectroscopy[5] at KISS.[6] As a preliminary effort, we report the measured extraction yields of $^{188–190}$W isotopes at KISS.

The KISS facility at which we conducted the measurement is an argon-gas-cell-based laser ion source combined with an ISOL, designed to produce otherwise difficult-to-access nuclides by multi-nucleon transfer (MNT) reactions. Neutron-rich W isotopes were produced in MNT reactions using an ^{136}Xe beam (30 particle nA, 10.75 MeV/nucleon) impinging upon a ^{nat}Ir (22.7 mg/cm^2) target. The target-like fragments were stopped and neutralized in a gas cell pressurized to 75 kPa with purified Ar gas. The neutralized W atoms were transported by gas flow and ionized by element-selective laser resonance ionization at the gas cell exit. The W atoms were resonantly excited by laser irradiation at λ_1 = 260.7165 nm ($5d^46s^2\ ^5\mathrm{D}_0 \rightarrow J$ = 1°),[7] followed by non-resonant excitation to continuum states by laser irradiation at λ_2 = 308 nm from an XeCl laser. The post-accelerated ions (E = 20 keV/q) were mass separated using a dipole magnet with a mass resolving power of $m/\Delta m$∼900. After being thermalized in a gas cell cooler-buncher[8] (GCCB), the ions were analyzed in a multi-reflection time-of-flight (MRTOF) mass spectrograph for isobaric identification and ion counting. At a typical mass resolving power of $m/\Delta m$∼500,000,[9] the overall efficiency of MRTOF+GCCB was 2%.

Figure 1 shows time-of-flight spectra for A/q = 95 ions measured with (black) and without (red) resonant laser excitation of ^{190}W. An enhancement of ^{190}W ion counts accompanying resonant laser irradiation can be clearly observed. In addition to laser ionized ^{190}W, we observed intense isobaric contaminants consisting of ^{190}Re, ^{190}Os, ^{190}Ir, ^{190}Pt, and ^{190}Au, which are produced with much higher yields than the more neutron-rich ^{190}W; whether they are non-resonantly ionized alongside the ^{190}W or the result of a non-neutralized fraction in the argon gas remains uncertain. The recent improvements in MRTOF performance[9] at KISS allowed for the successful counting of ^{190}W^{2+} ions in spite of these intense isobaric contaminants. A similar situation was encountered in measurements of ^{188,189}W. The measured extraction yields of ^{188,189,190}W were 65, 5.6, and 1.6 pps, respectively. These yields are sufficient to perform future in-gas-cell laser ionization spectroscopy.

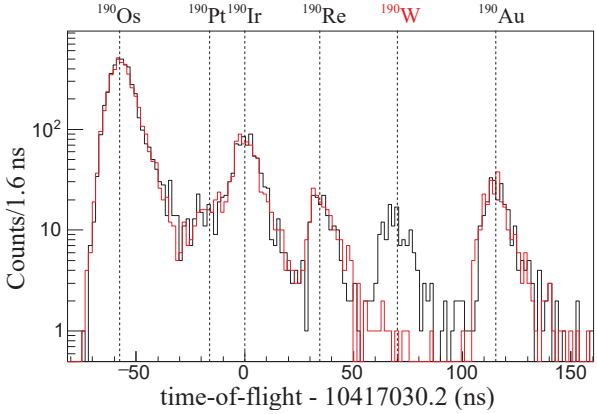

Fig. 1. Measured time-of-flight spectra with resonant excitation laser ON (black) and OFF (red) for ^{190}W.

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