Production of ^{262}Db in the ^{248}Cm(^{19}F,5n)^{262}Db reaction and decay properties of ^{262}Db and ^{258}Lr†

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We have been developing a gas-jet transport system coupled to GARIS as a novel technique for superheavy element chemistry.[1)] So far, isotopes of element 104, ^{261}Rf, and element 106, ^{265}Sg, have been produced for chemical studies in the ^{248}Cm(^{18}O,5n) and ^{248}Cm(^{22}Ne,5n) reactions, respectively.[1,2)] In this work, we produced element 105, ^{262}Db in the ^{248}Cm(^{19}F,5n) reaction and investigated its decay properties in detail for future chemical studies of Db.

^{248}Cm$_2$O$_3$ targets with thicknesses of 230, 290, and 330 µg cm^{-2} were prepared by electrodeposition onto a 2-µm Ti foil. The ^{19}F^{6+} or ^{19}F^{9+} ion beam was extracted from RILAC. The beam energies were 103.1 and 97.4 MeV at the middle of the target, and the typical beam intensity was 4 particle µA. The evaporation residues (ERs) separated by GARIS were guided into the gas-jet chamber through a 0.5-µm-thick Mylar window, which was supported by a grid with 84% transparency. Several magnetic rigidities were investigated in $B\rho$ = 1.73–2.09 Tm at a He pressure of 33 Pa; the optimal collection efficiency for ^{262}Db was 8.1 ± 2.2% at $B\rho$ = 1.89 Tm. The ERs were then transported by a He/KCl gas jet to the rotating-wheel apparatus MANON for α/SF spectrometry. In MANON, aerosol particles were deposited on a Mylar foil of 0.5-µm thickness, 40 of which were set on the periphery of a rotating wheel. The wheel was stepped at 15.5 s intervals to position the samples between 15 pairs of Si PIN photodiodes.

We searched for time-correlated α_1-α_2 event pairs in the time window of 58.5 s and in the energy range of 8.0 MeV ≤ E_α ≤ 9.0 MeV. As a result, 71 and 4 α_1-α_2 pairs were found at 103.1 and 97.4 MeV, respectively. By referring to the α-particle energies (E_α) and half-lives ($T_{1/2}$) adopted for ^{262}Db and its daughter ^{258}Lr,[3)] 74 α_1-α_2 were reasonably assigned to ^{262}Db → ^{258}Lr →. One exceptional α_1-α_2 pair at 103.1 MeV was ^{261}Db → ^{257}Lr → *via* the ^{248}Cm(^{19}F,6n) reaction. No α_1-α_2 pair on ^{263}Db produced in the ^{248}Cm(^{19}F,4n) reaction (^{263}Db → ^{259}Lr →) was observed. We also observed two SF events that correlated with the α decays with energies and decay times of ^{262}Db. This suggests that small SF and/or EC branches exist in ^{258}Lr; the EC decay daughter of ^{258}Lr, ^{258}No, is a short-lived SF decaying nuclide with $T_{1/2}$ ≈ 1.2 ms and b_{SF} = 100%.[3)] On the basis of the semi-empirical systematics of nuclear mass and half-lives, the EC decay would be favored in ^{258}Lr next to the α decay.[4)]

The observed decay patterns of ^{262}Db and ^{258}Lr are shown in Fig. 1. The α-particle energies of E_α = 8.46 ± 0.04 (α intensity I_α = 70 ± 5%) and 8.68 ± 0.03 MeV (30 ± 5%) were determined for ^{262}Db, though three energies of E_α = 8.45 (75%), 8.53 (16%), and 8.67 (9%) had been adopted.[3)] The half-life of ^{262}Db was measured to be $T_{1/2}$ = 33.8$^{+4.4}_{-3.5}$ s, and this agrees well with $T_{1/2}$ = 34 ± 4 s in Ref.[3)] In this work, the SF activity with $T_{1/2}$ = 30.2 ± 6.1 s was also assigned to ^{262}Db with a SF branch of b_{SF} = 52 ± 4%. This is larger than the currently adopted b_{SF} = ~33%.[3)] On the other hand, the α-particle energies of ^{258}Lr range from E_α = 8.43 to 8.73 MeV and the average α energy of E_α = 8.61 MeV agrees well with E_α = 8.605 MeV deduced from the α energies and intensities of ^{258}Lr in Ref.[3)] The half-life of ^{258}Lr, $T_{1/2}$ = 3.54$^{+0.46}_{-0.36}$ s also agrees with that in Ref.[3)] ($T_{1/2}$ = 3.9$^{+0.4}_{-0.3}$ s). The EC branch in ^{258}Lr was first determined to be b_{EC} = 2.6 ± 1.8%. The cross sections for the ^{248}Cm(^{19}F,5n)^{262}Db reaction were 2.1 ± 0.7 nb at 103.1 MeV and 0.23$^{+0.18}_{-0.11}$ nb at 97.4 MeV, while those for the ^{248}Cm(^{19}F,4n)^{263}Db reaction were the upper limits of ≤ 0.064 nb at 103.1 MeV and ≤ 0.13 nb at 97.4 MeV.

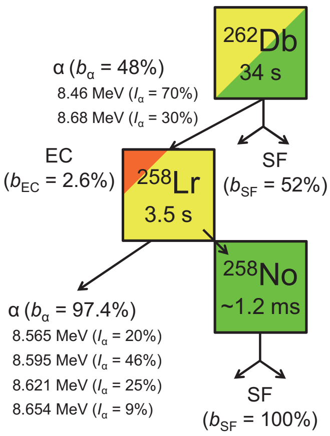

Fig. 1. Observed decay patterns for the chain ^{262}Db → ^{258}Lr → (^{258}No →). The α-particle energies and intensities (I_α) of ^{258}Lr and all decay data of ^{258}No are taken from Ref.[3)]

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References

1) H. Haba et al.: Chem. Lett. **38**, 426 (2009).
2) H. Haba et al.: Phys. Rev. C **85**, 024611 (2012).
3) R. B. Firestone and V. S. Shirley: *Table of Isotopes, 8th ed.* (John Wiley & Sons, New York, 1996).
4) H. Koura: private communication.