Direct determination of the atomic mass of ^{189}W

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We measured the atomic mass of ^{189}W in an experiment to investigate the yields of $^{188-190}$W[1)] produced in multi-nucleon transfer (MNT) reactions for future laser ionization spectroscopy at the KEK Isotope Separation System (KISS).[2)] The mass of $^{189}_{74}$W has previously been determined from Q_β[3)] and via Schottky mass spectroscopy at ESR,[4)] but both were excluded from the Atomic Mass Evaluation (AME2020)[5)] based on deviations from the trends of the mass surface, making a complementary mass evaluation highly desirable. We have produced ^{189}W at KISS in MNT reactions of ^{136}Xe + ^{nat}Ir and used the multi-reflection time-of-flight mass spectrograph (MRTOF-MS) for ion counting, isobaric identification, and atomic mass determination. A detailed description of the experiment is given in Ref. 1).

The identification of ^{189}W was achieved by confirming that the relative intensity of the ^{189}W TOF spectral peak reduced significantly when the resonant excitation laser was turned off. After correcting for TOF drift, *e.g.*, from thermal expansion of the MRTOF-MS, the mass resolving power was $m/\Delta m$∼500,000.[6)] Figure 1 provides the drift-corrected sum total measured spectrum for ions with mass-to-charge ratio A/q = 189/2 with and without laser ionization applied. Least squares fitting of the spectrum was performed to determine the TOF values of extracted isobars. The TOF for each ion species was determined using a Gaussian-exponential hybrid function with exponential tails on one side. The shape parameters were determined from a high-statistics TOF spectrum of the elastic particle ^{191}Ir^{2+} and scaled based on A/q. From the evaluated peak positions (t and $t_{\rm ref}$), the mass value (m) was calculated using

$$m = \frac{q}{q_{\rm ref}} m_{\rm ref} \left(\frac{t - t_0}{t_{\rm ref} - t_0} \right)^2 \quad (1)$$

where t_0 is constant offset, while $m_{\rm ref}$, $q_{\rm ref}$, and $t_{\rm ref}$ are the mass, charge, and TOF of a reference ion, respectively. The t_0 term was determined from Eq. (1) based on the results of high-statistics measurements of ^{85}Rb and ^{190}Os, which have well-known atomic masses. To limit mass-dependent systematic errors, nearly isobaric ^{190}Os^{2+} was used as a reference ion along with ^{85}Rb in a double-referencing scheme.[7)] Among the observed A/q = 189/2 ions, ^{189}Os has a long-lived isomer ($E_{\rm ex}$ = 30.82(2) keV, $T_{1/2}$ = 5.8(1) h),[8)] which can be extracted from the KISS gas cell but cannot be resolved by the MRTOF-MS. Due to the minimal TOF difference between ^{189g}Os^{2+} and ^{189m}Os^{2+}, a single peak was fitted, and the evaluated mass represents the weighted average of the two states.

Figure 2 shows the differences between our measured mass values and the AME2020 evaluation. Our measured mass values of ^{189}Re, ^{189}Os, ^{189}Ir, and ^{189}Pt are in good agreement with the evaluated values. Our measured mass for ^{189}W is within the AME2020 error band and is also consistent with the previously reported values in Refs. 3) and 4). This provides some confirmation of the validity of the previous data.

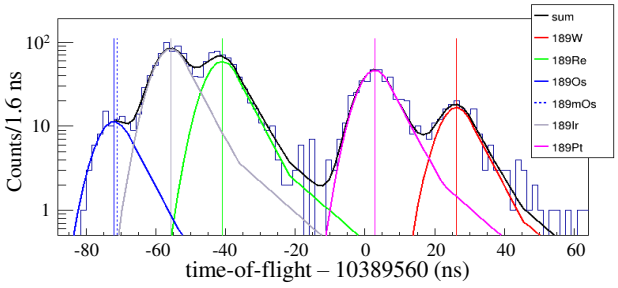

Fig. 1. Measured TOF spectra of A/q = 189/2 ions. The colored curves show the best fitting curves to the data. Solid vertical lines show the fitted TOF position of each isobar.

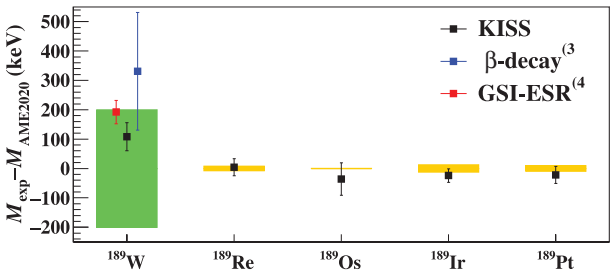

Fig. 2. Differences between our measured mass values and AME2020 evaluation. The AME2020 error bands are represented by yellow and green stripes.

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