A New Isotope of $Z = 105$ with Mass Number 259*

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Abstract An Isotope of element 105 with mass number 259 has been produced via the reaction ^{241}Am(^{22}Ne,4n)^{259}Db at $E_{lab} = 120$MeV. The reaction products were transported and collected using the helium-jet technique and rotating wheel apparatus. The α-decays of the products and their daughter nuclides were detected by a series of Si(Au) detectors. The Z and A of the nuclide have been unambiguously identified by the genetic relationship between the new activity and the known nuclide ^{255}Lr. The new nuclide ^{259}Db has a half-life of (0.51 ± 0.16)s and decay by alpha-particle emission with energy of 9.47MeV. The Q_α value for new isotope ^{259}Db is in good coincidence with the predicted result.

Key words new isotope, alpha decay, mother-daughter genetic relation, half-life measurement

1 Introduction

Early attempts to discover the isotopes of element 105 were made by Flerov in 1968[1] and Ghiorso in 1970[2]. So far the isotopes from ^{255}Db to ^{263}Db for element $Z = 105$, except ^{259}Db, are known[3-7]. The ^{259}Db nuclide is still completely unknown up to now. According to systematics and predictions by Wapstra et al.[8] and Möller et al.[9] this nuclide should be an alpha-emitter with a short half-life. Therefore it is the aim of our experiment to close this gap and to search the properties of ^{259}Db nuclide.

The reaction ^{241}Am (^{22}Ne,4n) was used to produce this new isotope. Its identification was performed by recoil-milking the 21s ^{255}Lr daughter. At the same time, its neighboring nuclide ^{258}Db has also been observed in the present work.

We compared the α-decay energy of this new isotope ^{259}Db to the values of the known isotopes in a "Q_α-systematics" for isotopes with $Z \geqslant 98$. It shows that the "Q_α value" for new isotope ^{259}Db fits quite well into the general trend.

2 Experimental Setup and Procedure

A 0.85mg/cm^2 ^{241}Am target was bombarded with 132MeV ^{22}Ne ions at the SFC

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(Sector Focus Cyclotron) of HIRFL (Heavy Ion Research Facility Lanzhou). The ^{22}Ne beam, after passing through a 1.94 mg/cm^2 Havar window and a 1.70 mg/cm^2 Al target backing, had an energy of 118 MeV in the target material. This energy corresponds to the maximum of the excitation function for the $^{241}Am(^{22}Ne, 4n)$ reaction, according to statistical evaporation calculations using the Alice Code[10]. The typical beam current of ^{22}Ne was about 0.8μA.

The reaction products recoiling out of the target were stopped in helium gas at 9.87×10^4Pa, which had been loaded with NaCl aerosols and swept out of the target chamber with the gas, then went through a 1.27 mm diam and 20 cm length capillary into a rough vacuum to impinge upon the periphery of a vertically mounted wheel. The experimental setup is shown schematically in Fig. 1. The wheel was periodically rotated by the preset interval to place the collected recoil atoms to the position in front of a series of peripherally mounted Si(Au) surface-barrier detectors in order to measure their alpha-particle spectra.

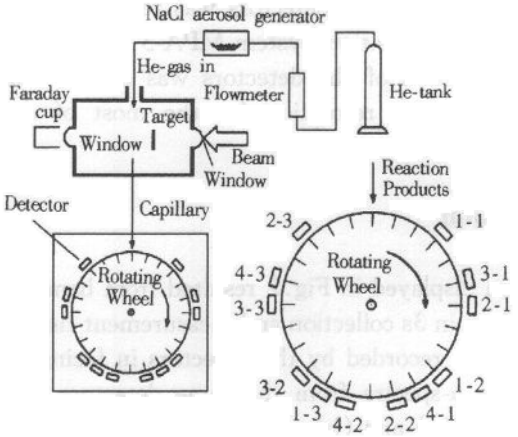

Fig. 1. Schematic diagram of the He-jet target chamber and capillary transport assembly and the rotating wheel collection and detection system.
The arrangement of the detectors is shown in the lower-right portion of the figure.

In the present experiment, the detectors were devided into four groups and each group included three Si(Au) surface-barrier detectors. They were arranged around the wheel according to the preset inequal intervals as shown in the lower-right portion of Fig. 1. The operating procedure of the wheel and detectors during experiment is as follows: when the first collected products source is rotated to the front of No. 1-1 detector, the α-decays from products and their daughters collected on the wheel could be recorded by this detector (measurement time equal to collection time). The second products source is collected and rotated to the front of No. 2-1 detector and recorded by No. 2-1 detector, while the first products source is rotated to No. 1-2 detector and recorded. In this time No. 1-1 detector due to no facing the product source on the wheel only records the daughter α-particle activities. Successively the third product source is rotated to No. 3-1 detector, simultaneously the 2-nd source is rotated to No. 2-2 detector, and the 1-st source goes to No. 1-3 detector. In this time detectors No. 1-1, No. 1-2 and No. 1-3 recorded the same source (1-st source), thus the time sequential spectra could be obtained. When 4-th source is rotated to the front of No. 4-1 detector, the 1-st source is returned to the collection position and the 5-th source will be collected there. By this way the measurement procedure will be repeated and continued up to

the end of the experiment.

In order to measure the longer and shorter half lives of the products, the two runs experiments, the collection time equal to 3 and 10s were performed. The total of 9 and 30s time sequential decays in each cycle for 3 and 10s collection, respectively, could be obtained.

In the measurement process one can see that there are one time-interval facing the source and three time-intervals no facing the source for each detector. During the detector no facing the source, it is recording only the decay of α-recoils (daughter) on the surface of the detectors. When the data are processed and analyzed we can accumulate the recorded counts for each detector in accordance with the wanted time-interval so as to obtain the time sequential spectra, the mother and daughter as well as the pure daughter decay spectra. In other words, the time sequential decay could be obtained both from the recorded counts of separated time intervals of each detector and from the recorded counts of the ordinal detectors of each group.

The information from each of the detectors was recorded event-by-event and analyzed using a Multiparameter Data Acquisition System MPA-3.

The alpha-energy calibration of the detectors was carried out by a standard Rad-Th source. The typical alpha-energy resolution for the most of detectors was 30—40keV (*FWHM*).

3 Results and Discussion

The α-particle spectra displayed in Fig.2 resulted from bombardment of the ^{241}Am target with 120 MeV ^{22}Ne ions in 3s collection and measurement time interval by No.1 detector of each group. The α-spectra recorded by the detectors in facing the product source on the wheel, combined with the α-spectra from the same detectors but not facing the product source, were shown in Fig.2(a) and (b), respectively.

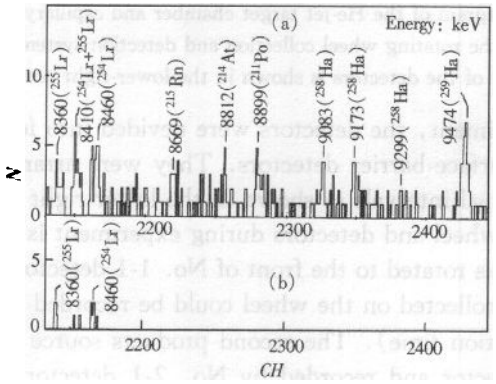

Fig.2. The α-particle spectra produced by bombardments of ^{241}Am with 120 MeV ^{22}Ne ions.
(a) The detectors facing the product source; (b) The detectors no-facing the product source (the α-spectrum of the recoiled daughter).

A obvious α-peak with the energy of 9.47 MeV appeared in Fig.2(a) is assigned to ^{259}Db in the present work. Its half-life is measured to be 0.51s (as shown in Fig.3). In addition a α-peak with an energy of 8.36 MeV has a measured half-life of 21s and thus could be assigned to the previous known nuclide ^{255}Lr. We believe that the nuclide ^{255}Lr is α-decay

daughter of ^{259}Db nuclide, and it could exclude the contribution of ^{255}Lr produced directly in the bombardment due to rather small production cross section of (α4n) reaction according to Alice Code calculation.

A complex group of peaks with the energies of 9.08, 9.17 and 9.30 MeV in the Fig. 2(a) could be assigned to ^{258}Db base on the whole complex group decays with a measured half-life of 4.3s. This nuclide arose from the reaction ^{241}Am (^{22}Ne, 5n). The α-decay daughter ^{254}Lr of ^{258}Db nuclide presented in Fig. 2(a) has a α-peak with an energy of 8.46 MeV. The decay curve of ^{254}Lr appeared a growth-decay phenomenon, thus it proved that the ^{254}Lr nuclide arose from the decay of the mother nuclide ^{258}Db but not in the reaction directly. The half-lives of 4.3 and 13.4s deduced from the decay curves of ^{254}Lr are in coincidence quit well with the known values of ^{258}Db and ^{254}Lr, respectively.

Furthermore, the peaks presented in Fig. 2(a) with energies of 8.669, 8.812 and 8.899 MeV should belong to ^{215}Rn, ^{214}At and ^{211}Po, respectively, they are due to the bombardment of a small amount of lead impurity in the target with ^{22}Ne ions.

The Fig. 2(b) represented only α-spectra of the recoiled daughter nuclides when the detectors were not facing the products source. In these "daughter" spectra the presented α-peaks have the same energies of 8.36, 8.41 and 8.46 MeV and same half-lives of 13.4 and 21.3s, respectively, as the values of ^{254}Lr and ^{255}Lr in the "parent" spectra [Fig. 2(a)], thus confirming the assignment of the ^{254}Lr and ^{255}Lr, and hence their precursors being ^{258}Db and ^{259}Db, respectively.

The ratio of counts in 9.47 MeV peak (^{259}Db) in the mother spectrum to those in 8.36 and 8.40 MeV (^{255}Lr) in the daughter spectrum is 5.2 ± 1.2, which agrees well with the value 5.8 ± 1.0 calculated by taking into account geometry and time factors.

The production cross sections are estimated from the yields of ^{259}Db and ^{258}Db α decays to be (1.6 ± 1.2) and (3.6 ± 1.8) nb, respectively. These values are much different from the 70 nb for ^{259}Db and 130 nb for ^{258}Db at 120 MeV bombarding energy given by evaporation calculation using the Alice code. The main reason of this difference probably come from the uncertainty of the fission competition in the Alice calculation.

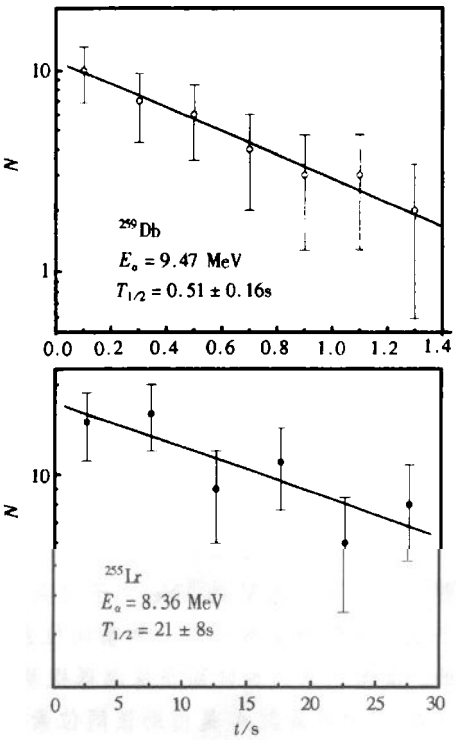

Fig. 3. The decay curves for α decays of ^{259}Db with α-energy of 9.47 MeV and ^{255}Lr with α-energy of 8.36 MeV when the detectors are facing the product source.
For ^{259}Db decay (upper portion) the counts are obtained from the sum counts by detector No. 1 of each group for 3s collection and measurement time in each cycle, and for ^{255}Lr (lower portion) the decay is obtained from the sequential detectors of each group for 10s, collection and measurement time in each cycle.

The comparison between the α-decay energies of new isotope ^{259}Db with the values of the known isotopes in a "Q_α-systematics" for isotopes with $Z \geqslant 98$ shows that the Q_α value

for new isotope ^{259}Db fits quite well into the general trend. ^{259}Db with neutron number N = 154 has a higher α-decay energy than the other Z = 105 isotopes. The Q_α value 9.62 MeV for new isotope ^{259}Db derived from this experiment is also in good agreement with the values of 9.60 and 9.61 MeV predicted by Wapstra[8] and Möller[9], respectively.

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Z = 105 质量数为 259 的新同位素的合成和鉴别*

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摘要 利用 120MeV 的^{22}Ne 离子束轰击^{241}Am靶,通过^{241}Am(^{22}Ne,4n)^{259}Db反应合成了一个 Z=105,质量数为 259 的新同位素. 反应产物是用氦喷嘴技术和转动轮装置传输收集的. 借助一系列金硅面垒探测器探测到了反应产物及其子核的 α 衰变. 新同位素的原子序数 Z 和质量数 A 是借助该同位素和已知的^{255}Lr核之间的遗传关系得到了确定的鉴别. 新同位素^{259}Db的测量半衰期为(0.51±0.16)s;它的 α 粒子能量为 9.47MeV. 由本实验导出的^{259}Db的 Q_α 值同理论预言结果能够较好地符合.

关键词 新同位素 α 衰变 母-子核遗传关系 半衰期测量

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