Eur. Phys. J. A **20**, 385–387 (2004)
DOI 10.1140/epja/i2004-10020-2

THE EUROPEAN
PHYSICAL JOURNAL A

Letter

New isotope ^{265}Bh

Z.G. Gan[1,a], J.S. Guo[1], X.L. Wu[1], Z. Qin[1], H.M. Fan[1], X.G. Lei[1], H.Y. Liu[1], B. Guo[1], H.G. Xu[1], R.F. Chen[1], C.F. Dong[1], F.M. Zhang[1], H.L. Wang[1], C.Y. Xie[1], Z.Q. Feng[1], Y. Zhen[1], L.T. Song[1], P. Luo[1], H.S. Xu[1], X.H. Zhou[1], G.M. Jin[1], and Zhongzhou Ren[2]

[1] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, PRC
[2] Department of Physics, Nanjing University, Nanjing 210008, PRC

Received: 4 March 2004 / Revised version: 19 April 2004 /
Published online: 26 May 2004 –
Communicated by D. Schwalm

Abstract. A new isotope ^{265}Bh was produced and identified at the Sector Focus Cyclotron of the Heavy Ion Research Facility in Lanzhou. This experiment was performed via the reaction of an ^{243}Am target with 168 MeV ^{26}Mg ions. Identification was made by observation of correlated α-particle decays between the new isotope ^{265}Bh and its ^{261}Db and ^{257}Lr daughter nuclei using a set of rotating-wheels system. A total of 8 correlated decay events of ^{265}Bh and 4 decay events of ^{264}Bh were observed. ^{265}Bh decays with a $0.94^{+0.70}_{-0.31}$ s half-life by emission of α-particles with an average energy of 9.24 ± 0.05 MeV. The half-life and α decay energy of ^{265}Bh from this experiment are in agreement with theoretical predictions.

PACS. 25.70.Gh Compound nucleus – 27.90.+b $220 \leq A$

To synthesize new superheavy isotopes is a hot point in nuclear physics. A series of new elements was produced by the cold-fusion reactions and by the hot-fusion reactions [1–3]. The present experimental data on superheavy nuclei strongly suggest that there exists a deformed region around $Z = 108$ and $N = 162$ [1,4]. Therefore, to produce the new isotopes around $Z = 108$ and to measure their decay properties is important to identify the deformed shell effect in this region.

The first identification on the element $Z = 107$ was made by G. Münzenberg *et al.* in 1981 [5]. They measured the α decay energy and half-life of ^{262}Bh via the reaction ^{209}Bi(^{54}Cr, n)^{262}Bh. After that, several other isotopes were produced [1,6]. In 2000, the ^{266}Bh and ^{267}Bh were synthesized by P.A. Wilk *et al.* [7]. Up to date six isotopes of bohrium were observed. However, the isotope ^{265}Bh is still unknown. The production of ^{265}Bh will bridge the gap between the known lighter isotopes ^{261,262,264}Bh and the known heavier isotopes ^{266,267}Bh. It is also useful to establish the systematic law of the α decay energies and half-lives of the Bh isotopes. In this paper we report an experimental result on the production of a new isotope of the element $Z = 107$: ^{265}Bh.

The experiment to produce ^{265}Bh was performed at the SFC of the HIRFL (Heavy Ion Research Facility, Lanzhou) via the ^{243}Am (^{26}Mg, 4n) reaction in 2003. A 1.27 mg/cm^2 ^{243}Am target as the oxide was deposited on a Be film [8], and it was covered with a 70 μg/cm^2 Al foil. The beam of 168 MeV ^{26}Mg^{8+} ions 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, and then bombed on the target material. The reaction products recoiled out of the target, and then were stopped in the helium gas which was loaded with the NaCl aerosols. The products attached to the aerosols were continuously swept out of the target chamber with the helium gas, and transported through a 1.2 m length capillary into a collection and measurement chamber. A new collection and measurement chamber was built at the IMP. It is similar to the MG wheel [9] and ROMA [10]. In this chamber, the products were deposited on a 50 μg/cm^2 polypropylene collection foil mounted near the periphery of a 48 cm diameter wheel. The polypropylene foils were placed in every other hole of the 60-position collection wheel. The transport time of the products from the target to the measurement position is about 0.3 s for our system. The transport efficiency was about 70%. For this experiment, a total of four pairs of PIPS detectors (200 mm^2 active area) were used to measure the kinetic energy of the α-particles. The α-particle

[a] e-mail: zggan@impcas.ac.cn

Table 1. List of correlated events between parents and daughters in this experiment. t_1 is the time after the end of a 5 s collection, t_2 is the time after α_1, t_3 is the time after α_2.

Parent	α_1/keV	t_1/ms	Isotope	α_2/keV	t_2/ms	Isotope	α_3/keV	t_3/ms
^{265}Bh	9268	1736	^{261}Db	9006	4860			
^{265}Bh	9300	1015	^{261}Db	8924	224	^{257}Lr	8905	4639
^{265}Bh	9219	574	^{261}Db	8921	1898	^{257}Lr	8887	1405
^{265}Bh	9274	193	^{261}Db	8918	5834			
^{265}Bh	9222	1140	^{261}Db	8942	436			
^{265}Bh	9179	1933	^{261}Db	8902	1523			
^{265}Bh	9245	2547	^{261}Db	8869	1608			
^{265}Bh	9199	1334	^{261}Db	8927	3480			
^{264}Bh	9440	555	^{260}Db	8988	2686			
^{264}Bh	9501	2770	^{260}Db	9085	1378			
^{264}Bh	9524	1203	^{260}Db	9003	259			
^{264}Bh	9481	2321	^{260}Db	9098	975			

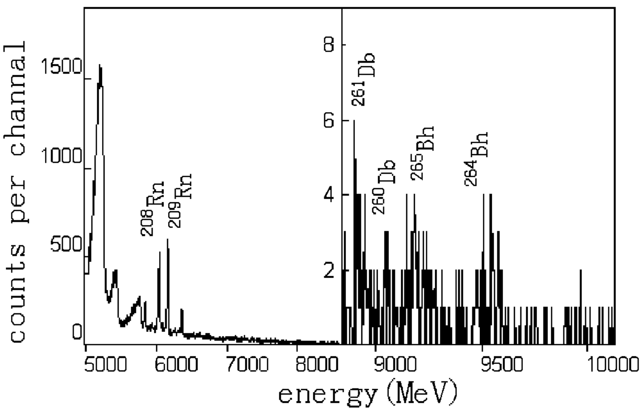

Fig. 1. The α-particle spectrum measured in the top detectors in the ^{26}Mg + ^{243}Am reaction.

energy resolution was about 40 keV for the top detectors and 100 keV for the bottom detectors because of energy degradation in the polypropylene foil. A parent-daughter nuclide searching mode was used to facilitate the detection of α-α correlations. Every 5 s which is appropriate for the detection of ^{265}Bh during the parent nuclide researching mode, the wheel is double stepped between the four pairs of α-particle detectors until an expected parent α decay (between 8.8 and 9.6 MeV) is detected in the bottom detector. In this case, it is assumed that the daughter has recoiled out of the sample and into the top detector, and a signal is generated which causes a single step and initiates the daughter searching mode. In this mode, only the holes of the collection wheel are between the detector pairs. Thus, a searching for the correlated α decay from ^{261}Db is initiated in a low-background environment nearly eliminating the possibility of random cases from the collected sample. In the daughter searching mode the detector pairs will search for the α decay of daughter nuclei for 10 s, which is appropriate for the 1.8 s half-life of ^{261}Db. At the end of each daughter searching cycle, the wheel will move one step to collect the products sample, and then resume

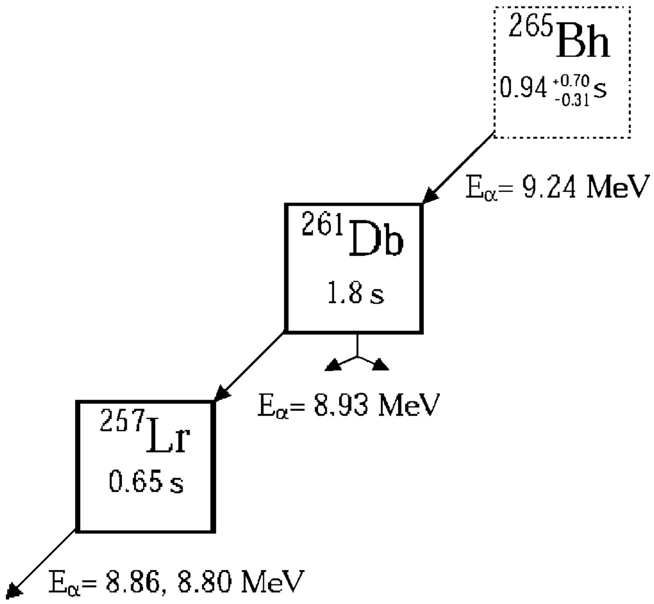

Fig. 2. Partial decay chain of ^{265}Bh, and the decay properties of ^{265}Bh are first observed in this experiment.

the parent searching mode. The measured pulses from α-particles were stored on disk in list mode with time of event, channel number, and detector number. This experiment was run at about 1.0 μA for approximately 250 h.

Figure 1 is a spectrum of the top detectors in this experiment. Two small peaks with energies about 9.2 MeV and 9.5 MeV were observed in the specturm. An off-line computer search was made for α-α correlations between Bh events ($8.8 < E_\alpha$ (MeV) < 9.6) in parent mode followed by daughter α decay events ($8.6 < E_\alpha$ (MeV) < 9.1) detected in the same detector pair during the ensuing daughter mode search. Six α-α correlations between ^{265}Bh and its daughter nuclide ^{261}Db events and two triple correlation events of ^{265}Bh,^{261}Db and ^{257}Lr were observed during the experiment. Table 1 lists the observed α energy and lifetime of each parent and daughter event, and fig. 2 shows the partial decay chain of ^{265}Bh. The average α energy of ^{265}Bh was 9.24 ± 0.05 MeV. Using the maximum likelihood technique, the half-life $0.94^{+0.70}_{-0.31}$ s for ^{265}Bh was obtained by MLDS code [9,11]. The derived Q_α from the measured α energy for ^{265}Bh was 9.38 MeV, which was in agreement with the expected Q_α value by Zhongzhou Ren *et al.* [12,13]. The experimental half-life of ^{265}Bh also agrees with the calculations [13] $T_{1/2} = 2.6$ s or $T_{1/2} = 0.60$ s. The average α energy of the daughter nuclide ^{261}Db of ^{265}Bh is 8.93 ± 0.04 MeV, and its half-life is $1.70^{+0.79}_{-0.49}$ s by the same MLDS code. The observed α energy and lifetime of the daughter ^{261}Db are consistent with the known values [14]. The half-life of ^{257}Lr was not analyzed because of few events. In addition, the known ^{264}Bh and its daughter ^{260}Db were observed in the experiment. The four events for ^{264}Bh were also listed in table 1. The obtained half-lives by the same code and average α energies are $1.17^{+0.88}_{-0.44}$ s and 9.49 ± 0.04 MeV for ^{264}Bh, $0.89^{+0.79}_{-0.35}$ s and 9.04 ± 0.06 MeV for ^{260}Db, respectively. All the observed α energy and half-life values are in agreement with the known values [14]. In particular, the determined half-life of ^{264}Bh in this experiment is consistent with the new value of the half-life of ^{264}Bh obtained from the decay chain of ^{272}111 [1]. The nuclide ^{264}Bh arose from the reaction channel of 5n evaporation in the same projectile-target combination in this experiment.

A total of 2000 events during the experiment made the searching mode change to the daughter searching mode. So about 2% of time during the experiment was spent in the daughter searching mode. In summary, a new nuclide ^{265}Bh has been observed by the ^{243}Am (^{26}Mg, 4n) reaction and identified by correlating the 9.24 MeV α decay of ^{265}Bh with the α decay of the 1.7 s ^{261}Db daughter in the present work. The measured α energy and half-life for ^{265}Bh are 9.24 ± 0.05 MeV and $0.94^{+0.70}_{-0.31}$ s, respectively.

The authors thank the staff and crew of the IMP SFC Cyclotron for providing the ^{26}Mg beam. We are indebted to Dr K.E. Gregorich for his friendly providing a revised code of the maximum likelihood technique. The authors also thank Prof. H.Q. Zhang and Prof. W.Q. Shen for their kindly discussion and valuable suggestion. This work was supported by NSFC (10275082, 10105010, 10125521, 10235020, 10221003), the Major State Basic Research Development Program (G2000077400), the Chinese Academy of Sciences (One Hundred Person Project, KJCXZ-SW-NO4), the National Key Program for Basic Research of the Ministry of Science and Technology (2001CCB01200).

References

1. S. Hoffmann, F.P. Heßberger *et al.*, Eur. Phys. J. A **14**, 147 (2002).
2. Yu.Ts. Oganessian, A. Yeremin *et al.*, Nature **400**, 242 (1999).
3. A. Ghiorso, D. Lee *et al.*, Phys. Rev. C **51**, R2293 (1995).
4. Yu.A. Lazarev, Yu.V. Lobanov *et al.*, Phys. Rev. Lett. **73**, 624 (1994).
5. G. Münzenberg, S. Hofmann *et al.*, Z. Phys. A **300**, 107 (1981).
6. R.B. Firestone *et al.*, *Table of Isotopes*, eighth edition (LBL, New York, 1996).
7. P.A. Wilk, K.E. Gregorich *et al.*, Phys. Rev. Lett. **85**, 2697 (2000).
8. Qin Zhi, Guo Junsheng, Gan Zaiguo, Appl. Radiat. Isotopes **54**, 741 (2001).
9. K.E. Gregorich, M.R. Lane *et al.*, Phys. Rev. Lett. **72**, 1423 (1994).
10. K. Sümmerer, M. Brügger *et al.*, GSI Annu. Rep. 1983, 84-1 (1984) p. 246.
11. K.E. Gregorich, Nucl. Instrum. Methods Phys. Res. A **302**, 135 (1991).
12. Zhongzhou Ren, Ding-Han Chen, Fei Tai, H.Y. Zhang, W.Q. Shen, Phys. Rev. C **67**, 064302 (2003).
13. Zhongzhou Ren, J. Nucl. Radiochem. Sci. **3**, 195 (2002).
14. G. Pfennig *et al.*, *Chart of the Nuclides*, 6th edition (Druckhaus Haberbeck, Lage/Lippe, 1995), revised reprint 1998.