Initial mass measurement of ^{258}Db by decay-correlated mass spectroscopy

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We present the first direct measurement of the atomic mass of the superheavy nuclide ^{258}Db. Atoms of ^{257}Db ($Z = 105$) were produced online at the RIKEN Nishina Center for Accelerator-Based Science using the fusion-evaporation reaction ^{208}Pb(^{51}V, $1n$)^{258}Db. The gas-filled recoil ion separator GARIS-II was used to suppress both the unreacted primary beam and some transfer products, prior to delivering the energetic beam of ^{258}Db ions to a helium gas-filled ion stopping cell wherein they were thermalized. Thermalized ^{258}Db^{2+} ions were then transferred to a multi-reflection time-of-flight mass spectrograph (MRTOF) for mass analysis. An alpha particle detector embedded in the ion time-of-flight detector allowed disambiguation of the rare ^{258}Db^{2+} time-of-flight detection events from background by means of correlation with characteristic α-decays. The extreme sensitivity of this technique[1] allowed a precision atomic mass determination from 22 decay-correlated events.

This measurement was made simultaneously with ^{257}Db while testing PbS targets produced via sputtering. The targets were capable of withstanding 2 particle μA primary beam without degradation in their performance. The pulsed deflector[2] inside the MRTOF was operated to allow passage of $A/q = 128.5$ and $A/q = 129$ while rejecting transfer products such as ^{211}Po that had previously produced spurious decay correlations. The observed rate of ^{258}Db relative to ^{257}Db is within expectations based on the excitation functions.[3]

Using a similar correlation method as employed for ^{257}Db,[4] extended to encompass spontaneous fission events, a mass was determined for the detected ion in each decay-correlated event. A histogram of the masses is shown in Fig. 1. Based on the mass resolving power seen for ^{257}Db^{2+},[5] there appears to be an excess of events in the low-mass tail. Applying two-peak fitting with fixed resolution results in a good reproduction of the observed distribution. Presuming this is not a statistical anomaly, it would indicate the isomeric excitation to be 300 (150) keV, a significant deviation from the α-decay derived NUBASE value[6] of 53 (14) keV.

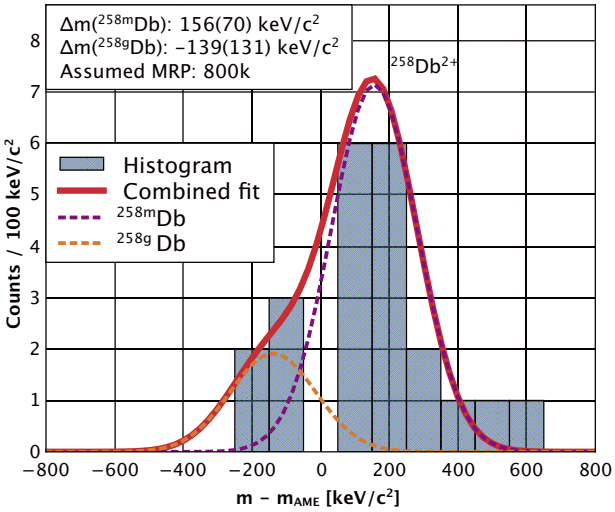

Fig. 1. Histograms of evaluated atomic masses for ions detected with subsequent α-decays consistent with ^{258}Db, ^{254}Lr, or ^{250}Md, ^{258}Rf, and spontaneous fission. The two-peak structure could indicate the isomeric excitation exceeds NUBASE estimates.[6]

A further followup effort to gather more data in order to better determine the isomeric excitation is planned for FY2022. However, due to the small differences between α-particle energies emitted from the two states, determination of the state ordering via precision decay-correlated mass spectroscopy will require a considerably improved detector station. Such a detector station is presently in the initial design phase.

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