Article ID: 1007-4627(2006)04-0400-05

Alpha-decay Properties of ^{266}Bh *

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Abstract: The isotope of ^{266}Bh was produced and identified definitely in bombardments of ^{243}Am target with 162 MeV ^{26}Mg ions at HIRFL. Identification was made by observation of correlated α-particle decays between the Bh isotopes and their Db and Lr daughters using a rotating wheel system. The measured α energy for ^{266}Bh is (9.03±0.08) MeV, and this value close to the 9.07 MeV for ^{266}Bh observed in the first chain of element 113 at RIKEN. The half-life of ^{266}Bh is $0.66^{+0.59}_{-0.26}$ s. The Q_α value derived from this experiment fits well into the general trend in a "Q_α-N systematics" for the isotopes with $Z = 107$.

Key words: ^{266}Bh; E_α; half-life; rotating wheel system

CLC number: O571.3　　　**Document code**: A

The α-decay of ^{266}Bh produced in the reaction of ^{22}Ne + ^{249}Bk was first reported by Wilk et al at Lawrence-Berkeley National Laborotary (LBNL), USA[1]. One sequential decay chain which followed by the α-decay of ^{262}Db and ^{258}Lr was assigned to ^{266}Bh. The α particle energy and the decay time for ^{266}Bh were (9.29±0.10) MeV and 0.87 s, respectively. Later on, two events of the 113th element, ^{278}113, and its daughter nuclei ^{274}111, ^{270}Mt, ^{266}Bh, ^{262}Db were observed by Morita et al at Institute of Physical and Chemical Research (RIKEN), Japan[2]. The measured α particle energies of ^{266}Bh were 9.07 and 9.77 MeV, respectively. The discrepancies in E_α value of ^{266}Bh between LBNL and RIKEN may be explained by the rather wide spread in α energies for odd-odd nuclides in this region[3]. However, Gupta et al evaluated the nuclear data for A = 266—294, and they believe that with only two events of ^{266}Bh the assignment should be considered as a tentative result[4]. Therefore, it is of great importance to investigate the α-decay of ^{266}Bh using different projectile-target combinations, so that the isotope of ^{266}Bh could be assigned definitely. The reaction of ^{243}Am(^{26}Mg, 4n(5n))^{264,265}Bh has been used to produce a new isotope of ^{265}Bh and known isotope of ^{264}Bh at the Heavy Ion Research Facility in Lanzhou (HIRFL), People's Republic of China[5]. In that work, an ^{243}Am target was bombarded with 168 MeV ^{26}Mg ion beam, the beam energy of 135 MeV in the middle of target was chosen for producing ^{265}Bh through 4n-evaporation channel based on the HIVAP code. Identification was made by observation of α-α correlations between the new iso-

* **Received date**: 8 Oct. 2006; **Revised date**: 20 Oct. 2006
* **Foundation item**: National Natural Science Foundation of China (10575122)

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tope of ^{265}Bh and its daughter of ^{261}Db and ^{257}Lr using a set of rotating-wheel system. A total of 8 α-α correlated events of ^{265}Bh and 4 events of ^{264}Bh were observed in the experiment. The aim of the present experiment is to produce the isotope of ^{266}Bh through 3n-evaporation channel in the reaction of $^{26}Mg+^{243}Am$ at lower incident energy compared with the experiment mentioned above.

The decay properties of ^{266}Bh and its daughters from the literature are shown in Fig. 1. Because the α-decay of ^{266}Bh is followed by the α-decay of ^{262}Db ($T_{1/2}=34$ s; $E_\alpha=8.45$, 8.53, 8.67 MeV) and ^{258}Lr ($T_{1/2}=3.93$ s; $E_\alpha=8.60$, 8.62, 8.57, 8.65 MeV), we can make a positive identification of ^{266}Bh by observation of these α-α correlations.

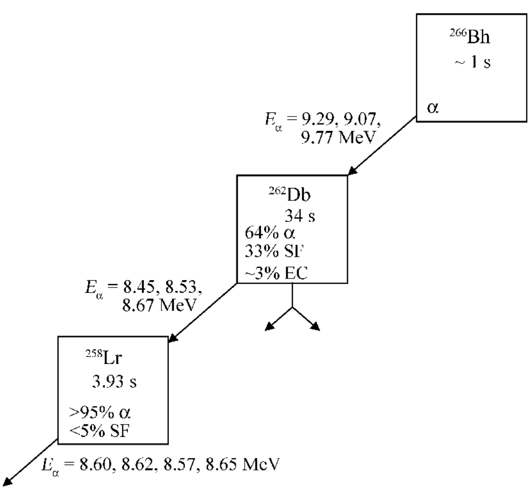

Fig. 1　Partial decay scheme of ^{266}Bh reported by Wilk et al[1] and Morita et al[2].

The experiment was performed at the Section Focus Cyclotron of HIRFL. The ^{243}Am target (99.3% ^{243}Am, 0.7% ^{241}Am) with thickness of 1.2 mg/cm^2 as the oxide was deposited on a beryllium film by the molecular platting method[6], and it was covered with a 70 μg/cm^2 Al foil. A beam of 162 MeV $^{26}Mg^{8+}$ ions delivered from the cyclotron passed through a 2.1 mg/cm^2 Havar entrance window, helium gas and a 3.0 mg/cm^2 Be target backing before into the target material. The total energy loss was ~34 MeV. The beam energy was chosen so as to result in a $^{26}Mg^{8+}$ energy of 126 MeV (laboratory system) in the center of target. The energy loss in the target was about 4 MeV. This beam energy corresponds to the maximum cross section for the 3n-evaporation channel for producing ^{266}Bh according to the HIVAP code. The average beam current was approximately 2 eμA during the entire experiment. The beam stop which is made of graphite served as a Faraday cup measured the current. The irradiation lasted for 200 h.

The reaction products recoiling out of the target were stopped in a volume of helium gas(≈1.1 atm) that had been loaded with sodium chloride (NaCl) aerosols which was generated by the sublimation of the surface of NaCl powder at a temperature of (610±3)°C. The reaction products attached to the NaCl aerosols were continuously swept out of the target chamber with the helium gas flow, and were transported through a capillary (1.27 mm inner-diameter, 1.1 m long) into a rotating wheel system which is similar to the MG wheel[7] and ROMA[8]. The detection system consists of a 48 cm diameter wheel and four pairs of passivated ion-implanted planar silicon detectors (PIPS) (200 mm^2 active area). The transported reaction products were deposited on polypropylene foils with thickness of 50 μg/cm^2. The transport time of the products from the target to the measurement position is about 0.3 s for our system, and the transport efficiency is about 50%. The polypropylene foils were placed in every other hole of the 60-position collection wheel. The collection wheel is rotated between the detector pairs. For this experiment, the parent and daughter searching modes were used to detect α-α correlations with a greatly reduced background. Every 4 s during the parent-searching mode, the wheel is double stepped between the four pairs of α-particle detectors until the possible parent decay is detected in a bottom detector. If a α particle is detected in the bottom detector within an energy window that is expected for ^{266}Bh (between 8.5 and 10.5 MeV), it is assumed that the daughter dubnium nucleus ^{262}Db has recoiled out of the NaCl layer and into the top detector. When such a possible parent decay event is detected, a 60 s daughter searching mode is initiated by single stepping the wheel to move an empty position between the detectors in order to detect the daughter or granddaughter α-decay in the absence of the activity on the collection sample. At the end of the daughter mode interval, the wheel is single stepped again and the parent-search mode is resumed. Pulses from α-particle event with time information, channel number and detector number were digitized and stored in list mode.

The energy calibration was performed off-line using the known α particle energies of 6.05 MeV (^{212}Bi) and 8.78 MeV(^{212}Po) from RaTh source. The energy resolution of the top detectors is 30 keV for 8.78 MeV, while that of the bottom detectors is 100 keV due to the energy degradation in the polypropylene foils. The representative α particle spectrum in the energy range of 8.0—10 MeV is shown in Fig. 2. A small peak of 8.78 MeV from

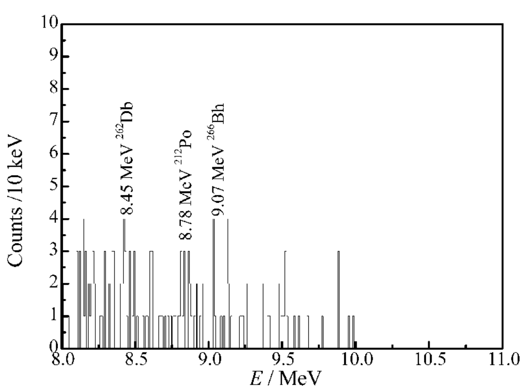

Fig. 2 The α particle spectrum measured in the top detector of products of the reaction of 126 MeV ^{26}Mg with ^{243}Am.

^{212}Po has been observed, which is produced from the transfer reaction of impurities of lead in the target. There are also some events with energies around 9.0 MeV and 8.5 MeV in the spectrum, where the expected Bh and its daughter Db are located. An off-line analysis for searching α-α correlations has made between Bh events ($8.5 \leqslant E_\alpha$ (MeV) $\leqslant 10.0$) in the parent mode followed by the daughter α decay events ($8.4 \leqslant E_\alpha$(MeV) $\leqslant 8.7$) detected in the same detector pair within a time widow of 60 s. A total of 4 α-α correlations including one triple correlation events were observed during the experiment. Table. 1 lists the correlation between parents events ($8.5 \leqslant E_\alpha$ (MeV)$\leqslant 10.5$) and daughter events ($8.4 \leqslant E_\alpha$ (MeV)$\leqslant 8.7$). The initiating parent event, each subsequent α-decays that occurred within the energy window, its isotope assignment, α energy, and relative time are listed for each event.

Table 1 The α energy and the life-time of each parent and daughter correlation event*

Event No.	$E_{\alpha1}$/MeV	$\Delta t_1{}^a$/s	$E_{\alpha2}$/MeV	$\Delta t_2{}^b$/s	$E_{\alpha3}$/MeV	$\Delta t_3{}^c$/s
1	8.989	1.13	8.459	33.62		
2	9.071	0.79	8.604	34.14		
3	8.959	0.51	8.542	29.23	8.641	5.07
4	9.106	1.52	8.518	53.09		

* a Time after end of 4 s collection, b Time after α1, c Time after α2.

The isotope ^{262}Db is known to decay by α emission and spontaneous fission with the branching ratios of 64% and 33%, respectively. Its α-particle energies of ^{266}Bh are 8.45, 8.53, 8.67 MeV, and half-life ($T_{1/2}$) is (34±4) s. We measured the daughter α-particle energy of 8.459, 8.604, 8.542, 8.518 MeV, and the decay time of 29—53 s for these four events. It is consistent with the literature data of ^{262}Db. Therefore, three α-α correlations between ^{266}Bh and its daughter nuclide ^{262}Db events and one triple correlation events of ^{266}Bh, ^{262}Db and ^{258}Lr were identified. The average α-particle energy of ^{266}Bh is (9.03±0.08) MeV, which is close to the 9.08 MeV for ^{266}Bh observed in the first chain of element 113 at RIKEN. Using the maximum likelihood technique, the half-life of $0.66^{+0.59}_{-0.26}$ s for ^{266}Bh was obtained by MLDS code[9].

A total of 2 606 events during the experiment made the parent searching mode change to the daughter searching mode. Based on this random daughter rate, the expected number of random α-α correlation is 0.054. Taking into account the gas-jet transportation efficiency of 50%, decay residence and transport time in the recoil chamber and capillary 0.3 s, detector efficiency for α-particle of 30%, collection and counting times, beam current, and assuming a 100% α branch for ^{266}Bh, the cross section of ^{266}Bh from the reaction of ^{243}Am(^{26}Mg, 3n) at 126 MeV was estimated to be (15±10) pb.

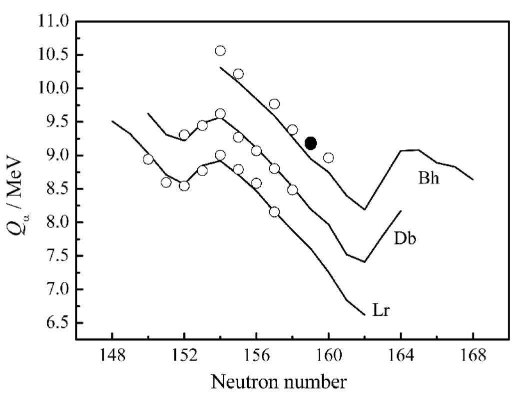

Fig. 3　The α-decay energy Q_α vs neutron number N for isotopes of odd-Z elements (Z=103—107) (◦), — are theoretical Q_α values[9]. The Q_α value for ^{266}Bh (•) was derived from the present work. For the Q_α value we took the highest known α-transition energy.

The Q_α value as a function of neutron number N for the isotopes of the odd-Z elements (Z=103—107) is shown in Fig. 3, and the theoretical Q_α based on macroscopic-microscopic approach calculated by Muntian et al[10] are also shown by the solid line. One can see that systematics of the α-decay energy Q_α vs neutron number N for the isotopes of the odd-Z elements (Z=103—107) can be reproduced by the theoretical calculation. The derived Q_α from the measured α energy for ^{266}Bh was 9.18 MeV, and this value fits well into the general trend as compared with the other Z = 107 isotopes.

In summary, the isotope of ^{266}Bh has been observed by the ^{243}Am (^{26}Mg, 3n) reaction and identified by correlating the α decay of ^{266}Bh with the α decay of the 34 s ^{262}Db daughter by the rotating wheel system. The measured α energy and half-life for ^{266}Bh are (9.03 ± 0.08) MeV and $0.66^{+0.59}_{-0.26}$ s, respectively. The E_α value is close to the 9.07 MeV for ^{266}Bh observed in the first chain of element 113 at RIKEN. Its Q_α value derived from this experiment fits well into the general trend in a "Q_α vs N-systematics" for the isotopes with Z = 107.

Acknowledgement We thank the staff and crew of HIRFL for providing the stable ^{26}Mg beam.

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^{266}Bh 的 α 衰变性质研究*

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摘 要：报道了利用兰州重离子研究装置提供的^{26}Mg 重离子束流轰击^{243}Am 靶产生和鉴别已知超重核素^{266}Bh的实验结果。利用转轮收集探测装置依靠母子核遗传关系通过观测 Bh 同位素与其子核 Db 和 Lr 之间的 α-α 关联事件来鉴别^{266}Bh。实验中观测到^{266}Bh 的 α 能量为(9.03 ± 0.08) MeV，与日本理化学研究所在合成 113 号元素中第一个衰变链中观测到^{266}Bh 的 α 能量为 9.07 MeV 相近。^{266}Bh 的半衰期为 $0.66^{+0.59}_{-0.26}$ s，从实验得到的 Q_α 也符合 Z=107 的 Q_α 随中子数变化的系统性。

关键词：^{266}Bh；E_α；半衰期；转轮系统

* 基金项目：国家自然科学基金资助项目(10575122)