2.15 Nuclear Chemistry Study of Transactinide Elements in JAERI *

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Nuclear chemistry study of transactinide elements in JAERI is currently being performed at the JAERI tandem accelerator facility. Recently, the transactinide nuclei ^{261}Rf and ^{262}Db have been successfully produced for the first time in Japan via the reactions of ^{248}Cm(^{18}O,5n) and ^{248}Cm(^{19}F,5n), respectively. In this report, the present status of nuclear chemistry studies of transactinides in JAERI is briefly summarized.

Studies of chemical properties of the transactinide elements - starting with element 104 (Rf) - offer the unique opportunity to obtain information about trends in the Periodic Table at the limits of nuclear stability and to assess the magnitude of the influence of relativistic effects on chemical properties. According to the calculations of the electron configurations of the transactinide elements, it is predicted that sudden changes in the structure of electron shells may appear due to the relativistic effects which originate from the increasing strong Coulomb field of the highly charged atomic nucleus.

Thus, it is expected that the transactinide elements show a drastic rearrangement of electrons in their atomic ground states and as the electron configuration is responsible for the chemical behavior of the element, such relativistic effects can lead to surprising chemical properties. Increasing deviations from the periodicity of chemical properties based on extrapolation from lighter homologues in the Periodic Table are predicted. The main objective of the present group is to explore experimentally the influence of the relativistic effects on the electron shell structure by studying the chemical properties of the transactinide elements. The comparison studies of such fundamental chemical properties as the most stable oxidation states, complex ability and ionic radii with those of lighter homologues, and with results of relativistic molecular orbital calculations are invaluable in evaluating the role of the relativistic effects.

The transactinide elements must be produced by bombarding heavy radioactive actinide targets with high-intensity heavy ion beams and must be identified by the measurement of their decay or that of their known daughter nuclei with unambiguous detection techniques. Detailed studies of nuclear decay properties of transactinide nuclides are also the important subject.

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Since 1998, we have developed some experimental apparatus for the transactinide nuclear chemistry study, *i.e.* a beam-line safety system for the usage of the gas-jet coupled radioactive ^{248}Cm target chamber, a rotating wheel catcher apparatus for the measurement of the α and SF decays of the transactinides and an automated rapid chemical separation apparatus based on the high performance liquid chromatography.

Quite recently, we have successfully produced the transactinides, ^{261}Rf and ^{262}Db, by using the ^{248}Cm(^{18}O,5n) and ^{248}Cm(^{19}F,5n) reactions, respectively. Figure 1 shows the schematic of the experiment for the production and identification of ^{261}Rf and ^{262}Db: the target chamber coupled to the gas-jet transport and the rotating wheel catcher apparatus. The ^{248}Cm target of 590 μg/cm^2 thickness was bombarded by the ^{18}O and ^{19}F beams with the intensity of 200-300 pnA. The recoiling products were stopped in He gas, attached to a KCl aerosol, and were continuously transported through a Teflon capillary to the rotating wheel catcher apparatus. The transported nuclei were deposited on polypropylene foils of 240 μg/cm^2 thickness and 20 mm diameter at the periphery of an 80-position stainless steel wheel of 80 cm diameter. The wheel was stepped at 30 s time intervals to position the foils between six pairs of Si PIN photodiode detectors. The details of the experimental procedures are described elsewhere [1].

The sum of α-particle spectra measured in the six top detectors in a 3.9 h irradiation for the production of ^{261}Rf is shown in Fig. 2(a). In the α energy range of 8.12-8.36 MeV, α lines from 78-s ^{262}Rf (8.28 MeV) and its daughter 26-s ^{257}No (8.22, 8.27, 8.32 MeV) are clearly shown. No contributions from other nuclides in this energy window are observed, although there exit several α lines originating from the Pb impurities in the ^{248}Cm target. A total of 98 events in the singles measurement and 28 α-α correlation events were registered. The production cross section of ^{261}Rf in this reaction was evaluated to be about 6 nb at the ^{18}O energy of 99 MeV.

Figure 2(b) shows the sum of α-particle spectra for the production of ^{262}Db in the 100 MeV ^{19}F-induced reaction of ^{248}Cm. From the mother-daughter correlation of α-energies between ^{262}Db-mother and ^{258}Lr-daughter, the cross section of this reaction was about 1 nb.

Because of the short half-lives and the low production rate of the transactinides, each atom produced decays before a new atom is synthesized. This means that any chemistry to be performed must be done on an *atom-at-a-time* basis. Therefore rapid, very efficient and selective chemical procedures are indispensable to isolate the desired transactinides.

We have developed the gas-jet coupled automated chemical separation apparatus to perform rapid, repetitive and high performance liquid chromatography separations on the second time scale. It is equipped with two magazines, each containing twenty micro-columns (1.6 mm in diameter and 8 mm long). A series of chromatographic pumps, valves, mechanical sliders, and micro-columns are all controlled by a personal computer. The performance is almost the same as that of ARCA developed by the GSI-Mainz group [2]. On-line ion exchange experiments with the above apparatus have been carried out using the Rf homologues Zr and Hf produced via the ^{89}Y(p,n)^{89m}Zr and ^{152}Gd(^{18}O,x n)^{165,167}Hf reactions. The first experiment on the Rf chemistry based on the ion exchange behavior has been conducted in the beginning of 2001. The data analysis is now in progress, the results will be soon appeared.

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References

[1] Haba H. *et al.*: *Extended Abstracts of the 5th International Conference on Nuclear and Radiochemistry*, Pontresina, Switzerland, September 3-8, 2000, p. 195, and submitted to Radiochim. Acta.

[2] Schädel M. *et al.*: Radiochim. Acta **48**, 171 (1989).

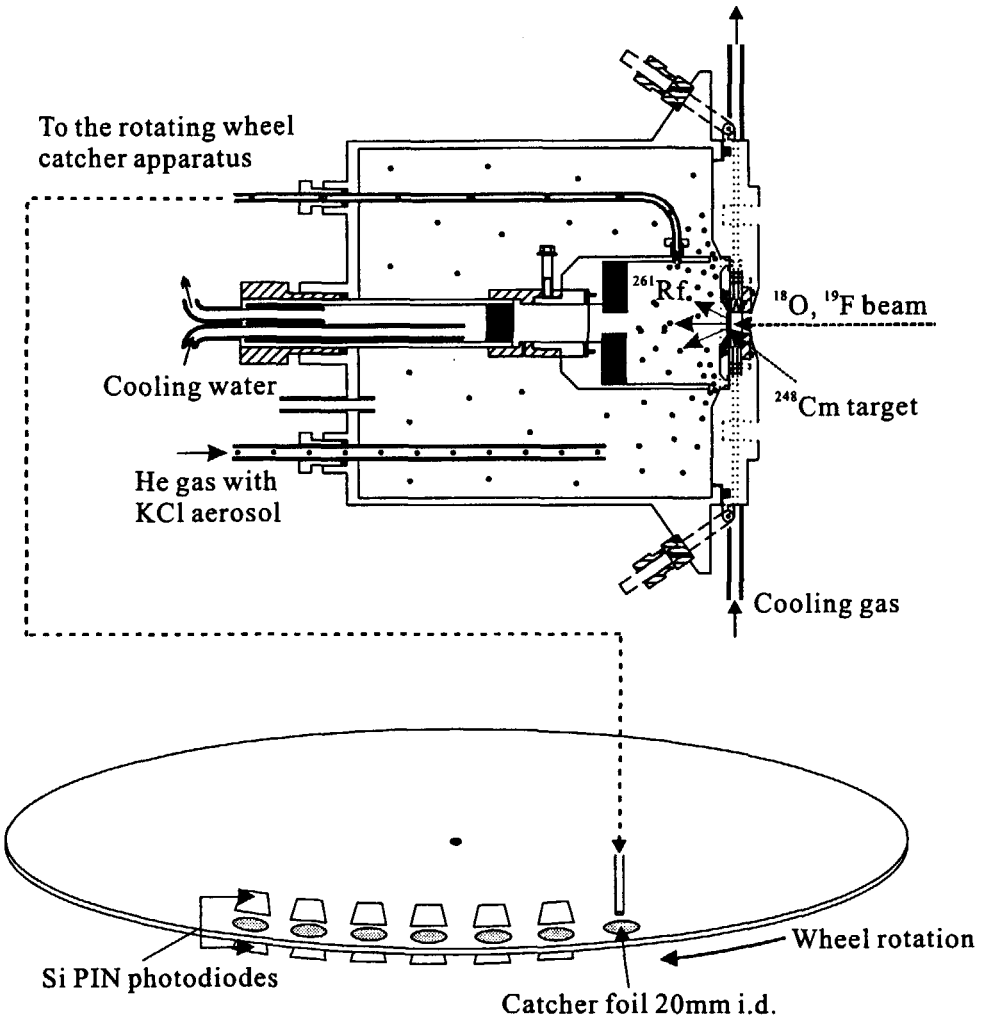

Figure 1: Schematic of the experiment for the production of ^{261}Rf and ^{262}Db.

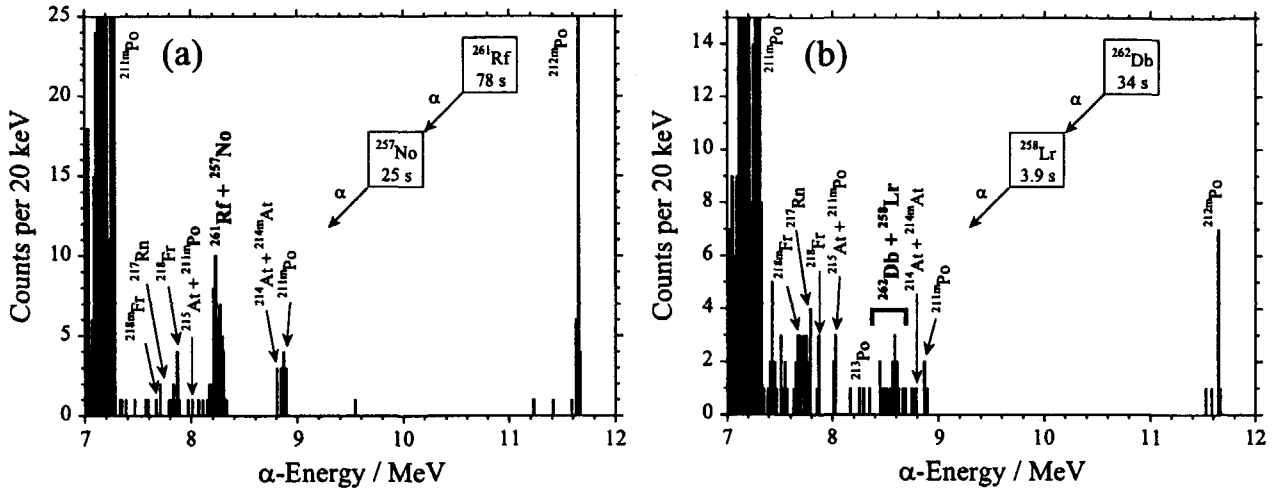

Figure 2: (a) Sum of α-particle spectra measured in the bombardment of the ^{248}Cm target with 99 MeV ^{18}O ions, and (b) that in the bombardment of the ^{248}Cm target with 100 MeV ^{19}F ions.